

2.29% while Pakistan's gain is quite low (0.20%). The world as a whole is expected to gain 0.54% of its baseline income. The study also compares the gains from this FTA with some other proposed FTAs such as ASEAN+3 – India FTA and EU-India FTA. The results corroborate our recommendation as the gains from ASEAN+3 – South Asian FTA are expected to be the largest amongst all.

REFERENCES

Asia Regional Integration Center – Tracking Asian Integration. Asian Development Bank, n.d. Web. 11 Nov. 2014. <http://aric.adb.org/fta>

Bachetta, Marc. Beverelli, Cosimo. Cadot, Olivier. Fugazza, Marco. Grether, Jean-Marie. Helble, Matthias. Nicita, Alessandro. Piermartini, Roberta. (2012). A Practical Guide to Trade Policy Analysis. World Trade Organization.

Bhagwati, Jagdish. (1995). US Trade Policy: The Infatuation with FTAs. Columbia University, Discussion Paper Series No. 726

Direction of Trade Statistics – DOTS. International Monetary Fund, n.d. Web. 11 Nov. 2014. <http://elibrary-data.imf.org/DataReport.aspx?c=1449337 &d=33061&e=170921>

Durgesh, K. Rai, Asian Economic Integration and Cooperation:

Challenges and Ways Forward for Pan-Asian Regionalism (November 22, 2010). GIGA (German Institute of Global and Area Studies) Working Paper No. 152.

Fergin, Elina. (2011) Tangled Up in a Spaghetti Bowl-trade effects of overlapping preferential trade agreements in Africa. Lund University, School of Economics and Management.

Menon, Jayant (2009). What to do about Asia's spaghetti bowl. Malaysia: Office of Regional Economic Integration Asian Development Bank.

Rana, P. and J. M. Dowling (2009) South Asia: Rising to the Challenge of Globalization, World Scientific Press, Singapore.

Rana, P. Prandumna (2012). Renaissance of Asia. Evolving Economic Relations Between South Asia and East Asia. World Scientific.

Wignaraja, Ganeshan (2014). Assessing the Experience of South Asia-East Asia Integration and

India's Role. ADBI Working Paper 465. Tokyo: Asian Development Bank Institute.

World Development Indicators. World Bank, n.d. Web. 11 Nov. 2014. <http://data.worldbank.org/data-catalog/world-development-indicators>

World Integrated Trade Solution. World Bank, n.d. Web. 11 Nov. 2014. <<http://wits.worldbank.org/>>.

Thermodynamics and Economics: Entropy, Environment and Globalization

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Abstract: *The paper focuses on an obscure yet fascinating analogy between the laws of physics and the proofs and laws that govern economics. It seeks to understand the reasons for economic entropy such as movement of human capital through the laws of physics and builds upon the argument that as economic entropy is maximized, the economic outcome would largely be detrimental.*

"It is the business of the student of nature to know assign the "why" in the way proper to his science—the matter, the form, the mover, that for the sake of which" - Aristotle

Using theoretical constructs of physics to make sound arguments and deductions in economic analysis is a major, yet rare trend today. Econophysics, while being

strong in foundation and analysis is an infant branch of economics and its relevant analogies are not talked about in mainstream discussions. "Modeling itself on mathematics, mainstream economics is primarily deductive and based on axiomatic foundations. Econophysics seeks to be inductive, to be an empirically founded science based on observations, with the tools of mathematics and logic used to identify and establish relations among these observations." (Sinha & Chakrabarti, 2012) This paper intends to diminish the gap between pure empiricism and inductive social science and hence, presents the case for a confluence of the study of the nature/properties of matter/energy and mainstream economic analysis.

The main argument of this paper revolves around an

analogy, first mentioned by Nicholas Georgescu-Roegen, a protégé of Joseph Schumpeter, who related entropy and the second law of thermodynamics with the nature of economic activities and deduced vital conclusions that are of concern to environmental economists. He mentioned that economic activities convert all energy into a state of high entropy (less usability) and while the quantity of energy remains constant (as per the first law of thermodynamics) the quality does not. Hence, as soon as economic entropy reaches its maximum value, economies will drain out and civilization will come to a standstill. The paper would not only build upon his argument but also extend it to other economic arenas such as developing-developed nations as high entropy-low entropy spaces with respect to the globalization policies being erected. The Washington Consensus can be dubbed as the legislative catalyst that would in fact, in all probabilities and absence of constraints, convert human identities, cultures and capital into a high entropy state beyond which innovation and economic growth would cease to exist. While the environment related analogy mentioned by Roegen and the globalization extension made here may sound prophetic and an exaggerated version of scientism, sound mathematical analysis can prove otherwise.

