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ECONOPHYSICS AND ECONOLINGUISTICS: A CONCEPTUAL ANALYSIS

Muhammad Nadzif Bin Ramlan
Faculty of Economics and Management, Bangi, National University of Malaysia

Abstract

This study aspires to discuss the capability of the economics study through its relevance with two distinguished subjects: physics, a branch of pure science concerned with the structure of matter and the interactions of the universe's fundamental elements, and linguistics – a social science study of the structure and formation of human language that applies to all aspects of human activity. This paper will cover the origin and nature of the two neologisms, the institutionalization of the terms by lexicography and publication trend in Google Scholar, the scope of the studies concerned as well as future potentials and challenges of the two interdisciplinary studies. The applications of econophysics covered in this paper based on previous research include valuation of stock options, exchange rate and economic performance due to COVID-19 pandemic. Econolinguistics includes labor market, game theory and the linguistic landscape in conjunction with the Tokyo Olympic 2020 event. The potentials of econolinguistics for future research and discovery and the challenges faced by econophysics regarding its role in economic analysis will also be discussed. This paper concludes with the hypothesis of econolinguistics and econophysics can be consolidated to perform a more comprehensive economic analysis, since the former delineates the microeconomic agents while the latter zooms out to explicate the macroeconomic events caused by those agents.

Keywords: Econophysics, Econolinguistics, Iinstitutionalization, Applications, Potentials, Challenges.

INTRODUCTION

The study of economics has been at the forefront of academia besides other dominant human-related studies such as engineering, law and medicine. Economics assists society in deciding and formulating the best methods to allocate its finite and scarce resources. Economics offers us the mechanisms and analytical methods we need to maximize the use of existing resources while minimizing waste. Macroeconomics – a sub-field that analyses how a whole economy such as the market or other large-scale systems functions, and also microeconomics which focuses on individuals' and corporates' decisions on the allocation of scarce resources as well as the interactions between them make it all the more reason to make economics as the haven of multidisciplinarity. On that occasion, it is inevitably entangled with other relevant studies which conveniently fits in any size of research in question such as political economy, socioeconomics and behavioral economics. Nonetheless, there are other disciplines in which Economics still find limited compatibility and relation such as those in the pure sciences (biology, chemistry etc.) and other social sciences like archeology. Despite that, academicians and researchers attempted to connect economics with seemingly unrelated two scopes of studies before the turn of a new millennium in mid-1990s: physics and linguistics. The connection and nature of these interdisciplinary studies will be covered henceforth.

TERMINOLOGICAL OVERVIEW

Before we delve into the origins of econophysics and econolinguistics, it is worth pondering upon the convention of the relations among different disciplines. Săvoiu and Simăn (2013) eloquently define multidisciplinary, interdisciplinary and transdisciplinary studies:

> Multidisciplinary suggests distinct disciplines in discussion, as with an economist and a physicist talking to each other. Interdisciplinary suggests a narrow specialty created out of elements of each separate discipline, such as a "water economist" who knows some hydrology and economics. However, transdisciplinary suggests a deeper synthesis of approaches and ideas from the disciplines involved, and this is the term favored by the ecological economists for what they are trying to develop.

Based on this definition, we can start evaluating the nature of econophysics and econolinguistics through the opinions of various scholars regarding this matter.

The origin of the term econophysics is agreed among scholars that it was postulated by Eugene Stanley at a Kolkata conference held in 1995 to refer to the huge number of articles produced by physicists on stock and other market issues. The term was later established in written work via Physica A proceeding publication the following year. Even after 25 years, the term is still a novel one, and it refers to physicists' work in which financial and economic processes are considered as intricate mechanisms. The word econophysics is blandly explained as "nothing more than a combination of the words economics and physics" (Săvoiu & Simăn, 2013). On that account, the nature of econophysics is seen by a majority of academicians as an interdisciplinary study. Some scholars such as Yakovenko (2009) describes it as "an interdisciplinary research field applying methods of statistical physics to problems in economics and finance". Even Organization for Economic Cooperation and Development (OECD) – an international organization consisting of 37 nation members that promotes policy coordination and economic freedom among developed nations – defines econophysics as "an interdisciplinary research field, applying theories and methods originally developed by physicists in order to solve problems in economics, usually those including uncertainty or stochastic processes and nonlinear dynamics." However, there were several attempts by researchers and scientists alike to upgrade or rebrand the current label of econophysics, such as Schinckus and Jovanovic (2013) already considering econophysics as a multidisciplinary study. They aspired to claim that econophysics can be further integrated towards being a transdisciplinary one by rethinking economics' theoretical basis as well as building entirely new models and theories more adapted to the management of financial risks and markets. However, based on the scholars' arguments, this idea is subject to the probable development of econophysics in the future. Thus, I may conclude this by giving a simpler definition of econophysics: an interdisciplinary field utilizing theories in physics to address economic phenomena via empirical analysis.

As for econolinguistics, although there is no apparent work documenting the history of this term, I believe this term had its debut in the same year as that of econophysics – 1996. The term econolinguistics appeared in the paper compilation book "Towards a Social Science of Language: Papers in honor of William Labov. Volume 1: Variation and change in language and society" with one of the articles entitled "Dimensions of A Theory of Econolinguistics" by John Baugh from Stanford University. He posited two arguments that he claimed were "neglected language universals":

1) Linguistic behaviors including speech and literacy are economic commodities; the (in)ability to employ language(s) has a direct impact on personal economic prospects; and

2) language development and literacy are substantially determined by socioeconomic circumstances. In other words, this is similar to the sociology of language which highlights the impact of language on society.

Fumio Inoue's *Nihongo wa ikinokoreru ka: Keizai gengo-gaku no shiten kara* (Can Japanese language Survive? From an Econolinguistic Perspective) in 2001 also discussed similar topics regarding the appeal of Japanese language in economic activity. Holding on to the aforementioned premise and the discussion on econophysics, we can assume that econolinguistics is also an interdisciplinary study. Thus, I can conclude this with a simpler definition of econolinguistics: an interdisciplinary field implementing linguistic components to explain socioeconomic issues.

INSTITUTIONALIZATION OF ECONOPHYSICS AND ECONOLINGUISTICS

Econophysics

This bridging between economics and physics has been nominated with multiple names. Some describe this bridging as a portmanteau of physics and finance – phynance (Kakushadze, 2015). Although this might be equivocal since economics and finance are two different fields, the roles and approaches of phynance as described by researchers are same as how econophysics would be operated. Others merely put it as financial physics (Jovanovic & Gall, 2001). Few researchers instead insist on using the term sociophysics due to association of human behaviors in a sociological perspective as atoms, thus influencing socio-political phenomena and large-scale systems such as the global economy (Galam, 2012). Econophysicists have used a variety of tactics to share their knowledge to acquire presence in academia for their field of study. To encourage scientific acknowledgment and establishment of this new term, physics departments have hosted symposia, published many specialist publications, and developed particular courses as well as joint-collaborations with Economics faculty.

