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MEASURING SPATIAL EXTENSION OF ECONOMIC GLOBALIZATION

Abstract

Is the economy really globalizing? Economic globalization is not only characterized by increased trade flows but also by increased interweavement of trade flows. To analyze the evolution of globalization in different macro-geographic regions a new inequality measure based on a paradigmatic interpretation of Boltzmann's entropy will be applied.

Boltzmann's interpretation of entropy is based on disorder of a thermodynamic system. The greater the disorder within the system, the higher is the entropy of the system. The concept of thermodynamic entropy can be re-interpreted figuratively as risk of an economic system by creating an economy-genotypic risk inequality measure covering the spatial nature of globalization; the greater the disorder (i. e. equality) within the system, the lower the risk within the economic system. Due to the fact that thermodynamic systems are evolving naturally to the state of higher entropy, we can take the dualistic view that economic systems are evolving naturally to a state with lower risk. This leads finally to the enouncement of the Central Theorem of Globalization covering the spatial nature of economic globalization decisions. By substituting the pole of statistics variance (i. e. the mean) with the inequality measure, we get a measure of the risk level for the economic trade system, resulting in a statistics based interpretation of entropy. Therefore, by measuring the spatial concentration of trade flows, we get the risk of the trade flow matrix. By adding the concept of thermodynamic enthalpy to the economic system, we can also explain the presence of an eventual de-globalization trend (i. e. an increased order of the economic system corresponding to an increased inherent economic risk of the system). This

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matches the fundamental economic law that a higher risk corresponds generally to a higher return.

The paper analyzes the WTO trade figures (type 1 globalization) between 2003 and 2009 with regard to the different evolution of globalization within the macro-geographic economic regions. The new economic interpretation of entropy allows not only to quantifying the globalization degree of an economic system, but with its genotypic nature, it also allows to give an explanation to the globalization phenomenon. In addition, it can also be applied to quantify the globalization level of FDI (Foreign Direct Investment, i. e. type 2 globalization) or to quantify the globalization level of migration flows (type 3 globalization) as well as to be applied to judge the risk of product composition of supply (or demand) of a national economy.

Key words:

Inequality, Entropy, Trade Flows.

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1. Introduction

Traditional statistics and concentration indexes lack of describing sufficiently the spatial extension and the effects of globalization; a systemized new approach has to be established. Hereafter a new statistical entropy-based inequality risk metric will be applied, defined according to [1]. The reason is twofold:

- the new measure is not a pure phenotypic indicator measuring the manifestation of an attribute, but it is a genotypic metric linked to the Central Theorem of Globalization, reflecting the underlying law of globalization evolution
- the so defined individual inequality measures can be aggregated within a single risk measure to the subsystems or to the entire system with one single figure measuring the interweavement of economy.

Hereafter, the globalization measure will be applied to the foreign trade matrix (table A2 of WTO).

2. Theoretical Background

In the following, we will apply the globalization measure according to appendix A [1] to foreign trade flows. Briefly, from the paradigmatic interpretation of thermodynamic entropy we can define risk as a dualistic view of order in an economic system, therefore the more order (i. e. inequality) that exists in an economic system the more risky the economic system (or vice versa, the more equality a system shows the less risk it presents). Take, for example, the big difference in welfare among different regions being potentially a social bomb. The greater the inequality compared to the riskless state with inequality $\psi_{XY} = 1$, the larger the risk of an atomic element. Whereas in the here presented context inequality refers rather to a single element of a system, the concept of risk can be aggregated to the entire system by defining risk as the second momentum of the inequalities compared to the attractor 1 (a brief introduction to the algorithm is shown in the appendix A). This definition is very similar to the statistics variance with the exception that the pole is not the mean but the attractor. We can interpret this risk metric as a statistical entropy measure of the system. According to the Pigou-Dalton Transfer Principle and the interpretation of entropy law, we can enounce the following

Minimum Risk Principle:

An economic system has the latent tendency to evolve into a state with more equality corresponding to a state with a lower risk.

