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FURTHER IMPLICATIONS OF BOHM'S WHOLENESS AND IMPLICATE ORDER CONCEPT ON THEORIES OF FINANCE

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Abstract. *This paper discusses and develops the prospects of quantum finance from a Bohmian point of view. Discussed is an ontological interpretation of quantum theory, and such ontology is extended to include economics and finance. At first, we discuss the more general relevance of quantum theory to economics and finance. The basic assumption is that because Bohm's interpretation of quantum theory emphasizes the role of wholeness, it might be relevant to economics and finance, where fragmentation is a major characteristic of these domains. We then discuss the role of financial information in economic and finance, and consider specific connections with quantum theory in this field. In particular, we apply David Bohm's notion of active information, which arises in his ontological interpretation of quantum theory. It is here suggested, also by expanding Shannon's theory, that active information can play a fundamental business role as the bridge between economic theory and financial practice. Some such bridge is needed if we are to understand how subtle financial properties are able to influence more manifest business properties in companies (all the way to microeconmics and potentially at deeper business levels), and how changes in those possibly quantum-level business processes are able to influence higher financial planning functions. We also consider the implications of the notion of active information for financial derivatives. The potentialities of implementing the Bohmian scheme in quantum finance and connections with other*

laws are then briefly considered. Finally, we draw conclusions on interconnectedness between wholeness and implicate order and activation of financial information.

Key words: *Bohm; quantum finance; ontological interpretation of quantum theory; active business information; quantum approaches to economics and finance*

1. INTRODUCTION

One of the most pressing problems uncovered by the groundbreaking discoveries of David Bohm, in the view of the present author, is to develop many concrete examples that will assist in the comprehension of wholeness and implicate order as it relates to economics and finance. On the basis of several Bohmian applications in economics and finance introduced originally in our previous works [Vemić, 2019a; 2020] we will now pursue them further still. Specifically, in this paper we shall try to defend the claim that there are many inferential chains which lead to something important in physics on one side and economics and finance on the other because these sciences are mutually compatible [Mantegna & Stanley 1999].

The aim of this article is also to provide ground for further integration of some perspectives on quantum finance and econophysics as interdisciplinary research fields, alongside other articles existing in these fields. At this point we should mention some main econophysics and quantum finance viewpoints.

Besides H. Eugene Stanley who originated the term in 1995, econophysics is also much discussed by Mirowski [1989], McCauley [2004] and by Chakrabarti, Chakraborti & Chatterjee, A. [2006] .

Similarly, *Baaquie*, Coriano & Srikant [2002] and Meyer [2009] usefully review the methods of lattice simulations of path integrals for the pricing of options. Accardi and Boukas [2007] effectively studied a quantum extension of the Black-Scholes formula. Zeqian [2010] proposed a quantum model for the binomial market in finance. Matacz [2018] ambitiously discusses a new computational method for pricing path dependent options. Khrennikov [2018] recently analyzed the complexity of financial (and general economic) processes by comparing classical and quantum-like models for randomness.

Some of these concepts seem still fairly condensed and I hope that in future research these theories will be further developed and elaborated so as to make the prospect of the emerging field of "quantum finance" even more attractive and useful to a wider audience of economists and finance specialists. Various other finance development theories can probably augment each other and each can play a role in un-

folding the full significance and applicability of quantum finance. Therefore, we shall not enter into a detailed discussion of the mentioned theories here which are useful and complex. This is because we do have a feeling that there exists a simpler way to develop a quantum ontology, proposed by David Bohm, and that it would be very useful for any "quantum finance" to *also* be aware of a financial alternative developed along these lines. This is not to contest the practical usefulness of mentioned theories but rather to try to reveal the *potential* of translating Bohm's wholeness and implicate order concept into quantum finance. It is perhaps useful here in the beginning to explain the origin of the word 'potential' which will be used frequently from both quantum physical and economic standpoints. It will become evident as we proceed. The term was derived from a Latin root meaning '*potentia*', which means 'force', 'strength' and 'power'. We carry this definition further by suggesting that financial potential, our central underlying theme, implies emergent unused forms of volume, structure, sources and conditions of financing which could be used under changed conditions with same or improved efficiency.

What we would like to do in the rest of this paper is to discuss the prospects of "quantum finance" from what might be termed a "Bohmian" focal point, where our priority is upon trying to discuss a coherent ontological interpretation of quantum theory, and to extend this ontology to corporate finance.

We will continue by discussing the very general, indirect relevance which quantum theory might have to quantum finance. This actively relates to the new general world-view that quantum theory and relativity seem to suggest. An important trait of this world-view is David Bohm's notion of *wholeness*, a theme relevant to interconnectedness of financial markets emphasized by Battiston et al. [2009], where breakdown of unity in one market domain seems to have a significant reflection in other markets, and for SMEs [Calabrese and Girardone 2020]. We will then discuss the role of perfect and imperfect *information* in financial markets, and whether there are relevant connections with quantum theory in this field. In particular, we will consider David Bohm's notion of *active information* which arises in the ontological interpretation of quantum theory, facilitating a fundamental link between mind and matter, financial and commodity markets. Some such platform is required if we are to understand how financial market processes are able to influence manufacturing processes in business (all the way to the small enterprise level), and how changes in those possibly quantum level finance processes are able to influence higher cognitive functions for management decision making. After considering Bohm's notion of active information, we will briefly discuss its possible implications for financial

reporting and management decision making.

2. SIGNIFICANCE OF THE WHOLENESS OF ECONOMIC AND FINANCIAL PROCESSES

Bohm's groundbreaking wholeness and implicate order theory was originally intended to complement and upgrade the scientific thinking of classical Newtonian-Cartesian concepts and those of relativistic mechanics [Bohm, 1971, 1973]. Similarly to classical concepts in physics in this paper the classical and relativistic views are interpreted as 'explicate order' in static financial and economic indicators [Vemić, 2019b]. Despite being useful in many contexts an explicate order of the former inhibits an optimal financial view while in the latter case it precludes an optimal economic view. This is where the significance of Bohn's 'implicate order' becomes apparent in optimizing economic approaches through dynamic and coherent enfoldment and unfoldment of indicators. The complementarity is reflected through Bohm's perpetual unfolding and enfolding process leading to wholeness of 'explicate' and 'implicate' economic and financial developments. It should be obvious from the foregoing that the author foresees fields of influence between static and dynamic economic and financial indicators unfolded to overcome the separable indicators applied through the static-dynamic continuum. In developing the discussion it is perhaps useful to first specify the meaning of these key terms as they will be used throughout the work. By static indicators we have in mind pointers [Vemić, 2019b] which provide a static description of firm's specific financial position, in a limited field, at a fixed point in time. Consider for example the balance sheet or an income statement and their individual components. However, performing static comparisons between financial ratios does not fully exploit all the potential of business information the ratios offer. So, a dynamic analysis assists us further to compare the ratios between either two firms or between the ratios of individual firm and that of an industry average and here the time concept of money becomes significant. Finally, this kind of relationship can be used to forecast any future ratios or business developments.

