Model Ontology for Economic Models

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Abstract--**In an earlier paper, we introduced the distinction between a 'model-structure' (consisting of the system components and lines connecting components) and a 'model-ontology' (consisting of the measurement methodology in the model and the translation of information to another model). Here we apply this distinction to the methodological challenge of measurement and integration of economic models. The economics literatures had divided into two schools over the nature of models -- of commodity markets and of financial markets. The Neo-Classical Synthesis school emphasized a model of commodity markets. The Keynes-Minsky school emphasized a model of financial markets. In the first school, commodity markets are modeled in 'price-equilibrium' models; and in the second school, financial markets are modeled in 'price-disequilibrium models'. We investigate the ontological issues of transmitting data from one kind of economic model to the other.**

I. INTRODUCTION

In an earlier paper, we introduced the concept of a 'model ontology', which consists *of the measurement methodology in the model and the translation of information to another model.* [3] We indicated that model ontologies were needed to communicate data/information when:

1. Models wherein quantities are not commensurate, such as 'dollarizing' in economic models. Examples include the government figuring a value of $6.5 million per life saved in health care budgeting; researchers using 'price as a proxy for quality'; etc.
2. Models where commensurability is not required, e.g. in Data Envelopment Analysis, or in simple dimensional analysis ("a" degrees temperature change per foot, times "b" feet/second).
3. Models where approximate commensuration is achieved by estimation, e.g. max-entropy estimation of distributions from histogram data [16]; associative methods in semantic processing; or fuzzy queries (e.g.,[17]).
4. Models where a higher-level variable and/or formal meta-language must be created to accommodate researchers in more than one discipline, each having conflicting traditional criteria, e.g. the social worker who feeds the homeless (giving policy priority to their welfare) vs. the economist who advises against the practice (giving policy priority to the possibly perverse incentives created by free meals). Sometimes the researchers can agree on a higher-level variable such as "number of lives saved."
5. Models that can be pre-structured such that sub-models pass information to each other in iterative fashion in the form of prices, for example via linear programming decomposition. [16]
6. Models of discrete tasks that exchange simple signals with other discrete task models via the passing of tokens, as in e.g. kanban systems, in order to model a larger process (in the case of kanbans, to model the entire factory flow.)

The use of model ontologies involve the communication of two kinds of models, such as Models A and B have different authors: Phase I: Model B can decide whether to use, and then use, output of Model A. This does not involve re-running Model A. Phase II: Authors of Model A upload a cloud-based template of Model A. Model B can pass data to Model A, run it, and incorporate results into Model B. In either case, the two models will need metadata statements for:

1. *Model assumptions.* Assumptions are about human behavior, technology trends and capabilities, and ranges of variables. Some assumptions are explicit, and some are implicit – the latter sometimes so much so that they are unspoken parts of a discipline's worldview, for example, the rationality assumption in neoclassical economics.
2. *Data*. In addition to the usual data ontologies and the considerations mentioned earlier in this paper, metadata will be needed on the grouping and transformation of raw data. For example, "All entries with 'Y' in column 5 were control group"; or, that a factor analysis was performed with such and such criteria and outcome; etc.
3. *Purpose of the model*: Models are variously intended to optimize, ameliorate, satisfice, prove, measure, test, etc. Model A's authors' intent will have to be made plain, via metadata, in order for Model B to communicate with Model A.
4. *Results*. This is a simpler matter. Many results statements may be taken directly from the SPSS manual. Example: A simple ANOVA leads to result "There is/isn't a difference between groups 1 and 2."
5. *Limitations*. Model limitations, also essential for MTTM, may be encoded in terms of:
6. *Reasoning.* Within a model, its 'inference machine' of the software running the simulations in the model must be clearly understood, articulated, and communicated -- as to the principles and assumptions in the inference-reasoning of the model.

In this paper, we apply the concept of model methodology to enabling two kinds of economic models to communicate: economic price-equilibrium models and economic price-disequilibrium models.

II. BACKGROUND – COMMODITY MARKETS PRICING MODELS

One of the authors has explored the difference between economic models of two different schools of economics: the price-equilibrium model of the Neo-Classical Synthesis School and the price-disequilibrium model of the Keynes-Mensky School. [14] The price-equilibrium model is appropriate for commodity markets, and the price-disequilibrium school is appropriate to financial markets.

For a commodity market, such as in Figure 1, the price of a commodity is charted as the quantity of the supply of the product (dotted line), the price will decrease in an economy as the supply increases. Because of business competition, more goods flooding a market will force prices down. Also if the demand for a product (solid line) increases, then the price will increase (as more consumers buy a limited amount of product). The optimal pricing of a product (commodity) in an economy will occur when supply equals demand. This is the equilibrium price, as supply and demand meet in quantity. If a market behaves like this, it is economically 'perfect'. No control over pricing is necessary, as 'supply-demand equilibrium' sets the optimal price. (One notes that there is no time-dimension in this graph, which assumes that the equilibrium of pricing was quickly attained in a market and remained stable.)

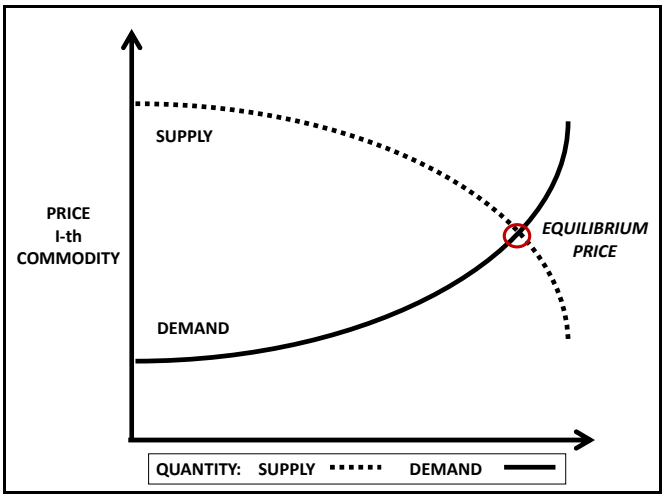

Figure 1. Economic Equilibrium Pricing of an I-th Product When Supply Equals Demand

This pricing equilibrium model is specific for a particular market. So the next economic model one needs upon which to track a price-equilibrium is a list of all the markets in an economy. This model was created by Wassily Leontief, when he formulated a model of a national economy as a topological flow model of all the products from industrial sectors produced or consumed in the economy.[11] He described the total production (P_i) from an economic sector (such as manufacturing or agriculture) and traces that quantity of production P_i plus inports of the Ith product are distributed into the economy for consumers (C_i) or for other industrial sectors (X_{Ij}) or exported to other countries E_I. Then a Leontief input-output matrix equation describing the economy in sectors can be written as: $\mathbf{P_i + I_I = C_i + \Sigma_J X_{IJ} + E_I}$.