2.1. Risk as a Measure for Globalization

Let us go a step further by applying the Minimum Risk Principle to analyze the foreign trade (corresponding to type 1 globalization according to [1]), i. e. the material globalization dealing with physical flows of a product α, applying to which country exports to which countries, and which country imports from which countries represented by the trade matrix $T^{\alpha}=[t^{\alpha}_{XY}]$. For a trade system we can build the market share vector of an economy and calculate the inequality measure ψ_{XY} as the market share of X in Y compared to the overall market share of X. The overall market share of X for e.g. type 1b globalization (globalization of specialties according to [1]) will most probably be similar to the factors proportion according to Heckscher-Ohlin. For economy X we can calculate the risk $r_X(\psi_{XY})$ of its portfolio of activities in the countries Y. The lower the inequalities in each country Y the lower the risk value and therefore the higher the globalization degree of the country X. If the inequality is $\psi_{XY}=1$ for all Y then country X has the same market share in all countries Y and its portfolio of trade-flows is proportional to the market composition according to its competitiveness. Due to the fact that a low risk corresponds to an even-distribution we can now enounce [1] the

Central Theorem of Globalization (CTG):

The lower the risk of an economy or the whole economic system, the more globalized the present economy or the whole economic system for the product under evaluation. Hence, a globalized economic system is less risky.

as well as the

Corollary to the CTG:

Generally, according to the Minimum Risk Principle, systems have the latent tendency to evolve to the state of lower risk. This means of course fueling of globalization because of exporting to other countries and with that decreasing inequality. Therefore the evolution of globalization can be explained with the concept of minimizing risk presented here.

The result of the CTG and its corollary is due to the built-in intrinsic forces of globalization and why globalization will take place assisted by new growth opportunities in newly emerging economic regions. We can consider the CTG and its corollary as the basic concept to explain that our economy will globalize naturally with the existing deregulation tendency. This risk metric is a genotypic measure, bearing the intrinsic law of economic globalization.

2.2. Maximizing Value Net of Risk

But entropy is not the sole governing physical law of thermodynamics. Indeed, if a transformation happens is determined by free enthalpy. The same is also applicable to economics [1]. By adding the concept of thermodynamic enthalpy to the economic system, we can also explain the presence of an eventual de-globalization trend (i. e. an increased order of the economic system corresponding to an increased inherent economic risk of the system). This matches the fundamental economic law that a higher risk corresponds generally to a higher return.

Minimizing risk is only one cardinal law (this law models the globalization extension), maximizing profit is the other cardinal one (this law models the final rational acting). Indeed, an economic actor is ready to accept a higher risk if finally it yields a higher profit. Globalization is extending the business scope to new geographic areas, and the aim is

- to increase the profit generation (explicit strategy of profit maximization), and at the same time
- it reduces the risk of the portfolio (implicit law of risk minimization).

The final governing principle of economic globalization is therefore risk deducted value maximization. With this principle we can explain the rational of any economic actor comprising MNE (Multi National Enterprises) and why glob-

alization happens independently of which globalization type 1 (material) and related subtypes (1a, 1b, 1c) or type 2a (financial participation by FDI). It explains why we can have at the same time in different economic regions a progression or a regression of globalization, intended as interweavement of trade network.

3. Methodological Approach

The upper part of table 1 shows the world trade flow matrix of the year 2009 (source WTO, Table A2) as well as, in the middle part, derived trade share measures of the geographic regions, and in the lower part, relative inequalities calculated according to appendix A.

Table 1

World trade matrix with inequalities and risk measure for 2009

Network of world merchandise trade by region (source: WTO International Trade Statistics, Table A2)

2009 t_{XY}	North Am A	SC Am B	Europe C	CIS D	Africa E	Middle E F	Asia G	Supply	p_X
A	**768.66**	**128.22**	**291.92**	**9.35**	**28.30**	**49.47**	**324.23**	1600.15	0.13
B	**114.82**	**119.96**	**89.85**	**5.83**	**12.99**	**11.33**	**95.59**	450.37	0.04
C	**365.93**	**74.65**	**3619.53**	**146.59**	**161.88**	**153.52**	**425.98**	4948.08	0.41
D	**23.39**	**5.10**	**238.89**	**86.85**	**7.20**	**14.32**	**62.78**	438.53	0.04
E	**65.68**	**9.25**	**148.84**	**1.26**	**44.91**	**11.51**	**85.27**	366.72	0.03
F	**60.30**	**4.62**	**75.81**	**3.66**	**33.65**	**106.78**	**356.96**	641.78	0.05
G	**627.27**	**95.48**	**640.53**	**57.43**	**101.60**	**163.41**	**1846.43**	3532.15	0.29
Demand	2026.05	437.28	5105.37	310.97	390.53	510.34	3197.24	11977.78	1.00
p_Y	0.17	0.04	0.43	0.03	0.03	0.04	0.27	1.00	