According to Bohm these two sides of the process represent *passivity* and *activity* [Bohm & Biederman, 1999, p. 69]. Therefore, as the business history of a given moment appears folded up as a trace, the moment plays a static-passive role, being formed by the past. Consequently, as that moment disintegrates and re-emerges folded up in its future moments, it is playing a dynamic-active role in the business, entering into and supporting its development. Obviously, groups of indicators which

interweave or inter-infiltrate in companies and markets can actually be differentiated, but only in reference to various total business contexts in which the members of each group of indicators are connected through the significance of an overall necessity, implicit in these situations, that can relate them together in a concrete context. It is the implicate economic, business and financial order that is autonomously active while the explicate order of static indicators emerges from a law of the implicate order, so that it is secondary, derivative, and appropriate only in certain limited contexts. The proposed emerging significance of implicate order is that it may serve as a tool for making predictions about explicitly made economic and financial phenomena. The use of explicate and static concepts does indeed remain indispensable but it does not suffice. Examples of this sort can be multiplied infinitesimally. For example, let us consider the financial statements, the main ones being balance sheet and profit and loss statement. With static predictions they cannot provide all relevant information for the users, because the statements reflect historical data and non-financial information is not always included. But with the dynamic indicators included we no longer have to make a somewhat arbitrary division of a single unified business system into two separate parts and describe them according to mutually incompatible economic-financial theories. In this view the static indicators appear as limited or terminate, occurring only after a business event has spilled this way or that way, or only after the financial manager has taken his decision from out of the multiple choices available to him. After that the multitude of financial choices is manifest again. In this situation what has become static or determinate serves as a static criterion for future financial decisions that have to be made out of the new set of a variety of choices. The static or the determinate then becomes a tool for defining, in the form of abstractions, the character of our inquiry of the infinite, unlimited nature of dynamic financial indeterminism. The truth about the totality of financial reporting is therefore to be upheld by first upholding its unity, by then defending its duality in terms of opposing classes of indicators, and then proving the interconnected unity of the two duals.

But then there is another distinction revealed by the static-dynamic continuum in economics and finance: the difference or similarity between the two is that one starts with uncertainty of the dynamic side to end up in only temporary certainty of the static side. What this really means is that dynamic financial statements serve as a corrective factor against the mechanical static financial indicators. Vice versa also holds and projected dynamic indicators are eventually corrected by the static information.

Here we have two different types of financial theory covering the same sub-

ject-matter and which are not capable of being obviously factorized to one another. We should, however, approach their relationship as approximating two different types of projection of the same scientific field; that is, they are distinct because they address different types of financial questions, but they are not in fact mutually conflicting. We must take into consideration the fact that each existent financial report or decision enriches the totality of business reality in its own unique way that is not fully reducible to anything other than that. This is where creativity, experimentation and innovation can play a developmental role. Individual economic entities are therefore not separate substances but relatively autonomous fractal sub-wholes, like vortices in a simplicial complex [Cattani, Laserra, & Bochicchio, 2012] interweaving with each other. We should like to point out that our approach is not ontological reductionism by which the behavior of a complex financial system is simply a sum of the behavior of its fundamental parts, be it companies or their financial reports. Instead, the predictions of combinatorics which we have in mind appear under conditions described by David Bohm: "The new form of insight can perhaps best be called *Undivided Wholeness in Flowing Movement*". In a classical economic view, we assume that society can be reduced to business organizations in interaction. In a holistic and flowing view, we say that each business is a manifestation of the whole, which includes society and the business environment, information about which is enfolded in the memory of the business organizations. This is also important when considering economic and financial crises. For example during the 2008 global financial crisis and the 2020 Covid 19 pandemic we easily recognized the *V, L, K, U, W and Z shaped recoveries from downturns* (WEF, 2021) as a characteristic of almost all separately existing national economies, which in turn can made us feel worse and even more isolated from other economies. However, in the holistic approach, our economic and financial irregularities are likely often to be manifestations of the state of the economic exchanges in which we participate. The ensuing global crises proved to be indeed universal interconnecting consequences in all economies and markets. Furthermore, the holistic view seems to indicate correctly that an important part of the efforts to maintain economic and financial order ought to be directed to diagnosing different types of incoherence at the global level (e.g. in mismanagement and failure of cooperation in climate change), instead of an exclusive focus upon the national and regional economies, whose decline in economic and business activity to some extent is just a manifestation of the global incoherence.

In fact, economic and financial disorders frequently relate to a breakdown of wholeness or unity at micro, meso or macroeconomic level. And while the holistic

implication of quantum theory became apparent already with the further development of the usual Copenhagen interpretation [Bohm, 1952a; 1952b], the classical and mechanistic theories energized the fragmentary approaches in physics and economics which give strong significance to individual economies and businesses interacting relatively mechanically with others. Even with obvious effects of globalization. In this whole concept, it is argued that the basic realities at each economic level are entities that interact more or less mechanically. Ensuing disorders, such as the Covid 19 crisis, can then be seen as a failure of such interactions between these separate entities considered as primary. In contrast, in Bohm's enfolding-unfolding approach fragmented economies and businesses can be interpreted as autonomous sub-wholes like vortices in an interconnected global simplicial complex.

Speaking in very general terms, this is significantly correlated to the concept that what is central in the micro-economic aspect is a stream of business activity, out of which emerge relatively autonomous entities at one level such as sales, marketing, finance, human resources management, logistics, innovation activities and similar. At the next level there emerge further autonomous entities in the supply chain, towards the macro-economic and global-economic level. In this view micro-economic level is dynamically inter-connected to the undivided wholeness and coherence in the underlying stream of business activity, and the same can be said for the macro-economic and global-economic level; economic-financial disorders result in part when this wholeness disappears for whatever reason.

For example, one national economy might place too much significance to certain types of different divisions that often naturally arise in the global economy (e.g., trade, climate, etc.,) thus disrupting the level-playing field and allowing the emergence of conflicts between such separate economies. Clearly, inductive and fragmentary economic analysis can work successfully only up to a certain extent as an explanatory strategy both in the micro-economic domain and in the underlying macro-economic developments. However, Bohm's approach reveals how significant it is not to underestimate the intrinsic undivided wholeness in enfolding-unfolding order in our economic development flows.

Quantum theory and relativity (both the general and special), and the cognitive orientation of the economy arising from them (and possibly even the more specific quantum economic models), can play a major role in raising awareness to the underlying wholeness. Therefore, one of the more ensuing recommendations of any "quantum theory model of economics" [Samuelson, 1979] could be that we need to

consider the importance of such wholeness for economic and financial health of the world.

A holistic economic mindset can also fundamentally change the way we understand the relationship between the individual microeconomic entities and their macroeconomic habitat. In a mechanistic approach, we generally tend to assume that an economy can be reduced to companies in simple business cooperation. However, in a holistic view, we realize that each company is an expression of the whole economy, which includes micro and the macro habitat, information about which is enfolded in the actual balance sheets of companies. Therefore, we no longer reduce economy to a group of companies, but rather *consider each individual business organization as an expression of the global economy*. What this view actually does is that it inverts the mechanistic world view. To me it makes a lot of sense when dealing with an economic downturn or depression. When the economy is plunging, we frequently see the disorder being a consequence of our own economic actions, be it individual companies or national economies, which as a result can make the global economy and market outlook seem worse and even more disengaged from other economies or businesses. However, Bohm's wholeness and implicate order theory suggests that, our economic and business disorders are probably expressions of the condition of the global economy in which we take part. As can be clearly seen from the ongoing *COVID-19* pandemic a potential economic downturn is actually ubiquitous. Applied in economics this theory further entails that a significant part of the strategies to regain economic health should be directed to diagnosing different types of SWOT incoherence at the macro and global level (e.g., in weaknesses and threats), instead of an exclusive focus upon the micro-economic level, whose economic downturn tends to be an expression of the global incoherence [Bohm, 1995]. Hence we herewith arrive at the translation of quantum couplings (a physical phenomenon that occurs when particles act in such a way that the quantum state of individual particles cannot be determined independently of others, but looks at the quantum state of the system as a whole) into economic and financial phenomena. There is an enfolded-unfolded synergy between fundamental interactions in physics of gravitational, electromagnetic, weak and strong forces and factors of production or resources represented by land, labor (human resources), capital, technology and entrepreneurship as applied in economics.