This is read as the quantity of production P_i in the I-th economic sector is distributed to a summation of all (a) the consumers of the i-th products and (b) the industrial consumption and (c) the exports. The summation sum $(\mathbf{\Sigma_J})$ taken over all other J-th economic sectors. (In mathematical notation, the quantities of P, C, E are vectors and X is a matrix.) This is a 'system' model of the production system of an economy -- with inputs to the economy by production (P_I) in I-th sectors of the economy -- and outputs from the production into the economic sectors of consumer consumption (C_I) and the other J-th sectors of industrial consumption (X_{IJ}) and exports (E_I) to other nations. As shown in figure 2, one can reorder the equation to obtain the classic economic import-export equation:

$$\mathbf{(I_i - E_I) = (C_i + \Sigma_J X_{IJ} - P_i)}$$

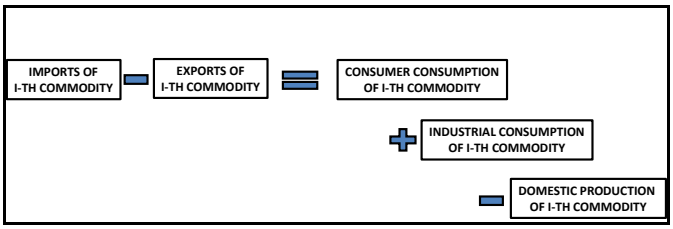

Figure 2. Leontief Production-consumption-balance Model

For each I-th sector of production in a national economy, there is a import-export balance equation: $\mathbf{(I_I - E_I) = (C_I + \Sigma_J X_{IJ} - P_I)}$. To obtain the total différence for a whole economy, one sums over all the I-th commodities in the nation: $\mathbf{\Sigma_I (I_I - E_I) = \Sigma_I (C_I + \Sigma_J X_{IJ} - P_I)}$.

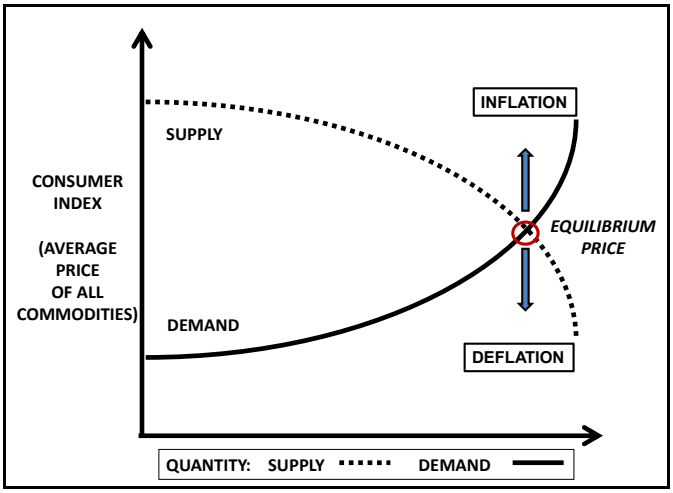

Figure 3. Economic Equilibrium Pricing of All Products When Supply Equals Demand in a National Economy

Each price-equilibrium chart is particular for each I-th commodity-market. To obtain a price-equilbrium commodity chart for the whole production of an economy, one must average over all the I-th markets. One current measure for this kind average of price-changes for a 'market basket' of commodities is the so-called 'consumer price index'. As the index moves upwards, the economy is indicated to be in a monetary inflation ; and a downward movement indicates a deflation (recession), Figure 3.

III. BACKGROUND – FINANCIAL MARKETS PRICING MODELS

John Maynard Keynes, long ago, and later Hyman Minsky both had emphasized that a financial market does not operate in pricing as do commodity markets. [9] [14] However many economists ignored this key distinction, including Alan Greenspan. In the late 1990s, Greenspan was chair of the Federal Reserve System and, with his colleagues, argued that financial markets were perfect (just like commodity markets). This false argument was used to justify deregulation of banking in the U.S. and to avoid regulation of the emerging derivatives market. In 1999, the Glass-Steagle Act separating investment and commercial banking was repealed. This allowed the creation of integrated banks – which proved 'too-big-to-fail' and then needed the huge bailing out by the Federal Government in 2008.[19]

The 'too-large banks' created a major economic risk in the whole financial system, if and when they made too large risky trades and bad investments in an unregulated derivatives market. Both American and British regulatory authorities had assumed this equilibrium model was empirically appropriate for a 'financial market.' For example, Binyamin Appelbaum wrote: " The Fed (Federal Reserve System) began 2007 still deeply immersed in complacent disregard for problems in the housing market. Fed officials knew that people were losing their homes. They knew that subprime lenders were blinking out of business with every passing week. But they did not understand the implications for the broader economy. . . August 2007 was the month that the Fed began its long transformation from somnolence to activism." [1] Afterwards, the Fed started the biggest bank 'bail-out' in U.S. economic history.

What was the soporific which had put the Fed to sleep? It had been this misuse of a commodity market model -- by the so-called 'mainstream economic theory' -- the Neo-Classical Synthesis School. Such economics had assumed all markets were perfectly self-regulating, even financial markets. This soporific was not only in U.S. regulatory policy but also in British. Sir Meryn King (Governor of the Bank of England in 2007) later said: "With the benefit of hindsight, we (Bank of England) should have shouted from the rooftops that a system had been built in which banks were too important to fail, that banks had grown too quickly and borrowed too much, and that so-called 'light-touch' regulation hadn't prevented any of this." [8] The big banks had gained such large capital assets and at risk, that their failure would bring down a whole economy.

In particular, 'mainstream economic theory' had paid little attention to the role of 'financial-bubbles-and-bank-panics' as precursors to recessions. For example in 2009, Paul Krugman wrote: "It's hard to believe now, but not long ago economists were congratulating themselves over the success of their field. Those successes — or so they believed — were both theoretical and practical, leading to a golden era for the profession. . . . . Few economists saw our current crisis coming, but this predictive failure was the least of the field's problems. More important was the profession's blindness to the very possibility of catastrophic failures in a market economy. . . . There was nothing in the prevailing models suggesting the possibility of the kind of collapse that happened last year in 2008. . . Macroeconomists (remain) divided in their views. The main division was between those who insisted that free-market economies never go astray and those who believed that economies may stray now and then (but that any major deviations from the path of prosperity could and would be corrected by the all-powerful Fed). Neither side was prepared to cope with an economy that went off the rails despite the Fed's best efforts. . . . And in the wake of the crisis, the fault lines in the economics profession have yawned wider than ever."[10]

In contrast, the Neo-Keynesians had argued that the Neo-Classical Synthesis School economists were too narrowly focused on viewing an economy only as a production system. Ben Bernanke wrote: "Economists have not always fully appreciated the importance of a healthy financial system for economic growth or the role of financial conditions in short-term economic dynamics. . . ." [2] Bernanke was pointing out the school of classical economists had assumed that 'instability' in financial markets had little or no effect upon an economy.

