

The GH-Method

Viscoelastic or Viscoplastic Glucose Theory (VGT #82): An Investigation of Economics Markers versus COVID Pandemic Markers During 9 Quarters from Y2020Q1 to Y2022Q1 Based on GH-Method: Math-Physical Medicine, Especially the VGT Energy Tool (No. 672)

Gerald C. Hsu*

eclairMD Foundation, USA

Abstract

The author is a mathematician and engineer who has conducted medical research work over the past 13 years. To date, he has written 672 medical research papers. Beginning with paper No. 578 dated 1/8/2022, he has written a total of 80 medical research articles using the viscoelasticity and viscoplasticity theories (VGT) from physics and engineering disciplines on 80 different medical problems with their associated data. These papers aim to explore some hidden biophysical behaviors and provide a quantitative understanding of the inter-relationships of a selected medical output (symptom) versus singular input or multiple inputs (root causes, risk factors, or influential inputs). The hidden biophysical behaviors and possible inter-relationships exist among lifestyle details, medical conditions, chronic diseases, and certain severe medical complications, such as heart attacks, stroke, cancers, dementia, and even longevity concerns. All of these chosen medical subjects with their associated data, multiple symptoms, and influential factors are “time-dependent” which means that all of these biomedical variables are changing from time to time because body cells are dynamically changing. This is what Professor Norman Jones, the author’s adviser at MIT, suggested to him in December of 2021 and why he utilizes the VGT tools from physics and engineering to conduct his medical research work since then. From 1980 to 1981, the author attended a college in California for his MBA degree, emphasizing finance and marketing. In addition, he spent many years managing a successful high-tech semiconductor business in Silicon Valley, where it involved many key factors of economics and finance, such as gross domestic product (GDP), inflation rate, stock performance, price/earnings ratio (P/E ratio), investment decisions, return on investments (ROI), etc. As a result, the money subjects associated with finance and economics are familiar subjects to him. During

his recent medical research work using the tool of viscoelastic or viscoplastic behavior theory, he suddenly realized that there is a strong similarity between medicine and economics. The behaviors and patterns of economics variables (inputs and outputs) he observed are comparable to the behaviors and patterns of medical variables he studied and researched (causes and symptoms), in terms of their curve shape & waveforms, the pattern of fluctuations, moving trends, physical behaviors, etc. For example, he applied the candlestick chart or K-line diagram from Wall Street as an effective glucose representation tool in medicine. In addition, both variables in medicine and economics possessed the common “time-dependent” characteristics. The recent COVID-19 pandemic is a severe and unique experience to worldwide people other than the Spanish flu that happened over 100 years ago. He wondered what type of economic impact or inter-relationship from this pandemic had on some of the key economic indices. Therefore, he selected the US GDP numbers as the output variable along with the US inflation rates (inflation) and the US COVID-19 death cases (COVID) as two input variables to conduct his first combined study of both economics and medicine. In total, he has conducted three related VGT studies in this article. The first is a hybrid study of the GDP of economics versus the inflation rate and COVID death. The second is also a hybrid study of an inflation rate of economics versus the COVID death rate and COVID infection rate from medicine. The third is a pure medical study of COVID death from medicine versus COVID infection from medicine. Mathematically, these 3 studies have used the same research method and VGT equations, but they have arrived at different outcome observations with their related perspectives and different interpretations. Initially, he Googled the US national data about economic indices and the COVID pandemic. It

should be mentioned that his COVID data are rough “rounded-off” numbers that are directly extracted from the published “graphic charts (not from data tables)” from the Center for Disease Control (CDC) and Johns Hopkins University. The COVID data are simplified with rounded numbers to thousands for death and millions for infection because using the precise digits would not alter the accuracy or change the observed physical characteristics of the results. Next, he searched for and reviewed a few economic articles related to GDP, inflation, consumer price index (CPI), etc. Over the past 2+ years, due to his medical research interest, he has already been exposed to many news and articles on media, as well as published medical research papers with clinical data regarding the COVID pandemic. This study is of particular interest to him since it links the US national economy with a severe infectious disease in modern history. This article is his first attempt to link COVID disease with some critical economic measurements, specifically GDP and inflation rate. The established theory of viscoelasticity and viscoplasticity (from the physics branch of science) should not only be limited to a smaller scope of engineering applications. Its ability to link certain variables’ time-dependent characteristics and their associated energy estimation via the hysteresis loop area is equally powerful for applications in both medicine and economics. The author would like to describe the essence of the VGT in 6 simple steps using English not equations for readers who do not have an extensive academic background in engineering, physics & mathematics - an excerpt from Wikipedia is included in the Method section of the full-text article. The first step is to collect the output data (strain or ϵ) on a time scale, e.g. annual GDP or quarterly inflation rate. The second step is to calculate the output change rate with time ($d\epsilon/dt$), e.g. GDP change rate each year or inflation change rate each quarter. The third step is to collect the input data (viscosity or η) on a time scale, e.g. quarterly COVID infection number or quarterly COVID death number. The fourth step is to calculate the time-dependent input (time-dependent stress or σ) by multiplying $d\epsilon/dt$ and η together. This input equation is time-dependent stress $\sigma = \text{strain change rate } d\epsilon/dt * \text{viscosity } \eta$. The fifth step is to plot the input-output (i.e. stress-strain or cause-symptom) curve in a space domain with strain (output or symptom) as the x-axis and stress (time-dependent input or time-dependent cause) as the y-axis. The sixth step is to calculate the total enclosed area within this input-output curve (or hysteresis loop area) which is also the indicator of associated energy (either created energy or dissipated energy) of this dataset of input and output. This energy value can also be considered as the degree of influence on output by input. After his English description, he would like to use the following re-defined VGT equation from engineering and physics to address the unique “time-dependency characteristic” of economics and