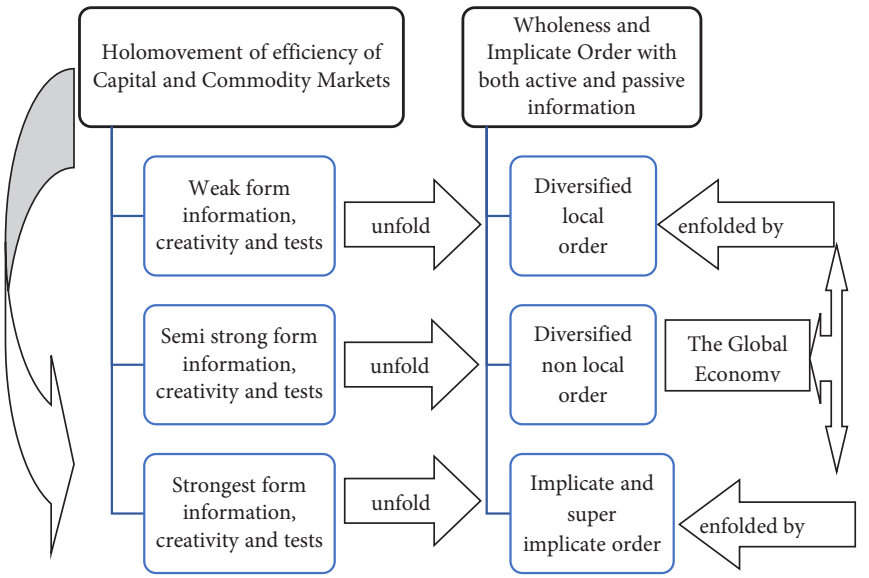
3. THE POTENTIAL ROLE OF ACTIVE INFORMATION IN DIVERSIFIED UNFOLDING OF BULL AND BEAR MARKETS

Economic-financial crises can be interpreted in terms of deficiencies in the flow of information. Reactions of economic policies and businesses should consider that past information can improve future market forecasts [McKenzie & Holt, 2002, p.1519-1532]. In economic aberration there is bewilderedness by one type of micro-economic or macroeconomic information which takes the place of what is a true or real development. For example, a manager of a business might come to a conclusion that a major economic downturn is imminent and associates internal threats and weaknesses with the external environment. In this case a special kind of information is lacking (*i.e.* information that the given conclusion is internally-portrayed), and as a result a certain wrong information predominates (*i.e.* information implying that there is a major economic downturn in front of our company "over there" in the external environment).

When analyzed on the basis of information, it has been proposed by Fama (1970) that market efficiency requires prices which fully reflect available information implying that the lack of information only allows *weak form tests* based on historical prices. Consequently investors lack required information and attribute this property to the market where diversification cannot eliminate all variance [Markowitz, 1952, p. 79]. This might lead to a collapse of the market system and Fama suggests that this prevents the *semi strong and strong form tests*. Information inefficiencies in the market lead investors to experience their plans as information driven investments based on external events. A question is raised whether investors should consider market information as external or not. However, investments often just „unfold" without compulsion or external choice. But there are frequently investments which require much more meaningful active information thus eliminating information asymmetries which, according to Gompers and Lerner facilitate financing constraints [2002, p. 130]. Therefore, it seems clear that many economic and financial crises necessarily involve information, and more specifically absence of information, wrong information (misattribution) and various kinds of failures to provide feedback and control information adequately. Can quantum theory shed any new light upon the nature of information, which might also help us to understand the role of active information in economic and financial disorders? Now, David Bohm's ontological interpretation of quantum theory provides some responses to this issue and will now be briefly discussed. Hence, we can perhaps first symbolically decipher the Bohmian term of 'holomovement' meaning to write the whole, so that the whole financial market has

holographic properties. Which may perhaps include a diversified portfolio [Markowitz, 1952, p. 87]. In our explicated approach each test and bit as unit of financial information are one fragment as shown in figure1:

Figure 1. Bohmian holomovement in diversifying financial and commodity markets



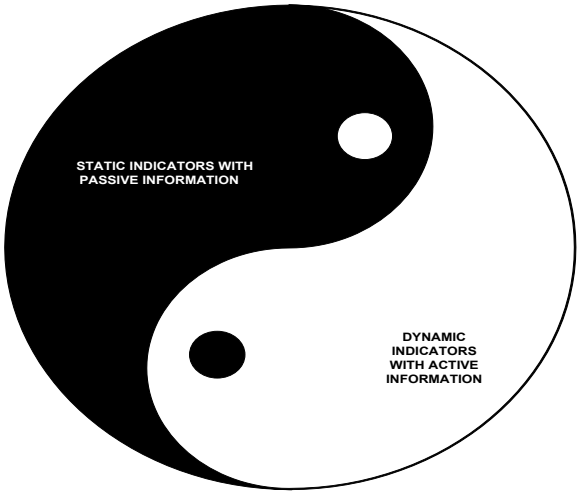
Source: Adapted Markowitz (1952), Fama (1970) and Bohm (1980) with author's input and presentation of interconnectedness

And while the weak form reflects historical sequence of security prices, the strongest form maintains that all available information is captured in the current price of a security [Eales, 1995, p.37]. Thus, in figure 1 we exhibit the unfolding-enfolding significance of active information as it permeates capital and commodity market efficiency through wholeness and implicate order. Clearly, Bohm's interpretation of active information allows the further development of markets in which information has already been recognized as a key factor of efficiency [Fama, 1970]. Varying degrees of diversified information activity definitely add significance to the initial plausibility of quantum economic and finance theories. Therefore, quantum theory could be pertinent to understanding the market-information relationship. Possible applied strategies will be discussed further later on from the standpoint of theory of information and quantum potential in business.

4. OVERALL SIGNIFICANCE ACTIVE INFORMATION IN THE HOLO-MOVEMENT OF FINANCIAL STATEMENTS

In the undivided wholeness of financial statements we recognize Bohm's universal flux [Bohm, 1980, p. 12-14] of both financial and economic events and processes which are dynamically and implicitly interconnected through what he called active information. And while, in his theory, active information is contained in a quantum field giving rise to a unique quantum potential this is translated onto economics and finance through the permeated non-duality potential of static and dynamic indicators, of the bull and bear market, of the micro-economics and macro-economics. As indicated in figure 2, now creatively using a Yin Yang symbol [Ray & Myers, 2000, p.196], the movement of *potential* between these categories, which we have in mind, is actually quite subtle.

Figure 2. Subtle movement of potential between dynamic and static financial indicators



Source: Compiled by the author

As Bohm indicated for physics suggested subtlety is observed through quantum potential which constitutes active information that can give form to the movements of the particles [1990]. Now, the fundamentally new economic-financial feature is that these fields do not push and pull each other mechanically, but rather the influ-

ence only depends upon the *form* of the economic-financial fields. Implicating then yet further Bohm's concept of order, there is no reason not to expect a series of orders of super economic potentials, with each order constituting information and giving form to the activity of the next lower order which is less subtle [Bohm, 1990]. Each of the fields actually *informs* (or puts form into) the economic energy onto the coupled other economic field. We therefore have in mind a non-mechanical relationship between economic fields and not a mere form instituted from external sources. The active information contained in the suggested economic fields can rather be seen as an ordered and structured "inner" development that is inherent to them as an economic whole. Information is clearly a fundamental factor of economic-financial theory and practice. In the implied Bohmian quantum field theory, this idea is even more radical, as the information contained in the so-called "super-implicate" order plays a key role in organizing the first level into various structures and is capable of tremendous development of structure. The super-implicate order makes the implicate order non-linear [*Baaquie*, Coriano & Srikant, 2002, p.2] and organizes it into relatively stable forms with complex structures [Nichol, 2003]. The relevant idea here is that economic-financial information is a fundamental part of the inherent complex processes where information contained in micro-economics is assumed an important generative part of the essence of the macroeconomics. Every microeconomic process has a subtle macroeconomic aspect which carries active information that is part of the crux of that process. Clearly the suggestion is that at the micro level information *acts* – it actively guides the movement of businesses and then energizes the whole economy. There are many different kinds of economic problems today. One won't learn very much by managing them one after another and will be surprised by every next economic phenomenon. From a particular economic problem treated as particular one cannot really learn very much. But if one can see these phenomena as general – as not only belonging to 'your' company or 'national' economy, but being 'common' to the whole world or even before economic history started, then perhaps this may lead one to the origin of the various economic problems.

