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On Economics and Energy

Jürgen Mimkes, Physics Department
Paderborn University, Germany

Content

Future Model

Why do we teach our children and students the knowledge of our past, even though they need the tools of tomorrow?

We do this, because many things of today will be valid (V) in the future, but, of course, many things of the future are today still unknown (U):

The future elements may be divided into two categories:
V: always valid – now and in the future known
U: presently unknown – only in the future known

<u>Examples of the Future Model</u>

Science

In science all elements may be divided into two categories:

V: <u>always valid</u> – now and in the future valid – Teaching facts

U: <u>presently unknown</u> – in the future known – Research results

Economics

In economics all elements may be divided into two categories:

V: <u>ex ante</u>: (always known) – like functions

U: <u>ex post:</u> (only in the future known) – like income

(We can file our income tax return only at the end of the year!)

Physics

Physical systems may be divided into two categories:

V: <u>conservative</u>: (always known) – e.g. motion in conservative forces

(Kepler´s laws (1619) are still valid today, as space has no friction.)

U: <u>non-conservatice:</u> (only in the future known) –e.g. turbulent motion

Mathematical Examples of the Future Model

Calculus

Two dimensional calculus may be divided into two categories:

V: exact differentials (d f, with known stem function f)

U: not-exact differentials (δ g, with not existing stem function)

Integrals

In calculus integrals may be divided into two categories:

V: Riemann integrals (path independent, known)

U: Stokes integrals (path dependent, path unknown)

Statistics

In statistics all elements may be divided into two categories:

V: constraints (precise value known)

U: probable (precise value unknown)

Data

Data are real numbers and may be divided into two categories:

V: rational (solution of a linear equation: $x = B/A$, solution is known)

U: irrational (solution of a non-linear equation, $x \neq B/A$, gen. unknown)

<u>Economics:</u> Possible mathematical tools:

<u>Differential forms</u> (Macroeconomics)
V: all <u>ex ante</u> terms must be written as <u>exact differentials</u>
U: all <u>ex post</u> terms must be written as <u>not-exact differentials</u>

<u>Line integrals</u> (Macroeconomics)
V: all <u>ex ante</u> terms must be written as <u>Riemann</u> integrals
U: all <u>ex post</u> terms must be written as <u>Stokes</u> integrals

Statistical Theory (Microeconomics)
V: all <u>ex ante</u> terms must be written as constraints, as functions
U: all <u>ex post</u> terms must be written as <u>probability</u> terms

Chaos Theory and Differential Equations (Complexity)
V: all <u>ex ante</u> terms must be written as linear diff. equations
U: all <u>ex post</u> terms must be written as non-linear diff. equations

Differential Forms and Line Integrals

Calculus of two variables

V: Exact differential dF

F is the stem function:

$$\mathbf{F = F(x, y)}$$

$$\mathbf{dF = F_x\, dx + F_y\, dy}$$

$$\mathbf{F_{xy} = F_{yx}}$$

Example

$$F = x^4\, y^7$$

$$dF = 4x^3 y^7\, dx + 7x^4 y^6\, dy$$

$$28x^3 y^6 = 28x^3 y^6$$

U: Not exact differential δM

There is no stem function M:

$$\delta\, \mathbf{M = x\, dF}$$

$$\mathbf{M_{xy} \neq M_{yx}}$$

Example

$$\delta M = 4x^4 y^7\, dx + 7x^5 y^6\, dy$$

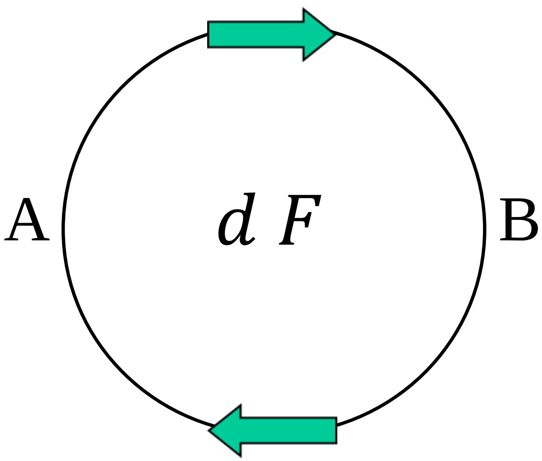
$$28x^4 y^6 \neq 35x^4 y^6$$

U→V: Integrating factor (1/x): $\mathbf{dF = (1/x)\, \delta M}$

V: A Closed Riemann line integral

of an exact differential (d F) is always zero!

Integral along path AB is equal to the integal along path BA (**Equilibrium**)



$$\oint d\,F = 0$$

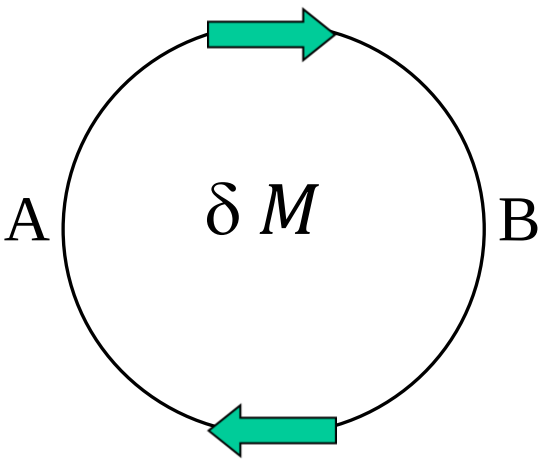
Ring

Example: mechanical energy at conservative forces

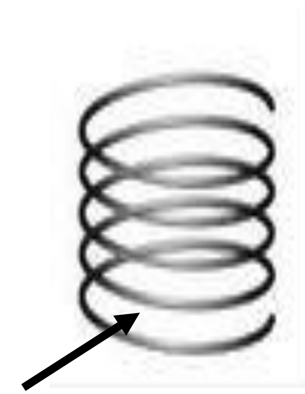
U: A Closed Stokes line integrals

of not-exact differentials (δ M) is never zero!

Integral along path AB is not equal to integral along path BA (**Non-equilibrium**)



$$\oint \delta M = \Delta M \neq 0$$



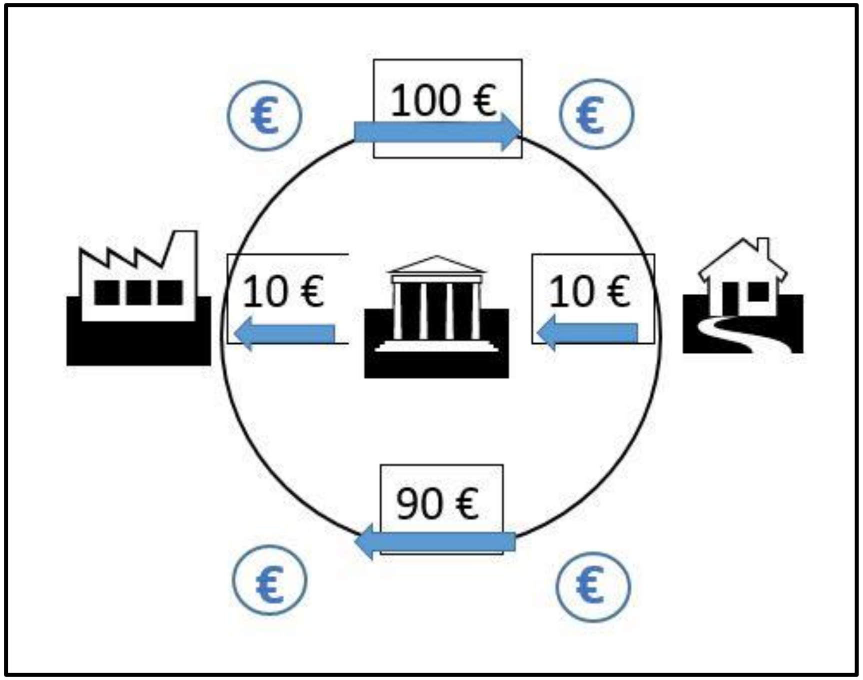
Δ M spiral

Example: magnetic field, vortex field: High, Low in weather.

Accounting

Neoclassical flow model

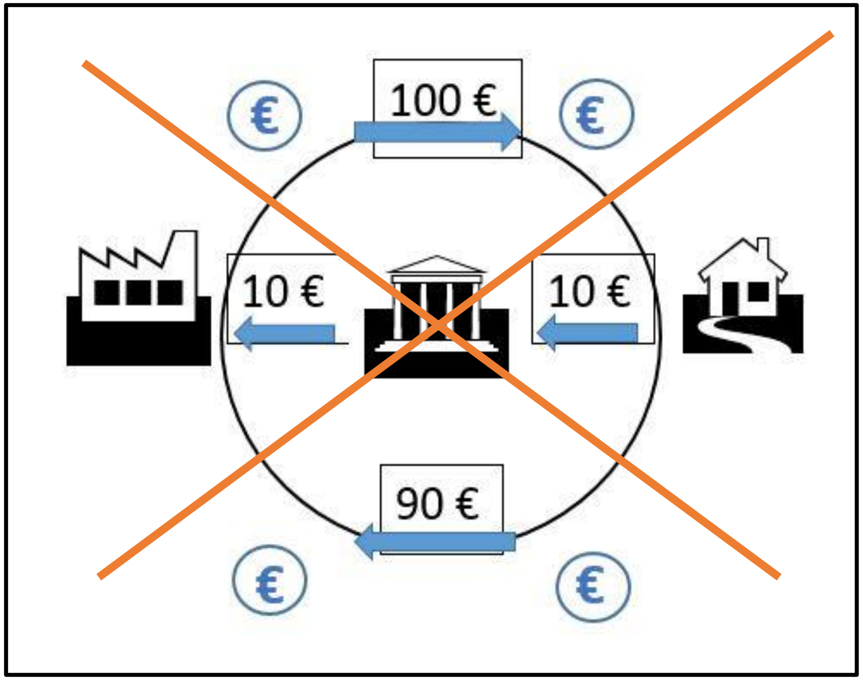
A household (H) works in industry (In) earning 100 € per day and spending 90 € for food and goods. The surplus is 10 € per day.