About this, Hyman Minsky commented: "As Ben Bernanke points out the dominant microeconomic paradigm is an equilibrium construct . . . that determines relative prices . . . . (The assumption is that) money and financial interrelations are not relevant to the determination of these equilibrium variables. . . . But if the basic microeconomic model is opened to include 'yesterdays, todays, and tomorrows' . . . (then finance can influence price equilibrium)." [15] Minsky was pointing out that the temporal dynamics (time-dimension) of financial markets did have an effect upon the stability of an economy.

Minsky was insisting that a 'dimension-of-time' needs to be introduced into economic models. Drawing upon John Maynard Keynes work, Minsky wrote: "In the *General Theory*, Keynes sought to create a model of the economy in which money is never neutral (to pricing). He did this by creating a model . . . in which the price level of financial . . . assets is determined in (financial) markets. . . . Each capital and financial asset yields an income stream, (which) has carrying costs and possessing some degree of liquidity. . .

The price level of assets is determined by the relative value . . (of) income . . . and liquidity . . ." [15]

In Keynes' model of a financial system, a 'time-dependence' is implicit in the concept of a 'capital asset' having both a 'present-income' and a 'future-liquidity'. A capital-asset is an investment which creates income and can later be sold. It produces an income stream (present-income) and also can be sold in the future (future-liquidity). The time dimension is from ($\mathbf{T_1}$) of a present-income to ($\mathbf{T_2}$) of future-liquidity. This present-to-future ($\mathbf{T_1}$ to $\mathbf{T_2}$) temporal process occurs in a financial system as a transaction of 'credit-debt'.

Minsky wrote: "Every capitalist economy is characterized by a system of borrowing and lending . . . . The fundamental borrowing and lending act . . . is an exchange of 'money-now' for 'money-in-the-future'. This exchange takes place . . . in a negotiation in which the borrower demonstrates to the satisfaction of the lender -- that the money of the future part of the contract will be forthcoming. . . The money in the future is to cover both the interest and the repayment of the principle of the contract." [15]

A financial market makes the 'credit-debt-contracts' sellable over time, as a future-liquidity. Thus in a financial sub-system, three things are essential: (1) 'credit-debt-contracts' as a fundamental financial process, and (2) a 'capital-asset-market' for liquidity of the asset, and (3) 'money' as a medium of value-exchange. Using Minsky's emphasis on a time dimension to model a financial market, the author diagramed such a temporal financial process, as in Figure 4. [4]

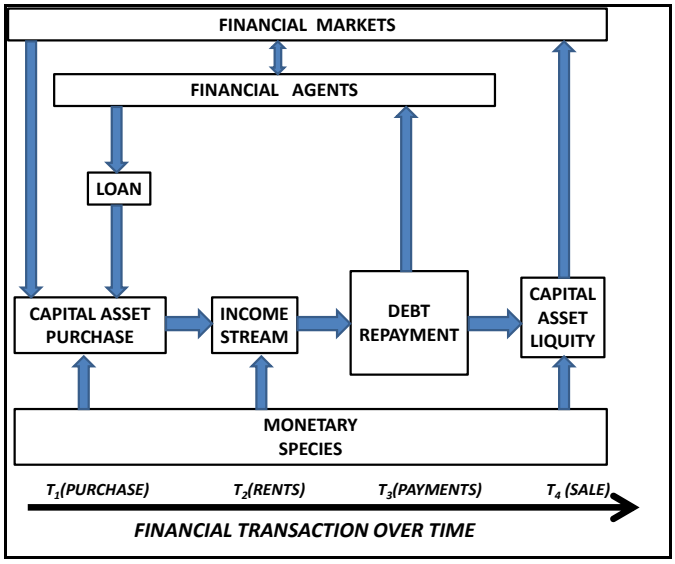

Figure 4. Keynes/Minsky Financial Process

A financial capital-asset-transaction occurs over time, beginning with a loan for an asset purchase, followed by rents (income stream) from the productivity of the capital asset, which are used for payments of the loan until the sale of the asset. Financial agents provide a purchase loan to the purchaser of the asset, receiving in turn from the purchaser loan payments on the debt over time from T_1 through T_3. Financial markets price the capital asset for purchase at time T_1 and later for sale at time T_4.

Debt makes a financial process operate. Yet one aspect of debt can destabilize the process; and this is 'leverage'. To increase profit, a financial system uses debt to finance the purchase of capital assets. Profits can be increased through financial leverage; and this is the financial rational of 'leverage' (more 'present-debt' toward greater 'future-wealth'). However, when present-debt is too large (too highly leveraged), it might not create future-wealth but, instead, bankruptcy. *Excessive 'leverage' increases the likelihood of bankruptcy and not future-wealth.* This was earlier pointed out by Irving Fisher, who called a financial state of excessive-leverage as 'debt deflation'. [7] Later Hyman Minsky called a state of excessive financial leverage as a 'Ponzi finance'. [13]

A financial market can change from a state of equilibrium pricing (which Minsky called 'conservative' financing) to an unstable 'speculative' financing, and even to the very unstable 'Ponzi' financing. These states occur when lending focuses upon different rewards from a loan – as income stream, as capital asset liquidity with debt repayment, and as capital asset liquidity without possibility of debt repayment -- as shown in Figure 5.

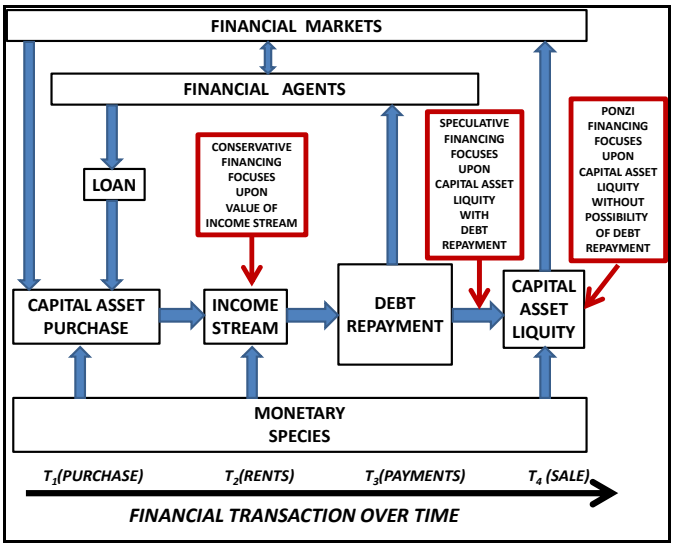

Figure 5 Keynes/Minsky Financial Process

Later, Paul McCulley continued to emphasize the importance of the economic role of 'leverage': "At its core, capitalism is all about risk taking. One form of risk taking is leverage. Indeed, without leverage, capitalism could not prosper. . . And it is grand, while the ever-larger application of leverage puts upward pressure on asset prices. There isnothing like a bull market to make geniuses out of levered dunces. ...(Speculation) begets ever riskier debt arrangements, until they have produced a bubble in asset prices. Then the bubble bursts . . . "[12]