Therefore, there is a sophisticated aspect of active microeconomic information guiding the behavior of a more manifest aspect (the macroeconomics) from which we can discern an axiom that is relevant whenever microeconomics is related to the macroeconomics. Bohm referred to soma-significant *and* signasomatic *activity.* Here "soma" refers to hypothetical and by extension to any economic structure or process, while "significance" refers to its concrete meaning. These terms are intended to propose complementary dimensions of one indivisible economic process, rather than

two qualitatively distinct domains. With this model Bohm advanced his rationale that there is no fundamental difference between reciprocal processes in the objective world based on what we suggest that active economic meaning is enfolded and unfolded throughout the whole of economic life. Somasignificant and signa-somatic processes are therefore herewith viewed as aspects of the dynamics of implicate and explicate economic orders. Therefore, active information contained in economic processes and business experience is channeled by some subtle medium corresponding to a quantum field in physics but carrying also special qualities such as sensations, emotions and thoughts of business managers, financial market actors and economic planners. Active information then generally "implicates" the macroeconomics ultimately guiding overall business behavior and vice versa.

In terms of the implicate order, we may say that even economics maintains itself in a perpetual process similar to the growth of a biological organism (von Bertalanffy, 1968). Using Bohm's ink-in-fluid analogy and notation (Bohm, 1980. pp.230-231) let us now consider a sequential economic order in the series of economic relationships among distinct elements:

$$A : B :: B : C :: C : D \ldots . \qquad (1)$$

Now, instead of Bohm's ink-in-fluid analogy, let us assume that we have established and financed in the economy a large number of medium sized enterprises, set close to each other and arranged in a line (this time we do not suppose differences among the companies). These we label as *A*, *B*, *C*, *D…* We then mix the economic structure many times, so that each of the medium sized enterprises gives rise to an ensemble of '*business particles*', enfolded in so large a region of economic space that particles, meaning business functions (marketing, finance, HR, etc) from all the companies intermingle. We label the successive ensembles *A*', *B*', *C*', *D*'. . . Obviously, in a figurative meaning, an entire linear order has been enfolded into the economy. This order may be expressed through the relationships in Bohm's notation

$$A' : B' :: B' : C' :: C' : D' \ldots . \qquad (2)$$

Bohm explained that order is not present to the senses. According to him, its reality may be demonstrated by reversing the motion, in our example of the '*economy*', so that *his* ensembles, *A*' : *B*' :: *B*' : *C*' :: *C*' : *D*', will unfold to give rise to the original linearly arranged series of *medium sized enterprises*, *A*, *B*, *C*, *D* . . This approach

follows from Lerner's definition of an original and the model [Lerner, 1972]. In the given example, which may be replicated to the earlier suggested similarity between bear and bull markets, or small and large firms, we have taken a pre-existent explicate order, consisting of ensembles of medium sized enterprises arranged along a line, and transformed it into an order of enfolded ensembles, which is in some key way similar. In this way it was indeed possible to give economics a certain kind of immediate intuitive significance, which seems to require a purely mathematical presentation.

For the purpose of more effective thinking in quantum economics we will try to integrate the intuitive with the mathematical side. For the sake of simplicity we begin with the above notation and let us assume that there are four markets A,B,C and D whereby we consider 'A' to represent all stock markets of an observed economy, 'B' shall represent the single largest stock market, 'C' shall be its bear market and 'D' its bull market.

Let us follow up on the example of bear and bull markets. To demonstrate the above-suggested concepts in terms of mathematical theory we first point out that K(T) is a state vector whereby *K* represents a financial result of the observed stock market expressed as a stock market index at a particular time, while *T* is the combined book value of listed companies. The ideas discussed in the previous paragraphs imply that the suggested *initial* transformation can be kinematically expressed as:

$$A : B :: B : C :: C : D \Longrightarrow \mathrm{dK/dT=W/K(T)/} \qquad (3)$$

where $\underline{w}$ is an operator through which the stock market is transformed from one state into another. We are now able to continue the procedure of regarding specific stock market subsets of the *subsequent implied* transformation in the following kinematic expression:

$$A : B :: B : C :: C : D \Longrightarrow \mathrm{dK/dT=W/K(T)/} \Longrightarrow A' : B' :: B' : C' :: C' : D' \qquad (4)$$

Now, introducing the contextual concept of time (*i.e.*, that of one moment of time and that of a subsequent one) we can observe a business process which has in itself *a multitude* of logical contexts:

$$Bt :: Bt : Ct :: Ct : Dt \Rightarrow \mathrm{dK/dT(t)=W/K(T)/(t')} \Rightarrow A't' : B't' :: B't' : C't' :: C't' : D't' \quad (5)$$

A similar transformation can be made using other mentioned examples from quantum economics. Before moving ahead to suggest an explanation of active information in economic and financial crises we shall develop in a systematic way Bohmian active information, universalization, particularization and fragmentation processes as they pertain to financial statements.

4.1. Specific potential role of active information in interpreting economic-financial crises

We saw above the various fundamental aspects of active information for the development of economic potential. Now, what might be of significance in Bohm's ontological interpretation of quantum theory to economics, more specifically what might a "Bohmian quantum economic recovery" look like compared to *V, L, K, U, W and Z shape* (WEF, 2021)? It would obviously manage economic-financial crises from the frames of reference offered by active information. We know very well from economic-financial history that crises necessarily seem to succeed failures in the flow of strategic data based wisdom [Girard, Klein & Berg, 2015] and have a cause-effect relationship with information. Bohm's insistence on the concept that information is typically active seems to be very useful if we want to understand how various disorders at the level of information lead to economic-financial crises. In economic aberration internally generated data is misguided for externally produced data. As a consequence this data acts to give rise to an impression of, for example, a global economic-financial crisis. This impression, in turn, can give rise to all sorts of reactions in the local economy, as the economic situation unfolds the significance in subtler levels of economic analysis. Therefore, the strategy of a particular company or local economy may be dependent on a specific type of provided data. Managers may not be immediately aware of the significance of attributed economic misinformation but face it when making decisions about specific solutions or exit strategies. Companies or economies facing crises then focus on provided unfavorable weaknesses and threats emerging from the data while opportunities and strengths are underestimated and vice versa. As a result the latter are constrained and take the form of '*inactive economic data*'. Ensuing economic uncertainty may even lead to panic which is a direct consequence of failing to make use of available 'active economic information'.