medical variables. He can then establish a stress-strain diagram in a space domain (SD) where: Strain = ϵ (GDP, Inflation rate, or COVID death) = individual strain value at the present quarter. Stress = σ (based on the change rate of strain multiplying with a chosen viscosity factor η , e.g. inflation rate, COVID death case, COVID infection case) = $\eta * (d\epsilon/dt) = \eta * (d\text{-strain}/d\text{-time}) = (\text{viscosity factor } \eta \text{ using individual viscosity factor at present quarter}) * (\text{strain at present quarter} - \text{strain at previous quarter})$. These causes or viscosity factors are further normalized by dividing them by the average viscosity factors. This normalization process can remove the dependency of the individual unit or characteristics associated with each viscosity factor. This process allows him to turn those variables into a set of “dimensionless variables” for easier comparison and interpretation of results. In this study, there are three sets of strains versus stresses as described below: (1) GDP versus Inflation rate and COVID death - a hybrid study of both economics and medicine. (2) Inflation rate versus COVID death and COVID infection - a hybrid study of both economics and medicine. (3) COVID death versus COVID infection - a pure medical study. In summary, there are 5 observations listed from this combined study of US economics & COVID pandemic: (1) From the time domain (TD) analysis, the correlations are GDP vs. Inflation % = 84% (high correlation); GDP vs. COVID death = 3% (no correlation); Inflation rate vs. COVID infection rate = 54% (moderately high correlation); Inflation rate vs. COVID death = 2% (no correlation); and COVID infection vs. COVID death = 61% (moderately high correlation). The 84% high correlation of GDP vs. inflation % matches with existing findings from many published economics papers. (Except for one UK report of GDP versus inflation, which shows a negative correlation within a shorter period). On the surface, these collected COVID data should behave like a set of independent numbers which has nothing to do with the economics dataset. But from the statistical correlation studies, the above statement holds true for COVID death only. The COVID death dataset has no correlations with other economic datasets except with COVID infection of $R=61\%$. Of course, this high correlation of 61% between COVID death and COVID infection is also dependent upon the situations such as availability of vaccine and degree of herd immunity, as well as individual new COVID variant strength and speed of spread, mortality rate, and the treatment method improvement, and availability of medical facilities. A clear observation from this TD analysis is that COVID situations of both infection rate and death rate would have influences on certain measurements of economy, such as GDP and inflation rate. (2) Researching the part of strains from the VGT results, the GDP reached its peak (19.81 trillion dollars) in Y21Q4; the inflation rate exceeded 5% (5.37% - 7.97%) for the last three quarters after

Y21Q3; the COVID death started high (120k) at the beginning quarter of Y20Q2 and then reached to its peak (270k) on Y21Q1 and then decreased until a recent mild surge during Y21Q4-Y22Q1 due to the burst of Omicron variant. (3) Researching the part of stresses from the VGT results, the first study showed that the highest stress of inflation (0.62) happened in Y21Q4, and the highest stress of COVID death (0.62) occurred in Y20Q2 due to initial shock. The ups and downs of stress (COVID death) values have indicated the actual development of the COVID pandemic situation. The second study depicted the highest negative stress of COVID death (-2.01) in Y20Q2 due to initial shock and the highest positive stress of COVID death (1.97) in Y21Q4, while the highest positive stress of COVID infection (2.84) happened in Y22Q1 due to Omicron. The third study reflected the highest stress of COVID infection (240) in Y21Q1. These stress peak timings match with the history of the COVID pandemic. (4) The combination of strain and stress components determines the actual size of the hysteresis loop area or its associated energy, i.e. the degree of influence of the stress on the strain. The first VGT study showed an inflation area of 0.65 (31%) versus a COVID death area of 1.49 (69%), a 2:1 ratio for this longer 9-quarter period. The largest loop area for inflation (0.19) happened in Y20Q3 and the largest loop area for COVID death (1.62) occurred in Y20Q2. Therefore, the author took a dividing time at Y20Q4 and then calculated the sub-loop areas. The sub-loop area ratios from Y20Q4 to Y22Q1 were inflation with 0.333 (41%) versus COVID with 0.47 (59%), a 1.5:1 ratio for this shorter 6-quarter period. In other words, these two stresses contributed different degrees of influence with a ratio of 6 to 4 on GDP during this shorter 6-quarters. The second VGT study revealed the COVID death area of 9.47 (52%) versus the COVID infection area of 8.89 (48%)

where the two stresses contributed almost equal degrees of influence on inflation %. The third VGT study depicted the degree of influence on COVID death via COVID infection with a loop area of 14,824 (there is no comparison between two inputs or stresses). This single area only represented a relative number which has no specific meaning for comparison purposes. (5) From the first VGT study, the COVID death had a stronger influence on GDP than the inflation % on GDP regardless of using the full-period of the longer 9-quarters (69% vs. 31%) or the sub-period of shorter 6-quarters (59% vs. 41%). From the second VGT study, the contributions to inflation % from either COVID death or COVID infection were almost equal. This finding is similar to some statements cited in Reference 5. The third VGT study is pure medical research work. The stress-strain curve during 2020 behaved like a skewed straight line which meant a higher infection rate indeed brought a higher death rate under the clear observation of lacking effective vaccines and availabilities of treatments and facilities in Y2020. This specific phenomenon of Y2020 also reflected the combination of realities with the initial shock of Americans, lack of preparation by the US government, and not having any effective vaccines and treatment methods in the medical community. However, after Y21Q1, with the availability of vaccines and more effective treatments in hand, the death rate dropped except for the last 2 quarters of the Omicron variant (higher transmission power but with lower mortality). This explains the twisted-rope shape of the stress-strain curve after Y21Q1. This VGT energy tool adopted from engineering and physics disciplines can indeed provide some interesting clues for useful interpretation of results from this particular research work of combined economics and medicine.