Income flows from industry to households and consumption costs flow back to industy. The surplus flows to the bank and back to industry for investments.

Neoclassical flow model

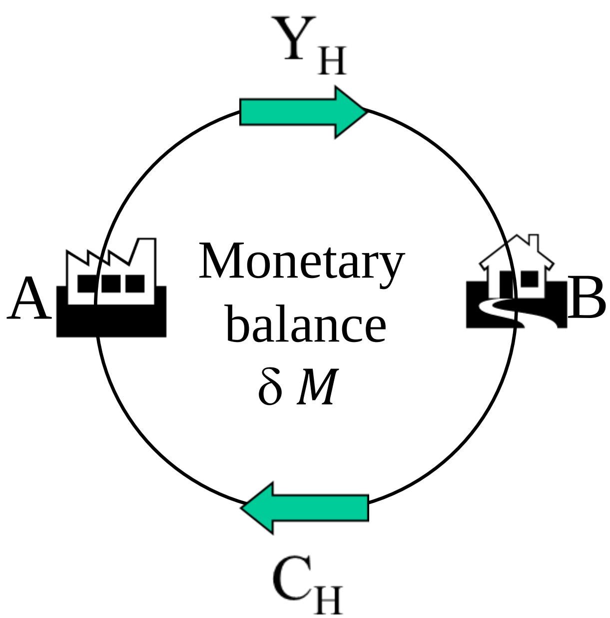
A household (H) works in industry (In) earning 100 € per day and spending 90 € for food and goods. The surplus is 10 € per day.



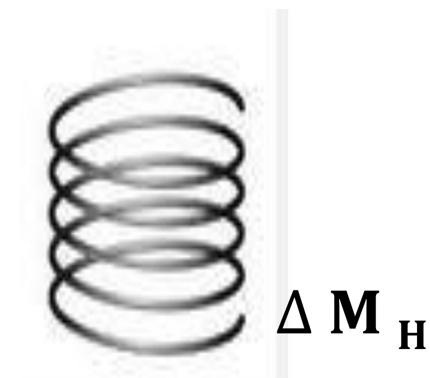
Imagine: Industry pays 100 € and receives only 90 € as consumption costs.
The next day industry must borrow 10 € from the bank to pay the income again!
This model does not work for industtry! **The neoclassical flow model is invalid!**

An **unbalanced** account is a closed **Stokes** line integral

A household (H) works in industry (In) earning 100 € per day and spending 90 € for food and goods. The surplus is 10 € per day.



Y_H	=	100	€
C_H	=	-90	€
ΔM_H	=	10	€



spiral

Stokes: $\oint \delta M = Y_H - C_H = \Delta M_H$

Luca Pacioli (1494): Double-entry accounting

A household (H) works in industry (In) earning 100 € per day and spending 90 € for food and goods. The surplus is 10 € per day.

(monetary units: €) *(naturally: energy units, kcal, MJ)*

Y_H =	100	€		W_H =	-100	€
C_H =	-90	€		G_H =	90	€
ΔM_H =	10	€		ΔP_H =	-10	€

monetary account + productive account = 0

The monetary account measures the productive account (in €)

Double-entry accounting in Stokes integrals

A household (H) works in industry (In) earning 100 € per day and spending 90 € for food and goods. The surplus is 10 € per day.

(monetary units: €) *(naturally: energy units, kcal, MJ)*

$$\oint \delta \boldsymbol{M} + \oint \delta \boldsymbol{L} = \mathbf{0}$$

The monetary account measures the productive account (in €)

Double-entry accounting – the basis of economics for 500 years

The Laws of Economics

Econophysics: The laws of Macro-Economics

$$\oint \delta \mathbf{M} = - \oint \delta \boldsymbol{L}$$

Pacioli law in integrals

1. law: $\delta \mathbf{M} = \mathbf{d\,K} - \delta\, \mathbf{L}$

Output = Capital Labour

Differential balance

2. law: $\delta \mathbf{M} = \lambda\ \mathbf{d\,F}$

Existence proof of the production function F

Econophysics: The laws of Macro-Economics

$$\oint \delta \mathbf{M} = - \oint \delta \boldsymbol{L}$$ *Pacioli law*

1. law: $\boldsymbol{\delta}\,\mathbf{M} = \mathbf{d}\,\mathbf{K} - \boldsymbol{\delta}\,\mathbf{L}$ *Differential balance*

Output = Capital Labour

2. law: $\boldsymbol{\delta}\,\mathbf{M} = \boldsymbol{\lambda}\;\mathbf{d}\,\mathbf{F}$ *Existence proof of the production function F*

The 2. law replaces the neoclassical Solow equation;

$\delta\,Y = \lambda\;\; d\,F$ instead $Y = A\,F\,(K, N)$

The Solow model is valid only for constant $\lambda = A$.

The fundamental laws of Economics

monetary units	energy units
$\oint \delta M = - \oint \delta L$	$\oint \delta Q = - \oint \delta W$

1. law: $\boldsymbol{\delta M = dK - \delta L}$ $\boldsymbol{\delta Q = dE - \delta W}$

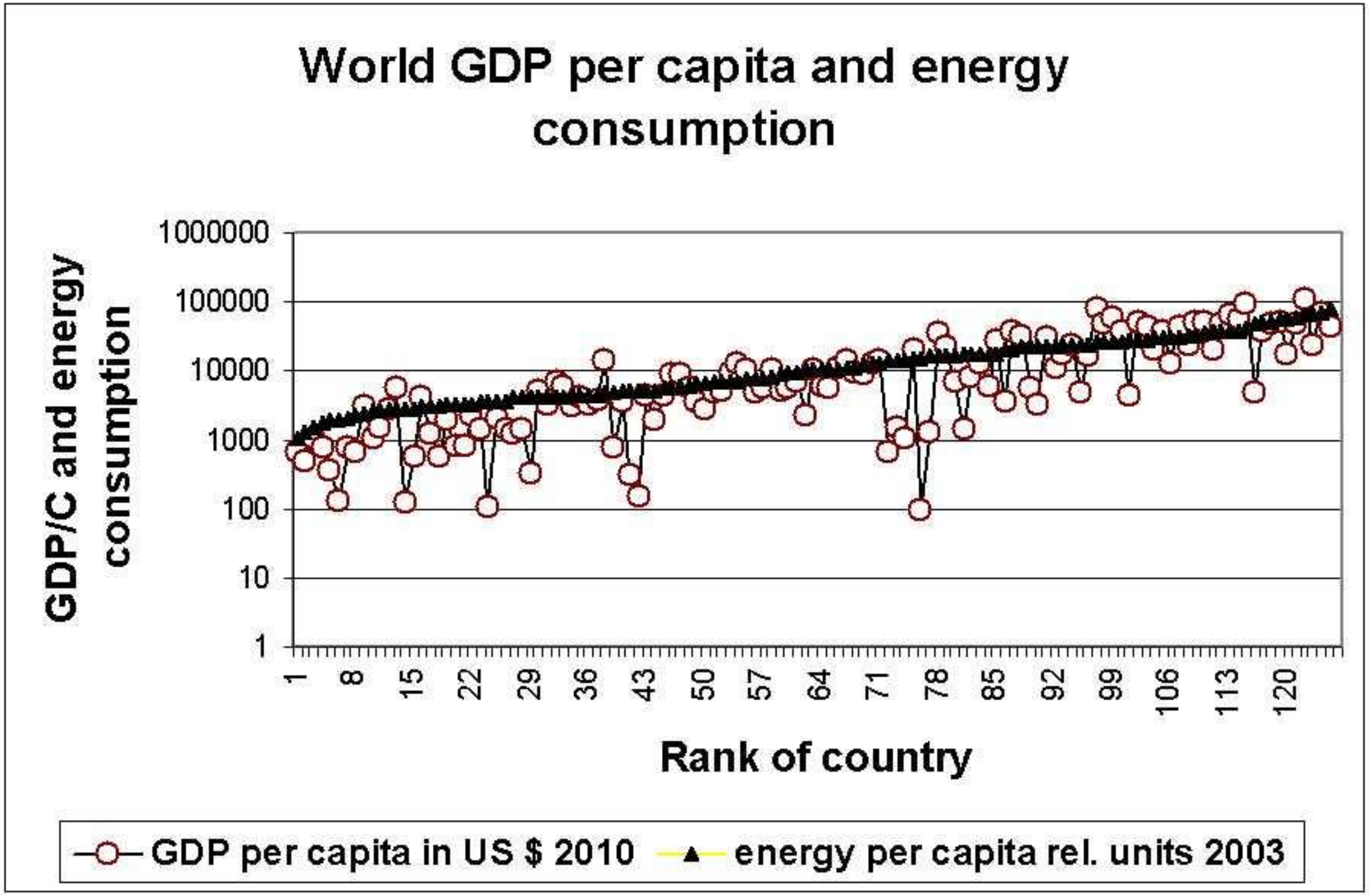
2. law: $\boldsymbol{\delta M = \lambda\ dF}$ $\boldsymbol{\delta Q = T\ dS}$