Although several attempts have been made to rename this bridging between these two disciplines, The New Palgrave Dictionary of Economics 2nd Edition includes the term ‘econophysics’ as an entry, defining “economy as a complex system; econophysics; realized volatility”. This certainly creates a strong foundation in making econophysics as an official term, further stimulating researchers to be proponents of this field.

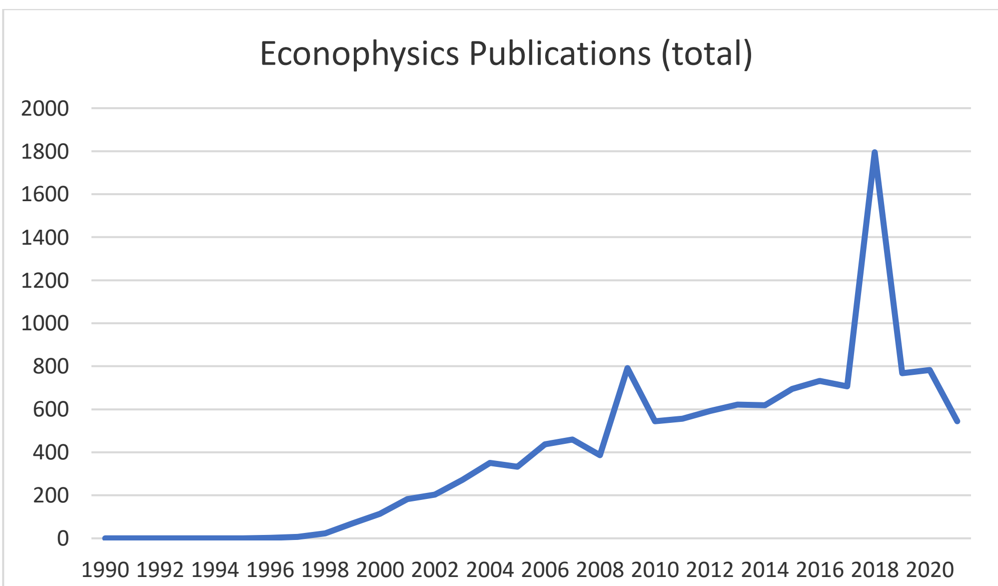

FIG. 1. GOOGLE SCHOLAR TREND FOR ECONOPHYSICS

Based on Figure 1, the trend seems to steadily increase since the debut of econophysics in 1996 with the initial publications totaling only 3 about it at the moment. Since then, the popularity of econophysics among zealous r esearchers continues to bloom at a steady rate, with the exception of skyrocketing change in 2009 (785 publications) and 2018, in which the year 2018 hoards the largest amount of publications under this topic with 1,792 publications. These publications amount to 12,348 documents overall. Econophysics is not extracted to have its own journal; the physicists include this discipline among the prominent journals in Physics such as Physica A and European Journal of Physics B, according to Jovanovic and Schinckus (2012).

There are reasons for the two spikes in publication of econophysics-related articles. 2009 was the post-financial crisis of 2007-2008, also called as subprime mortgage crisis yet still during the Great Recession from 2007-2009. The financial crisis was "a severe contraction of liquidity in global financial markets that originated in the United States as a result of the collapse of the U.S. housing market. It threatened to destroy the international financial system…" (Duignan, 2019). Therefore, Professor Dirk Helbing of Switzerland's ETH Zurich along with his colleagues James Breiding and Markus Christen claim – along with other prominent econophysicists – that markets are capricious, inefficient, but self-regulating by nature as they tend to deviate from the market equilibrium. Their theories, which are based on years of experience in understanding the complex dynamics of a variety of physical systems, explain extreme occurrences like financial crises as occurring naturally as a result of interactions and feedbacks between market players (ETH Zürich, 2010).

2018 is marked by some scientists as the start of a 'scientific revolution' (Jakimowicz, 2018), with a majority of researches detailed the deeper integration of data science and economics via techniques commonly used in physics. In econophysics, methodological disagreements prompted physicists to admit that dealing with financial complex systems helped to a broader modelling of their discipline. The methods used by econophysicists implies that physicists may try to understand physical processes by combining aspects from financial economics and economics in general (Jovanovic et. al, 2019). Meanwhile, Colander (2018) also opined the notion of a 'complexity revolution', a revolution that encourages envisioning of the economy as a complex dynamic system influenced by the frequently unforeseen effects of intentional agents' activities. Hence, 2018 might not be a significant year due to global incidents, rather it is a breakthrough moment for both economists and physicists to rethink their ideas on econophysics all this time.

Econolinguistics

Meanwhile, theoretical linguistics has attempted to claim its rightful place in the field by setting the boundary of how language should be perceived and studied. However, the emergence of multiple prefixed linguistics disciplines to accommodate various sub-branches of applied linguistics such as neuro-, psycho-, and sociolinguistics is inevitable, thus showing the pivotal role of language in human life. As for econolinguistics, on the other hand, there has never been a consensus regarding the exact term or phrase to describe the relationship between the two disciplines. Linguists and economists try to find a common ground based on the roles languages play in daily life, culminating in different phrases to connect their respective disciplines such as the language economy (Marazzi, 2011) or even its obverse like the economics of language (Marschak, 1965) (Chiswick & Miller, 2007). A few of them use economic linguistics (Zabarskaitė, 2017) albeit this is the least popular among all aforementioned terms. Coulmas (2009) however took a bold remark regarding the term, saying that unlike the other established areas previously stated, econolinguistics is not a recognized subdiscipline of the language sciences, nor is there a cohesive body of knowledge that qualifies it as "economics of language," with its own journals and academic societies, as the sociology of language does.

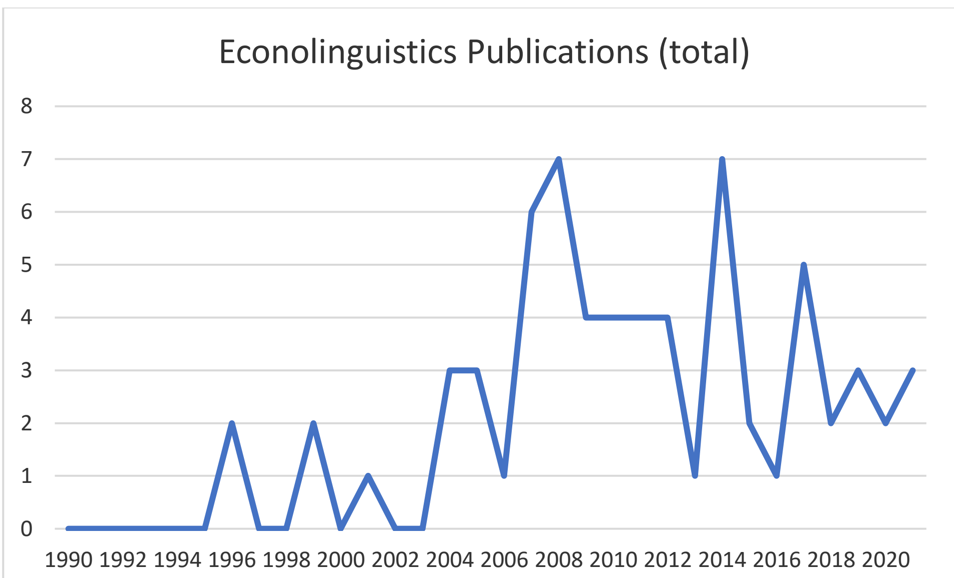

FIG. 2. GOOGLE SCHOLAR TREND FOR ECONOLINGUISTICS

Based on Figure 2, it is clear that Coulmas's opinion on the term holds since the maximum amount of publications ever released in any particular year is only 7 (which occurs only twice since its debut). Yet, the term remains afloat in scholars' radar starting in 2004 despite being undeniably exiguous among the myriads of publications released every annually. Thus, for the sake of explaining this bridging between economics and linguistics, we will discuss the scope of study based on the previous researches under any aforementioned phrase, with those under econolinguistics would be prioritized.