$p_{XY\infty}$	A	B	C	D	E	F	G		p_X
A	0.38	0.29	0.06	0.03	0.07	0.10	0.10		0.13
B	0.06	0.27	0.02	0.02	0.03	0.02	0.03		0.04
C	0.18	0.17	0.71	0.47	0.41	0.30	0.13		0.41
D	0.01	0.01	0.05	0.28	0.02	0.03	0.02		0.04
E	0.03	0.02	0.03	0.00	0.11	0.02	0.03		0.03
F	0.03	0.01	0.01	0.01	0.09	0.21	0.11		0.05
G	0.31	0.22	0.13	0.18	0.26	0.32	0.58		0.29
	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00

Ψ_{XY}	A	B	C	D	E	F	G		$r_X(\Psi_{XY})$
A	2.84	2.19	0.43	0.23	0.54	0.73	0.76		**0.87**
B	1.51	7.30	0.47	0.50	0.88	0.59	0.80		**5.81**
C	0.44	0.41	1.72	1.14	1.00	0.73	0.32		**0.25**
D	0.32	0.32	1.28	7.63	0.50	0.77	0.54		**6.49**
E	1.06	0.69	0.95	0.13	3.76	0.74	0.87		**1.22**
F	0.56	0.20	0.28	0.22	1.61	3.90	2.08		**1.71**
G	1.05	0.74	0.43	0.63	0.88	1.09	1.96		**0.21**
									2.37
$r_Y(\Psi_{XY})$	**0.66**	**6.10**	**0.29**	**6.62**	**1.21**	**1.27**	**0.41**	***2.37***	***r(Ψ XY)***

Further, according to [1], these world-wide trade flows correspond to the physical, material type 1 globalization flows, comprising the commodities (globalization type 1a), the specialties (globalization type 1b), and the opportunistic low-cost related (globalization type 1c) flows. This distinction in subtypes is relevant to understand globalization, because they show different patterns as well as different underlying driving logics [1], but the distinction is not necessary for measuring globalization. The single inequalities are then aggregated to a risk measure of each economic region according to the two dimensions of supply portfolio (exports) and demand structure (imports); the matrix contains also geographic intra-trade t_{XX}. These individual «geographic» risk figures $r_X(\psi_{XY})$ for exports, and $r_Y(\psi_{XY})$ for imports, are finally aggregated to the world risk index $r(\psi_{XY})$ measuring the economic globalization degree, i. e. the extension of the world economic trade system. The economic regions are: A for North America, B for South and Central America, C for Europe (27), D for Commonwealth of Independent States (former Russian confederation), E for Africa, F for Middle East, G for Asia comprising China, Japan, and other SE Asian countries.

4. Cross-Section Analysis of the year 2009

From the lower part of table 1 we can derive the following observations: high inequalities are usually observable in the domestic economic region of emerging economies. These inequalities ψ_{XY} are comparing subsystems market shares p_{XY} with total market share p_X. The high inequality values originate, for obvious reasons, from being more focussed on home market and having low total market share, resulting finally in high risk values e. g. 5.81 for South and Central America or 6.49 for CIS. The aggregated supply risk for each economic region compares the own export structure to the total supply structure and corresponds to the market risk in CAPM (Capital Asset Pricing Model); the same applies to the imports for the demand structure. The analysis shows that the Asian region has with 0.21 the lowest export risk of all geographic regions; hence according to the CTG it is the most globalized region (highest geographic interweavement) followed by Europe with 0.25. CIS have with 6.49 the highest risk and therefore the lowest globalization degree being more focussed regionally. Analysing the import side, we discover that Europe has with 0.29 the lowest demand risk value, i. e. the highest demand globalization degree, sourcing worldwide. Again, CIS present with 6.62 the highest risk value sourcing more locally. Despite the lowest supply value of 366 b$, Africa with 1.22 has a supply risk value which is lower than Middle East with 1.71, the CIS countries with 6.49, and South and Central America with 5.81, i. e. Africa showing a balanced worldwide supply. The reason is due to the type of goods (mainly commodities with type 1a pattern) which are requested evenly through the world. The total risk value of the economic world trade system in 2009 is 2.37; this value alone does not say anything about the evolution of the globalization degree but has to be seen in the context of trend analysis.