The structural identity of economics and thermodynamics

Symbol	**Economics**	**Unit**		**Symbol**	**Thermodynamics**	**Unit**
M	Profit, loss	€, $, £. ¥	↔	**Q**	Heat	kcal, kWh
K	Capital	€, $, £. ¥	↔	**E**	Energy	kcal, kWh
W	Wealth	€, $, £. ¥	↔	**H**	Enthalpy	kcal, kWh
P	Production, Labour	€, $, £. ¥	↔	**W**	Work	kcal, kWh
λ	Mean capital	€, $, £. ¥	↔	**T**	Mean energy	kcal, kWh
F	Production function	-	↔	**S**	Entropy	-
N	Number	-	↔	**N**	Number	-
p	Price per item	€, $, £. ¥	↔	**p**	Pressure	kcal / m^3
V	Volume, amount	-	↔	**V**	Volume	m^3
L	Lagrange function	€, $, £. ¥	↔	**F**	Free energy	kcal, kWh
L*	LeChatelier function	€, $, £. ¥	↔	**G**	Free Enthalpy	kcal, kWh

Table I Corresponding terms in economics and thermodynamics

The temperature (λ) of an economic/social system:

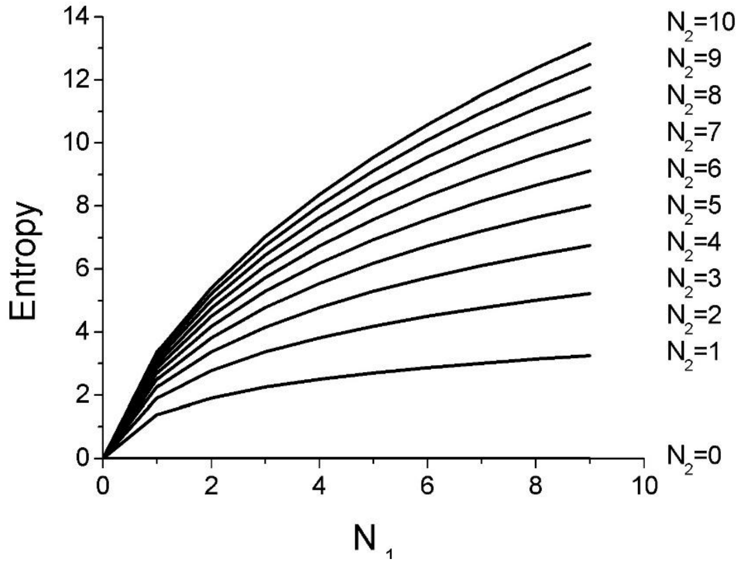


GDP per capita and energy consumption per capita

Production Function and Entropy

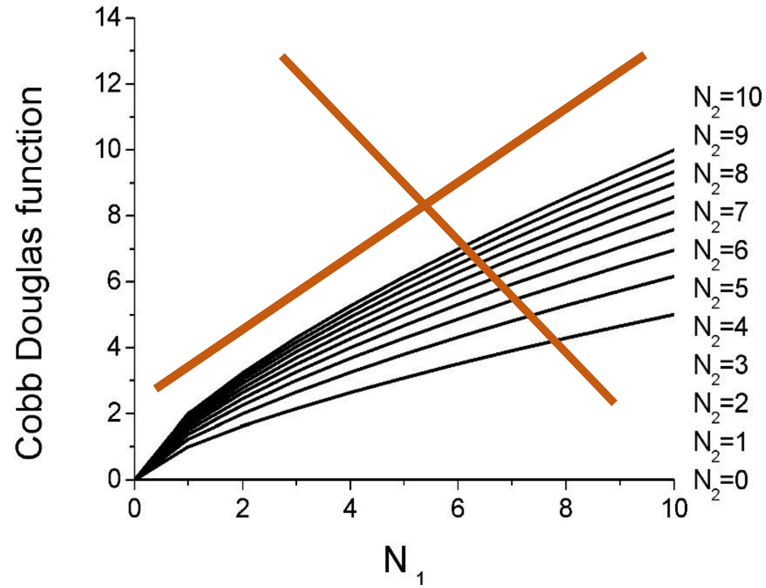
Entropy replaces the Cobb-Douglas production function

<u>S : Shannon Entropy</u>
(Georgescu-Roegen)



$$S/N = -\ln \{ x^{x} y^{y} \}$$
$$= -\{ x \ln x + y \ln y \}$$

<u>F : Cobb Douglas</u>
(binary system)



$$F/N = \{ x^{\alpha} y^{\beta} \}$$
$$1 = \alpha + \beta$$

Entropy S = ln p is the link between macro- and microeconomics

Entropy and Disorder

$$\delta W = d E - T \, d S$$

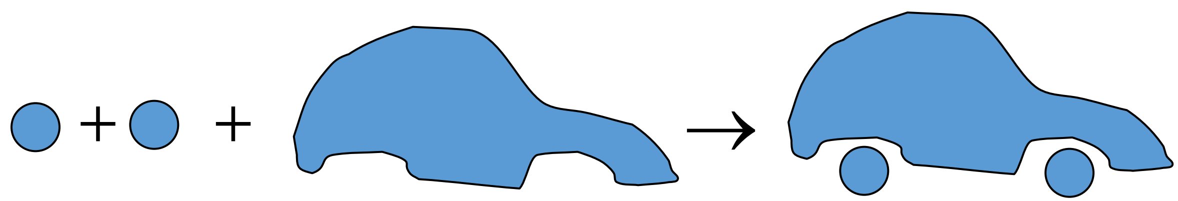
A light breeze (E) in a park will easily empty a paper basket and generate disorder (S). The paper will never come back into the basket.

But a janitor may work and sweep the paper together and put it back into the basket. Work (W) reduces entropy: Work is ordering!

Entropy and Work/Production/Labour

$$\delta L = dK - \lambda\, dF$$

Production (δL) is ordering, entropy reduction ($- dF$)

Production: 