Furthermore, this paper aims to justify several reasons why econolinguistics seems to be so underrated and its potential in the later section to fill in the literature gap in the academia about this interdisciplinary study.

APPLICATION

Econophysics

The goal of econophysics is to explain and actualize models of a market's universal behaviours as an open system, where more external information is combined with new investments, similar to energy/particle inputs in quantum physics (Jimenez & Moya, 2005). Recapping the definition of econophysics in New Palgrave Dictionary of Economics stating it as "economy as a complex system; econophysics; realized volatility". Unsurprisingly, one of the most prominent branches of physics related to econophysics is quantum mechanics. Many other physical phenomena, such as turbulence theory, scaling, random matrix theory, and the renormalization group, have been integrated and applied to the economy, boosting modern computational approaches in data analysis, risk management, artificial markets, and macroeconomics (Burda et al., 2003). Most econophysics approaches to date have focused on economic processes with a large number of components, such as financial or banking markets, stock markets, incomes, production or product sales, and individual incomes, which are primarily studied using statistical physics methods (Săvoiu & Simăn, 2013). We can see that econophysics has established its grounds on making significant contribution to the economics discipline overall. 3 applications of econophysics will be discussed in this paper: option price, exchange rate and COVID-19's impact on the economy.

Valuation of Stock Options (Quantum Physics)

The Black-Scholes-Merton model, frequently known as the Black-Scholes model, is a mathematical model of financial derivative markets that may be used to derive the Black-Scholes formula. This formula calculates the call and put option pricing. It was the first commonly used mathematical method for pricing options, and it was first used to price European options. Some credit this approach with causing a large rise in options trading, as well as having a big impact on contemporary financial pricing. Options traders did not all utilize a consistent mathematical method to value options prior to the development of this formula and model, and empirical research has demonstrated that price estimates generated by this formula are near to observed values.

Fischer Black and Myron Scholes came up with a partial differential equation known as the Black-Scholes equation in their original formulation of the model. Then, using stochastic calculus, Robert Merton published a mathematical explanation of their model, which helped to develop the Black-Scholes-Merton formula:

$$\frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 S^s \frac{\partial^2 V}{\partial S^2} + rS\frac{\partial V}{\partial S} - rV = 0$$

in which,

σ is the volatility or arbitrariness of the asset;

S is the stock price;

V is the value of the option;

t is time; and

r is the risk-free interest rate.

Using log-normal distribution probabilities to account for volatility in the underlying asset, their approach calculates the price of an option by subtracting the return an investor receives from the amount that the investor must pay. The model's log-normal distribution of returns is based on Brownian motion theories, with asset values behaving similarly to the biological movement in Brownian motion. The formula of a call option:

$$C = S_0 e^{-qT} N(d_1) - Ke^{-rT} N(d_2)$$

In which,

S_0 is the stock price;

e is the exponent;

q is the dividend yield percentage;

T is the term (one year equating to twelve months is T=1);

K is the strike price;

$N(d_1)$ is the delta of the call option, meaning the difference in the call price over the stock price shift; and

$N(d_2)$ is the probability that the future stock price will be higher than the strike price, thus increasing chances that the option will be bought.

The stock price is multiplied by cumulative standard normal distribution of d_1 on one side, while the strike price is discounted to time T and then multiplied by cumulative standard normal distribution of d_2 on the other. We can calculate the d1 and d2 via these formulae:

$$d_1 = \frac{ln\frac{S_0}{K} + \left(r - q + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

The formula of a put option:

$$P = Ke^{-rt}N(-d_2) - S_0e^{-qT}N(-d_1)$$

There are several weaknesses to this pioneering approach. Firstly, it is limited to the European market: As previously stated, the Black-Scholes model accurately predicts European option pricing. For the rest of the world, it does not properly value stock options. It's because it believes that options can only be exercised when they reach their expiration/maturity date. The second one is that this model assumes constant interest rates, although this is seldom the case. The third one is that Black-Scholes model is conditioned in a frictionless market or simply explained as with no transaction costs. In the trading market, this is hardly the case because transaction expenses, such as brokerage fees and commissions, are common in trading. The fourth one is Black-Scholes model implies that the stock options have no returns. In the real trading market, however, this is not the case. The returns are the primary consideration when purchasing and selling options. Despite these drawbacks, the Black-Scholes model provides the perfect foundation for further improvement in financial economics and macroeconomics.

Since the 1950s, when mathematicians first became interested in stock market price modelling, many writers have studied the issue of price distribution. The initial concept of Gaussian distributed price movements was quickly superseded with a log-normal distributed stock price model. (Mantegna & Stanley, 2000). To put it another way, stock prices follow a geometric Brownian motion. The discrepancies in the logarithms of prices are Gaussian-distributed in a geometric Brownian motion with Itô stochastic calculus to explain the phenomenon. As a result, this is a crucial turning point of econophysics coming into play.

According to Segal and Segal (1997), quantum effects may be easily integrated into Black-Scholes model analysis by adding a separate process X(t) to the Wiener process W(t) that represents the development of public information influencing the market (t). X(t) may be a Brownian motion in and of itself, but the combination of W(t) and X(t) cannot be described as a two-dimensional Brownian motion process. They concluded that the quantum extension of the Black–Scholes theory offers a logical, scientifically sound, and testable model for explaining market events with larger extreme deviations than classical theory would predict. Another scientist reviewed this that in order to include market characteristics such as the difficulty of simultaneous measurement of prices and their immediate derivatives, Segal and Segal incorporated quantum effects into the Black-Scholes model. They did so by adding a process Yt to the Brownian motion Bt, which reflects the impact of variables not concurrently quantifiable with those engaged in Bt, to illustrate the development of public knowledge influencing the market (Accardi & Boukas, 2007). While this one suggested an enhanced Black-Scholes model, other scientists ventured an entirely new model by connecting Black-Scholes equation with that of Schrödinger, thrusting Black-Scholes model into the core of quantum physics (Contreras et.al, 2010)27. They proposed a Black-Scholes-Schrödinger model based on the cross-interpretation of Black–Scholes equation from the point of view of quantum mechanics, as the imaginary time Schrödinger equation of a free particle. The econophysicists already considered market imperfection factors – short-term volatility, severe disruptions, transaction cost, asymmetric information, serial correlations, flaws in the production systems such as monopoly – that would null the assumption of Black-Scholes model regarding non-arbitrage which indirectly suggested risk-free portfolio. As a result, they developed a more general quantum model of option pricing that includes arbitrage as an external time-dependent force with a potential linked to the random dynamics of the underlying asset price. This novel model may be thought of as a Schrödinger equation in imaginary time for a particle of mass $1/\sigma^2$ with a wave function in an arbitrage potential-generated external field force. As previously stated, this new model may be seen as a broader formulation, with the Black–Scholes model's perfect market equilibrium state serving as an example. Then they utilized semiclassical techniques - which are popular in theoretical physics – to obtain an approximate analytical solution to the Black–Scholes equation in the presence of market defects, such as an arbitrage bubble. Revisiting the Black-Scholes equation utilizing partial differential equation:

$$\frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 S^s \frac{\partial^2 V}{\partial S^2} + rS\frac{\partial V}{\partial S} - rV = 0$$

we can compare that the Schrödinger equation uses a similar mathematical technique:

$$H(t)|\Psi(t)\rangle = i\hbar \frac{\partial}{\partial t}|\Psi(t)\rangle$$

$$\mathrm{H}\Psi = \mathrm{E}\Psi$$

in which,

H is Hamiltonian operator.

∂ is the partial derivative with respect to time, t;

Ψ(t) is Schrödinger wave function;

i is the imaginary number, √ (-1) ;

ℏ is Planck's constant, 6.62607015×10−34 JHz−1 divided by 2π ≈ 1.054571726 Js;

E is energy; and

H is Hamiltonian operator.

Vukovic (2015) supported the idea of a Black-Scholes-Schrödinger model and proved that the two equations could indeed be integrated, forming a new equation for option pricing:

$$\frac{\partial C(t,x)}{\partial t} = -\frac{1}{2}\sigma^2(S)S^2\frac{\partial^2 C(t,x)}{\partial S^2} - rS\frac{\partial C(t,x)}{\partial S} + rC(t,x)$$

in which

C is the option price;

$\partial^2(x)$ is an arbitrary function of x; and

S is a variable of choice in most literature in finance.

The researcher stated that his finding confirmed the capability of quantum physics in observing the options price mechanism whereas Contreras et.al. (2010) mentioned that this is the fundamental of quantum social science.

Exchange Rate (Chaos Theory)

Statistical physics is being used by an increasing number of finance researchers to investigate the dynamical and statistical characteristics of financial data, such as time series of stock prices, exchange rates, and the growth of companies (Fan et al., 2008). In addition, a growing number of physicists from the fields of statistical physics and complexity are turning to finance as a study topic. Econophysics is mostly made up of physico-mathematical models that relate to markets. The notion of self-similarity has been expanded to read out functions that emerge as time series from economic systems, with the exchange rate being one of the most accessible parameters (Drożdż et al., 2007). Consequently, Scarlat et al., (2007) simulated a time-series analysis on the exchange rate between Romanian Leu and the US Dollar (ROL-USD) as well as considering four external factors that – according to them – would affect the performance of the exchange rate: economic reactions, the political situation, and the environmental psychology driving economic behavior; as a fourth factor, they used the closure condition which represents both the mathematical condition of probability normalization and long run economic equilibrium. There are two intriguing features in their analysis and one of them is the fact they synthesized the "Generalized Devil Staircase" (GDSC) method into their research. The other one being the usage of Hurst Exponent and the Lyapunov Exponent.

Devil's Staircase, also known as the Cantor Function, was based on the extensions of the Fundamental Theorem of Calculus to the case of discontinuous functions by Georg Cantor in the 19th century (Dovgosheya et.al, 2006). It is an infamous counterexample in mathematics because it contradicts innocuous intuitions about continuity, differentiation, and calculation. It is also thought to portray the pattern of earthquakes happening worldwide "where clusters of earthquake events are separated by long but irregular intervals of seismic quiet" (Seismological Society of America, 2008). That being the case, assuming the basic assumptions and theories about quantum physics were included in the performance of the exchange rate, the researchers attempted to interpret exchange rate movement with that of a bizarre idea explaining the pattern of a seismological phenomenon.

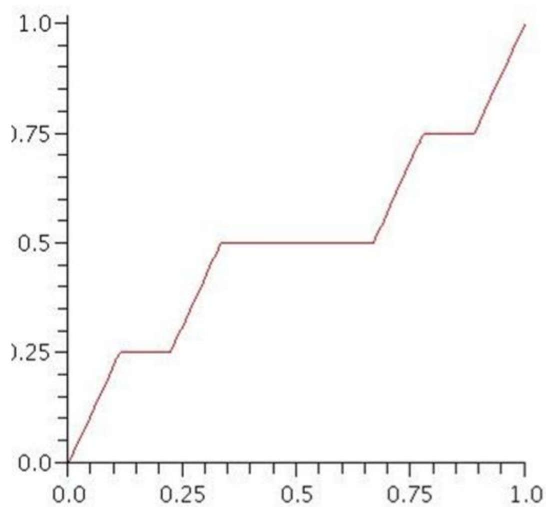

FIG. 3. THE DEVIL'S STAIRCASE (Kemp, 2015)

This concept needs a revisit of the basic understanding of basic calculus. In broad terms, a function is said to be continuous if it has no abrupt transitions. Continuous functions exhibit many desirable characteristics, including the central limit theorem. The derivative of a function at a particular point in its domain, if it exists, quantifies the function's rate of change at that point. If the x-axis represents time and the y-axis represents an object's location along a one-dimensional track, the derivative may be thought of as the object's velocity. If a function is differentiable at a point, it must be continuous at that point but vice versa is not always possible. For an instance, if a function's graph has a sharp corner at a point, the function cannot be differentiable at that point.

Consider what it means for a function to have a derivative of 0 at a certain point. This indicates that the function's rate of change has ceased to exist at that moment. That is, if we zoom in close enough to that point, the function should resemble a constant function.

It should have a graph that resembles a horizontal line. If a function is to always have a derivative nearing the zero value ubiquitously throughout the whole graph, one could assume that this implies that the function is constant. At nearly any point in its domain, its function's rate of change is zero. Thus, the viable way to understand this obnoxious concept is via iterative construction from (0,0) to (1,1) and some clarified that as n goes to infinity, the sequence of functions $\langle f_n \mid n \in \mathrm{N} \rangle$ would eventually converge uniformly to a single function (Hanson, 2018).

The second interesting concept is the usage of Hurst Exponent and the Lyapunov Exponent, two statistical methods related to time-series analysis which are pivotal in the explanation of the chaos theory covering both statistical mechanics and pure mathematics disciplines. There are two antithetical ideas that deterministic chaos attempt to connect: unpredictability of the particles' and molecules' trajectories, and predictable motions of the celestial bodies, pendulum and the sort (Britannica, 2021). As bizarre as it may be, Dostál (2002) mentioned that the chaos theory is among the theories being more competent at explaining complex events that include nonlinearity. These theories allow us to analyze the time series as complex social, psychological, economic, and financial occurrences unfold. These theories include Hurst and Lyapunov exponents. The Hurst exponent allows us to define the chaotic degree and fractal dimension of time series. The Lyapunov exponent would gauge the prediction's power, whereas its inverted value indicates predictability.