5. Trend Analysis of Globalization between 2003 and 2009

According to WTO source, world-trade increased during 2003–2008 from 7,290 to 15,523 b$, and shrunk during the economic crisis in 2009 to 11,978 b$ as shown in figure 1. Now the question: Has only the trade volume increased (between the same economic regions) or has also the globalization degree increased (i. e. the interweavement of old and new economic partners)? For that we refer to tables such as table 1 also for the years 2003 to 2008 calculating for each supply portfolio (row vector) the correspondent inequalities and risk measures according to appendix A. The evolution of risk values of the whole economic trade system during 2003–2008 has diminished from 4.43 to 1.80 documenting the increased globalization degree of physical, material type 1 globalization, but experienced an increase in risk level during the crisis in 2009 to 2.37 (figure 2), i. e. a concentration of trade flows.

Considering figure 1 and 2, as intuition suggests, there might be an obvious correlation between world trade and globalization degree. Indeed, figure 3 shows a clear negative correlation between world trade and risk level, the higher the world trade, the lower the risk level, i. e. the higher the globalization degree, intended as interweavement of economies. The regression model seems even suitable for extrapolative prediction. Analyzing figure 4 (scatterplot of data from table 2) of the different economic regions, on macro level we recognise a similar pattern as in figure 3 with decreasing economic risk level as soon as economic trade is growing. Indeed, an efficient portfolio diversification needs a critical mass of trade.

Figure 1

Evolution of world trade 2003–09

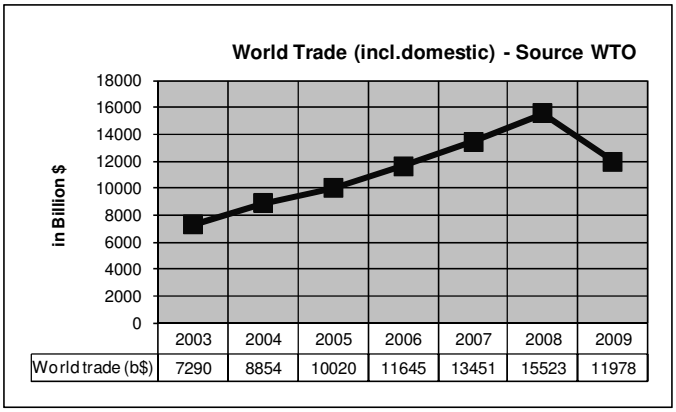
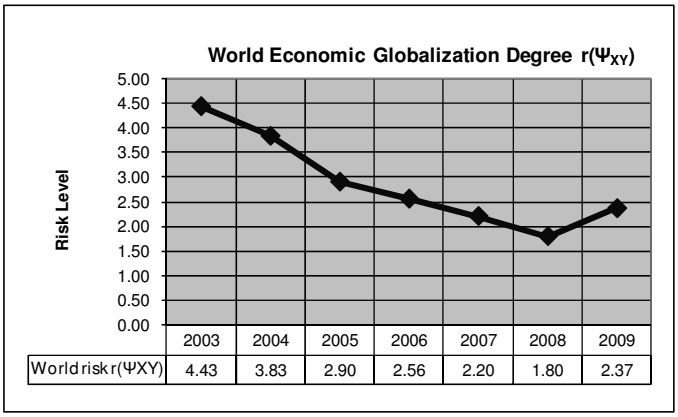


Figure 2

The economic system is globalizing



	2003	2004	2005	2006	2007	2008	2009
World risk r(ΨXY)	4.43	3.83	2.90	2.56	2.20	1.80	2.37