Keywords: Viscoelastic; Viscoplastic; Economics; COVID-19; Gross domestic product

Abbreviations: SD: space domain; GDP: gross domestic product; TD: time domain; MPM: math-physical medicine

1. INTRODUCTION

The author is a mathematician and engineer who has conducted medical research work over the past 13 years. To date, he has written 672 medical research papers. Beginning with paper No. 578 dated 1/8/2022, he has written a total of 80 medical research articles using the viscoelasticity and viscoplasticity theories (VGT) from physics and engineering disciplines on 80 different medical problems with their associated data. These papers aim to explore some hidden biophysical behaviors and provide a quantitative understanding of the inter-relationships of a selected medical output (symptom) versus singular input or multiple inputs (root causes, risk factors, or influential inputs). The hidden biophysical behaviors and possible inter-relationships exist among lifestyle details, medical conditions, chronic diseases, and certain severe medical complications, such as heart attacks, stroke, cancers, dementia, and even longevity concerns. All of these chosen medical subjects with their associated data, multiple symptoms, and influential factors are “time-dependent” which means that all of these biomedical variables are changing from time to time because body cells are dynamically changing. This is what Professor Norman Jones, the author’s adviser at MIT, suggested to him in December of 2021 and why he utilizes the VGT tools from physics and engineering to conduct his medical research work since then.

From 1980 to 1981, the author attended a college in California for his MBA degree, emphasizing finance and marketing. In addition, he spent many years managing a successful high-tech semiconductor business in Silicon Valley, where it involved many key factors of economics and finance, such as gross domestic product (GDP), inflation rate, stock performance, price/earnings ratio (P/E ratio), investment decisions, return on investments (ROI), etc. As a result, the money subjects associated with finance and economics are familiar subjects to him.

During his recent medical research work using the tool of viscoelastic or viscoplastic behavior theory, he suddenly realized that there is a strong similarity between medicine and economics. The behaviors and patterns of

economics variables (inputs and outputs) he observed are comparable to the behaviors and patterns of medical variables he studied and researched (causes and symptoms), in terms of their curve shape & waveforms, the pattern of fluctuations, moving trends, physical behaviors, etc. For example, he applied the candlestick chart or K-line diagram from Wall Street as an effective glucose representation tool in medicine. In addition, both variables in medicine and economics possessed the common “time-dependent” characteristics. The recent COVID-19 pandemic is a severe and unique experience to worldwide people other than the Spanish flu that happened over 100 years ago. He wondered what type of economic impact or inter-relationship from this pandemic had on some of the key economic indices. Therefore, he selected the US GDP numbers as the output variable along with the US inflation rates (inflation) and the US COVID-19 death cases (COVID) as two input variables to conduct his first combined study of both economics and medicine. In total, he has conducted three related VGT studies in this article. The first is a hybrid study of the GDP of economics versus the inflation rate and COVID death. The second is also a hybrid study of an inflation rate of economics versus COVID death rate and COVID infection rate from medicine. The third is a pure medical study of COVID death from medicine versus COVID infection from medicine. Mathematically, these 3 studies have used the same research method and VGT equations, but they have arrived at different outcome observations with their related perspectives and different interpretations.

Initially, he Googled the US national data about economic indices and the COVID pandemic. It should be mentioned that his COVID data are rough “rounded-off” numbers that are directly extracted from the published “graphic charts (not from data tables)” from the Center for Disease Control (CDC) and Johns Hopkins University. The COVID data are simplified with rounded numbers to thousands for death and millions for infection because using the precise digits would not alter the accuracy or change the observed physical characteristics of the results. Next, he searched for and reviewed a few economic articles related to GDP, inflation, consumer price index (CPI), etc.

Over the past 2+ years, due to his medical research interest, he has already been exposed to many news and articles on media, as well as published medical research papers with clinical data regarding the COVID pandemic. This study is of particular interest to him since it links the US national economy with a severe infectious disease in modern history.

This article is his first attempt to link COVID disease with some critical economic measurements, specifically GDP and inflation rate. The established theory of viscoelasticity and viscoplasticity (from the physics branch of science) should not only be limited to a smaller scope of engineering applications. Its ability to link certain variables' time-dependent characteristics and their associated energy estimation via the hysteresis loop area is equally powerful for applications in both medicine and economics.

The author would like to describe the essence of the VGT in 6 simple steps using English not equations for readers who do not have an extensive academic background in engineering, physics & mathematics - an excerpt from Wikipedia is included in the Method section of the full-text article.