Hurst exponent:

$$H(\tau) = \frac{\log\left(\frac{R(\tau)}{S(\tau) * c}\right)}{\log(\tau)}$$

in which

R is range;

S is the standard deviation

c is the constant; and

τ is the lag(s).

If the value of H is 0.5, it indicates a random walk process or normally distributed. If the value of H > 0.5, then it indicates a consistent or trend enhancing time-series. If otherwise (H < 0.5), this shows anti-persistent or mean switching over time. Hurst exponent may be utilized in investing methods based on trend trading. An investor would seek companies that have a high degree of persistence. These equities would have a H-value $\geqslant 0.5$. A H-value < 0.5 may be used in conjunction with technical indicators to identify price rollbacks.

Lyapunov exponent:

$$\lambda = \lim_{n\to\infty} \frac{1}{n} + \sum_{i=1}^{n} ln\left(\frac{\Delta R_i}{\Delta R_0}\right)$$

In which

λ is the Lyapunov exponent; and

ΔR_0 is the average logarithmic rate of separation or convergence of two nearby points of two time-series Xt and Yt separated by an initial distance, $\Delta R0 = \|X_0 - Y_0\|$ (Rüdisüli et al., 2013)

Elert (2016) discussed the 3 conditions if the value of λ is as below:

1) $\lambda < 0$: Attraction occurs as the orbit approaches a stable fixed point or stable periodic orbit. Lyapunov exponents that are negative are indicative of dissipative or non-conservative systems (the damped harmonic oscillator for instance). These systems show asymptotic stability; the smaller the exponent, the more stable the system. The Lyapunov exponent of superstable fixed points and superstable periodic points is equal to $\lambda = -\infty$. This is similar to a severely damped oscillator in that the system accelerates toward its equilibrium point.

2) $\lambda = 0$: The orbit is a fixed location in space. A zero Lyapunov exponent implies that the system is in a stable state. With this exponent, a physical system is conservative. These systems are Lyapunov stable. Consider two identical simple harmonic oscillators with amplitudes that vary. Because frequency is independent of amplitude, the two oscillators' phase portrait would be a couple of concentric circles. The orbits would maintain a constant spacing in this case, similar to two specks of dust held in place on a spinning record.

3) $\lambda > 0$: The orbit is inherently insecure and erratic. Nearby points, regardless of their proximity, will diverge to any arbitrarily separated point. At some point, all regions inside the phase space will be visited. These are referred to as unstable spots. The orbits of a discrete system will resemble snow on a television set. This does not prevent any organization from emerging as a pattern. This phase space of a continuous system would resemble a tangled sea of wavy lines, similar to a pot of spaghetti. Brownian motion is a physical example. Although the system is predictable, the orbit that results is chaotic.

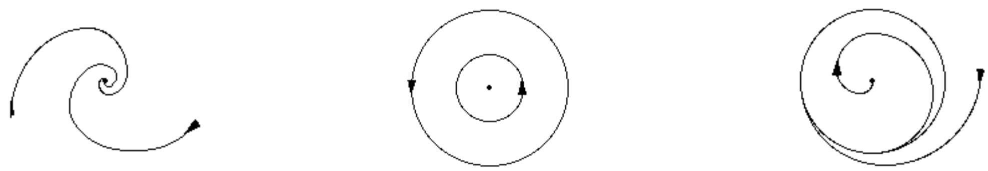

FIG. 4. FIDUCIAL ORBITS WITH DIFFERENT λ VALUES (Elert, 2016)

Lyapunov exponent is used to analyze and estimate economic and financial time-series (Yalamova et al., 2007). Thus, relating to the capricious nature of the chaos theory and the unprecedented devil's staircase, it is clear how deep the study of econophysics to explain the exchange rate mechanism.

Economic Performance and the COVID-19 (Relativity)

Some econophysics papers are centered towards mathematics-laden descriptions, such as implementing the engineering calculus of closed Stokes integrals to evaluate Japanese economy (Mimkes, 2017), using thermodynamics and statistical physics approaches to assess the distribution adjustment in the Eurozone economy (Stanciu et al., 2012), or employing bipartite graph theory to describe the competitive advantage due to the trade war between China and the United States (Xing et al., 2018). However, the COVID-19 pandemic has inspired researchers in all disciplines to find new perspectives in their study. Ruiz Estrada (2021) sought to explain the economic casualties caused by the ensuing pandemic with the aid of Einstein – the general theory of relativity and special theory of relativity which are related to space-time continuum, as well as his most famous equation to explain the conservation of mass-energy:

$$E = mc^2$$

in which,

E is the energy;

m is the mass; and

c is the constant for speed of light, exactly the value of 299 792 458 ms^{-1}.

Ruiz Estrada (2021) attempted to use special theory of relativity to measure adequate economic energy to overcome the COVID-19 crisis via the aforementioned formula as the foundation for this purpose, ergo a modified equation was formed to fulfill its role as an instrument to measure economic damage caused by COVID-19:

$$\ddot{E}c = IJ^2$$

in which,

Ëc is the economic energy against COVID-19;

I is the inflation rate due to COVID-19; and

J is the high employment absorption speed rate.

Ruiz Estrada (2021) explained that this formula can ignite 4 scenarios depending on the condition of the variables:

1) Low I, high J^2: constitute huge economic energy to surpass COVID-19 impact.

2) High I, low J^2: constitute tiny economic energy to surpass COVID-19 impact.

3) High I, high J^2: constitute tiny economic energy to surpass COVID-19 impact.

4) low I, low J^2: constitute tiny economic energy to surpass COVID-19 impact.

The modified version removed the constant in its equation due to the fact that economic occurrences are dissimilar to the physical phenomena in terms of measurement accuracy and predictability. J is squared to recognize the spillover effect that the employment absorption rate can bring upon the economy such as rise in consumption due to the wage that workers would spend after being recently employed. However, this fresh idea certainly needs further development and clarification, particularly regarding the three components needed to form J: the sum of all new part-time jobs, plus the sum of all new technological jobs, plus the sum of all new logistics jobs. While these specified scopes of data would likely be easier to attain in the United States, it would be almost impossible to trace them in other developing countries such as Malaysia in which some part-time employment would not be recorded into the system, unless otherwise done so by an enumerator via census or filling in online surveys by the government. Thus, I would like to suggest that the manipulated variable J be derived from more widely known or accessible data, such as employment-to-population ratio which would represent the employment absorption rate (Statistics South Africa, 2008) So, the equation might need to be adjusted to redefine J.

Econolinguistics

While econophysics focuses on the results of the market, econolinguistics zooms in to the agents themselves – humans. This makes the languages of humans as the center of economic analyses with linguistic tools – ranging from dialectology, sociolinguistics, language register etc. After all, foreign language education is enhanced by economic activity (Inoue, 2007), and this leads to several language rising in prominence on the global stage besides English (Crystal, 1997) such as German, Spanish, Arabic, Mandarin and Japanese. As Chiswick (2008) mentioned, "most of the research in the economics of language focuses on what can be described as microeconomics, that is, the behavior of individuals.". We are going to analyze 3 perspectives that are related to econolinguistics: labor market, game theory and the Tokyo Olympics 2020.