Brain work: g+i+r+r+n+o+d+e $\rightarrow$ ordering

Production costs (δL) depend on the standard of living (λ) of a country

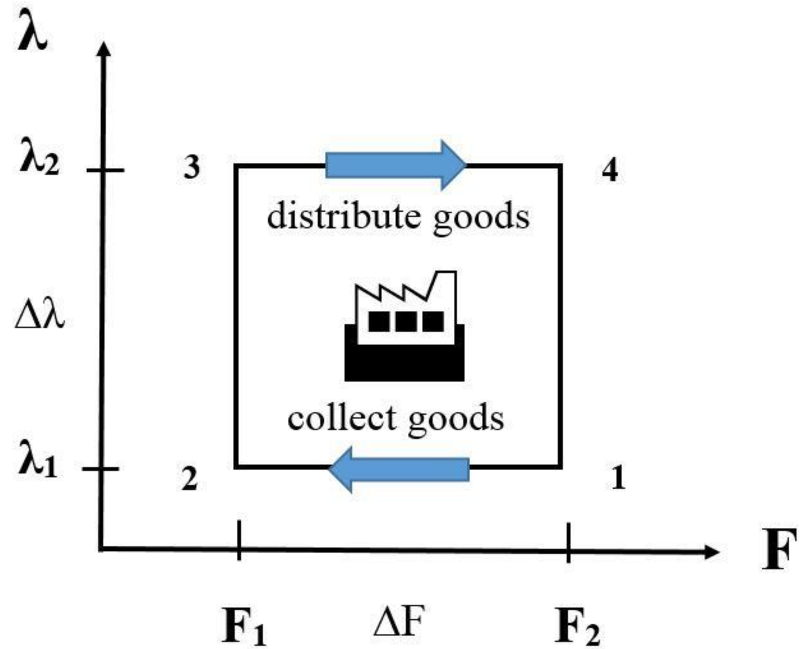
Production and Growth

<u>Carnot cycle</u> in motors and production circuits

$$\oint \delta Q = \oint T \,\mathrm{d}\, S$$

$$\oint \delta M = \oint \lambda \,\mathrm{d}\, \mathrm{F}$$

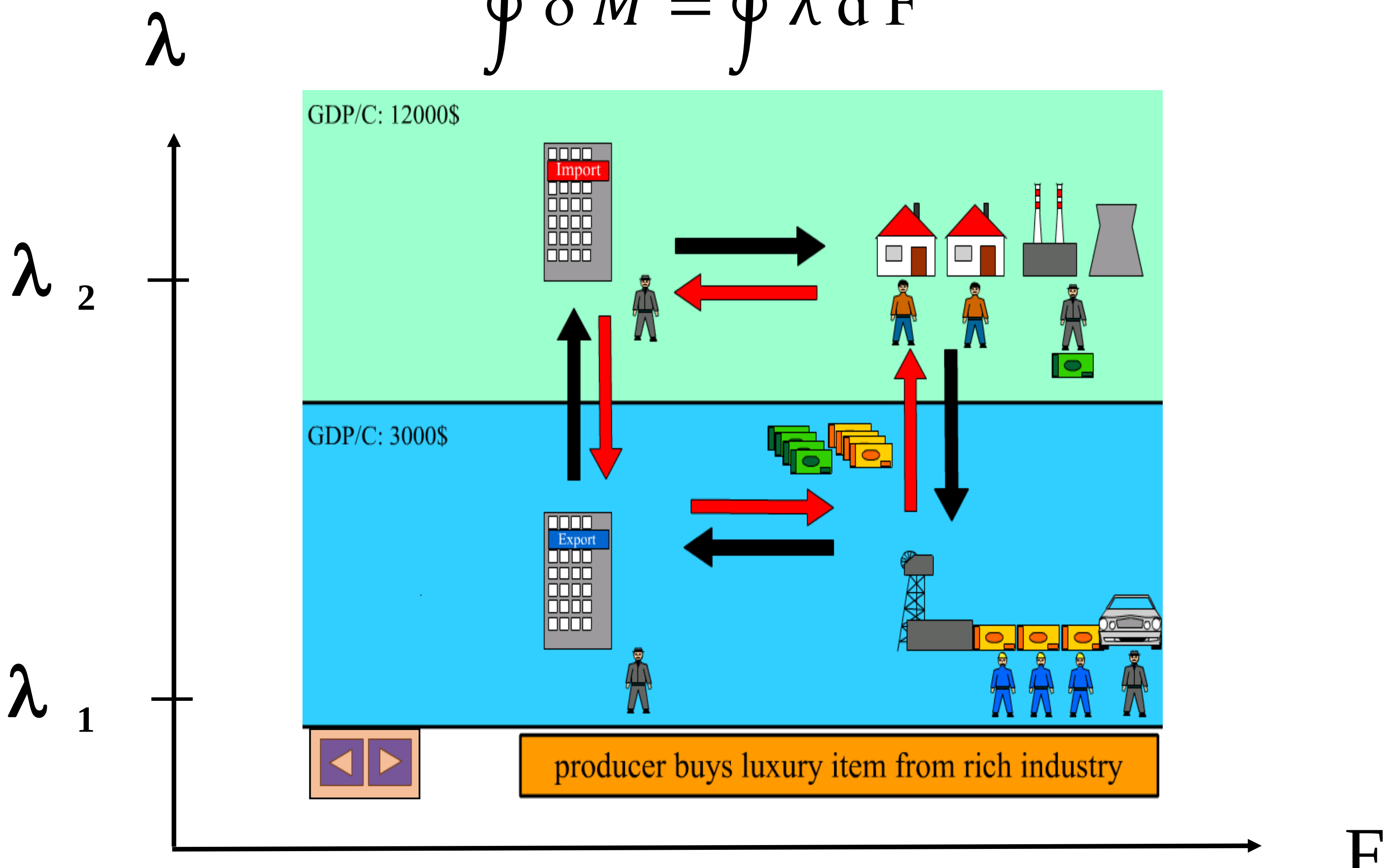
Motor



Production circuit

The mechanism of production (Carnot process)

$$\oint \delta M = \oint \lambda \, d F$$



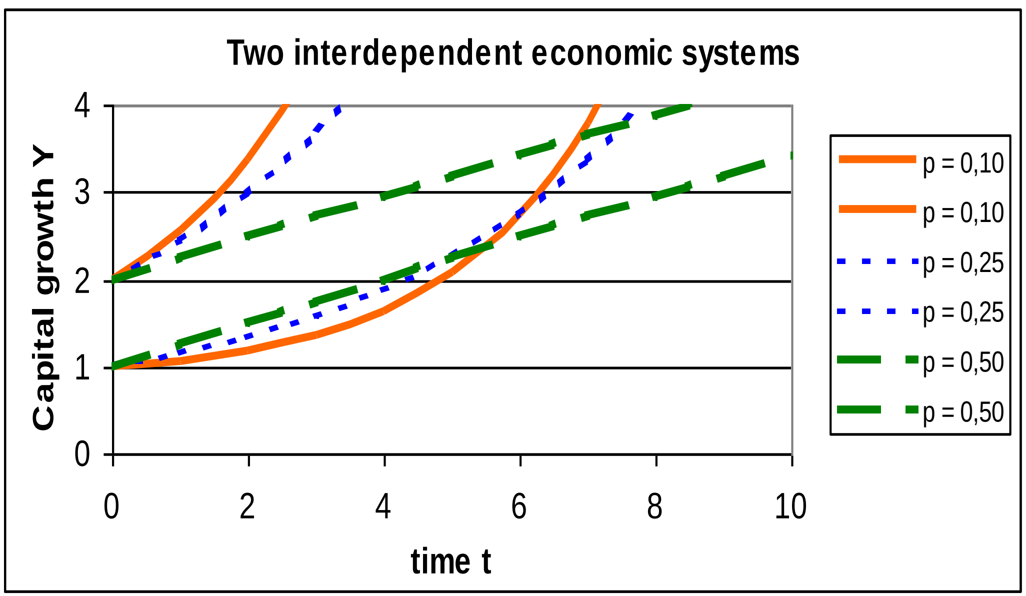
Production of coal in SA and trade with EU

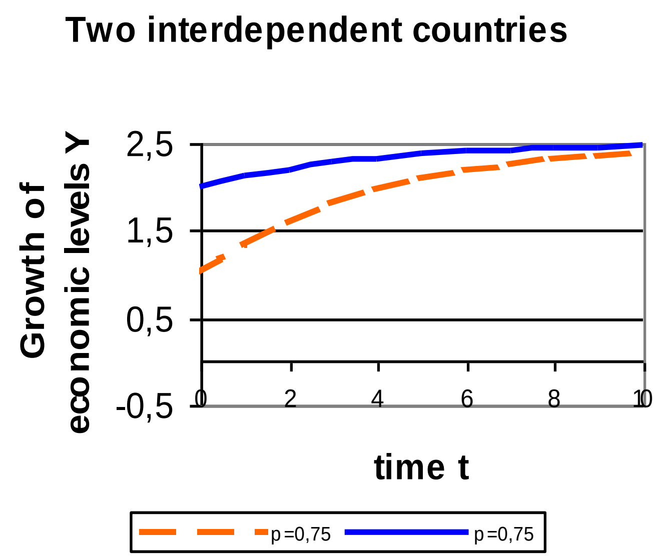
Economic growth: Distribution of profits

$$d\lambda_1(t) = \quad p \; (\lambda_2 - \lambda_1)\, d\alpha\, t$$

$$d\lambda_2(t) = (1-p)\, (\lambda_2 - \lambda_1)\, d\alpha\, t$$

p : distribution to lower side



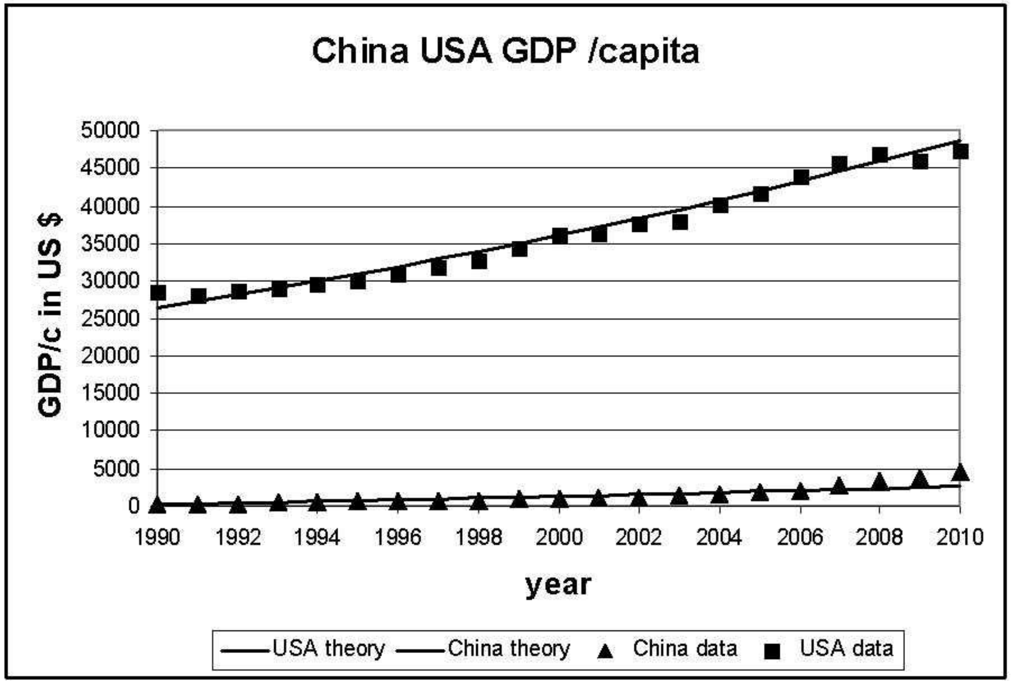


Growth: $0 < p \leq 0{,}5$

Stagnation: $p = 0{,}75$

Economic growth by international trade

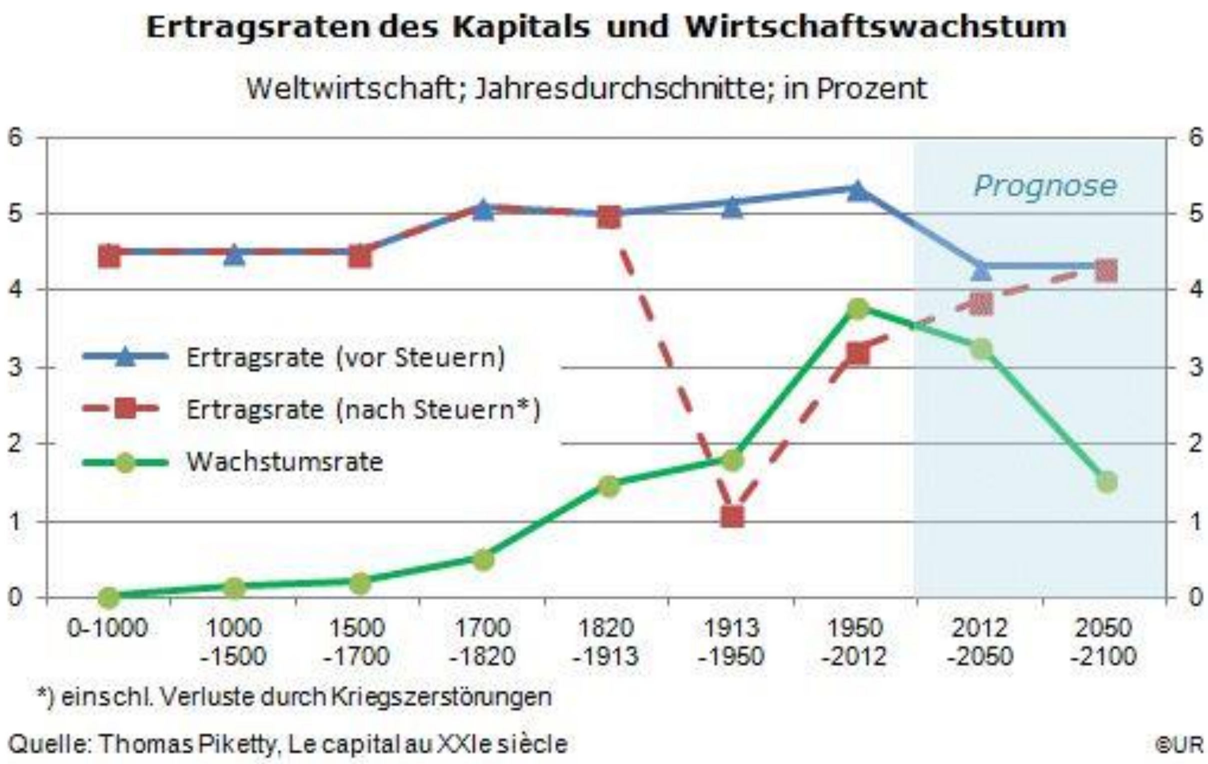
Growth by international trade:



US - China 1990-2010

<u>Economic growth by trade</u>

Growth in the world: Labour: 3 % Capital 6 %



Data by Thomas Piketty

Wealth: combining Capital and Energy

Economics	Thermodynamics
Wealth: $W = K + P\,V$	$H = E + p\,V$
1. law: $\delta M = d\,W - V\,d\,P$	$\delta Q = d\,H - V\,d\,p$
2. law: $\delta M = \lambda\,d\,F$	$\delta Q = T\,d\,S$
$L^*(P, \lambda) = W - \lambda\,d\,F \rightarrow \max!$	$G = H - T\,d\,S \rightarrow \max!$

Conclusion

The new approach to economics by calculus, stochastic theory or chaos theory leads to results, that differ considerably from mainstream economics.

From the approach by calculus we learn:

1. The laws of macro-economics must be written in differential or integral form.
2. The Solow model of neoclassical economics must be replaced by the second law, $\delta M = \lambda \; dF$. The integrating factor λ is the standard of living, the GDP per capita or the energy consumption per capita.
3. The Cobb Douglas production function F must be replaced by the Shannon entropy.
4. Business is not a cycle, but a spiral that goes up (growth) or down (deficit).
5. Production is a two level cyclic Carnot process: buying cheap and selling expensive, like hot and cold in a motor, EROI >>1.
6. The production factors capital and labour correspond to energy and work. Economic laws may be given either in monetary or in energy terms. Mixing capital and energy is not **$Y \neq F(K, E, L)$** but **$W = K + PV$.**

Thank you for your attention

EROI, economic and political state

Two level industrial production: **EROI** $\varepsilon \sim (\lambda_2 / \lambda_1)$

a) **Capitalism**: High surplus is divided between rich and poor, 90 : 10
$\varepsilon = 9$: High prices, low wages, high surplus, strong market,
low unemployment, high economic efficiency, *exponential* growth
Example: *Industrial countries (USA, Germany)*

b) **Socialism:** The surplus is divided between rich and poor, **ε =** 75 : 25
$\varepsilon = 3$: Lower prices, higher wages, less surplus, less strong market
higher unemployment, less exponential growth
Example: *Industrial countries*, *(France)*

c) **Rural production:** Without industrial production the surplus is small.
$\varepsilon \rightarrow 1$: Low prices, low wages, weak markets, slow economic growth,
rural seasonal employment, low efficiency
Example: Rural countries, *(many African countries: electrify Africa!)*

d) **Communism:** $\lambda_2 = \lambda_1$: capital is included in the proletarian class. $\varepsilon = 1$:
Low prices, low wages, markets crash. no growth, no unemployment
Example: *Communist countries (former USSR block countries)*

May we mix capital and electomagnetic energy?

$Y = F(K, E, L)$? No!

Thermodynamics introduces electomagnetic fields D, E, H, B by

$\delta W = (- B\, d H - E\, d D)\, V$

$\delta Q = d E + p\ d V + (D\, d E + H\, d M)\, V$

If we assume a corresponding terms in economics, we obtain

$\delta Y = d K + P\ d V + (D\, d E + H\, d M)\, V$

But so far the meaning of D, E, H, M in economics is unknown!

Economics: Calculus, Stochastic Theory, Chaos Theory

Calculus

1. 1. and 2. law of economics
2. Production and trade
3. Economic growth

Stochasic Theory

1. Heterogeneous agents
2. Financial markets, financial crisis
3. Networks
4. Game theory, cooperation, competition

Chaos Theory and non-linear differential equations

1. Order - disorder
2. Turbulence, chaos
3. Fractals

Outlook: Calculus based Economics and Social Sciences

Economics

1. Production and trade
2. Economic growth
3. Income distributions; How much should a manager earn?
4. Financial markets, financial crisis

Societies

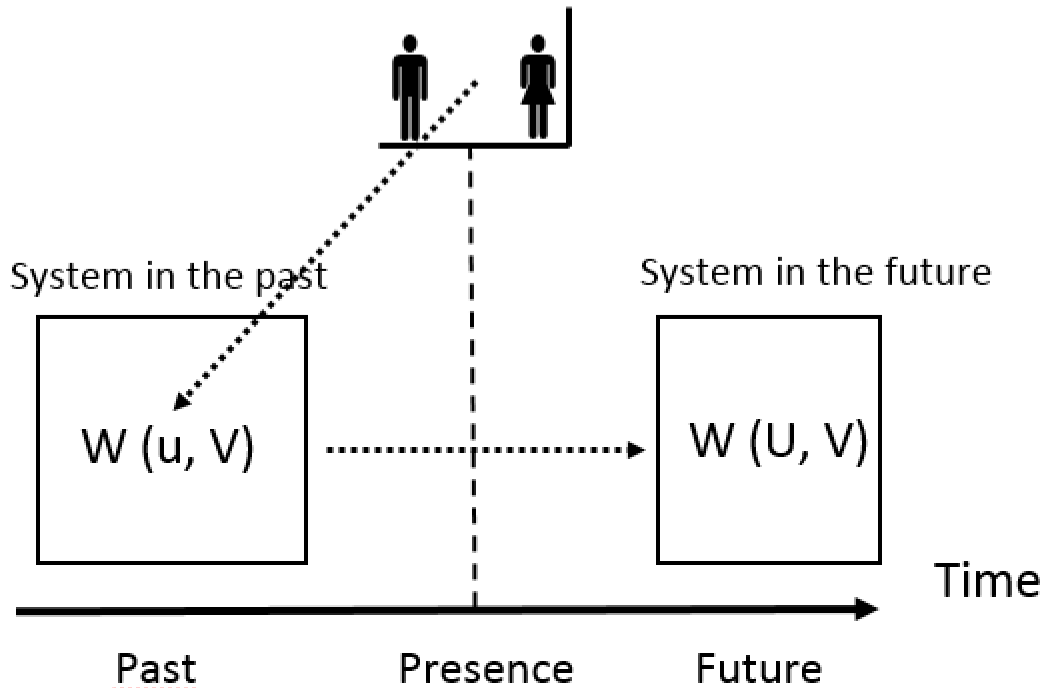
1. Homogeneous societies: state, army, church, companies
2. Phases: collective, individual, global, transitions: revolutions, crisis
3. Heterogeneous societies: cooperation, integration, segregation, aggression: Example: The war in Bosnia
4. Public decisions: The analysis of US elections
5. Marriage analysis: Mobility in Germany

Politics

1. Standard of living and political system; capitalism, socialism, communism
2. Oil and the Arab revolution
3. E U: From Marshall plan to integration and present problems: Greece
4. Migration and refugies in EU countries