The first step is to collect the output data (strain or ϵ) on a time scale, e.g. annual GDP or quarterly inflation rate. The second step is to calculate the output change rate with time ($d\epsilon/dt$), e.g. GDP change rate each year or inflation change rate each quarter. The third step is to collect the input data (viscosity or η) on a time scale, e.g. quarterly COVID infection number or quarterly COVID death number. The fourth step is to calculate the time-dependent input (time-dependent stress or σ) by multiplying $d\epsilon/dt$ and η together. This input equation is time-dependent stress $\sigma = \text{strain change rate } d\epsilon/dt * \text{viscosity } \eta$. The fifth step is to plot the input-output (i.e. stress-strain or cause-symptom) curve in a space domain with strain (output or symptom) as the x-axis and stress (time-dependent input or time-dependent cause) as the y-axis. The sixth step is to calculate the total enclosed area within this input-output curve (or hysteresis loop area) which is also the indicator of associated energy (either created energy or dissipated energy) of this dataset of input and output. This energy

value can also be considered as the degree of influence on output by input.

After his English description, he would like to use the following re-defined VGT equation from engineering and physics to address the unique "time-dependency characteristic" of economics and medical variables. He can then establish a stress-strain diagram in a space domain (SD) where:

Strain
 $= \epsilon$ (GDP, Inflation rate, or COVID death)
 $=$ individual strain value at the present quarter

Stress
 $= \sigma$ (based on the change rate of strain multiplying with a chosen viscosity factor η , e.g. inflation rate, COVID death case, COVID infection case)
 $= \eta * (d\epsilon/dt)$
 $= \eta * (d\text{-strain}/d\text{-time})$
 $= (\text{viscosity factor } \eta \text{ using individual viscosity factor at present quarter}) * (\text{strain at present quarter} - \text{strain at previous quarter})$

These causes or viscosity factors are further normalized by dividing them by the average viscosity factors. This normalization process can remove the dependency of the individual unit or characteristics associated with each viscosity factor. This process allows him to turn those variables into a set of "dimensionless variables" for easier comparison and interpretation of results.

In this study, there are three sets of strains versus stresses as described below:

- (1) GDP versus Inflation rate and COVID death - a hybrid study of both economics and medicine.
- (2) Inflation rate versus COVID death and COVID infection - a hybrid study of both economics and medicine.
- (3) COVID death versus COVID infection - a pure medical study.

2. METHODS

2.1 GDP, inflation & COVID

The author takes a few excerpts from several articles he has read and listed below:

“Over time, the growth in GDP causes inflation (the author’s note: There is a +84% correlation existed between GDP and inflation within these 9 quarters). However, inflation, if left unchecked, runs the risk of morphing into hyperinflation. If the overall economic output is declining, or merely holding steady, most companies will not be able to increase their profits (which is the primary driver of stock performance); however, too much GDP growth is also dangerous (From Reference 1).

Higher production leads to a lower unemployment rate, further fueling demand. Increased wages lead to higher demand as consumers spend more freely. This leads to higher GDP combined with inflation (From Reference 2).

There is a negative relationship between inflation and GDP in the UK, at least in the short run (the author’s note: this may result from one of the shortcomings, time-window size, of using statistics tools), which is consistent with most of the theories that have been developed throughout the years (From Reference 3).

The US Consumer Price Index (CPI) may understate the rate of inflation during the COVID-19 crisis because it does not reflect pandemic-induced shifts in spending patterns, according to findings reported in *Inflation with COVID Consumption Baskets* (NBER Working Paper 27352) (From Reference 4).

“We are experiencing this sudden surge in inflation for two main reasons,” says Craig Kirsner, President of Stuart Estate Planning Wealth Advisors in Coconut Creek, Florida. “First, for the past year and a half due to Covid, hardly anyone was spending money. Now that the economy is back open, people are spending and traveling and, as such, there is a bottleneck with very high demand. Our system isn’t set up for this high demand level, so that causes inflation in the short term. Second, with interest rates lowered to almost zero since March of 2020, these low-interest rates have spurred demand in housing which is experiencing a large backlog as well as adding to inflation worries.”

“It’s largely due to a perfect storm of supply chain disruption from Covid, government spending to fill the economic void, and a

synchronized global recovery driven by vaccine rollout and economies re-opening,” says John P. Micklitsch, Chief Investment Officer at Ancora in Cleveland. “The pandemic is probably just the event that exposed over a decade of underinvestment in the global commodity supply chain and the vulnerability of ‘just-in-time’ inventories to this sort of supply shock.”

“A large portion of what we are experiencing in inflation is due to the deflation which we saw in 2020 during the Covid shutdowns,” says Mike Windle, CEO at Custom Wealth Solutions in Plymouth, Michigan. “As prices work to normalize, it is causing inflationary pressure. Add to that the pent-up demand caused by the Covid lockdowns; we are seeing prices rise quickly.”

If many point a finger at Covid causing inflation, many point a second finger at national leadership.

“Legislation from Washington has likely played a role in increasing demand for goods over the last year,” says Saunders. “The CARES Act distributed direct cash payments to individuals and also increased unemployment benefits. These had a direct impact on increasing the incomes and savings rates of many individuals. Along with these transfer payments, the Act also allowed for those in need to defer payments on mortgages and student loans, ‘freeing up’ more cash for individuals to spend on goods and services.”

“Injecting large amounts of cash into an economy through stimulus and other spending programs like the proposed trillion+ dollar ‘infrastructure’ bill will ramp up economic growth, and will certainly not decrease inflationary pressures,” says Taddei. “It is a combination of issues, fiscal stimulus, the Federal Reserve’s loose monetary policy and the subsequent increase in the money supply that creates more money chasing fewer goods and services.” (From Reference 5)”

2.2 MPM background

To learn more about his developed GH-Method: math-physical medicine or MPM methodology, readers can select the following three articles from the 400+ published medical papers.