Thus leveraged 'present-debt' can increase 'future-wealth'; but 'excessive leverage' can lead to 'bankruptcy'. In Figure 6, we graph this impact of leverage on a price equilibrium model – by modifying the 2-dimentional 'price-equilibrium chart' -- with the addition of a 3rd-dimension of time. This graph shows a supply-demand curve at two different times, T_1 and later T_2. In the time-dimension, one can see how a 'price-disequilibrium' situation can arise over time, as a 'financial bubble'.

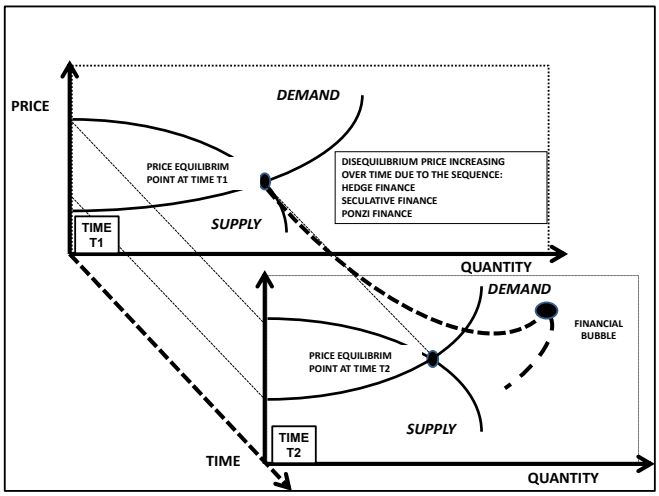

Figure 6. Three-dimensional (Price, Quantity, Time) Supply-demand-price-disequilibrium Chart -- Over Time

It is 'excessive leverage' in the financing of a financial market which allows a financial bubble to occur. If no speculation occurs in an asset market (financial market) then the equilibrium prices at T_1 and T_2 could be the same. But if speculation in the future-price at time T_2 occurs in a financial market, a price bubble can begin. Financial bubbles can be seen in stock markets. Figure 7 shows the NASDAQ stock market index in the United States for the time period from 1970 to 2010.

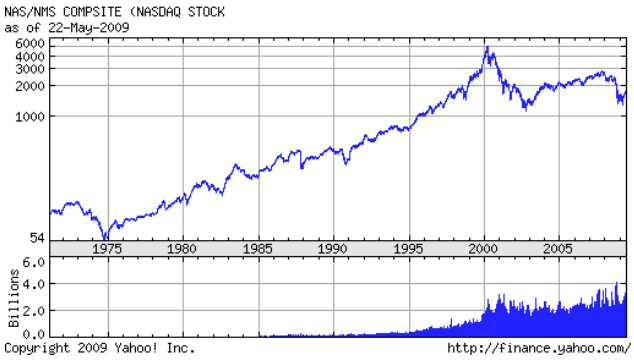

Figure 7. U.S. Nasdaq Stock Market Index 1970-2010

Therein one sees the 'dot.com' stock bubble from 1995 to 2000. Investor enthusiasm for businesses in the new Internet financed the start-up of hundreds of dot-com new ventures from 1998 to 2000. And the price index of the NASDAQ market rose from the index of '2000' in the year 1998 to the index of '6000' in the year 2000 -- a three-fold growth in two years -- a stock market bubble. The financial bubble burst in the year 2000, declining back to the index level of '2000' -- a three-fold drop -- wiping out the earlier stock market increase. Billions of dollars were lost by venture capitalist funds in this sudden collapse, due to their investments in new Internet companies -- hence called the 'dot.com' stock bubble. Later in the year of 2003, a terrible attack of terrorism with airplanes crashing into the twin-towers of New York City and into the U.S. Pentagon in Washington, DC brought the U.S. economy into a recession with the NASDAQ index dropping further from '2000' to nearly '1000'. Then the Chair of the U.S. Federal Reserve put in place a policy of 'cheap money', leading next to a real-estate bubble in 2005 and a financial crash of the U.S. banking system in 2008, due to the sale of fraudulent mortgage-asset-based financial derivatives. Upon a price-disequilibrium curve, one can fit a chart of a stock-market index over time onto the 'Price-Time' plane of the three-dimensional price-disequilibrium graph, as in Figure 8. [5]

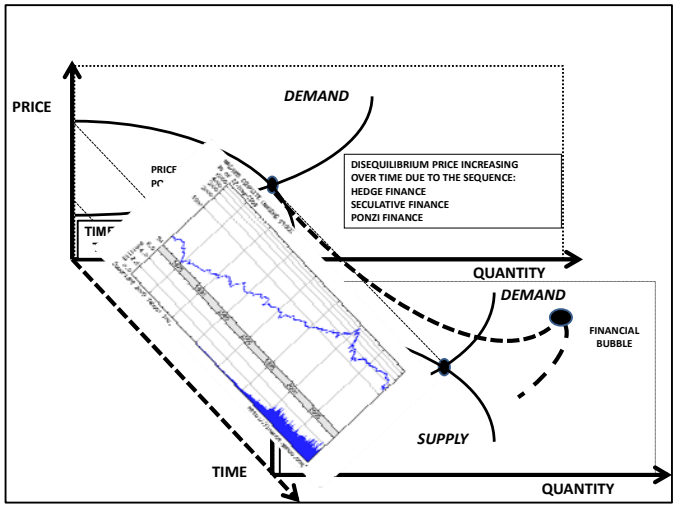

Figure 8. U.S. Stock Market Index as a Price-disequilibrium Chart

This shows that a stock-market index chart is actually a 'price-disequilibrium graph' over time. The advantage of looking at it in this way is to allow one to apply Minsky's categories of financial status to the stock-market graphs.

- When the average 'price-to-earnings' (P/E) of a stock market is in the 10-15 range, then the financial state of the stock market is in a 'Conservative-financial' range.
- When the average 'price-to-earnings' (P/E) of a stock market is in the 16-25 range, then the financial state of the stock market is in a 'Speculative-financial' range.
- When the average 'price-to-earnings' (P/E) of a stock market is above 26, then the financial state of the stock market is in a 'Ponzi-financial' state. And Minsky emphasized that when any financial market is in a 'Ponzi-

financial' state, a financial bubble exists, just ready for bursting.