Financial markets

Look back into the Future

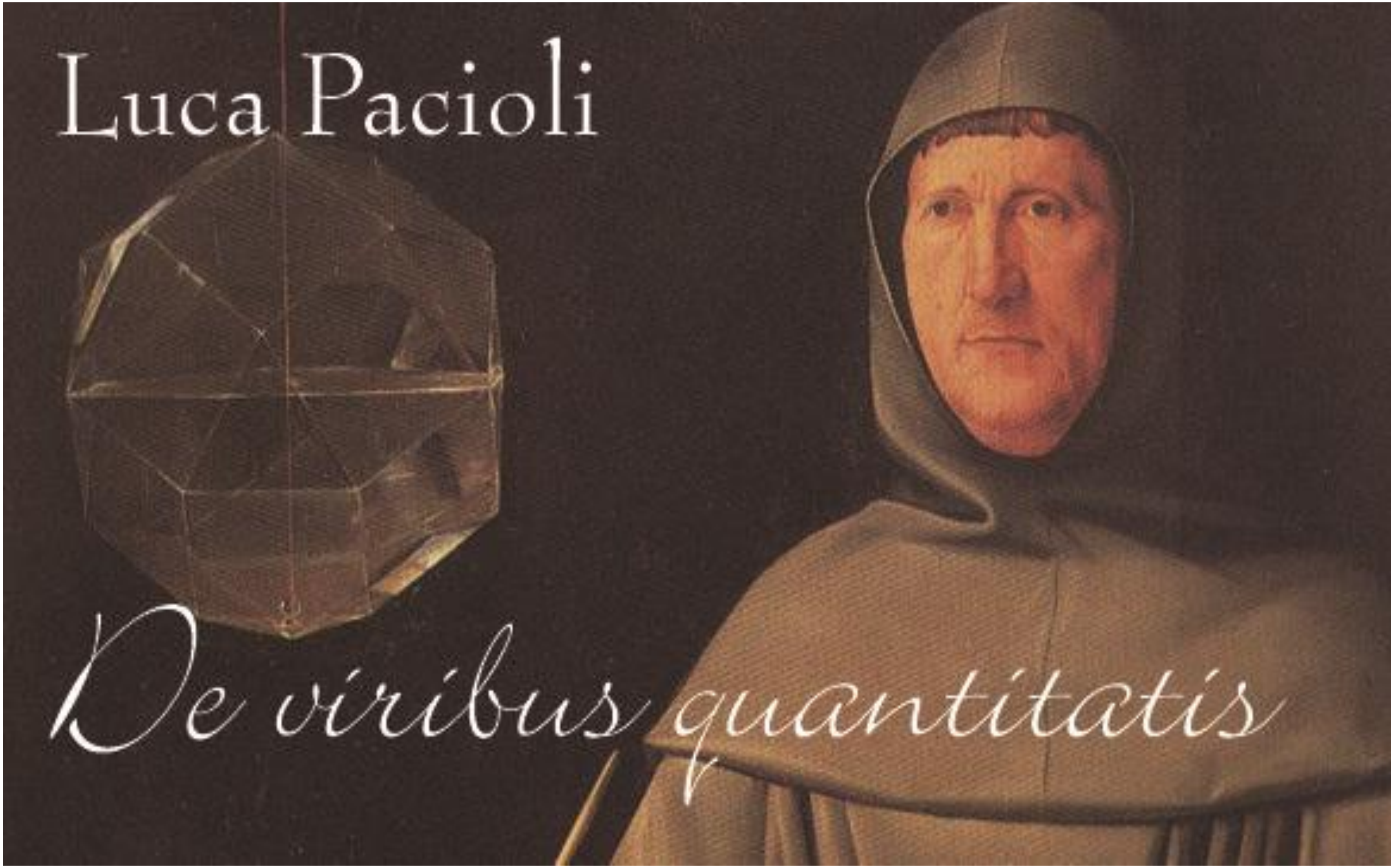


U: Unknown variable in the future System

V: valid variable in the future and past

u: former unknown variable now measurable in the past

W: Interactions between (u, V) in the past and between (U, V) in the future after u → U


Luca Pacioli
De viribus quantitatis

The fundamental laws of Economics

monetary units	energy units
$\oint \delta M = - \oint \delta L$	$\oint \delta Q = - \oint \delta W$

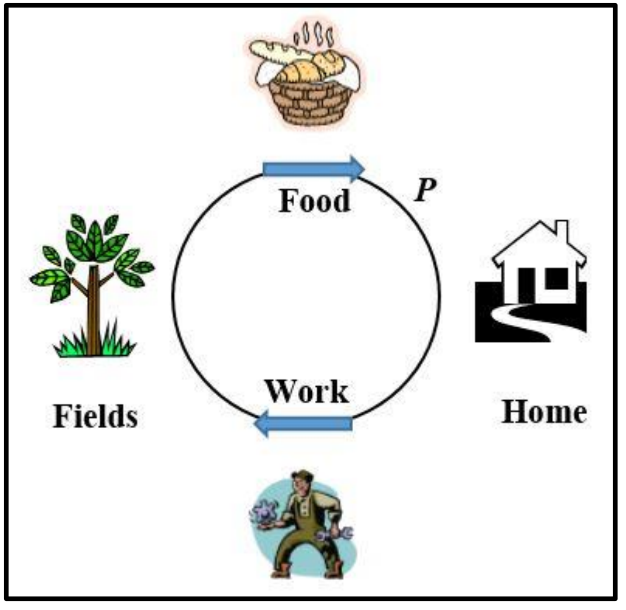
1. law: $\boldsymbol{\delta M = d K - \delta L}$ $\boldsymbol{\delta Q = d E - \delta W}$

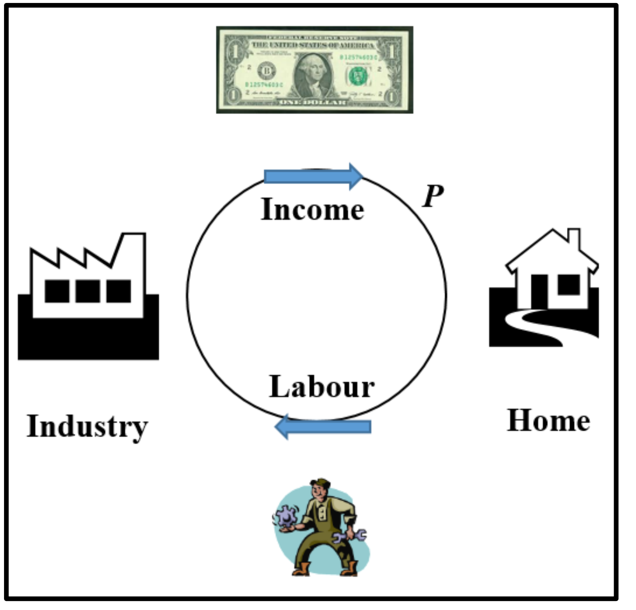
2. law: $\boldsymbol{\delta M = \lambda \;\; d F}$ $\boldsymbol{\delta Q = T \;\; d S}$

Oilprice: 

$\rightarrow$ 118 MJ= 33 kWh

Look back into the past: from energy to money





Natural production circuit

Food: kcal

Work: MJ

Capital: Fields

Modern production circuit

Income: €, $

Labour: €, $

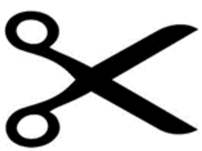
Capital: Industry

The dynamics of industrial production

Production is a two level (Carnot) process with λ_2, λ_1

Efficiency: $\eta \sim (\lambda_2 - \lambda_1)$ $\rightarrow$ max!

A running motor gets hotter, the efficiency grows with time!
A running economy gets richer, the efficiency,
the difference between capital and labour grows with time!



**The growing gap between rich and poor is the result of the dynamics of production.
(Carnot process)**

What determines the rising gap between rich and poor?

The distribution of annual surplus between the levels λ_2 and λ_1,
between rich and poor, between capital and labour.

Application: Finance

Banks invest in financial (d K) and productive (δ L) markets.

$$\oint \delta Q = \oint dK - \oint \delta L > 0!$$

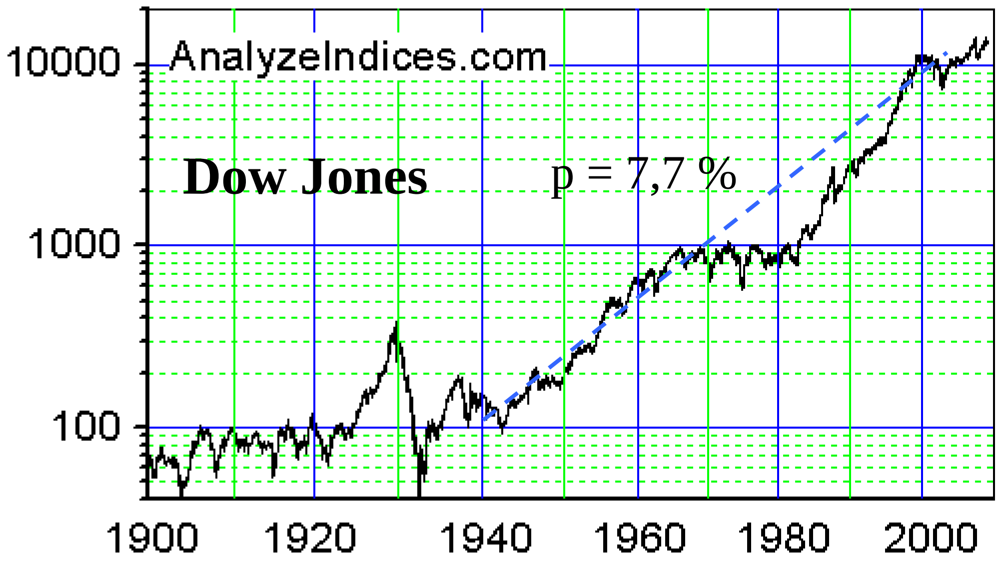
$$\begin{array}{cc} \uparrow & \uparrow \\ = 0 & \neq 0 \\ \downarrow & \downarrow \end{array}$$

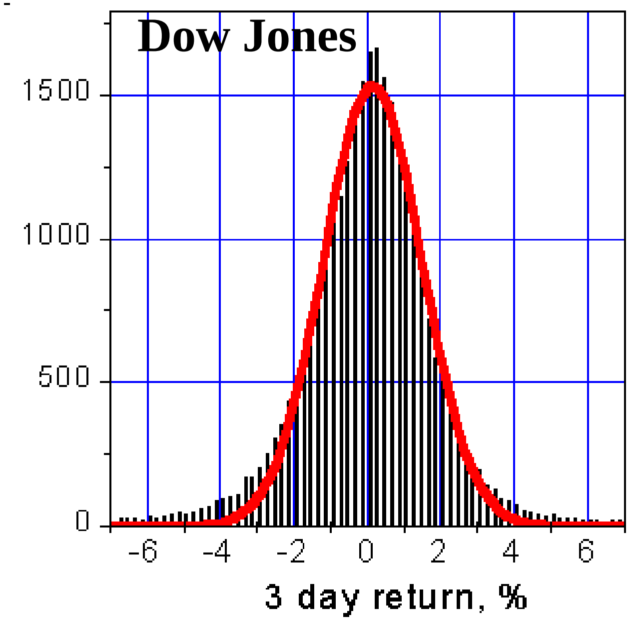
Only investments in labour/production (δ L) lead to economic growth