This is where theory of entrepreneurship [Hisrich & Peters, 2002] can be useful to provide an explanation of what is meant by the term 'active economic information'. Consider: *while an entrepreneurial organization will seek to take advantage of opportunities and strengths emerging from available information a company with misat-*

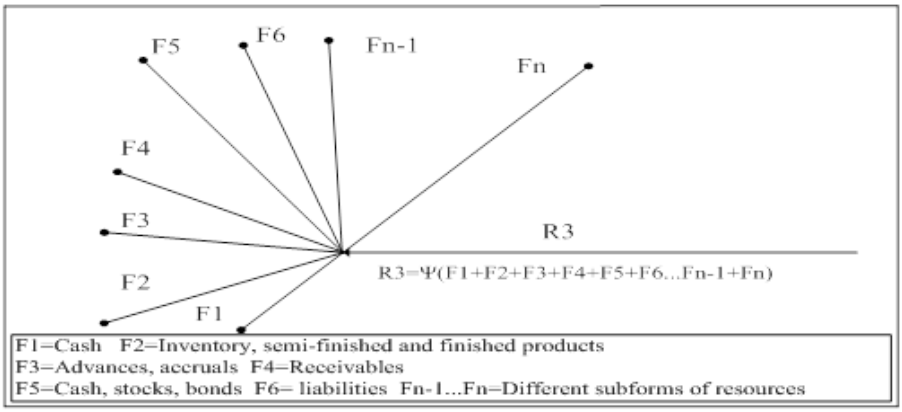
tributed economic information focuses on threats and weaknesses. Therefore it cannot successfully manage the information consisting of different types of incentives, and as a result an economic collapse can be sparked. Regardless of what companies and local economies may consider, economic disorders and collapses represent useful illustrations of the significance of active information. A question is raised whether a more comprehensive discerning of the subtle meaning of active economic information empowers the business and companies to manage it properly. In Bohmian terms information will remain active and instead of simply addressing its dynamic activity to manage it suggested is development of economic-financial coherence of information which requires the understanding of meaning of the various economic states, without necessarily actually judging them.

4.2. A proposed topological translation of active information from universalization, particularization and fragmentation processes in financial statements

Let us consider here the complimentary position of financial statements from the standpoint of process. Each business process has a multitude of pairs of directions. These pairs of directions can be interpreted as business developments between two opposing states; i.e., states which either include or exclude each other (so that the appearance of one implies the appearance or disappearance of the other). The key implication for our discussion is that according to Bohm the opposing states are not themselves generally existent, but they are simply *limits* of the process, which would be approached if the process continued indefinitely *in one direction*. However, as we shall see in figures 3, 4 and 5 the implication of each business process moves simultaneously in both directions. Bohm attaches significance to opposition in the two directions of the movement and not in the limits of the business process we suggest. Three basic concepts of Bohm's general world-view also logically arise for the business world-view: the universal, the particular and the fragmentary. For example, a universal economy relates to the whole economy or the totality of economic relations. Clearly, a particular business relates to a part of the total economy, i.e., it represents less than the economic totality. This is where the effective bond between the mentioned opposing economic states becomes relevant. We first note that every finite business is particular. Here particularity applies to the economic totality in the sense that *particularity is universal.* Consequently, universal economy is particular, since, according to Bohm, universality is not particularity, and therefore universality does not include the totality of all possible concepts (which must include particularity).

We can therefore observe that the three economic states which seem contrary in fact maintain a strong bond comprising of logical inference. In order to illustrate the bond, let us first revert to the notation of two sequential economic orders delineated by two times, tF, and tR, each having a series of points F1, F2,… Fn (indicating for the sake of simplicity particular subcomponents of financial reports; and R1, R2,.… Rn indicating different financial reports such as balance sheet and profit and loss statement). Here I translate Bohm's *process* from tR to tF. It is implied here that each point Ri… Rn splits up and goes on to make up points F1,…Fn, as indicated by the lines from tR to tF. A typical financial case is illustrated showing how R3 (i.e., balance sheet) for example splits up (an economic analyst can imagine a whole parallelogram of financial forces emerging for the sake of simplicity from R3 to F1…Fn). Inside each force, a very complex set of business events and processes is generally taking place (e.g., movements of the various constituent parts of the financing endeavor, going all the way down to individual transactions, etc.).

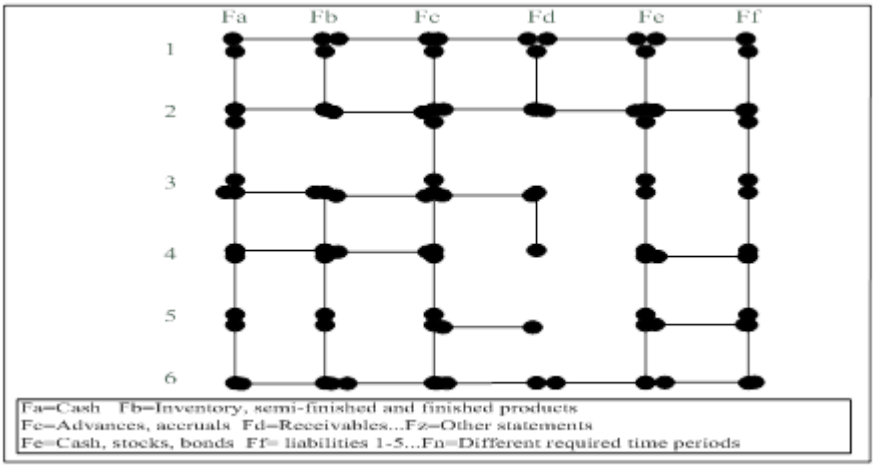
Figure 3. Particularization processes with financial statements



Source: Adapted illustration of Vemic (2010, p.70) and Bohm & Biederman (1999, p.63)

Similar to particularization, yet fundamentally still different, is the process of fragmentation, also observed recently in SME access to finance by Calabrese and Girardone [2020]. This issue in financial statements is herewith illustrated in figure 4.

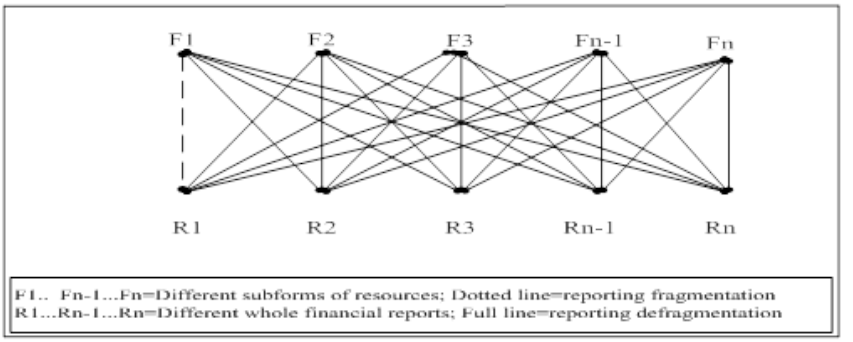
Figure 4. Fragmentation processes with financial statements



Source: Compiled by the author

We have tried to indicate the fragmentation along the vertical *financial* orientation of Fb, Fc, Fd and Fe lines and along the horizontal *temporal* orientation for different time periods numbered as 3, 4, and 5. Note the gaps in the middle of the above diagram. To illustrate the economic-financial possibilities even further let us consider that all the other points, R1…Rn, from all financial reports, split up in the same way as above. Total analytical outcome, for finance, is illustrated in figure 5.

Figure 5. Parallel universalization, fragmentation and particularization processes



Source: Adapted illustration of Vemic (2010, p.70) and Bohm & Biederman (1999, p 63)

What are the facts that come to our mind? Note the intersection of key pathways along the F3-R3 diagonal and consider their economic-financial significance. Clearly,

also, from every point F there is a set of lines connecting with every point R. Indeed, it is well known that how we see an economic-financial phenomenon depends on what we know about it. (*E.g.,* an uttermost case is that of an enigmatic business account, subject to two interpretations, one obvious and the other less so). Following are additional approaches for interpreting the depicted connections:

1. In diagram 5 a part of a financial report, for example Rn-1, splits and enters into all points of Fn. Let us consider the wholeness of points of Fn as the business universe at the time Rn(t). Then if we take off from a given point, Rn-1, we obtain a process of economic-financial universalization, i.e, some particular point Rn-1, becomes economically-financially universal.