The *objectives* of this paper are as follows-

- a) To understand how energy transformation, production of entropy and economic activities are intrinsically related in the modern industrial era and what implications it may have on the environment. Show how economic policies based on empiricist and unemotional/unbiased constructs can prevent the high entropy-low usability doom predicted by analysis.
- b) To relate thermo-economic constructs with the Washington Consensus and the innate nature of globalization in bringing about social degeneration. The Boltzmann Expression can be used to understand how greater realization of possibilities would lead to greater entropy and hence, less usability of matter. With the economic parallel of W, having different values across nations, nations would have disparate levels of entropy leading to massive inequalities, post liberalization. The paper, taking a Marxist perspective, would investigate whether the entropy levels would finally be maximized leading to a high entropy global state or not.

Physics and economics are considered to be vastly different sciences but certain inter-connections can be used to make the latter more empiricist and analytical. "While it is perhaps not surprising for physicists working on social and economic phenomena to be critical of mainstream economics and suggest the emerging discipline of *Econophysics* as a possible alternative theoretical framework, even traditional economists have acknowledged that not everything is well with their discipline." (Sinha & Chakrabarti, 2012) Theories rooted in physics can be used to make improvements in economic theory and can certainly change the way an economist looks at his discipline. Using the thermodynamic construct of entropy, this paper intends to do the same.

Nicholas Georgescu-Roegen mentions that the entropy law is the "the most economic in nature of all natural laws" and "the taproot of economic scarcity". Entropy refers to number of different ways in which a thermodynamic system may be arranged and therefore, it qualifies to be a measure of systemic disorder. While scholars differentiate between entropy and disorder, it can be said that, greater the level of disorder in a given system, the higher its entropy. While the first law of thermodynamics states that energy cannot be created nor destroyed, the second law states that the sum of entropies of all thermodynamic systems increases naturally over time. Further, it has been proven that "higher the entropy, the lower the quality of energy, whereas the lower the entropy in a system refers to higher quality energy being used" (Glucina & Mayumi, 2010). Considering the two, scientifically evident statements, it can be said, that- as sum of entropies of thermodynamic systems is bound to increase, the quality of energy deteriorates. Expressed in a mathematical form, this implies,

$\max (\sum_{i=1}^n S_i)$ implies q_e falls. Where S refers to entropy of a given system, the summation represents the total sum of entropies of n thermodynamic systems and q_e refers to the quantity of energy. Hence, given $S(t+1) > S(t)$, $q_e(t+1) < q_e(t)$. It is this nature of entropy and its relation with energy which can have major repercussions in the field of environmental economics, the first of which was mentioned by Roegen. He maintains that entropy is equal to unavailable energy divided by temperature and hence, the equation by itself is a tautological representation

of the above-mentioned axiom that relates entropy and energy quality. (Roegen, 1986) Two basic constructs need to be established before analyzing his deductions-

- a) All thermodynamic laws, as opposed to natural laws, express an impossibility
- b) In order to survive, a living organism, does not only need energy but also, low entropy.

Having these two constructs in place, one can relate a thermodynamic system to that of a macroeconomic state. Since every production process involves a series of input-output processes which relies on energy consumption and energy quality is bound to decrease (since entropy is bound to increase), economic processes are in fact leading humanity, involuntarily, to a “technological crisis, an energy crisis as we call it.” (Roegen, 1986). Coal, for example, after being used up gets converted into gaseous form (possessing higher entropy and more disorder in the nature of its existence in gaseous form), which has far less economic value (less usability/low quality) and thus, becomes unavailable for economic use. The economic system, consisting of several such nonrenewable input production functions is driving itself to form a high entropy state, which would lead to the much anticipated collapse. While this prediction is of minor importance to environmental economists today, since the energy crisis is well discussed, it gets aggravated if two things are realized. One, the law exhibits an impossibility and hence, no renewable energy substitution can *prevent* the inevitable crisis from taking place (can only *prolong* it further), and two, Roegen’s predicts that given energy consumption standards, 2100 would be the year when entropy of the energy sources would be maximized, economies would drain out and production functions would have access to zero inputs. “No matter how much our technology may improve, no technology can reach thermodynamic maximum, thus 100% efficiency is impossible. Indeed, no matter how efficient our technology can be, all of our resources will be depleted by 2100.” (Roegen, 1986) The cataclysmic prediction raises vital concerns for environment economists and has several academic followers who propose sustainability, village economy and steady state theories as mechanisms to prolong the crisis predicted. Roegen, himself, mentions that “there is a far more dreadful crisis than that of energy, namely, the crisis of the wisdom of the homo-sapiens” and raises the

concern to “economize energy” (conserve it) to prolong the crisis, since its occurrence is inevitable. Just like thermodynamic systems reach the entropy maximization state, economic systems also will. The period of occurrence, however, depends on the nature of economic processes and the sustainability of every micro-process involved. As entropy gets maximized, the ‘economic value’ of resources shall reduce, thus indicating a negative relationship between entropy and value.