Capital (d K) by itself does not create capital!
Investing only in financial markets (d K) is like gambling or playing roulette

$$\oint \delta M = \oint dK - \oint \delta L$$

$$= \quad 0 \quad + \quad 7{,}7\ \%$$



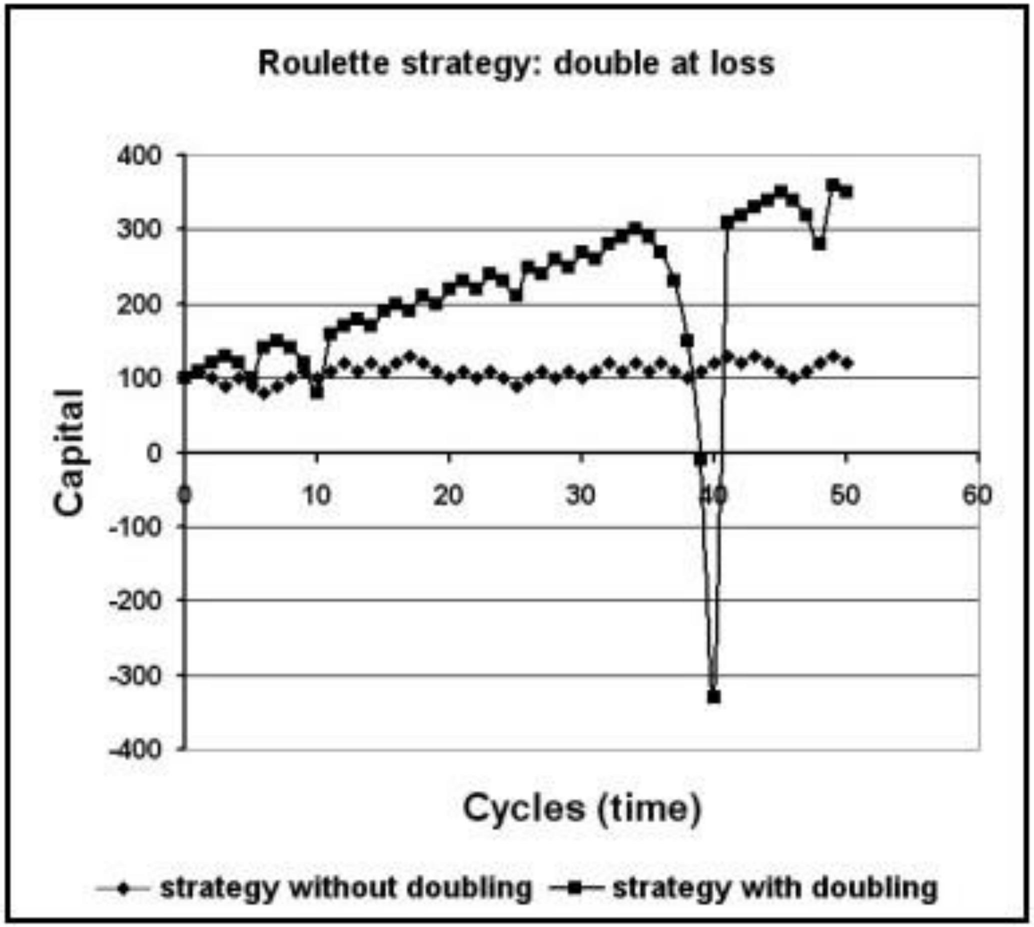


a) <u>- δ L</u>: <u>Long time</u> returns lead to growth in productive (stock) markets (7,7 % p. a for 60 y)

b) <u>d K</u>: <u>Short time</u> returns lead to symmetric volatility – no growth - in stock markets

Strategies in high risk finance

$$\oint dK = 0!$$



Creation of bubbles

Results

Double entry accounting: $$\oint \delta M = - \oint \delta L$$

Macroeconomics:

1. law: $\delta M = d K - \delta L$

2. law: $\delta M = \lambda \ d F$

Trade, Production: $\Delta M = (\lambda_2 - \lambda_1) \Delta F$

Lagrange: $L = K - \lambda F$

Microeconomics: Lagrange: $L = K - \lambda \ln p \rightarrow \min!$

Shannon entropy: $F = \ln p = - N \{x \ln x + y \ln y\} = - N \ln \{x^x y^y\}$

Financial systems: $$\oint d K = 0$$

Production and finance: **-** L = prod. market **+** λ financ. market $\rightarrow$ max!

Probability and constraints: **-** L = constraints **+** λ probability $\rightarrow$ max!

Systems: Social, Politics - L = order + λ disorder $\rightarrow$ max!

Lagrange function of systems: $L = V + \lambda U$

Lagrange:	L	=	E	+	λ	ln P	$\rightarrow$ maximum!
Probability:	L	=	constraint	+	λ	probability	$\rightarrow$ maximum!
Thermodynamics:	L	=	enthalpy	+	λ	entropy	$\rightarrow$ maximum!
Laws:	L	=	order	+	λ	disorder	$\rightarrow$ maximum!
System:	L	=	perfect	+	λ	imperfect	$\rightarrow$ maximum!
Reality:	L	=	ideal	+	λ	real	$\rightarrow$ maximum!
Complexity:	L	=	simple	+	λ	complex	$\rightarrow$ maximum!
Appearance:	L	=	uniform	+	λ	variety	$\rightarrow$ maximum!
Society:	L	=	collective	+	λ	individual	$\rightarrow$ maximum!
Behavior:	L	=	planned	+	λ	spontaneous	$\rightarrow$ maximum!
Games:	L	=	strategy	+	λ	defect	$\rightarrow$ maximum!
Welfare:	L	=	fair	+	λ	unfair	$\rightarrow$ maximum!
Common Law:	L	=	right	+	λ	wrong	$\rightarrow$ maximum!
Art:	L	=	beautiful	+	λ	ugly	$\rightarrow$ maximum!
Music:	L	=	harmony	+	λ	disharmony	$\rightarrow$ maximum!
Health:	L	=	healthy	+	λ	sick	$\rightarrow$ maximum!
Politics:	L	=	hierarchy	+	λ	democracy	$\rightarrow$ maximum
Economy:	L	=	capital	+	λ	chance	$\rightarrow$ maximum!

Weather

Identification of elements U and V: $U \neq V$

U: fluctuations

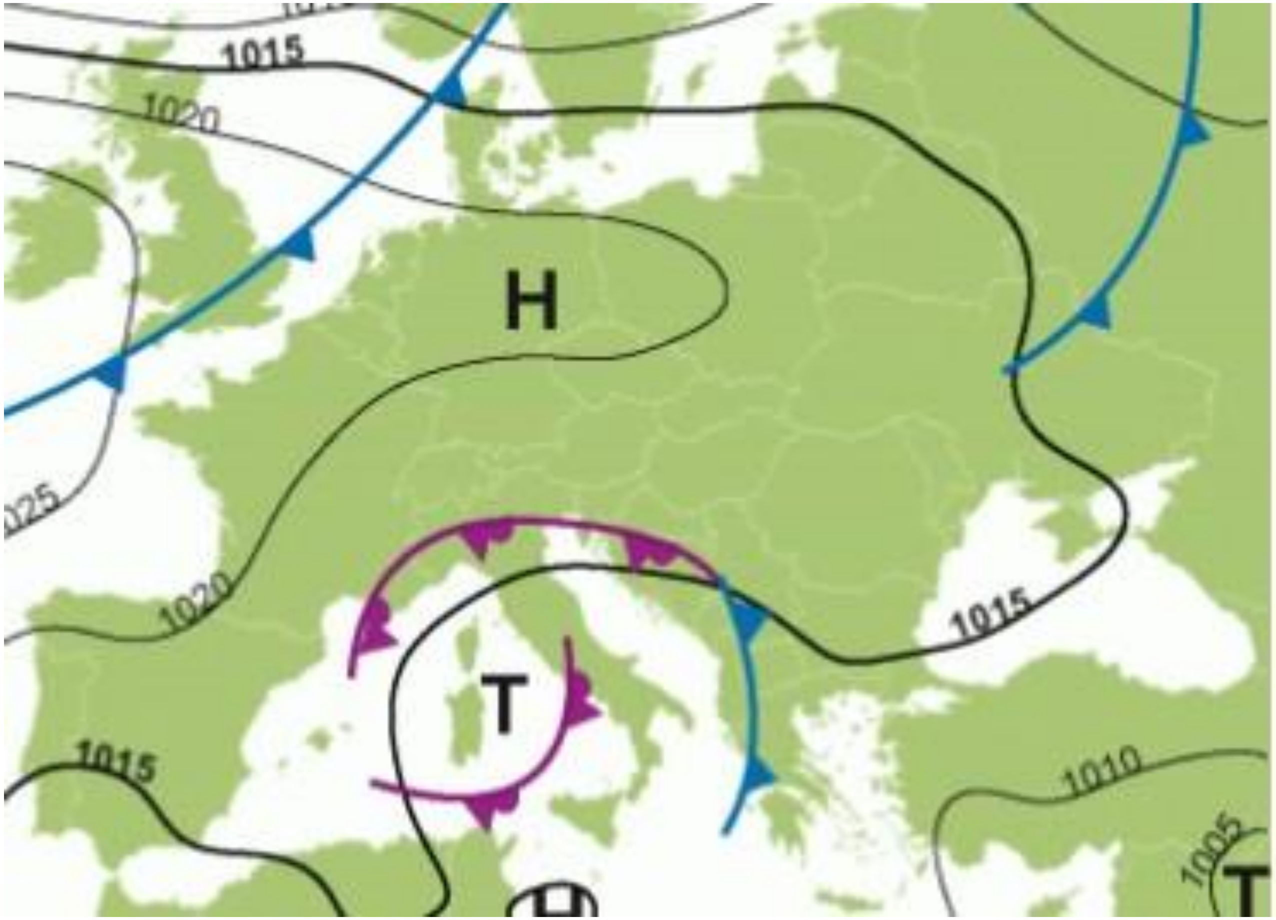
V: conservative variables T, p

Weather predictions are most difficult and can be done only at stable weather conditions with low fluctuations $u \rightarrow 0$:

$$(u \rightarrow 0) \rightarrow (U \rightarrow 0)$$

$$W(0, V) \rightarrow W(0, V)$$

Fluctuations require elaborate computer simulations



Financial state of Europe

<u>The Stokes integrals lead to</u>

<u>Economics (capitalism)</u> with two **separate** levels $\boldsymbol{\lambda}_1$ and $\boldsymbol{\lambda}_2$:

Companies:	capital and labor
Banks:	investors and savers
Societies:	rich and poor
Economies:	1. world and 2. world

<u>Carnot process</u> with two **separate** temperatures T_1 and T_2:

Motors	hot and cold
Refrigerators	hot and cold
Heat pumps	hot and cold
Generators	hot and cold

<u>Econophysics</u>:

Motor, generator → **productive circuit, company**
Heat pump, fridge → **monetary circuit, bank**

The Carnot process of companies and motors

$$\oint \delta M = \oint \lambda \, d F = - \oint \delta P$$

Capitalism and the **Carnot cycle** of motors, both run on the same fuel: **oil**.