Figure 3

Modelling on aggregated level

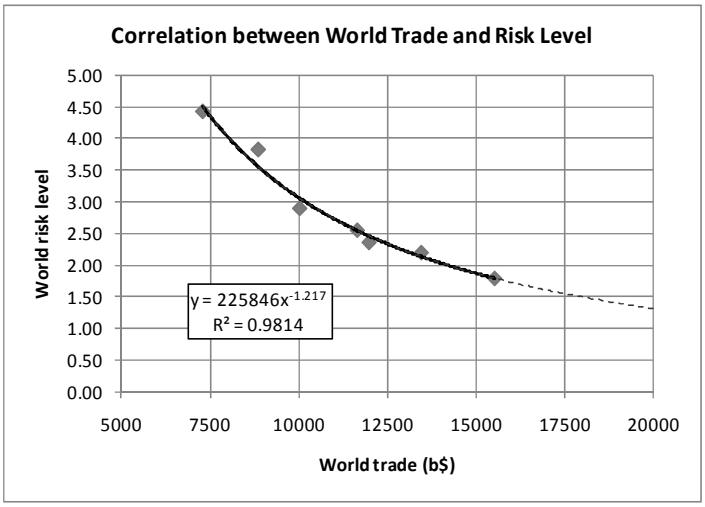
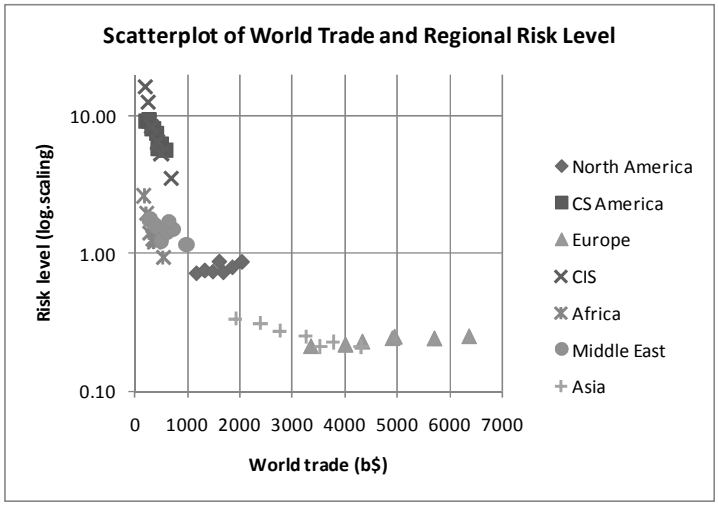


Figure 4

Emerging pattern on disaggregated level



On the other hand, analyzing the temporal evolution of supply risk (exports) of the different geographic regions (table 2 and figure 5), we notice that the risk level, i. e. the globalization degree, has evolved differently in the different economic regions, despite all geographic regions having steadily increased their trade volume during 2003–2008. Interesting is, until 2006 Europe with 0.24 was the most globalized region (lowest risk level), only in 2007 being surpassed by the Asian economic region with 0.23 although the European trade figure with 5705 b$ in 2007 is higher than this of Asia with 3774 b$. The Asian economic region has shown between 2003 and 2008 a steadily diminishing risk level (from 0.34 to 0.21) documenting the steadily increasing interweavement of Asian economics with other economic regions, whereas Europe has slightly increased the risk level (from 0.21 to 0.25) not enlarging proportionally enough the trade network beyond Europe. One reason is the concentration on the Eastern European countries (pertaining to the domestic market). The same is also valid for the North American region having increased the risk level from 0.71 to 0.87, i. e. the globalization degree has decreased. In 2003 the CIS region had a supply risk value of 16.16 remaining until 2005 the economic region less globalized and suffered a big step-back during the economic crisis in 2009. On the other side, South and Central America experienced only a slight step back in 2009 documenting an increasing steady international interweavement.

Table 2

Evolution of supply (export) and risk measures during 2003–2009 for macro economic regions

t_{xy}	2003	2004	2005	2006	2007	2008	2009	cagr(03-09)
North America	**1163**	**1323**	**1477**	**1678**	**1852**	**2034**	**1600**	5%
CS America	**212**	**274**	**341**	**420**	**488**	**587**	**450**	13%
Europe	**3351**	**4008**	**4332**	**4906**	**5706**	**6367**	**4948**	7%
CIS	**191**	**261**	**321**	**423**	**503**	**699**	**439**	15%
Africa	**172**	**218**	**277**	**352**	**407**	**541**	**367**	13%
Middle East	**287**	**378**	**510**	**615**	**720**	**984**	**642**	14%
Asia	**1916**	**2391**	**2761**	**3251**	**3775**	**4311**	**3532**	11%
World trade (b$)	**7290**	**8854**	**10020**	**11645**	**13451**	**15523**	**11978**	9%