Examine, the Boltzmann equation which relates entropy to the realization possibilities of a given system- $S = k \log (W)$ where S refers to entropy and W refers to the realization possibilities of a system (number of ways a thermodynamic system can be arranged). Comparing a thermodynamic system to the global economy, with independent units being human capital, one can say that W can represent the realization possibilities of human capital i.e. the way human capital can be allotted different type and nature of work in different ways. Consider the example, if the world consists of three people a,b,c and three jobs x,y,z, the realization possibility would be equal to three, since the three people can be allotted jobs in three ways- (ax,by,cz), (ay,bz,ca), (az,ba,cy) and hence, the realization possibility in this macro-economic state would be three. Just like different positions accorded to different units of a thermodynamic system (say atoms) form the realization possibilities of the system, the same can be done for human capital. As economies get liberalized and there is seamless flow of goods, services and human capital, the realization possibilities increase and hence, the entropy of the macroeconomic state (with respect to human capital) increases due to the nature of the Boltzmann equation. This implies higher disorder and less usability of human capital (higher the entropy, lesser the usability) and the factor that explains this phenomenon is technological substitution of labour. Further, just like heat flows from hotter to colder regions (regions with high entropy to regions with low entropy), human capital is bound to transfer itself from macroeconomic states exhibiting high entropy to states exhibiting low entropy. This raises the following concerns-

- a) Developing countries have higher realization possibilities for human capital post liberalization and hence, economic entropy is higher. Human capital thus flows from regions of high entropy to

low entropy (developed nations). Labour flows and brain drain are real-life examples of this thermodynamic analogy. Further, due to high entropy many developing countries have shown higher levels of unemployment post their watershed year. This is because of the job reallocation that takes place within the country premises. Just like heat movement in a thermodynamic state, “when trade is liberalized, workers relocate from the least to the most productive firms (high entropy to low entropy states), leading to an increase in aggregate productivity and welfare gains. But, when labor markets are characterized with search frictions, job destruction due to small firms exit exceeds job creation by large firms” (Janiak, 2006)

- b) Several policies working in ‘favor’ of the under developed nations, are in fact converting such nations into high entropy states (by rapidly increasing the realization possibilities of human capital through liberalization policies) and just like transfer of heat from high to low entropy states, transfer of labour takes place leading to the shut-down of domestic producers. (United Nations statistics for the year 2000 mention that over 175 million people in the world live outside the country of their birth, two thirds of which are in advanced nations). Hence, global immigration flows post globalization; necessarily favor advanced nations, which according to the entropy-analogy is inevitable. If the proletariat-bourgeoisie relationship was analogous to the developing-developed country relationship and the second law of thermodynamics was applied, one would deduce that “the laborer works, exerts energy, and is thus the source of heat. The heat then flows to the entity that is not working, that is generating less energy: the ‘cold’ heartless capitalist.” (Meritt, 2000) The physics of Marxism applied to the ‘global state’, then reveals a lot of what mainstream economics refers to as ‘outsourcing’.

The transfer of labour and decline of domestic producers would continue till the time, total entropy of the economic system with respect to human capital is maximized. Hence, if S_1 and S_2 are respective entropies of developed and developing nations before the economy of the latter is opened up, we have- $S_1 = \log W_1$ and $S_2 = \log W_2$ where W_1 and W_2 represent the

respective realization possibilities of the macroeconomic systems. Now, since entropy is bound to get maximized, two cases emerge-

- a) If the two macroeconomic systems remain isolated-

$\frac{dS_1}{dW_1} = \frac{1}{W_1}$ and $\frac{dS_2}{dW_2} = \frac{1}{W_2}$ Thus, respective entropies are maximized, when the realization possibilities rise to infinity. Hence, if the two macroeconomic states remain isolated their respective entropies (with respect to human capital) are maximum when the realization possibilities for the two economies are infinite. Keeping endogenous growth theory in mind, the previous statement is an obvious fact and hence, doesn't need reiteration.