2. Also illustrated in figure 5, a part of a financial report, for example, R1 enters into F1 with a fragmented structure while in all other cases particular points along the F1…Fn1-1 axis are fully reached.

3. Figure 5 further illustrates that stock market integration and globalization is higher for stock markets which are high on universalism. Their areas of overlap are indicated by the crossings. Therefore, there is a greater degree of stock market overlap for the universalized markets with high stock market capitalization-to-GDP ratio. Similarly, the fragmented markets are characterized by stock lower market capitalization-to-GDP ratio, higher legal and regulatory barriers, problems in clearing and settlement, bookkeeping differences and higher information costs [Schröder, 2001].

4. Integration absence is indicated in figure 4 along the horizontal orientation for different time periods numbered as 3,4 and 5.

5. Let us take a look at the process from the contrary side. Each point of Fn consist of inputs from the wholeness of points Rn. This is a process by which the universal (the universal at the time Rn(t) splits up and establishes particular points F1…Fn at the time Fn(t). Hence it is a process of economic-financial particularization, which is a process in which the economic macrocosm becomes particular as illustrated in figure 3.

4.3. Active information in nonlocal correlation between quantum and business potential

Let us begin this section by expressing more precisely quantum and business potential. Distinguishing it from mere classical potential, V(x), Bohm defined time independent quantum mechanical potential (containing an information potential in terms of probability density (*R*)) formulaically in the following way [Bohm, 1952a,

p.170]:

$$U = -\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R} (6)$$

Bohm then extended his discovery to the '*many body problem*' under rapid and violent fluctuations [Bohm, 1952b] and *electromagnetic potential* [Bohm & Aharonov, 1959] showing that the movement of particles unfolds the meaning of the information that is implicit in the many dimensional quantum field [Bohm, 1980, pp.102-103]. As Bohm succinctly summarized it: "…This information brings about nonlocal interaction, but quantum wholeness implies even more than this. From it arises out of the quantum field which cannot be understood solely in terms of preassigned properties and interrelationships of the particles alone. Rather the whole is presupposed in the quantum wave function and it is the active information in this wave function that forms and dissolves wholes…Participatory quantum potential can introduce nonlocal connections between all constituents of the total system which are not preassigned functions of the properties of this system", [Bohm, & Hiley, 1993, p. 95, 108].

It is relevant for our figure 6, which follows, to relate equation (6) with *information* entropy of a continuous distribution, also with the notation of density distribution function, in this case with notation P(x), [Shannon & Weaver, 1964, p. 94]:

$$H = -\int_{-\infty}^{\infty} p(x) log\, p(x) dx \quad (7)$$

Let us now note the difference between (6) and (7): and while in the former quantum potential conditions the form of and measures the quantum field through active information, calculation of entropy in the latter relies on passive information. Thus we write their interrelationship, *not in terms of Shannon's entropy*, but in terms of *total information resource activity*, where we obtain a relationship as follows:

$$H = \nabla Ha + \nabla Hp \ (8)$$

and where *Ha* stands for probability of active and *Hp* for degree of probability of passive information. Both are needed to assess extreme management potentiality [Lerner, 1972]. One can compare suggested entropy with the description of negative entropy originally introduced by Schrodinger [1944] implying a measure of distance of the *V, L, K, U, W and Z shapes (WEF, 2021)* to normality. We distinguish here a priori probability inferred through deductive reasoning, that is, probability on information before it is received, and probability of information after it is received (a posteriori). From the total financial information resource activity equation (8) we can

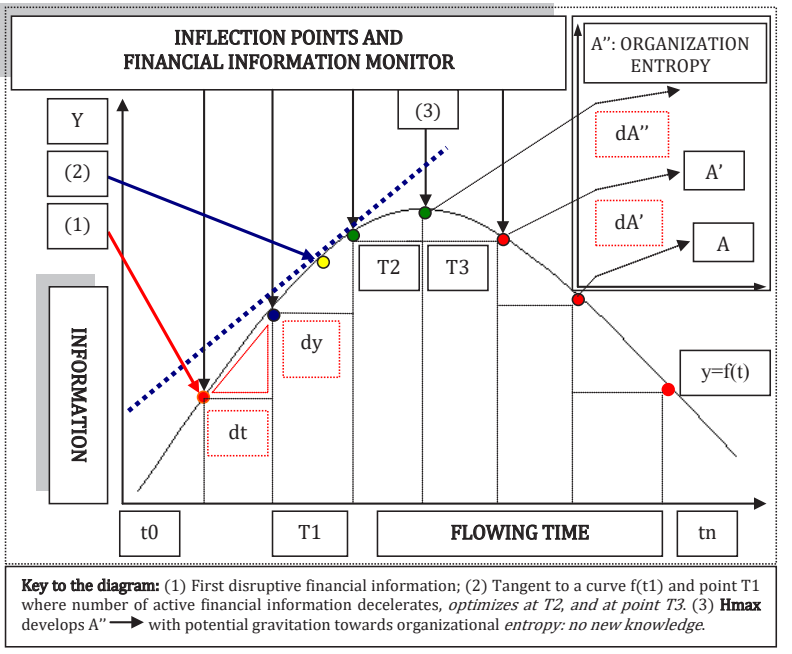
express active information as a special case in terms of probability where we obtain

$$H = log\ \frac{p_1}{p_0} (9)$$

It is clear that represents a priori probability of total information, which is the number of possible cases before the information is received, while stands for a posteriori probability of possible *active* financial information after the information is activated and received.

We will now show that there is real coherent meaning in the active information that is implicit in the business field as well. Therefore, let us go on to consider financial potential and how this notion interplays with quantum potential. Potential examples are numerous and include potential risk, costs, profit and loss, potential debt, potential cash flows, sources of finance (under other unchanged conditions financial potential also depends on the structure of sources which can be borrowed and own while the conditions of financing and investing influence the structure), environment, lenders, competitors and borrowers, potential buyers, customers, investors, potential IPOs, potential growth and rating, upside and downside potential, potential market and net present value, etc. The influence of active information for dissemination of financial potential in business performance through translation of equations (3) to (5), A:A':A"≥A", is now illustrated in figure 6. Suppose that financial information disseminates along the signed area of the region in the xt plane that is bounded by the graph of *f*. The potential function will now be represented by a curve [Vemić, 2005]. Here to the original potential the author has added incremental potentialities where the '*t*' and '*y*' changes are the distances from the edge of the surface of the graph shown in figure 6.

Figure 6. Ergodic inflection points in dissemination of active financial information



Source: Adapted illustration of Vemić (2005, p. 257).