Source: WTO

$r_X(\Psi_{XY})$	2003	2004	2005	2006	2007	2008	2009	cagr(03-09)
North America	**0.71**	**0.75**	**0.73**	**0.72**	**0.79**	**0.86**	**0.87**	3%
CS America	**9.15**	**9.30**	**8.02**	**7.52**	**6.15**	**5.67**	**5.81**	-7%
Europe	**0.21**	**0.22**	**0.23**	**0.24**	**0.24**	**0.25**	**0.25**	3%
CIS	**16.16**	**12.66**	**8.39**	**6.43**	**5.29**	**3.50**	**6.49**	-14%
Africa	**2.64**	**1.95**	**1.42**	**1.29**	**1.24**	**0.94**	**1.22**	-12%
Middle East	**1.77**	**1.60**	**1.24**	**1.44**	**1.50**	**1.16**	**1.71**	-1%
Asia	**0.34**	**0.31**	**0.28**	**0.25**	**0.23**	**0.21**	**0.21**	-8%
World risk $r(\Psi_{XY})$	**4.43**	**3.83**	**2.90**	**2.56**	**2.20**	**1.80**	**2.37**	-10%

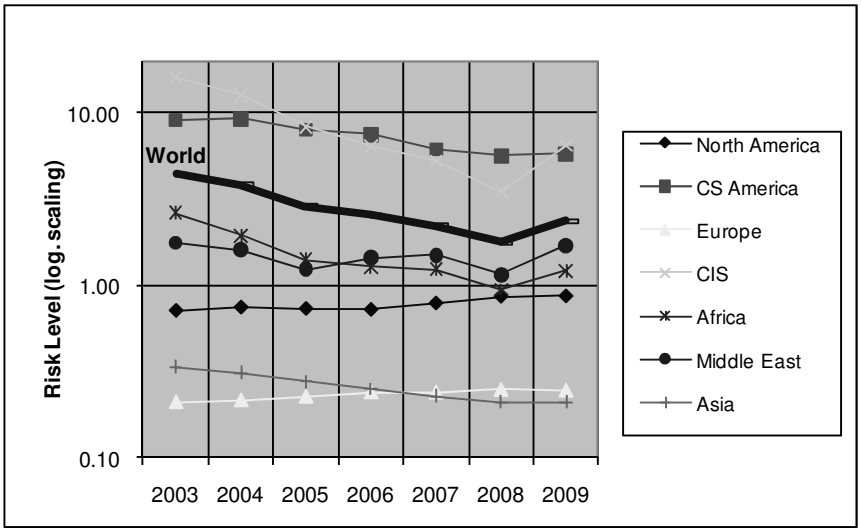
Source: Rüttimann

Moreover, it is interesting to observe that all emerging geographic regions have reduced their risk profile with CAGR of -14% to -1% between 2003 and 2009 (table 2), whereas the two main advanced economic regions, namely Europe and North America, have increased their risk profile (CAGR +3%), thus they have becoming less globalized regarding trade. The reason, why advanced economies are focussing on their present economic relationships, might be due to the fact that, their product portfolio is composed of rather specific goods (type 1b), sold to specific regions where yielding a higher profit and a specific growing demand exists (hypothesis to be confirmed). This is the evidence that also in economics entropy alone (attaining minimum portfolio risk) might not be the sole governing law but, according to thermodynamic free enthalpy, also the potential profit generation is a cardinal law, as seems to be obvious. The governing principle describing the essence of human rational is therefore maximizing value net of risk [1].

The economic entropy, i. e. the risk measure, has resulted to be a valid and most suitable genotypic indicator to measure the globalization extension of an economy or of the whole economic system related to an attribute. Interesting is to see the globalization evolution during the past crisis. During the crisis all region showed reduced exports and also a concentration of trade flows with two exceptions: Europe and Asia could at least maintain their globalization level. Especially Europe, despite its steady increasing risk level, showed a good regional diversification of supply portfolio.

Figure 5

Graphical comparison of evolution of regional risk levels according to table 2



6. Conclusions

The entropy-based inequality risk metric has been proven to be a suitable indicator to measure the interweavement of an economic trade system. It shows that the world economic trade system between 2003 and 2008 has increased its global interweavement. Nevertheless, the macro-geographic world regions have performed differently: diminishing economic globalization for North America and Europe, increasing globalization for the other regions.

In addition, the new metric can also be applied to quantify the globalization level of FDI (Foreign Direct Investment, i. e. type 2a globalization) or to quantify the globalization level of migration flows (type 3a globalization) as well as to be applied to judge the risk of product composition of supply (or demand) of a national economy.