Labor Market (Sociolinguistics)

Labor market consists of two aspects: ethnicity and bilingualism/multilingualism. The former is the main discussion of academicians whereas the latter one is commonly promoted by the benefits of bilingualism or multilingualism in the labor force by popular media and publications.

For the first aspect, individual earning is said to be corresponding directly to their literacy and even accents. The first generation of research in econolinguistics examined language as an ethnic feature. A person's mother tongue assigns him or her to a specific group, which may have an impact on the person's socioeconomic position and wages. Such researches included Dustmann and Fabbri (2003) by using two recent UK survey data of non-white immigrant employees, to examine the factors of language competence and the impact of language on non-white immigrants' wages and job prospects. Additionally, they addressed the issue of endogenous language learning and measurement error in language variables, which may bias or inaccuracies the study. Their findings indicate that language learning, job prospects, and wages vary significantly among non-white immigrants based on their ethnic background. Their research concluded that language competence increases job prospects, whereas a lack of English proficiency results in earnings losses. This claim is further strengthened by Saarela and Finnäs (2004) when discussing the role of two competing native languages of workers in Helsinki – Swedish and Finnish – in the income received. The study indicated that on average, Swedish-speaking men earn 17% more than Finnish-speaking males. Two-thirds of this pay disparity may be ascribed to variations in attributes, most notably education and age. The pay disparity among females of different mother tongues in this case was almost negligible. The results corroborate prior research in that they highlight the Swedish-speaking minority's favorable labor market performance in Finland and the fact that disparities across language groups are greater among men than females. But they mentioned that this research did not rule out the possibility of whether social integration would enhance wage discrimination or otherwise. While some of the research indeed postulated language as a major factor in the income inequality, a few papers refuted such claim as in a study by Cattaneo & Winkelmann (2003) which concluded that the difference of earnings between equally qualified natives and non-natives living in the German and French linguistic regions of Switzerland have the same earning regardless of their native language, suggesting labor integration in the Swiss economic landscape. Therefore, we can conclude that the accents and literacy of a local language by non-native speakers can indeed their wage rate, subject to the social integration in a particular environment.

Whereas the first aspect relied on certain congenital factors such as accents and ethnicity, the second aspect – bilingualism/multilingualism – is widely endorsed by both academicians and laymen as an unequivocal asset to those seeking employment. A report released in March 2017 by New American Economy pointed out that while businesses in the United States advertised about 240,000 jobs targeted at bilingual employees in 2010, that number has more than doubled to nearly 630,000 by 2015. The report further explained that in the same year, Bank of America advertised more than a third of their jobs as bilingual. Meanwhile, almost one in every four online job postings at health insurer Humana required similar abilities, including over 40% of the company's ads for registered nurses. The proportion of job posts seeking bilingual workers also rose, with the proportion of bilingual job advertisements online increasing by 15.7% during the same period. The 3 most sought-after foreign languages in the USA among the employers are Spanish, Arabic and Chinese. This claim is also supported by a more recent study by Liwiński (2019) on Polish speakers as he claimed that the majority of Polish speakers are at least bilingual. He argued that with advanced levels of the other global languages such as Spanish, French, Italian, German and English, they could yield a wage premium up to 32%, 22%, 15%, 12% and 11% respectively. Another research did not just reinforce the assumption that productivity would increase, consumption would also rise due to more choices of product from the comprehension of both languages, enabling wider reach to a large array of markets sometimes exclusively to speakers of a particular language. Toulemonde (2010) elucidated the two benefits gained by learning other languages: there is a demand for bilingual employees by businesses, which drives up bilingual workers' wages. Secondly, bilingualism enables the citizen to purchase products manufactured by monolingual businesses in the other community, increasing his/her consumer surplus.

Globalization, increased international commerce, foreign direct investment, and rapid labor mobility all contribute to an increase in demand for language skills, as both economists and linguists believe that this trend will continue in the future. With increased migration and internalization of businesses and agencies, command of foreign languages has become an essential competency in the global labor market.

Game Theory (Pragmatics)

Game theory has enthralled academicians throughout the ages due to its complexity and sophistication. It aims to comprehend the strategic activities of two or more "players" in a particular scenario with predefined rules and consequences. While game theory is used in a variety of fields, it is most often employed in the study of business and economics. Thus, the "games" may include how two rival companies will respond to one another's price reductions, whether a company would buy another, or how traders in a stock market will react to price changes. Theoretically, these games are related to prisoner's dilemmas, the centipede game, the hawk-and-dove game, and battle of the sexes, peace-war, Cournot competition and much more. Linguistics is of no exception related to this well-known concept.

One of the most popular examples is the Cournot competition. It is named after Augustin Cournot, a French mathematician who invented it in 1838. The Cournot model is most often used to describe a duopoly or two major firms in a market.

TABLE 1. COURNOT DUOPOLY

Cournot Payoff Matrix		Firm Z	
		Cooperate	Defect
Firm Y	Cooperate	(a) 5, 5	(b) 0, 9
	Defect	(c) 9, 0	(d) 1, 1

Note: Figures are in hundred millions of Yen, JP¥

This theory regarding decision-making makes it a viable foundation for a situation representing rapid exchanges of arguments and counterarguments in order for one to prevail in a particular discussion or persuasion. This particular situation is also present in debates and negotiations, and researchers attempted to explain the background of the decisions made by these players in those “games”. In his classic work on conventions, Lewis (1969) proposed to study communication by means of so-called signaling games, games that are of immediate relevance for linguistics. Meanwhile, extensions of Lewisean signaling games have become very important in economics and (theoretical) biology. This presents communication as the basis of decision via diplomacy, argument and persuasion, and researchers mentioned that a speaker conveys more than just the conventional truth-conditional meaning of a statement in a normal conversational context. (Benz et.al, 2015). The truth-conditional meaning is enhanced by what is implied in conversation by the usage of a phrase. According to thre cooperative principle, in pragmatics, it is conventional to believe that this method of enhancing conventional meaning is feasible because we presume that speakers adhere to, which posits that speakers are rational cooperative language users. According to this perspective on language usage, the archetypal discourse scenario involves cooperative information sharing. This cooperative principle is regarded as false by Iten (2000) that this debate-style and the rapid exchange between interlocutors cannot be regarded by cooperative, nor be explained by Anscombre-Ducort's (1983) Argumentation Theory (AT), rather it is best derived with Relevance Theory (RT). Some linguists also opined the necessity to relabel the classical assumption of game theory about rationality to bounded rationality. (Benz et al., 2015). As a result, Glazer and Rubinstein (2016) wrote a paper entitled *A Game Theoretic Approach to the Pragmatics of Debate: An Expository Note* in which they applied this economic technique to address the logic mechanism of debates in six points:

> 1) Debate is a mechanism for a decision-maker (the listener) to elicit information from two sides (the debaters). The correct choice, from the listener's perspective, is contingent upon the revelation of many pieces of information. Both debaters are completely aware of the pertinent facts, but the listener is not. The debaters have contrasting interests in the matter at hand. Throughout the discussion, participants make arguments to support their different views by presenting concrete facts regarding the reality of certain pieces of information. The listener reaches a conclusion based on these arguments.
>
> 2) The listener's judgement is based on what he infers from the arguments advanced throughout the discussion. The listener may draw conclusions beyond what is obvious from the facts included in the parties' hard evidence. The pragmatics of debate is a collection of principles that guides the audience in understanding the debaters' arguments in ways other than their literal meaning.
>
> 3) The listener's perception of the utterances and evidence is not a question of choice.
>
> 4) The two debaters regard the debate as a game for two players. The listener is not an active participant in the game. The actions in the game represent the possible arguments raised by the debaters. The result of the game reflects the debaters' shared knowledge of how their arguments would be interpreted by the listener.
>
> 5) The pragmatics of argument is regarded as though they were selected by an imaginary designer. The designer is aware that the rules he selects will dictate the game that the debaters will play, and thus that the listener's conclusion will be influenced indirectly by the rules he chooses. The designer's objective is to increase the likelihood that the listener would reach the same conclusion he would have reached had he known all of the debaters' facts.
>
> 6) The designer is limited by physical constraints such as the complexity of information processing, the duration of the debate, and the cost of presenting

strong proof.

Based on the six components, I believe that the researchers assume debate as a static "game" due to the phrases such as the listener reaches a conclusion on the basis of their arguments and also listeners are not considered to be aware of the facts exchanged by the debaters. Indicating that the debater/speaker would stay put with his decisions and opinions throughout the debate. It is obvious that any debate discourse is high-paced and thus subject to constant change of mind and opinions. Hence, I would recommend seeing debates as a dynamic game instead, in which several players can take upon several courses of action at once; another suggested additional premise is: both listeners' and debaters' views are subject to change over time and they are also viable to forming opinions amid the argument-counterargument exchanges at any point in time.

Game theory has both a prescriptive and descriptive component. It may instruct us on how to conduct optimally in a game, or it can be seen as a theory describing how agents really behave in a game. This applies to languages as well whether we realize it or not, all under different terms – whether it is adjudication, diplomacy, arbitration etc. - to describe a dynamic "game" going between two parties to emerge victoriously.

Tokyo Olympics 2020 (Corpus Linguistics)

Corpus linguistics is the study of language via the analysis of huge collections of "real-world" language usage recorded in corpora - computerized databases developed specifically for linguistic research. Additionally, it is referred to as corpus-based research. Some linguists see corpus linguistics as a research technique or methodology, while others regard it as a distinct field or theory in its own right. According to Kübler and Zinsmeister (2015), the answer to whether corpus linguistics is a theory or a technology is simply that it may be both as it relies on the use of corpus linguistics.

This branch of linguistics is used to examine the upcoming Tokyo Olympic Games' language problems, presenting two kinds of data collected from an econolinguistic perspective. (Inoue, 2016). He explained that the data includes utilizing Google Search to track changes in language-related mentions associated with the Olympics over time. The market value of language, which was historically heavily affected by conflict, is today heavily controlled by economics. In contrast to the temporary attention generated when the Olympics are held, interest in language is far more persistent, and consequently any athletic event can only have a limited impact on language.

The second issue is the city's linguistic landscape. A multilingual environment will accompany every international sports event. However, it is claimed that the 2020 Tokyo Olympic and Paralympic Games would be managed in a mix of Japanese, English, and pictograms, which seems to be a setback in terms of language services provision. On the other hand, private businesses may potentially use multilingual services to attract consumers and capitalize on this once-in-a-generation economic opportunity. Inoue (2016) further argued that the bottom line is that sporting events and their venues may be the first to show a multilingual landscape. In particular, the Tokyo Olympics can be the catalyst. Language landscapes leave long-term traces and influences, while books and Internet searches show temporary interest. The mere exposure effect unknowingly affects people's linguistic consciousness and should not be ignored, and this corresponds to heightening albeit temporary piqued curiosity in foreign languages, which could increase the demand for foreign languages education during the heat.

Corpus linguistics is also used to analyze the metaphors used in printed media such as newspapers and books, to portray economy with movement such as accelerated, stalled or veer off (Krennmayr, 2015) or to show how a corpus linguistics approach to critical discourse analysis of 334 banks' timebanking websites in the United States of America enables a more nuanced understanding of the counter-hegemonic discursive tactics used by alternative economic exchanges (Rice 2014). Nonetheless, the econolinguistic analysis by Inoue (2016) is certainly an interesting insight into the potential of econolinguistics in the future as we will discuss in the next section.

POTENTIALS AND CHALLENGES

Seeing how appealing econophysics can be and how undervalued econophysics has become to the researchers at the moment, we will discuss directly the challenges that the former faces throughout the years of its development and prospects into future contributions for the latter.

Econophysics

Econophysics faces two obstacles since its emergence: philosophy and methodology. The discipline has always been compared with econometrics, another statistical-based approach to explain economic phenomena. However, the basic principle of econophysics in which this particular approach effectively made, “data first, then model…” (Rickles, 2011) makes it questionable in terms of its capability to further contribute towards mathematical economics and econometrics, let alone replacing them. However, this has not stopped later researchers to prove that econophysics has the capability to even rectify some orthodox assumptions in economics, such as the one proposed by Zapart (2015) in which in small-time scales, he claimed that the central theoretical assumption underlying prevalent economic theories is violated, and he proved how alternative behavioral econophysics can instead generate such time-scale reactions of market participants to short-term movements in foreign exchange markets. Regarding methodology, it is a fact that sometimes social phenomena are harder to be explained comprehensively rather than physical phenomena, due to multiple intermingling of factors happening simultaneously – making the classical assumption of economics ceteris paribus no longer relevant. Roehner (2008) also confirmed this statement by stating that nascent stage of development of this discipline, physics was faced with the same problem, and the fundamental technique of experimental physics was established specifically to untangle these multifaceted events. On that account, we can infer a major point: we need to draw a line between econophysics and econometrics. We can say that econometrics would be the instrument to quantify economic phenomena, and econophysics would assist in improving any technique as needed, rather than having them skirmishing continually due to their differences in techniques and preferences.

Econolinguistics

The so-called bridging between linguistics and economics is actually more of the effect that a particular language on a whole could impact economy, rather than dissecting “language” into its constituents instead. If we look upon our previous analysis regarding applied areas of econophysics such as option price, we can see attempts by researchers such as Vukovic (2015) to integrate financial economics into the core of quantum physics by synthesizing the formula with Schrödinger’s wave equation. This implies that in order for econolinguistics to prosper and gain more research coverage, aspiring academicians need to step up their approaches and do the same technique – relating economics with the nucleus of linguistics. I am aware of the fact that econophysics is able to strive due to mathematics as “the common language” for communication between economists and physicists. It is harder though to find common grounds between economists and linguists since economics describes money transactions, the other expounds letters and words.