The first paper, No. 386, describes his MPM methodology in a general conceptual format. The second paper, No. 387, outlines the history of his personalized diabetes research, various application tools, and the differences between the biochemical medicine (BCM) approach versus the MPM approach. The third paper, No. 397, depicts a general flow diagram containing ~10 key MPM research methods and different tools.

All of the listed papers in the Reference section are his written and published medical research papers.

2.3 Elasticity, plasticity, viscoelasticity, and viscoplasticity (LEGT & VGT)

The difference between elastic materials and viscoelastic materials (from “Soborthans, innovating shock and vibration solutions”).

What are elastic materials?

Elasticity is the tendency of solid materials to return to their original shape after forces are applied on them. When the forces are removed, the object will return to its initial shape and size if the material is elastic.

Medical analogy: The medical application is when cause or risk factors are reduced or removed, the symptoms of certain disease would be improved or ceased.

What are viscous materials?

Viscosity is a measure of a fluid’s resistance to flow. A fluid with large viscosity resists motion. A fluid with low viscosity flows. For example, water flows more easily than syrup because it has a lower viscosity. High viscosity materials might include honey, syrups, or gels – generally things that resist flow. Water is a low viscosity material, as it flows readily. Viscous materials are thick or sticky or adhesive. Since heating reduces viscosity, these materials don’t flow easily. For example, warm syrup flows more easily than cold.

What is viscoelastic?

Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Synthetic polymers, wood, and human tissue, as well as metals at high

temperature, display significant viscoelastic effects. In some applications, even a small viscoelastic response can be significant.

Medical analogy: Viscoelastic behavior means material has “time-dependent” characters. Biomedical data, i.e. biomarkers, are time-dependent due to body cells are organic which changes with time constantly.

Elastic behavior versus viscoelastic behavior

The difference between elastic materials and viscoelastic materials is that viscoelastic materials have a viscosity factor and the elastic ones don’t. Because viscoelastic materials have the viscosity factor, they have a strain rate dependent on time. Purely elastic materials do not dissipate energy (heat) when a load is applied, then removed; however, a viscoelastic substance does.

Medical analogy: Most of the biomarkers display time-dependency; therefore they have both change-rate of time and viscosity factor behaviors. Viscoelastic biomarkers do dissipate energy when a cause force is applied on it.

The following brief introductions are excerpts from Wikipedia:

“Elasticity (physics):

The physical property is when materials or objects return to their original shape after deformation.

In physics and materials science, elasticity is the ability of a body to resist a distorting influence and to return to its original size and shape when that influence or force is removed. Solid objects will deform when adequate loads are applied to them; if the material is elastic, the object will return to its initial shape and size after removal. This is in contrast to plasticity, in which the object fails to do so and instead remains in its deformed state.

Hooke's law states that the force required to deform elastic objects should be directly proportional to the distance of deformation, regardless of how large that distance becomes. This is known as perfect elasticity, in which a given object will return to its original shape no matter how strongly it is deformed. This is an ideal concept only; most

materials that possess elasticity in practice remain purely elastic only up to very small deformations, after which plastic (permanent) deformation occurs.

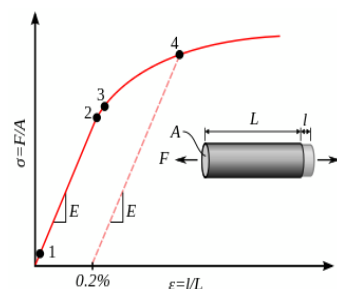
In engineering, the elasticity of a material is quantified by the elastic modulus such as the Young's modulus, bulk modulus or shear modulus which measure the amount of stress needed to achieve a unit of strain; a higher modulus indicates that the material is harder to deform. The material's elastic limit or yield strength is the maximum stress that can arise before the onset of plastic deformation.

Medical analogy: The elastic behavior analogy in medicine can be expressed by the metal rod analogy for the postprandial plasma glucose (PPG). Consuming carbohydrates and/or sugar acts like a tensile force to stretch a metal rod longer, while post-meal exercise acts like a compressive force to suppress a metal rod shorter. If lacking food consumption and exercise, the metal rod (analogy of PPG) will remain its original length, for a non-diabetes or less severe type 2 diabetes (T2D) patient.

Plasticity (physics):

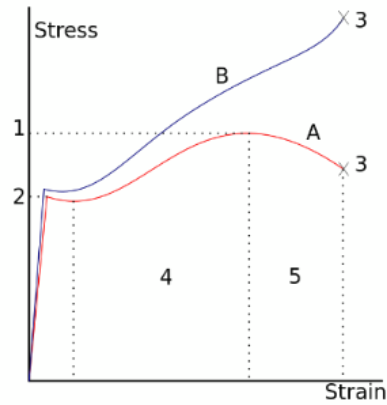
Deformation of a solid material undergoing non-reversible changes of shape in response to applied forces.

In physics and materials science, plasticity, also known as plastic deformation, is the ability of a solid material to undergo permanent deformation, a non-reversible change of shape in response to applied forces. For example, a solid piece of metal being bent or pounded into a new shape displays plasticity as permanent changes occur within the material itself. In engineering, the transition from elastic behavior to plastic behavior is known as yielding. Plastic deformation is observed in most materials, particularly metals, soils, rocks, concrete, and foams.



A stress-strain curve showing typical yield behavior for nonferrous alloys.

1. True elastic limit
2. Proportionality limit
3. Elastic limit
4. Offset yield strength



A stress-strain is typical of structural steel.