- b) However, if the two macroeconomic systems are combined- i.e. if the developing economy is opened up and total entropy S is to be maximized, where- $S = \log W_1 + \log W_2$ and $W_1 + W_2 = k$ (total realization possibilities at given time t are constant), the function can be maximized with respect to W_1 , if the equation is re written as $S = \log W_1 + \log (k - W_1)$, $\frac{dS}{dW_1} = \frac{1}{W_1} + \frac{1}{k - W_1} = 0$ and hence, maximum entropy is established when, $k = 0$ i.e. $W_1 = -W_2$ i.e. realization possibilities of one nation are formed by reducing the realization possibilities of the other. It can be said that opening up of the economy with higher entropy S_2 , would inevitably lead to reduction of its innate realization possibilities in the long run, as total entropy is maximized. According to this perspective, liberalization policies will always favor the developed nation (the stronger nation exhibiting low economic entropy). Hence, the inherent inequities involved in the formation of the multinational global state are visible.

The Washington Consensus which proposes deregulation and trade liberalization as policy imperatives is essentially combining macroeconomic spaces and maximizing total entropy where realization possibilities of one nation are formed by reducing the realization possibilities of the other. If W_1 is said to represent the realization possibilities of capital-intensive developed nations and W_2 is said to represent the realization possibilities of labour intensive developing nations, the Washington Consensus leads

to maximization of economic entropy with the maxima condition- $W_1 = -W_2$. Hence, the second law of thermodynamics, applied to modern economic frameworks, can show how a policy like the Washington Consensus is a legislative catalyst that maximizes global entropy and leads to the formation of massive inequities in the process. However, the third law (also known as the zero law) which says that heat transfer between two bodies of the same temperature does not take place (molecular motion ceases at absolute zero) implies that as soon as inter-nation entropies are equal and total entropy is maximum, human-capital flows will stop. Thus, according to this perspective, inequalities arising as a result of globalization appear to be unavoidable and would maximize at a particular time period. (shown in the graph below).

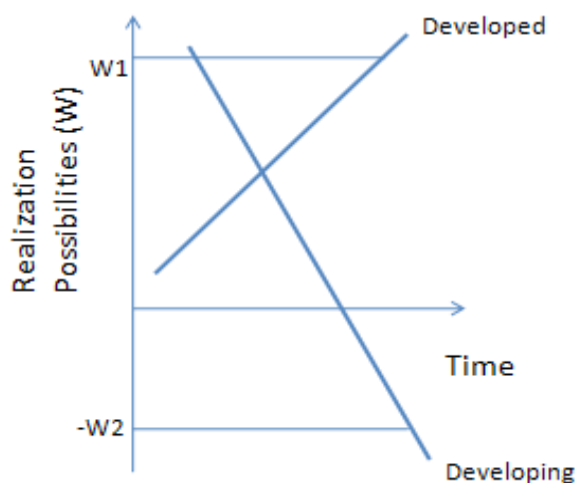


Figure: Entropy Maximization with respect to the Washington Consensus Paradigm

While the above made analysis can be criticized on the basis of scientism, it leads to the conclusion that several economic activities that base themselves on rational, empiricist models are primarily focused on short-run objectives. Using various analogies from the study of matter, one can make various predictions, which might highlight the 'dismal' character of the economic science if they come true. Economic inequality is not just a social phenomenon but a lot of its causes and effects have a strong scientific logic. Since the matters of a natural science are considered indisputable in popular discussions, certain analogies have been used to interpret the social science in a new way. What qualifies as progress and development in the pure economic sense, might lead to a catastrophic outcome, which given the prophecies made using physics, can be prolonged but not avoided.

BIBLIOGRAPHY

- Bullock, & Trombley. (1999). *The New Fontana Dictionary of Modern Thought*. London : Harper Collins .
- Glucina, M., & Mayumi, K. (2010). Connecting thermodynamics and economics. *Annals of the New York Academy of Sciences* .
- Janiak, A. (2006). Does Trade Liberalisation lead to Unemployment? Theory and Some Evidence.
- Meritt, M. (2000). The Physics of Marxism.
- Roegen, N. (1986). The Entropy Law and the Economic Process in Retrospect . *Eastern Economic Journal* .
- Sinha, S., & Chakrabarti, B. (2012). Econophysics, An Emerging Discipline . *Economics and Political Weekly* .
- UCL. (2011). Econophysics: Entropy and its discontents? *Approaches to Knowledge* .

The Validity of the Cournot Model in Present Times

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ABSTRACT: Game theory is one of the most studied topics in the subject of Economics. The presence of many firms, increased competition and market conditions give scope for research. Strategic behavior of the firms in an industry is an interesting aspect. Strategic decision making with the use of mathematical models enables the producer of a firm to achieve

leadership in the market. Nash equilibrium, Cournot Competition model, the Bertrand model, the Stackelberg model and price and quantity leadership models are various strategies that producers use in their best interests. This paper attempts to understand the Cournot competition model and analyze it by understanding the Cement industry in India. The paper