Because of the phenomena of financial bubbles, economic instability was seen by Neo-Keynesians as *inherent* to economic financial models. For this reason, the Neo-Keynesian School has also been called an '*endogenous'* school of economics, meaning instability is indigenous (inside) an economy -- through the disequilibrium pricing of asset markets in a financial bubble. The Neo-Classical Synthesis School was then called an '*exogenous*' school of economics -- because they believed instability was *external* to the economic system, of perfect markets. W*hen financial markets track away from an equilibrium pricing point (demand increasing dramatically over time with excessive leverage and without supply increasing), then a financial bubble begins.*

Fueled by 'leveraged speculation' in the future price of an asset, a 'disequilibrium pricing' of the asset grows -- increases and increases until the financial bubble bursts. Then the banks which funded the 'leveraged speculation' hold assets greatly decreased in value (from the bursting of the bubble); and this places these banks at risk of 'insolvency'. When depositors perceive a bank has put itself at risk, through funding too much speculation, depositors run to take their money out of the bank -- a bank panic. Bank panics close down risky banks, and freeze available credit. When too much credit is frozen in an economy, businesses have no access to operating funds and must lay off workers or close doors. Financial bubbles have led to bank panics, which created credit freezes, which have led to business failures and unemployment -- triggering an economic recession/depression.

What happens to the Neo-Classical model of production (price-equilibrium model), when a financial instability (Minsky financial bubble) occurs? As shown in Figure 9, an economically-recessed production system happens, with the consumer demand fallen, and the consumer-price index declining.

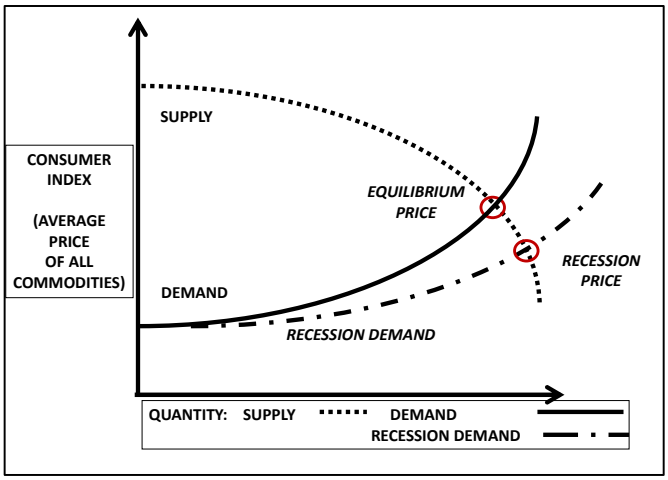

Figure 9. Economic Equilibrium Pricing of a Product When Supply = Demand and Pricing When Recession Reduces Demand

A financial instability (as a market bubble followed by bank panic) induces an economic recession -- through the freezing of credit in the economy. Prices decrease in a recession, as demand declines due to unemployment -- when suppliers lay off workers. Unemployed workers purchase less, and overall demand declines -- resulting in a recession.

The connection between financial bubbles and economic recession is -- through bank panics and increased unemployment -- due to the credit freeze by a bank panic on productive businesses. In Figure 10, the connection between financial and commodity models occurs as due to: (1) excessive financial leverage, (2) leading to Ponzi finance, (3) creating a financial instability (bubble burst), (4) triggering bank runs in the banks involved in the Ponzi financing, (5) closing down the needed credit for businesses to continue operating, (6) resulting in reduction in commodity production,(7) through laying off workers, (8) resulting in increasing unemployment, (9) resulting in decreased consumption, (10) leading to more workers laid off to reduce production expenses, (11) creating more unemployment, (12) resulting in reduced consumption and demand -- and so on -- from financial instability to bank runs to economic recession.

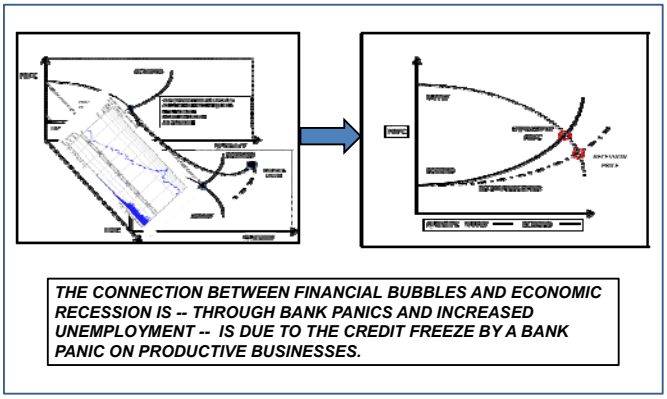

Figure 10 . Impact of Instability in Financial Markets Upon Commodity Markets

IV. CROSS-DISCIPLINARY FRAMEWORK FOR CONNECTING COMMODITY AND FINANCIAL MARKETS MODELS

Because commodity-market models and financial-market models differ in economic nature (one for production and the other for finance, one needs a larger cognitive framework) for showing how to connect information from one type of model to another -- a cross-disciplinary meta-framework of society dynamics.[4] Figure 11 places commodity-market models and financial market models in different economic sectors of a societal economic system. This shows how models from the two schools of economics, exogenous and endogenous, relate to each other as complementary models -- in production and in financial sub-systems.

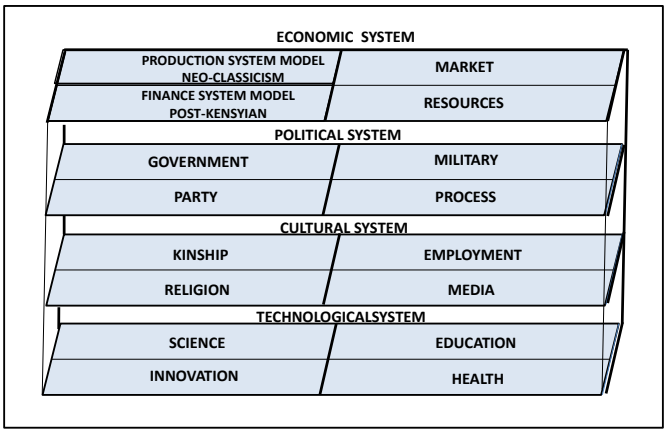

Figure 11. Topological Model of Society as Interacting Systems of Economy, Politics, Culture, and Technology

Thus one can place economic models upon a larger model framework of a society's economic system, Figure 12. The two economic models of commodity and financial are partial models in an economy -- not a model of the whole economy. The information relationships between such societal partial models are functional and not causal. Therefore data specific to each model needs to be empirically developed from research and statistics, functionally defined as appropriate for each model.

