

Chapter 2

A Kabbalah System Theory Modeling Framework for Knowledge Based Behavioral Economics and Finance

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Abstract Kabbalah and its Tree of Life integrate the cognitive, behavioral/emotional and action levels of human existence, explaining the relations between these and their unity. This makes it an ideal framework for behavioral economics and finance where cognitive and emotional biases and heuristics play a central role. In Burstein and Negoita [9], we began to develop a Kabbalah system theory, modeling the Tree of Life as a hierarchical three level feedback control system corresponding to the cognitive, behavioral/emotional and action levels. We will further develop this here by focusing on system dynamics, in order to create a Kabbalah system theory modeling framework for a knowledge based behavioral economics and finance. In this new framework, emotional intelligence theory [19–21, 40] and Polanyi personal tacit/explicit knowledge theory [36, 37] are used to model the emotional and cognitive level processes. Here we are connecting these theories with behavioral economics and finance. While behavioral finance focuses on the impact of knowledge/cognition and emotional factors, the intrinsic dynamics of these factors is not considered in depth. This is why behavioral economics and finance can benefit from integrating emotional intelligence and knowledge theory in their modeling. Our Kabbalah system theory creates the modeling framework for that. In particular, it allows connecting the recent knowledge based economic theory attempts with behavioral economics in a unified knowledge based behavioral economics. We apply this in particular to Kabbalah behavioral, knowledge based asset pricing modeling.

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1 Introduction and Outline

One of the primary causes of the present economic and financial crises we are witnessing now is the failure of the applied classical economics and finance to address in practice in a unified way: (1) the personal knowledge and cognitive level, (2) the emotional and behavioral level and (3) the action level of economic and financial dynamics.

There is now considerable progress of modern economic and financial theory in addressing how behavioral biases and heuristics due to levels 1 and 2 affect processes at level 3 [9, 21, 22, 36, 39, 40]. However, these do not include models for the intrinsic mechanisms at knowledge and emotional/behavioral levels but rather focus on the impact of those levels on economics and finance.

The knowledge theory of Polanyi [34, 35] and emotional intelligence theory of Goleman [17–19] and Salovey and Mayer [38] provide ideal frameworks for the dynamics at levels 1 and 2.

An interdisciplinary holistic, system theoretic framework is needed to integrate these together. At the present, modeling approaches in behavioral economics and finance are predominantly statistical or empiric, reductionist rather than holistic integrative and system theoretic. In order to approach simultaneously levels 1, 2, 3, one needs a holistic integrative common modeling language that is both quantitative and structural qualitative. This is exactly our objective here: a holistic Kabbalah system theory modeling framework for knowledge and behavioral based economics and finance, integrating knowledge theory and emotional intelligence.

General system theory (GST) and cybernetics [42–44] emerged as a program to address in a holistic way all aspects of different type of systems and the interdependence between these in a unified formalism. System theory has been so far very little applied to economics and finance. Lange was among the first one attempting to formulate an “economic cybernetics” [23].

A new type of system theory models are required to approach the different quantitative and structural qualitative natures of multi-faceted complex systems involving the human element. In the first part of this chapter we are introducing our Kabbalah based system theory that we began developing in [6] in order to address simultaneously in a unified framework the triple nature of economic and financial systems. We will then focus here on how to apply it to behavioral economics and finance and this will require developing new system dynamics modeling introduced here for the first time.

Kabbalah and its Tree of Life integrate together the cognitive, emotional/behavioral and action levels of human existence and is thus an ideal integrative framework for knowledge based behavioral economics and finance. The Tree of Life actually has three interconnected levels and they are exactly the cognitive, the emotional/behavioral and the action level.

We are first presenting basic elements of Kabbalah, the ancient philosophical and scientific analysis of creation and existence, a truly scientific thinking developed across many centuries by Rabbis Shimon Bar Yochai (Rashbi), Isac Luria

(Ari or Arizal), Moshe Cordovero (Ramak), Chayyim Vital, Moshe Hayim Luzzatto (Ramhal), Yehuda Lev Ashlag (Sulam) and many others [1, 11, 25, 30].

Since its ancient days, Kabbalah proposed the Tree of Life as an integrative framework to understand the creation and development of the three basic levels of human existence: cognitive, emotional/behavioral and action levels. We will show how the Tree of Life contains elements for a system theoretic approach to economics and finance: feedback, hierarchical control etc. We will then show how to use these and the Tree of Life to integrate personal knowledge theory [34, 35], emotional intelligence [17–19, 38] with classical economic theory and the findings of behavioral finance and economics [2, 9, 13, 21, 22, 36, 39, 40].

In the second part we will develop for the first time system dynamics models, expanding further our earlier Kabbalah system theory to model knowledge based and behavioral economics and finance:

- (1) Behavioral asset pricing system models including macro and micro economic factors, asset market technical and quantitative factors and asset prices together with an emotional and cognitive knowledge level
- (2) Aggregate supply and demand behavioral and knowledge based models for goods prices
- (3) Knowledge based production models linking invested capital, labor force and total production with knowledge and behavior (knowledge based and behavioral Cobb Douglas theory)
- (4) Knowledge based and behavioral economic sectorial models linking productive sectors, consuming sectors, individual and household consumers, export (knowledge based and behavioral static and dynamic Leontieff sector balance models).