Entropy: the natural production function

<u>Shannon</u>: $d\,S = -\,d\,N\,\Sigma\,(p_i)\ln(p_i) \geq 0$

If we open a perfume bottle, the perfume will leave the bottle to occupy a more probable state and it will never return into a less probable state in the bottle.

Examples of model equations:

Thermodynamics

The first law of thermodynamics:

$$\delta Q = d E - \delta W$$

V: the conservative term *energy* is written as exact differential: d E

U: the not-conservative terms *heat* and *work* are written as not-exact differentials: δ Q, δ W.

Neoclassical Macroeconomics

The Solow model:

$$Y = F(\lambda, K, L) = \lambda F(K, L)$$

V: the ex ante term *production function* is **not** written as exact differential: d F

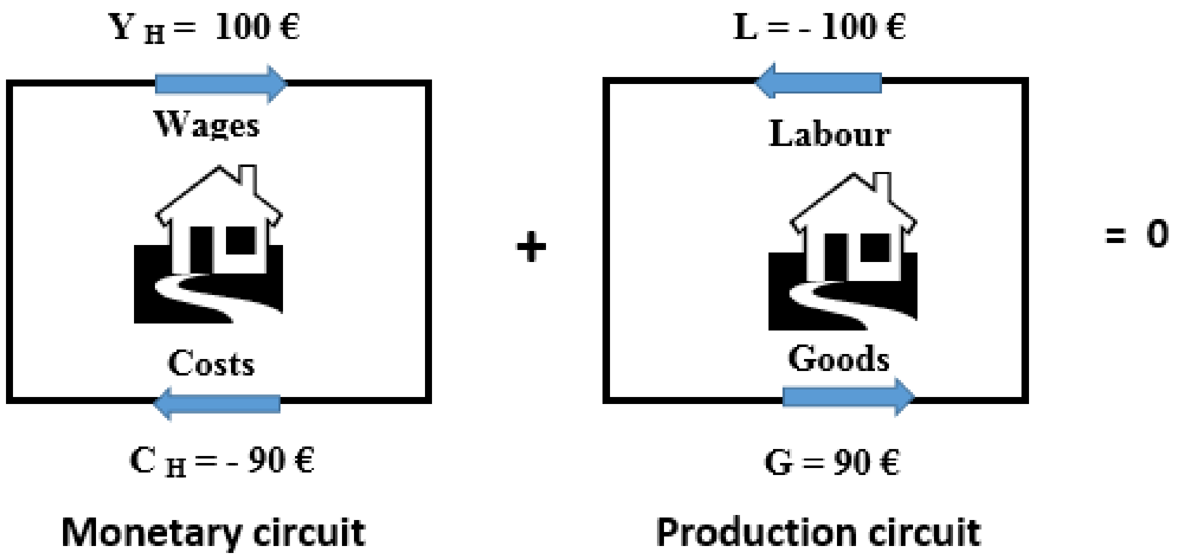
U: the ex post term income is **not** written as not-exact differential: δ Y

Neoclassical theory does not follow the rules of the future model

Double-entry accounting: Luca Pacioli (1494)

A household (H) works in industry (In) earning 100 € per day and spending 90 € for food and goods. The surplus is 10 € per day.

(monetary units: €) *(naturally: energy units, kcal, MJ)*



Double-entry accounting – the basis of economics for 500 years

<u>Neoclassical Macroeconomics</u>

The Solow model:

$$\mathbf{Y = F(\lambda, K, L) = \lambda\ F(K, L)}$$

Y : output, income (ex post)
F : production function (ex ante)
K : capital (ex ante)
L : labour (ex post)
λ : factor of technology

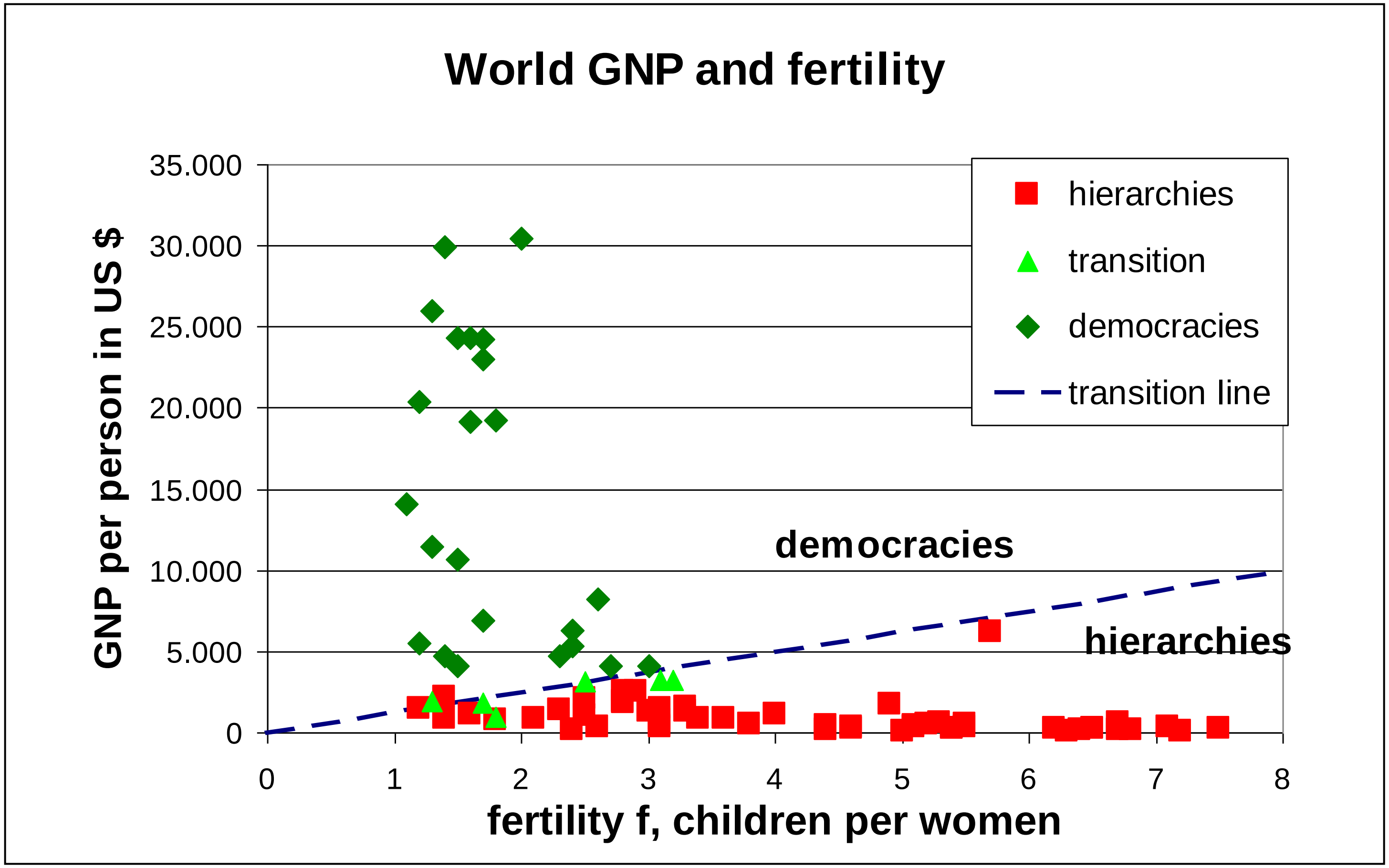
V: the <u>ex ante</u> term *production function* is **not** written as
<u>exact differential</u>: d F
U: the <u>ex post</u> term income is **not** written as
<u>not-exact differential:</u> δ Y

The Solow model does not follow the rules of the future model

Y: only ex post known, cannot be equal to F: ex ante known: **Y ≠ F**

The future model contradicts the Solow model

<u>The dynamics of capitalism in the world</u>



GdP per capita and fertility for 90 countries

The fundamental laws of Economics

monetary units	energy units
$\oint \delta M = - \oint \delta L$	$\oint \delta Q = - \oint \delta W$

1. law: $\boldsymbol{\delta M = dK - \delta L}$ $\qquad$ $\boldsymbol{\delta Q = dE - \delta W}$

2. law: $\boldsymbol{\delta M = \lambda \; dF}$ $\qquad$ $\boldsymbol{\delta Q = T \; dS}$

$$\boxed{\textbf{Oil price: } P = K / E = [\text{US } \$ / \text{kWh}]}$$