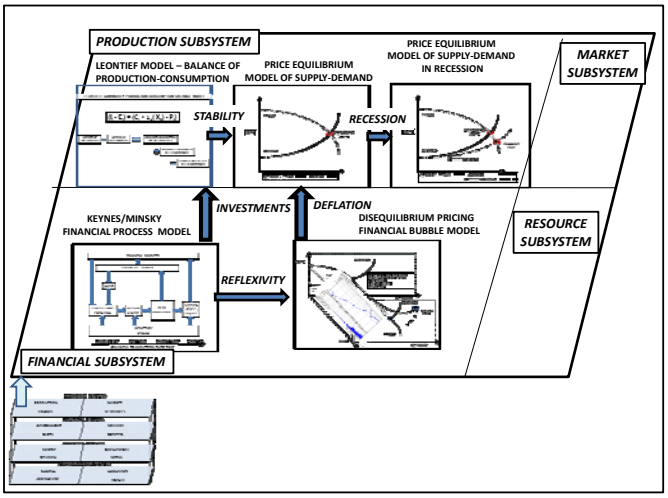

Figure 12. Economic System Plane with Production & Financial Sub-systems

In this meta-framework, the economic models relate to one another-- through the dynamics of the actions of economic agents in the respective commodity and financial markets. The first Leontieff commodity-market-balance model describes how: the I-th industrial sector produces an I-th type of commodity (P_I) in a nation for both domestic consumers (C_I) and industrial-sector consumers ($\Sigma_J X_{IJ}$) of this I-th product type and for export. (E_I). In the nation at the time, this I-th type commodity sells in the national market at an equilibrium price.

On the financial side, the model of a Keynes/Minsky financial process describes how: a financial market in the nation can arrange financing for the purchase or sale of a capital asset business(producing the product type) or can arrange financing for expansion of production capacity in the I-th business sector.

The vertical arrow which connects information from the Keynes/Minsky-financial-process model to the Leontieff-market-balance model are investments -- decisions to finance the sale or expansion of production capacity (by launching, buying, or selling businesses and by loans for business expansion).

Indicated by the horizontal arrow (between the Leontieff commodity model and the supply-demand model), investments in production capacity for a market can facilitate economic stability, (to enable demand matching supply for equilibrium pricing).

Investor enthusiam for large increases in capital asset liquidity can increase loan finance from conservative to speculative to Ponzi financing. This is a speculative financial bubble. As the size of the loan to the capital asset value increases, the loan is said to increase in 'leverage'. The larger the leverage, the greater the profit -- provided loan failure does not occur. Thus investor enthusiasm in the Keynes-Minisky-financial-process can also lead to excessive speculative financing for a financial market of increasing value of capital asset s.

Financial bubbles create bank runs in the banks which lend too much leveraged loans in the speculative financing leading to the bubble, Bank runs freeze credit lending by insolvent banks.

Credit freezes stops the daily loans needed to run businesses and markets; and economic recessions begin as commodity-producing companies scale back production and/or close down.

Employees laid off in commodity companies retrenchment, reduce overall demand in an economy and a business recession begins.

The connections between the commodity models and financial models are not merely information communications (e.g., data transmissions) but economic processes – such processes can be called respectively as: *investments, stability, reflexivity, deflation, recessions*.

V. MODEL ONTOLOGIES FOR ECONOMIC MODELS

In modeling economic systems, data does not necessarily feed automatically from one economic model to another. This occurs because economic models are not causally connected but functionally related. If economic and societal models were mechanistic with causality, then partial models could be integrated into one large causal model, with direct transfers of information. (And this is only possible in the physical sciences, such as special-relativity-mechanics

integrating down to Newtonian-mechanics at slower speeds than light.)

In functional models of society, societal processes transform from one functional concept to another. Information is not merely transmitted from one model to another; but instead, economic processes provide the transmission of information from model to another. As shown in Figure 12, there are five connective economic processes which are basic -- *investments, stability, reflexivity, deflation, recessions*. *Social science models are functional models and not mechanistic models and are functionally connected by social processes.*

A. Model Ontology – Reflexivity

George Soros described the price disequilibrium movements in financial markets as operating in a process, which he call 'reflexivity. Soros wrote: "What makes reflexivity interesting is that a prevailing bias (in a market) has ways, via market prices, to affect the so-called fundamentals that market prices are supposed to reflect. . . It does not happen all the time, but when it does it gives rise to the boom/bust sequences and other far-from-equilibrium conditions that are so typical of financial markets." [18]

Soros defined 'reflexivity' as a 'cognition-action' interaction of participants in a society. The interaction is between: (1) what people think about a possible future and their actions based upon such thinking and (2) how a particular future may occur influenced by the action. He called this a "cognition-participation' interaction in influencing future outcomes of events in society. People think about the future, having 'expectations' of the future. People can then act, in the present, to make such expectations come true, in the future. All human actions occur in the present, aimed at an envisioned future outcome. This reflexivity (between present-thinking-and-present-action as impacting upon future outcomes) is essential to how a financial market can move from a price-equilibrium to a price-disequilibrium.

As an example of a stock market bubble, Soros explained the dot.com bubble of 1995-2000 (shown earlier in Figure 7). George Soros wrote: In the Internet and telecom boom, inflated stock prices accelerated the introduction of new technologies. There was a misconception involved. . . . In the technology boom, the error was (that) . . . stocks were valued at a multiple of revenues (not valued about earnings) and growth was financed by selling stock (not by following sound business plans). Expectations were inflated, until they became unsustainable . . . Eventually a turning point was reached." [18] The reflexivity was the interaction between investors' 'expectations' and the 'inflated stock prices. That reflexivity did result in a rapid stock market rise to a financial bubble. This burst, when investor 'thinking' saw the bubble as unsustainable (too high prices of stocks) and sold out (bust). All stock market bubbles are driven by a 'reflexivity' between a present 'expectations & purchases' and a future' unsustainable-situation'.

The technology of the Internet was real and would continue to create business opportunities. A decade later, the largest stock offerings were in Internet companies, such as Google, Facebook, Twitter, etc. In any stock market 'reflexivity', Soros emphasized that there were two kinds of factors – an underlying trend in the market (such as technology) and the expectations of investors about the future. *It is the interaction between underlying-trends and investor-expectations which provide the reflexivity that moves financial markets from equilibrium to disequilibrium pricing.*

In society, cognition which choses an action in a present can help bring about an anticipated future. Sociologists have called such a consciousness of consequences-of-action-in-society as occurring either as expected or unexpected – 'foreseen consequences' or 'unforeseen consequences'.