- 1: Ultimate strength
- 2: Yield strength (yield point)
- 3: Rupture
- 4: Strain hardening region
- 5: Necking region
- A: Apparent stress (F/A_0)
- B: Actual stress (F/A)

For many ductile metals, tensile loading applied to a sample will cause it to behave in an elastic manner. Each increment of load is accompanied by a proportional increment in extension. When the load is removed, the piece returns to its original size. However, once the load exceeds a threshold – the yield strength – the extension increases more rapidly than in the elastic region; now when the load is removed, some degree of extension will remain.

Medical analogy: A plastic behavior analogy in medicine is the PPG level of a severe T2D patient. Even consuming a smaller amount of carbs/sugar, the patient's PPG will rise sharply which cannot be totally brought down to a healthy PPG level even with a significant amount of exercise. This means the PPG level has exceeded its "elastic limit" and entering into a "plastic range".

Viscoelasticity:

Property of materials with both viscous and elastic characteristics under deformation.

In materials science and continuum mechanics, viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like water, resist shear flow and strain linearly with time when a stress is applied. Elastic materials strain when stretched and immediately return to their original state once the stress is removed.

Viscoelastic materials have elements of both of these properties and, as such, exhibit time-dependent strain. Whereas elasticity is usually the result of bond stretching along crystallographic planes in an ordered solid, viscosity is the result of the diffusion of atoms or molecules inside an amorphous material.

In the nineteenth century, physicists such as Maxwell, Boltzmann, and Kelvin researched and experimented with creep and recovery of glasses, metals, and rubbers. Viscoelasticity was further examined in the late twentieth century when synthetic polymers were engineered and used in a variety of applications. Viscoelasticity calculations depend heavily on the viscosity variable, η . The inverse of η is also known as fluidity, ϕ . The value of either can be derived as a function of temperature or as a given value (i.e. for a dashpot).

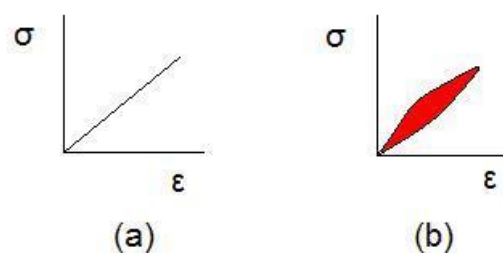
Depending on the change of strain rate versus stress inside a material, the viscosity can be categorized as having a linear, non-linear, or plastic response. In addition, when the stress is independent of this strain rate, the material exhibits plastic deformation. Many viscoelastic materials exhibit rubber-like behaviors explained by the thermodynamic theory of polymer elasticity.

Cracking occurs when the strain is applied quickly and outside of the elastic limit. Ligaments and tendons are viscoelastic, so the extent of the potential damage to them depends both on the rate of the change of their length as well as on the force applied.

A viscoelastic material has the following properties:

- hysteresis is seen in the stress-strain
- stress relaxation occurs: step constant strain causes decreasing stress
- creep occurs: step constant stress causes increasing strain
- its stiffness depends on the strain rate or the stress rate.

Elastic versus viscoelastic behavior:



Stress-strain curves for a purely elastic material (a) and a viscoelastic material (b). The red area is a hysteresis loop and shows the amount of energy lost (as heat) in a loading and unloading cycle. It is equal to $\oint \sigma d\epsilon$ where σ is stress and ϵ is strain. In other words, the hysteresis loop area represents the amount of energy during the loading and unloading process.

Unlike purely elastic substances, a viscoelastic substance has an elastic component and a viscous component. The viscosity of a viscoelastic substance gives the substance a strain rate dependence on time. Purely elastic materials do not dissipate energy (heat) when a load is applied, then removed. However, a viscoelastic substance dissipates energy when a load is applied, then removed. Hysteresis is observed in the stress-strain curve, with the area of the loop being equal to the energy lost during the loading cycle. Since viscosity is the resistance to thermally activated plastic deformation, a viscous material will lose energy through a loading cycle. Plastic deformation results in lost energy, which is uncharacteristic of a purely elastic material's reaction to a loading cycle.

Viscoplasticity:

Viscoplasticity is a theory in continuum mechanics that describes the rate-dependent inelastic behavior of solids. Rate-dependence in this context means that the deformation of the material depends on the rate at which loads are applied. The inelastic behavior that is the subject of viscoplasticity is plastic deformation which means that the material undergoes unrecoverable deformations when a load level is reached. Rate-dependent plasticity is important for transient plasticity calculations. The main difference between rate-independent plastic and viscoplastic material models is that the latter exhibit not only permanent deformations after the application of loads but continue to undergo a creep flow as a function of time under the influence of the applied load.

Medical analogy: In viscoelastic or viscoplastic analysis, the stress component equals the strain change rate of time multiplying with the viscosity factor, or

Stress (σ)
 = strain (ϵ) change rate * viscosity factor (η)
 = $d\epsilon/dt * \eta$

The hysteresis loop area
 = the integrated area of stress (σ) and strain (ϵ) curve
 = $\oint \sigma d\epsilon$

Note: For a more detailed description, please refer to the “consolidated method” section which is given at the beginning of the special issue.

3. RESULTS

Figure 1 shows VGT stress-strain analysis results of GDP versus inflation and COVID death with an associated data table.

Figure 2 depicts VGT stress-strain analysis results of Inflation versus COVID death and COVID infection with an associated data table.

Figure 3 displays VGT stress-strain analysis results of COVID death versus COVID infection with an associated data table.