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Appendix A

The mathematics to compute globalization

Let us define

$$\psi_{XY} = \frac{p_{XY}}{p_X}$$

where ψ_{XY} is a measure of inequality or diversity of a subsystem ($X \cap Y$) compared to the system X where $p_{XY} > 0$ and $p_X > 0$ is the attribute (market shares in our case). Further, let us define the risk function of a single element,

$$r_{XY} = (\psi_{XY} - 1)^2 = \left(\frac{p_{XY}}{p_X} - 1 \right)^2$$

interpreted as inequality of a characteristic $\psi_{XY} = p_{XY}/p_X$ within a system compared to the riskless state $\psi_{XY} = 1$ of the system. Let us define the following world supply/demand or origin / destination matrix of trade for a product α

$$T^{\alpha} = \begin{bmatrix} t^{\alpha}_{AA} & t^{\alpha}_{AB} & \dots & t^{\alpha}_{AZ} \\ t^{\alpha}_{BA} & t^{\alpha}_{BB} & \dots & t^{\alpha}_{BZ} \\ \dots & \dots & \dots & \dots \\ t^{\alpha}_{ZA} & t^{\alpha}_{ZB} & \dots & t^{\alpha}_{ZZ} \end{bmatrix} = \left[t^{\alpha}_{XY} \right]$$

The trade flows are represented by the quadratic matrix T^{α} where each element t_{XY} denotes the physical quantity of the product α exported from the country of origin X to the country of destination Y. The corresponding inequality matrix ψ^{α} for the trade matrix T^{α} is

$$\psi^{\alpha}_{\infty} = \begin{bmatrix} \psi^{\alpha}_{AA} & \psi^{\alpha}_{AB} & \dots & \psi^{\alpha}_{AZ} \\ \psi^{\alpha}_{BA} & \psi^{\alpha}_{BB} & \dots & \psi^{\alpha}_{BZ} \\ \dots & \dots & \dots & \dots \\ \psi^{\alpha}_{ZA} & \psi^{\alpha}_{ZB} & \dots & \psi^{\alpha}_{ZZ} \end{bmatrix} = \left[\psi^{\alpha}_{XY} \right]_{\infty}$$

Where each element of ψ^{α} is computed as

$$\psi_{XY\infty}^{S\alpha} = \frac{p_{XY\infty}}{p_X} = \frac{t_{XY}^{\alpha} \Big/ t_{\bullet Y}^{\alpha}}{t_{X\bullet}^{\alpha} \Big/ t_{\bullet\bullet}^{\alpha}} = \frac{t_{XY} \cdot t_{\bullet\bullet}}{t_{\bullet Y} \cdot t_{X\bullet}}$$

The elements $\psi_{XY} > 0$ of the quadratic matrix ψ^{α} represent the market share diversity ratios of all supply economies *X* for a certain product α. The rows correspond to the inequality vectors ψ_X for the economies *X*.

$$\psi_X^{\alpha} = \left[\psi_{XA}^{\alpha}, \psi_{XB}^{\alpha}, ..., \psi_{XZ}^{\alpha}\right]$$

The corresponding risk $r(\psi_X)$ of the portfolio of activities of economy *X* can be defined as

Risk of a Portfolio:

The risk $r_X(\psi_{XY})$ of a portfolio ψ_X of inequalities is the 2nd momentum of the elements belonging to the inequality vector relative to the attractor 1

$$r(\psi_X^{\alpha}) = \frac{\sum_{y=A}^{Z} (\psi_{Xy}^{\alpha} - 1)^2}{card(Z)}$$

where the value 1 means equality and card(*Z*) is the number *n* of elements from *A* to *Z* of the inequality row vector.

Extending the concept of risk from an economy *X* to all economies corresponding to the whole trade matrix T^{α} we can compute the risk of the economic system

$$r(\psi_{\infty}^{\alpha}) = \frac{\sum_{x=A}^{Z} r(\psi_x^{\alpha})}{card(Z)}$$

And generalizing for a competitive system with *m* competitors and *n* customers

$$r(\psi^{\alpha}) = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} (\psi_{ij}^{\alpha} - 1)\mathrm{I}}{m \cdot n}$$

The inverse value of risk defines the statistical entropy of the economic trade system. The same concepts can also be applied to type 2a globalization dealing with FDI (Foreign Direct Investments) or type 3a human factor globalization (migration flows). It may also apply to which goods are produced (or demanded) by which country calculating the portfolio risk of goods composition regarding supply and demand of a national economy.