B. Model Ontology – Deflation

Deflation is an economic process which lowers the values of capital assets. It typically occurs when banks have lent too much money to speculators for their leveraged investments in financial markets. When the financial bubble bursts, banks are left with worthless collateral, upon which they had lent to money speculators. For example in 1933, Irving Fisher wrote: "(In deflation) . . . two dominant factors (are) . . . over-indebtedness to start with and deflation following soon after . . . . the big bad actors are debt disturbances and price level." [7]

For example, the 1930 deflation of the U.S. Great Depression was triggered by the stock market crash in 1929. Subsequent banks insolvencies resulted from worthless assets the held for margined loans. The stocks banks then held as loan collateral became more worthless with each year, 1930, 1931, 1932. Bad banking practices had set in motion the chain. Bank assets became illiquid, resulting in bank insolvency. The bad practices were risky loans made to stock brokers who had allowed customers to purchase stock on margin. 'Margin loans' by banks leveraged the investments in stocks toward a financial 'bubble'. Bad banking practices had triggered the depression. When the stock market crashed in 1929, many margined-stock owners lost all the wealth they had in the market and some stock brokers went bankrupt. It was the margined-stock (held as collateral) in the banks' assets which triggered more bank runs. Finally when in March 1933 bank runs were continuing across the nation. President Roosevelt called a 'bank holiday', temporarily shutting down all the banks to stop the runs. The infrastructure of the banking system of the U.S. had collapsed.

C. Model Ontology – Investments

Investments are of different kind, such as: equity investments in productive corporations, financing of trades in commodities, futures investments in agricultural products, corporate loans, loans for corporate take-overs, loans for buying stocks, speculative gambling in markets, such as exchange-rates or derivatives. Some investments contribute to economic growth (e.g, investments in productive

corporations or financing of commodity trading). Other investments make markets liquid (e.g, stock offerings). But some investments only redistribute wealth, move wealth around (e.g. such as corporate take-overs or speculative trading/gambling). Identifying and monitoring the types and quantities of investments are essential.

For example in 2013, the New York Times reported: "A detailed report put out by JPMorgan Chase last week on how it lost $6 billion from ill-fated trading in 2012 should be required reading for policy makers and financial executives. The 129-page document serves as a case study of how excessive complexity and poor oversight still threaten many parts of the financial system more than four years after the failure of Lehman Brothers. The subject of the report is the bank's trading of complex derivatives known as credit default swaps that are similar to the instruments that forced the government to bail out the American International Group in 2008. At JPMorgan, the nation's largest bank and one of many that received government aid during the crisis, these investments did not threaten the institution's survival as they did with A.I.G. But they caused losses large enough to dent the bank's reputation for managing risk well . . . " (New York Times Editorial, 2013)

D. Model Ontology – Recession

Recessions occur on the conditions of an financial sub-system -- a 'fragility of the banks' and an 'instability of credit' -- both in process and in structure of the U.S. financial system.

For example in the case of the U.S. Great Depression of the 1930s, there was not a single 'cause' to the depression. Some scholars have argued that the banks failed because the economy contracted; others that depositors' expectations turned to fear and withdrew deposits 'en masse'. Was bank failure caused by economic collapse? Or was bank failure caused by expectations collapse? Both conditions contributed to the collapse. Money-credit was the 'process' connecting banking runs to industrial decline; and bank margin-loans to brokers was the 'structure' connecting the stock market to bank fragility. Human society is not a mechanism. It was stasis changing events which altered the U.S. society – the 1929 stock market crash and three successive years of bank panics in 1930, 1931, 1932. [4]

E. Model Ontology – Stability

The stability of an economic system depends upon a production capability in a nation to produce needed goods and services in a nation – a commodity production subsystem. Production capability needs to be built with financial investments and sustained by a workable stock market and effective credit in loans to operate businesses. Price equilibrium is reached with supply-meets-demand, but only in a marketplace of effective and honest competition. Government regulation over a commodity market is needed to avoid monopolies in the market, and to ensure that products are safe and business contracts are honorably enforced. The economic goal of a 'perfect market' for commodities is a normative statement, which needs proper societal contexts for empirical occurrence.

VI. RESULTS

A surprise in this research is that a connection (arrow) from one economic model to another is not a simple transmission of information -- but as a societal 'process'. In a causally related model, the ontology of a model consists of a information format, for data into the model, and an inference engine, for simulated the processes in a model. This is similar to the Von Neumann form of a computer, with the computer requiring a prior data format for data to be input into the computer, and the compute requiring a prior stored-program to perform computations upon the input data, with the computed analysis emerging as the information output of the computer. This is shown in Figure 13.

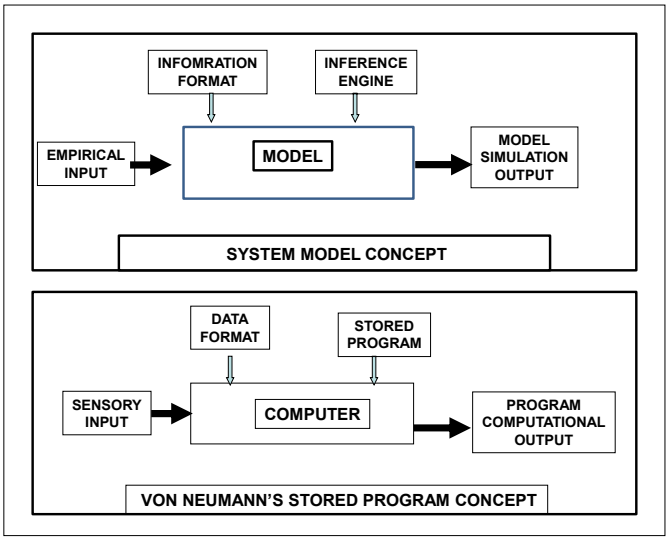

Figure 13. Comparing Model Simulation to Computer Computation

We have found that in the connections between functional economic models, data inputs to models and outputs from models were not simply 'formatted information' but, instead 'economic processes' -- processes of investments, stability, reflexivity, deflation, recessions. There is a methodological interpretation. The connective arrows between models may indicate yet more hidden models within the connections (models not yet discovered). However, if such hidden models cannot be developed, then information in the connection can only be found in 'indicators' of the results of processes. General models of societal processes may not be possible when and if some societal processes are wholly context dependent and without significant general forms.

For example, such complete context dependency has occurred in the context-dependency of reflexivity in stock markets. George Soros had thought that there might be a hidden model in the reflexivity process in stock bubbles. He

analyzed the U.S. stock market boom in the 1960s, fueled by corporate conglomeration. Soros wrote: The first time I used the model systematically was in the conglomerate boom of the late 1960s. It enabled me to make money both on the way up and on the way down. The key to the conglomerate boom was a prevailing misconception among investors. Investors had come to value growth in per-share-earnings and failed to discriminate about the way the earnings growth was accomplished. A few companies learned to produce earnings growth through acquisitions. Once the market started to reward them for their performance, their task became easier because they could offer their own highly priced stock in acquiring other companies." [18]

The trick lay in the financial 'magic' number of Price-to Earnings (P/E). For companies having a record of little or no earnings growth, stocks might be purchased at a ratio of P/E = 10. This means that earning of that level over ten years would return the capital invested of the stock purchase. The problem was this.. At what rate would a company grow in earnings? Therefore at what multiple of present earnings should a stock be purchased, to reflect expected earnings growth in the future?