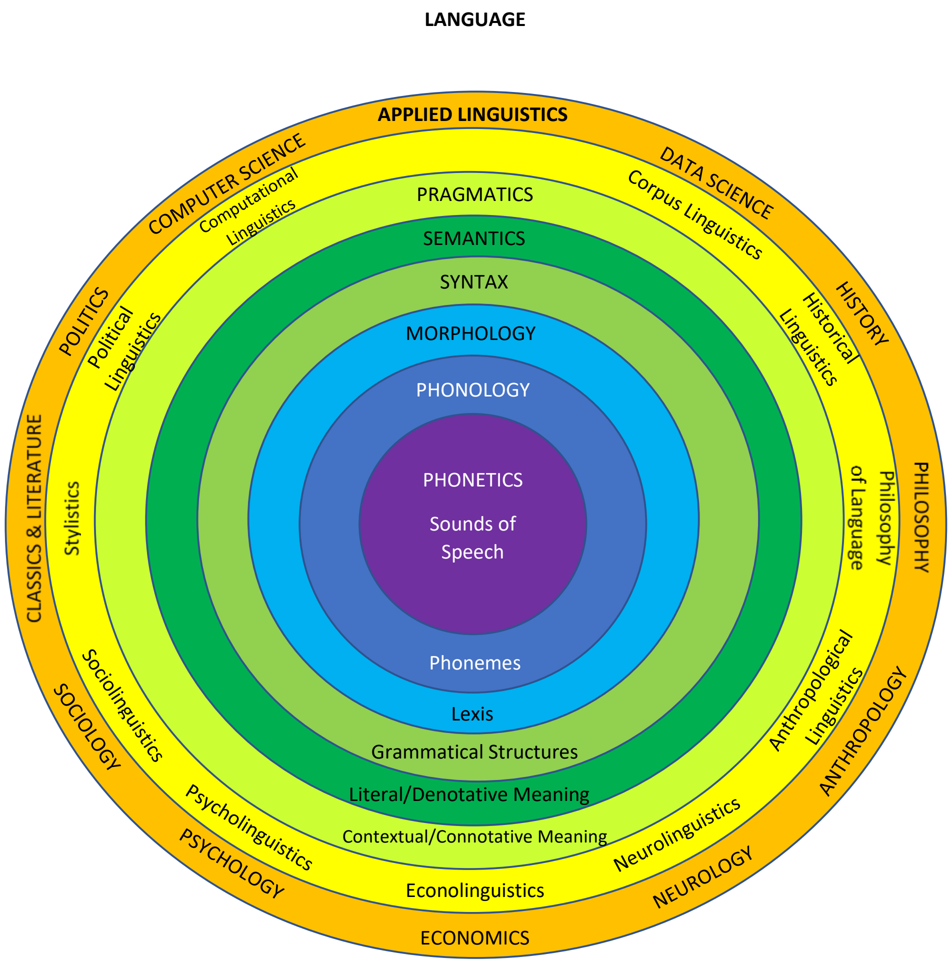

FIG. 5. LANGUAGE STRUCTURE LEVELS

Figure 5 shows my depiction of the language structure encompassing theoretical linguistics and applied linguistics. Although there are more disciplines related to linguistics besides the ones mentioned above, it goes without saying that econolinguistics can be developed further. I can propose an interesting situation into which econolinguists can consider in the future: an article in Astro Awani in September 2020 reported a view of the Deputy Minister of Science, Energy and Innovation, Ahmad Amzad Hashim on the claim about the fall of the incumbent government by the Malaysian Opposition Leader, Anwar Ibrahim. The deputy minister mentioned that "as soon as the opposition leader opens his mouth, the stock price drops drastically". We can first analyze the stock performance throughout the week and also consider which part of that opposition leader's speech in his news conference – such as his intonation (phonetics), lexical repertoire (morphology) or the specific words used to describe the fall of the government (semantics) - that would indeed cause the drop of stock prices, assuming that it is true. We can then scrutinize those findings to see how social media would contribute to the trending of particular phrases or words, leading to the concluding effect upon market sentiment by both local and foreign investors. This is one of the many real-life scenarios that I find tantalizing for prospective and current econolinguists to consider for their research in the future.

Considering that econophysics explains macroeconomic activities and econolinguistics describes the condition of the microeconomic agents involved such as individuals and firms, a more ambitious research prospect is to combine both interdisciplinary perspectives to form an entirely new and comprehensive economic explication, covering both microeconomics and macroeconomics. This idiosyncratic idea would be hypothetically dubbed as econolinguistic-econophysical analysis. Figure 6 features a Venn diagram illustrating this relationship that could be paramount to pique curiosity among researchers and academicians about this matter.

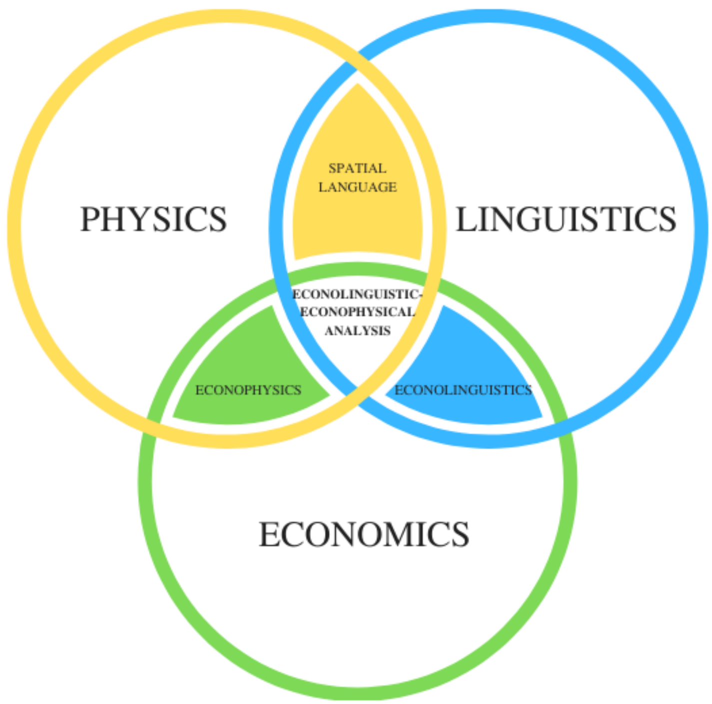

FIG. 6. VENN DIAGRAM RELATING THE THREE DISCIPLINES

CONCLUSION

Having their debuts both in 1996, econophysics and econolinguistics offer many opportunities for improvement in academia and the industrial world. Despite the former has formal recognition as an official term but not the case for the latter, both are able to stand firm for 25 years among the plethoras of other more popular academic publications released. The two interdisciplinary studies apply respective theories from their core disciplines – physics and linguistics – to explain economic phenomena. This tacitly proves the significance of economics itself as a possible center of knowledge, as dubbed by a few researchers as the "complexity revolution" or "scientific revolution" since economics is almost in sync with physics, a branch of pure science. However, econophysics certainly needs to be redefined to avoid any confusion and ambiguity of its role in economic analyses. Insomuch as econolinguistics not gaining total support at the moment, it is technically a new ground of research for both economists and linguists to contribute towards a better comprehension of the human-related phenomena.

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