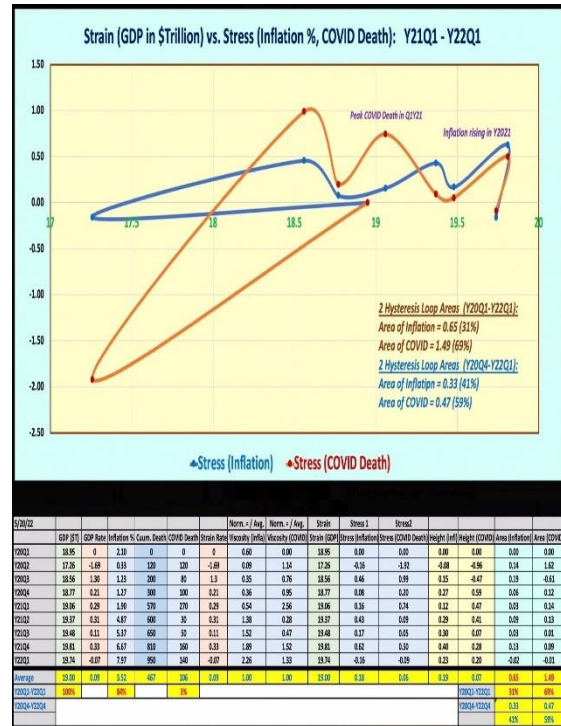


Figure 1: VGT analysis results of GDP versus inflation and COVID death.

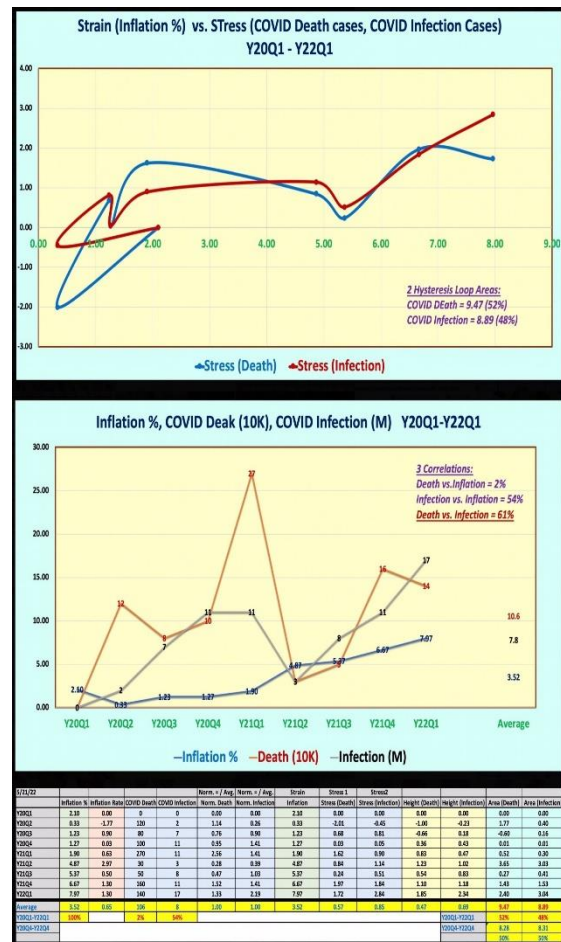


Figure 2: VGT analysis results of inflation versus COVID death and COVID infection.

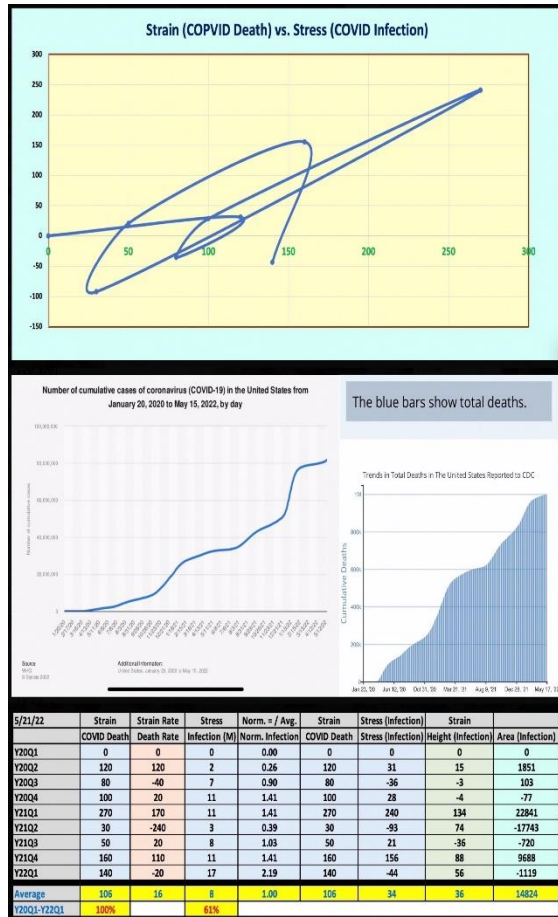


Figure 3: VGT analysis results of COVID death versus COVID infection.

4. CONCLUSION

In summary, there are 5 observations listed from this combined study of US economics & COVID pandemic:

(1) From the time domain (TD) analysis, the correlations are GDP vs. Inflation % = 84% (high correlation); GDP vs. COVID death = 3% (no correlation); Inflation rate vs. COVID infection rate = 54% (moderately high correlation); Inflation rate vs. COVID death = 2% (no correlation); and COVID infection vs. COVID death = 61% (moderately high correlation). The 84% high correlation of GDP vs. inflation % matches with existing findings from many published economics papers. (Except for one UK report of GDP versus inflation, which shows a negative correlation within a shorter period). On the surface, these collected COVID data should behave like a set of independent numbers which has nothing to do with the economics dataset. But from the statistical correlation studies, the above statement holds true for COVID death only. The COVID death dataset has no correlations with other economic datasets

except with COVID infection of R=61%. Of course, this high correlation of 61% between COVID death and COVID infection is also dependent upon the situations such as availability of vaccine and degree of herd immunity, as well as individual new COVID variant strength and speed of spread, mortality rate, and the treatment method improvement, and availability of medical facilities. A clear observation from this TD analysis is that COVID situations of both infection rate and death rate would have influences on certain measurements of economy, such as GDP and inflation rate.