In the above diagram *potential* active financial information in the period t1-t2 is herewith mathematized as follows:

$$A' = \int_1^2 A'y(t)dt \quad (9)$$

Consequently, the *difference* between potential financial information and conditioned strengths, opportunities threats and weaknesses yields:

$$\Delta A''\,(SWOT'') = Y = \int_1^2 (A''(t) - A'y(t))dt \quad (10)$$

In figure 6 financial movement from equations (3) to (5), A:A':A"≥A", takes place along the lines of a probability density function from equation (6). But, it is also important to explain what happens after *A"*. Here it is necessary to introduce the concept of *entropy*. The Oxford Dictionary of Science [Oxford's, 2006] defines entropy (sym-

bol *S*) as a measure of unavailability of a system's energy to do work. Of relevance to our work is an approach according to Shannon's entropy and is related to "missing information," inasmuch as it is related to the number of alternatives which remain possible to a physical system after all the macroscopically observable information concerning it has been recorded [Shannon & Weaver, 1964, p. 3]. Now, in a closed system an increase in entropy is accompanied by a decrease in energy that is to say of financial information availability. With higher entropy there is higher disorder or randomness in a closed system as it gravitates towards the greatest probability and organizational chaos. Being open organic enterprises nurture innovation and creativity producing continuous exchange with the external environment in order to survive [Chesbrough, 2003; 2011] which relates them to information potential. Conversely bureaucratic organizations operate in a mechanistic and closed style potentially leading to entropy because conditioned increase in financial information results in reduced performance indicators mentioned above.

According to Shannon a communication channel which has a capacity of C bits per second, accepts signals from a source of entropy (or information) of H bits per second. The entropy H here measures information per symbol, so that the ratio of C to H measures symbols per second, which is nearly C/H, but which, no matter how clever the coding, can never be made to exceed C/H [Shannon & Weaver, 1964, p. 17]. One may indeed compare Shannon's approach with the thermodynamic concept of *enthalpy* (symbol H), proving the same difference, defined as the total heat energy of a substance [Heys, 1974, p. 343]. If H is enthalpy, and G is free energy then their difference is the amount of energy involved in the entropy change. Thus, if T is the Kelvin temperature the difference between total heat energy and free energy is [Heys, 1974, 343] we obtain a relationship between H and G

$$\Delta H - \Delta G = T\Delta S \quad (11)$$

$$\Delta G = \Delta H - T\Delta S \quad (12)$$

Obviously there is a deeper figurative meaning in the difference between actual information and total free available information suggested by formula (11).

In view of the above achieved *actual performance of an enterprise*, in the period t0-t1, resulting from *actual usage of active financial information*:

$$Y = \int_0^1 (y\,(t)dt) \quad (13)$$

The above diagram reveals the finding that an improvement of financial perfor-

mance of an enterprise system can be achieved ambidextrously in at least four major ways viz.:

1. By minimizing the negative effects deriving from incomplete usage of active financial information relating to financial opportunities (dA"- dA'). This requires researching and quantifying information on internal and external sources of finance; comprehension of strengths, weaknesses, opportunities and threats which condition the usage of available sources of finance; adoption of management interventions for fuller and more rational usage of financial potential.

2. By activating and quantifying available financial information required for activation of potential mid-term and long-term sources of finance (dA"), including additional and innovative sources that may contribute to an improvement of financial performance.

3. Through organizational measures aimed at fuller exploitation of strengths, opportunities threats and weaknesses.

4. In strategic management initiatives aimed at activation of historical business and financial information potential.

Figure 6 and formulae 6-13 reveal that similar to corresponding energy levels in quantum theory, passive financial information through density of probability *and* active financial information through information potential somewhat similar to quantum potential, fit into the four basic corresponding reporting levels already built in equations (1) to (5). These levels contain the potential we have in mind. In order to confirm the information potential hypothesis, we presented various schemes and models. The results of our research confirm the latest theories of information potential that highlight the need for probability density functions [Acu, Başcanbaz-Tunca, & Rasa, 2021].

Consequently, as the information stored in the RNA (or DNA) encodes the mechanism of self-replication so the data in static financial reports also has the potential for self-tuning and self-replication. We believe that a similar process would occur with necklaces in companies, leading not only to a stationary but also a dynamic process of self-replication involving active business information.

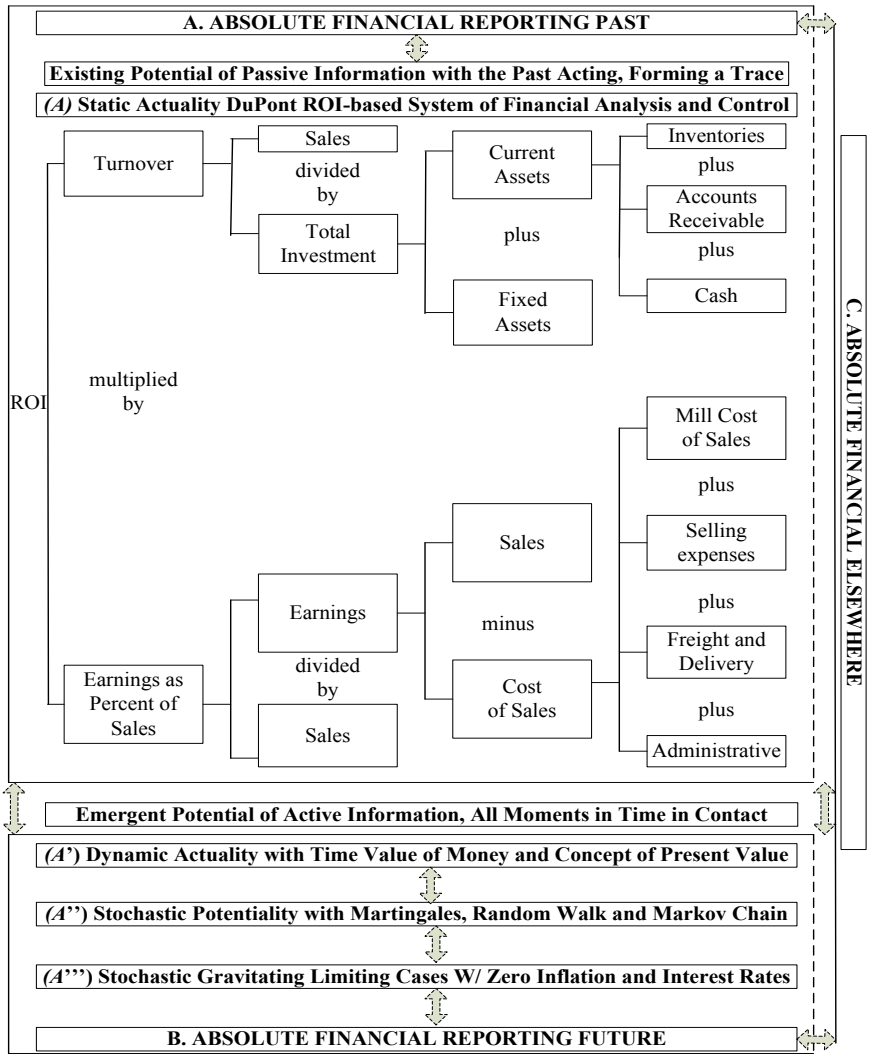
As an example, let us consider how effectively corporations of various sizes employ and measure the rate of return on investment [Carleton & Lerner, 1966, p. 16] or the rate of return on assets [Brigham & Houston, 2001, p. 107] resulting from their *total information resource activity*, explained in our eq. (8). And while the same approach can be obtained with any other system of financial analysis and control we

will illustrate our ideas with the *Du Pont ROI method* of combining items that appear on the balance sheet (inventories, accounts receivable, and cash) with elements of the income statement (cost of sales, selling expenses, etc.). In the dynamic movement of business information, both passive and active, from an absolute past toward an imaginary absolute financial future, a company optimizes its business strategy to maximize stockholder value through profit margin improvement, increased asset turnover and greater financial leverage within reasonable limits. This is now shown on the example of a complex financial reporting system in figure 7. Note the appearance of active financial information, discontinuous and indivisible transition from static actuality to a dynamic actuality. In relation to the problem of time [Bohm, 1980, pp. 267-269; Bohm & Biederman, 1999, p. 89], and in order to prove the relationship between active financial information and business potential let us as analogously take a case of a company (*e.g.*, SME). Its business reality-time is split into Bohm's three sections of a suitably oriented coordinate system: (A) absolute financial reporting past, (B) absolute financial reporting future, (C) absolutely financial elsewhere. The absolute SME past consists of all those financial reports that can act in the company. The absolute future of SME consists of all those events in which SME can act. The absolutely financial elsewhere, illustrated outside the main SME domain, include all those events which have no direct contact with the company, though indirect contact here is possible like for example through large supply chains.