For example, George Soros wrote: "In theory, the process works as follows. Let us assume that all of the companies involved have the same intrinsic growth in earnings but the stock of the acquiring company sells at twice the earnings multiple of the acquired ones; if the acquiring company manages to double its size, its earnings- per-share jump by 50%, and its growth rate increases accordingly. . . Several of the path-breakers were high-technology companies with a strong defense component, whose management recognized that their historic growth rate could not be sustained indefinitely. . . . They started to acquire more mundane companies, but, as their per-share earnings growth accelerated the multiple expanded instead of contracting. Their success attracted imitators and later on even the most humdrum companies could attain a high multiple by going on an acquisition spree. " [18]

'Reflexivity' was in the participants' 'expectation' that share price would increase as earnings-per-share grew. This expectation of the future price was reflexively made real in the future by purchasing shares at a higher price. This reflexivity created the 'boom' in stock market growth. The was growth by acquisitions could not last forever. It was a temporary corporate growth strategy that had a time limit. The boom became a bubble when stock investors realized that there was indeed a time limit to the strategy. An expectation-by-investors of growth-without-limit was unsustainable. George Soros calls such expectations by investors in a given market at a given time as a market 'bias'. Soros wrote: "Markets are always biased in one direction or another. Markets can influence the events that they anticipate."[18]

One can see the impact of the investor bias in the 1960s for corporate conglomeration in the share-price chart of Teledyne, then one of the conglomerates, Figure 14. Teledyne's share-price climbed before the earnings-per-share grew, as investors anticipated continued corporate growth through business acquisitions – through corporate conglomeration. This growth occurred from 1963 to 1968, as earning-per-share grew. But from 1968 through 1969, some investors began to perceive that continuing earnings growth from business acquisitions was not eternally sustainable, and stopped buying shares at higher prices. Share price leveled off from 1968 to 1969. As this expectation became widely shared, the prevailing investor bias about the company changed, and investors sold shares, precipitating a dramatic share-price fall, from 1969 through 1970. This is an example of Soros' concept of 'reflexivity' in financial markets, as present-decisions-by-investors are based upon expectations-of-the-investors-about-the-future. *'Reflexivity' in societal events is that societal participants can affect the future due to actions-in-the-present based upon thinking-about-the-future.*

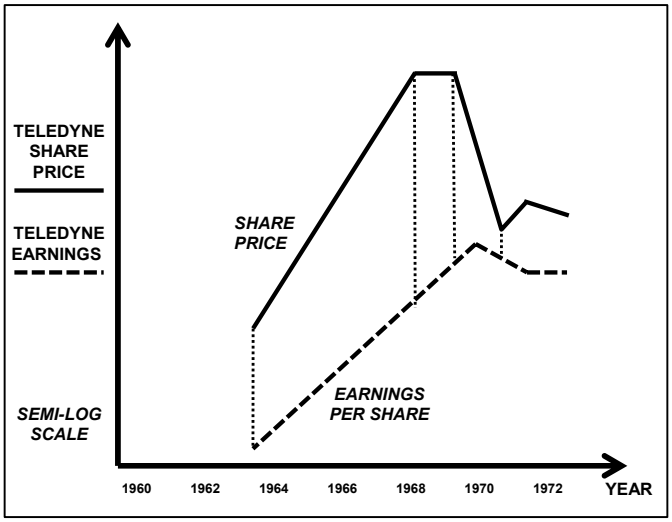

Figure 14. Reflexivity in Teledyne Stock from 1963 To 1973

In 2014, Teledyne Technologies still existed as a U.S. industrial conglomerate, with global operations. In 1960, Henry Singleton and George Kozmetsky had founded the company as Teledyne. In 1996, was acquired by Alleghey Ludlum Corporations and became part of Allegheny Teledyne. In 1999, that conglomerate broke into three companies, Teledyne Technologies, Allegheny Technologies, and Water Pik Technologies. (http://en.wikipedia.org/Teledyne_Technologies, 2014)

As see in this example, a kind of 'model' was implicit in the investor process of 'reflexivity', which contains an investor bias in a market at a time. Soros argued that financial markets are never a 'perfect' economic market because investors are never completely rational, 'unbiased'. But all financial markets operate within some investor bias at the time. The 'investor bias' is a shared expectation of the future of the market.

George Soros wrote: If there is any place where the theory of perfect competition ought to be translated into

practice, it is in the stock market. Yet there is little empirical evidence of an equilibrium, or even a tendency for prices to move toward an equilibrium. . . . Existing theories about the behavior of stock prices are remarkably inadequate. . . The market price of a stock is supposed to tend toward its fundamental value over a period of time so that an analysis of fundamental values (e.g. earnings-per-share) provides a useful guide to investment decisions. . . . I take a totally opposite point of view. I do not accept the proposition that stock prices are a passive reflection of underlying values . . . I contend that the market evaluations are always distorted and . . the distortions can affect the underlying values. Stock prices are not merely passive reflections; they are active ingredients in a process in which both stock prices and the fortunes of the companies whose stocks are traded are determined." [18]

This is why the connections between economic models are not merely information transfers (as assumed in the economic theory of a perfect market). Connections are themselves economic activities. As activities, the 'connections' (arrows between models) are themselves 'processes'. But such processes cannot be modeled as context-free. Each connection is context dependent upon the market and the time of the market. In the example of Teledyne, the context-dependent economic process was 'corporate conglomeration'. But this context did not last forever in the U.S. stock market. It lasted through the decade of the 1960s and ended in the decade of the 1970s – during which the OPEC oil cartel totally changed the economic and financial pictures of the world. In the case of the dot.com stock bubble of 1995-2000, it grew and ended upon overly-zealous expectations of rapid profitability in the Internet.

In both cases the model is so context-dependent (conglomerate-organization versus internet technology) that a general model of these reflexivity cases may not be useful. The nature of generality in context-dependent models is an important methodological consideration for model ontologies.

VII. DISCUSSION

Model ontologies of societal models are more complex than simply specifying the format of data into connectable models and the inference engine in the models. In mechanistic models with causal connections between models, then a model ontology consists of input and output data types and formats and inference engine type. However, in functional models of societal systems, one must also attend to any societal processes connecting models. In this research, we have identified five process connections between economic models of the production and financial markets in a society. These are connective processes of *investments, stability, reflexivity, deflation, recessions*. We will address these more deeply in a future paper.

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