(2) Researching the part of strains from the VGT results, the GDP reached its peak (19.81 trillion dollars) in Y21Q4; the inflation rate exceeded 5% (5.37% - 7.97%) for the last three quarters after Y21Q3; the COVID death started high (120k) at the beginning quarter of Y20Q2 and then reached to its peak (270k) on Y21Q1 and then decreased until a recent mild surge during Y21Q4-Y22Q1 due to the burst of Omicron variant.

(3) Researching the part of stresses from the VGT results, the first study showed that the highest stress of inflation (0.62) happened in Y21Q4, and the highest stress of COVID death (0.62) occurred in Y20Q2 due to initial shock. The ups and downs of stress (COVID death) values have indicated the actual development of the COVID pandemic situation. The second study depicted the highest negative stress of COVID death (-2.01) in Y20Q2 due to initial shock and the highest positive stress of COVID infection (2.84) happened in Y22Q1 due to Omicron. The third study reflected the highest stress of COVID infection (240) in Y21Q1. These stress peak timings match with the history of the COVID pandemic.

(4) The combination of strain and stress components determines the actual size of the hysteresis loop area or its associated energy, i.e. the degree of influence of the stress on the strain. The first VGT study showed an inflation area of 0.65 (31%) versus a COVID death area of 1.49 (69%), a 2:1 ratio for this longer 9-quarter period. The largest loop area for inflation (0.19) happened in Y20Q3 and the largest loop area for COVID death (1.62) occurred in Y20Q2. Therefore, the author took a dividing time at Y20Q4 and then calculated the sub-loop areas. The sub-loop

area ratios from Y20Q4 to Y22Q1 were inflation with 0.333 (41%) versus COVID with 0.47 (59%), a 1.5:1 ratio for this shorter 6-quarter period. In other words, these two stresses contributed different degrees of influence with a ratio of 6 to 4 on GDP during this shorter 6-quarters. The second VGT study revealed the COVID death area of 9.47 (52%) versus the COVID infection area of 8.89 (48%) where the two stresses contributed almost equal degrees of influence on inflation %. The third VGT study depicted the degree of influence on COVID death via COVID infection with a loop area of 14,824 (there is no comparison between two inputs or stresses). This single area only represented a relative number which has no specific meaning for comparison purposes.

(5) From the first VGT study, the COVID death had a stronger influence on GDP than the inflation % on GDP regardless of using the full-period of the longer 9-quarters (69% vs. 31%) or the sub-period of shorter 6-quarters (59% vs. 41%). From the second VGT study, the contributions to inflation % from either COVID death or COVID infection were almost equal. This finding is similar to some statements cited in Reference 5. The third VGT study is pure medical research work. The stress-strain curve during 2020 behaved like a skewed straight line which meant a higher infection rate indeed brought a higher death rate under the clear observation of lacking effective vaccines and availabilities of treatments and facilities in Y2020. This specific phenomenon of Y2020 also reflected the combination of realities with the initial shock of Americans, lack of preparation by the US government, and not having any effective vaccines and treatment methods in the medical community. However, after Y21Q1, with the availability of vaccines and more effective treatments in hand, the death rate dropped except for the last 2 quarters of the Omicron variant (higher transmission power but with lower mortality). This explains the twisted-rope shape of the stress-strain curve after Y21Q1.

This VGT energy tool adopted from engineering and physics disciplines can indeed provide some interesting clues for useful interpretation of results from this particular research work of combined economics and medicine.

5. REFERENCES

For editing purposes, the majority of the references in this paper, which are self-references, have been removed. Only references from other authors' published sources remain. The bibliography of the author's original self-references can be viewed at www.eclaircmd.com.

Readers may use this article as long as the work is properly cited, their use is educational and not for profit, and the author's original work is not altered.

- 1) The importance of inflation and GDP. Investopedia. 2022.
- 2) Why does inflation increase with GDP growth? Investopedia. 2022.
- 3) Ivory Research. The relationship between inflation and economic growth (GDP): an empirical analysis. 2019.
- 4) Inflation Measurement in the Era of COVID-19. NBER. D8:2020.
- 5) Fischer S. The role of macroeconomic factors in growth. *Journal of Monetary Economics*. 1993;32(3):45-66.
- 6) Carosa C. Covid Or policy: What's causing this inflation surge? *Forbes*. 2021.
- 7) Barro RJ. Inflation and growth. *Review of Federal Reserve Bank of St. Louis*. 1996;78(3):153-169.
- 8) Bruno M, Easterly W. Inflation crises and long-run growth. *Review of Federal Reserve Bank of St. Louis*. 1996;78(3):139-46.
- 9) Ghosh A, Phillips S. Warning: inflation may be harmful to your growth. *IMF Staff Papers*. 1998;45(4):672-710.
- 10) Engle RF, Granger CWJ. Co-integration and error correction: representation, estimation, and testing. *Econometrica*. 1987;55(2):251-276.

Viscoelastic and Viscoplastic Glucose Theory Application in Medicine

Gerald C. Hsu