The fundamental idea here is that any business process whatsoever which can be localized in the dynamic actuality of a company can be acted upon by what is in its absolute financial reporting past. Such a process does not completely actuate its financial elsewhere events but it does generate a projection of its past which infers its stochastic potentiality and may influence business processes elsewhere as well. However, there cannot be a total determination of the business potentialities be they related to elsewhere events or in the absolute future. Therefore, the internal structure of any given moment determines completely neither all the potentialities of the company's business future nor all that exists among the currently financial elsewhere events. As the internal structure of the financial reports are not completely self-determined their *development* is in some ways dependent on financial elsewhere events. Bohm termed this phenomenon *objective contingency* and stressed that it may later on turn into a *necessity* as the process of diagram 7 develops in conjunction with the external environment [Bohm & Biederman, 1999, p 90]. However, all suggested transformations of financial information, be it actuality, contingency or necessity, will never be sufficient to condition the financial future totally. This is evidenced in our research of

15 medium sized enterprises from Serbia [Vemić & Molnar, 2018].

Figure 7. Topological wholeness of ergodicity of static, dynamic and stochastic indicators



Source: Developed and integrated by author, with Du Pont illustration by Carleton & Lerner, 1966, p. 16, and problem of time conceived by Bohm & Biederman, 1999, p. 89.

In figure 7 it becomes clear that each different segment of the illustrated structure

of financial reporting, while being relatively dependent and independent, conditions the subsequent segment of the process in a certain field. This is similar to Bohm & Biederman [1999] who pointed out that an existing structure determines potentialities for a subsequent process on the basis of contingency and is sensitively dependent on the precise details of the track which started [p.88, p.162 and p.220]. The suggested *self-replication* of financial potentialities takes place along the lines already suggested in equations (1) to (5) as a total process and then also corresponds to the wave function identified with Bayesian expectation conceived as the brain's "self-tuning" capability subject to informative modification [Globus, 2017]. Each segment in figure 7 is only one abstracted side of a limited financial reporting totality. If we understand one segment, we may not understand the next, unless we remain vigilant to the total financial reporting context of a business, because something fundamentally new may evolve in the mean time. Misattribution derives from using inadequate abstractions and mistaking a reporting segment for a business totality. For example if we hold on too long to abstractions of the financial reporting past, which were once at the very center of management decision making but which no longer correspond to the new business context. In order not to forget that abstractions are abstract and not to confuse them for concrete business totality we need to see beyond known financial reporting patterns. What we must realize is a generated law of the totality [Bohm & Biederman, 1999, p 180], including the external (opportunities and threats) and internal environment (strengths and weaknesses) in their correct interconnection instead of resorting to varying fragmentary reports.

Let us now consider the illustrated interweaving static and dynamic financial indicators once again, expressed as oppositions. For example, consider their synonyms as potential and actual financial statements. At first sight these are two opposing processes within which (a) the potential becomes the actual; (b) the actual becomes the potential (actualization versus potentialization) [Bohm & Biederman, 1999, p 64] and (c) the stochastic potentially becomes static because of a limiting case in which the inflation and interest rates gravitate towards zero levels. In the total reporting process, the two financial processes are identical. But in each separate economic context, one or the other will dominate. Therefore, it appears that neither the potential, actual nor the stochastic exists as such independently as fragments but serve as derivatives of an abstract process extrapolated limitlessly in a given economic or business direction. The cause of correlation between the static and dynamic financial indicators is the business potential, such as analogously in quantum potential where such correlation is between particles [Bohm & Hiley, 1999, pp. 149]. Where ever the

business potential can be neglected the static indicators will hold, again analogously as a limiting case similar to that of classic limit versus quantum potential. But the potentiality of applied quantum wholeness in economics and finance implies even more than this. Obviously the quantum field cannot be understood solely in terms of preassigned properties and interrelationships of particles alone [Bohm & Hiley, 1993, pp. 95] and the same analogously holds for relations in the economic and financial field (*i.e.* inflation and interest rates) as presented in our analysis.

5. CONCLUSION

We wish to conclude this second paper which is based essentially on pure comparative, deductive (top down) and inductive (bottom-up) reasoning with some remarks on implications of Bohm's wholeness and implicate order concept and how it applies to finance.

Based at first on ideas about capacity of communication channels originally proposed by Shannon and new interpretation then carried further by the author the notions proposed bring us to the following deductive conclusion: there is an analogy between the second law of thermodynamics, the law of entropy and potential activation of financial information.

Since the quantum field cannot be understood solely in terms of preassigned properties and interrelationships of particles alone it turns out inductively that the business field cannot be interpreted only on the basis of static financial indicators and interrelationships of the financial ratios. The remaining two dimensions (dynamic and stochastic) are also required. Consequently, deductive reasoning from all of these three relevant and particular economic dimensions in fact uphold Bohm's earlier discovered quantum law of syllogism: "The whole is presupposed in the quantum wave function and active information in this wave function forms and dissolves wholes" [Bohm & Hiley, 1999, pp. 95] by acting nonlocally. On that basis we also arrive at the following ***economic law of syllogism***: wholeness of static, dynamic and stochastic financial indicators is presupposed and active business information in economic cycles forms and dissolves economic wholes nonlocally. Consequently, even though physics and economics are distinct disciplines, the hypothesis of the unity of science [von Bertalanffy, 1968] is herewith confirmed, through the correspondence principle, that fundamentally they must represent a constituent part of a unified intellectual enterprise: science.

We conclude that active information is a key component of Bohm's quantum in-

fluenced theory which successfully bridges static and dynamic indicators in economics and finance as a total process. With couplings, it bridges reporting fragmentation with reporting defragmentation in finance. The learning behavior of a financial analysis can be approximately explained with the static indicators, but further away the laws of dynamic interplay instead come into play. In this respect economic disorders and their solutions are then connected through active information. Our success to comprehend and use active information is therefore a condition for managing economic and financial crises. This further requires not any kind of active information but coherent and meaningful information. What this actually means is that managers of businesses and economic policy actors should be aware of the meaning of active information contained in various incoherent and upsetting accounting, market and policy reports.

In this article, we have also shown how further development of insights from wholeness and implicate order now clearly implies the development of a parallel, safer and more reliable financial reporting system based on the principle of quantum couplings the logic of which is herewith figuratively applied in economics and finance. Thus we have shown in relation to both the 2008 global financial crisis and the 2020 Covid 19 pandemic that a change in one of the quantum economic states, in one of the economic and financial systems, will inevitably cause an instantaneous change in all of the bound social-economic systems. We also noted earlier how this may lead to misattribution of economic data and thereby an accusation of external stakeholders while neglecting internal weaknesses and threats.

In addition we have with some passion and economic expectation discussed how the possible role of Bohm's notion of active information could become significant in a proper understanding of both economic-financial orders and disorders. A practical way of applying the notion of active information in the economic-financial context is not to try to replace existing theories on economic disorder by a theory based on this concept. Instead, suggested is to apply the notion of active information to optimize the concepts already supported by existing economic theories some of which were mentioned in our introduction and earlier works. In particular, discussed concepts signify the way active information is organized to support economic development. Clearly, much more remains to be researched about this potential application as we have only just begun to discuss quantum economics from the Bhomian angle of view.

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