We will focus in particular on expanding (1) as an application example. Emotional and cognitive biases are formulated in this framework

- overconfidence bias: the excessive faith in one's cognitive abilities.
- conservatism bias: bias due to fixation in previous personal knowledge to the detriment of processing new economic and financial information (underreaction).
- optimism bias: an emotional bias, while the biases defined above were cognitive. It is the bias according to which investors, based on their emotional structure, are over-optimistic about markets and economical situation.

2 The Tree of Life of Kabbalah as the Framework for a Kabbalah System Theory

According to Kabbalah, human existence, the physical and psychological, emotional world and the process of its structuring and creation have ten fundamental general attributes/qualities called “sefirot”, grouped in three categories [30]:

- (1) knowledge and cognitive level (including objective and spiritual knowledge): Crown (will, faith and desire, Keter in original Hebrew or Aramaic), Wisdom (Chochmah), Understanding (Binah) and Knowledge (Da'at) which in fact prepares the transition and implementation of understanding at the emotional level. We are not going here into the detailed structure of this sefira, we did so in [6]
- (2) emotional/behavioral level: Lovingkindness (Chesed), Judgment, Justice, Strength, Rigor or Severity (Gevurah) and Harmony or Beauty (Tiferet) which is connected to the next level below
- (3) action level: Perseverance or Endurance (Netzach), Victory or Majesty (Hod), Foundation (Yesod) and Kingship (Malchut).

These ten fundamental attributes of the creation, development and existence processes are called in Hebrew sefirot (plural, sefira singular) which means counts, fundamental units. Despite their metaphorical anthropomorphic names, they do represent a very general metaphoric coordinate system of 10 general basic attributes (11 including Knowledge which normally is not represented in the same time with Crown), properties, actions that can be used to describe complex systems in general. In the Tree of Life, the ten sefirot fundamental units or components are interconnected by 22 arcs based on the interactions between them and between each of the three fundamental levels described above, in which these sefirot are integrated.

The internal sub-structure of each sefira is again of the type of a Tree of Life made of 10 sub-sefirot of the same type as the original 10 sefirot. This way, each sefira contains an internal model of the Tree of Life and of each of the sefirot it is in interaction with. In principle, we can go on and speak of the sub-sub-structure of sub-sefirot which will also be in the shape of Tree of Life etc. This means that the Tree of Life has a fractal structure or an inter-inclusive structure. However, for purposes of our Kabbalah system theory we will restrict ourselves to the first order sub-structure of the Tree of Life described by sub-sefirot of sefirot (see Fig. 1).

The names of the sefirot should be understood in their whole metaphoric symbolic generality. Lovingkindness for example, is the sefira of expressing emotions, of producing, of accepting. Judgment is the sefira of judging and understanding emotions, of consumption, of rigor, discipline, aversion and rejection.

The Tree of Life can also be seen as a system made up of three triadic levels. This is the simplified structural representation that we will use here though the missing sefirot can always be added to it:

- (1) Cognitive: Wisdom-Understanding-Knowledge (ChabaD from Hebrew Chochmah-Binah-Dat denoted CBD),
- (2) Emotional and Behavioral: Lovingkindness-Judgment-Harmony (ChaGaT from Hebrew Chesed-Gevurah-Tiferet denoted C'GT),
- (3) Action: Endurance-Majesty-Foundation (NHY from Hebrew Netzach-Hod-Yesod denoted NHY).

Just like each sefira is made of 10 sub-sefirot, so each triad can be seen in its turn to be made up of three sub-triads. The Tree of Life has an inter-inclusive structure both in terms of sefirot and triads.

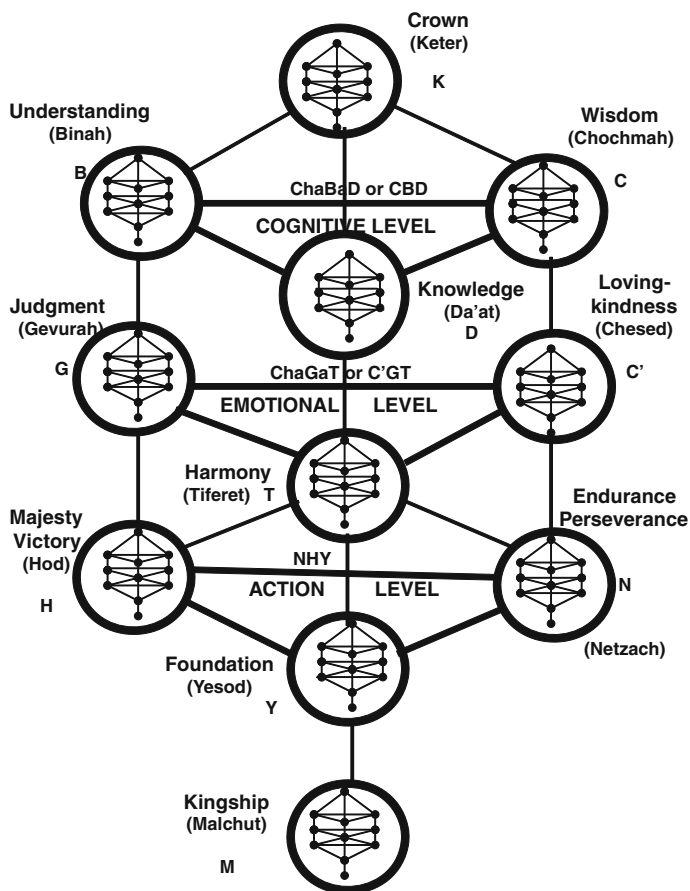
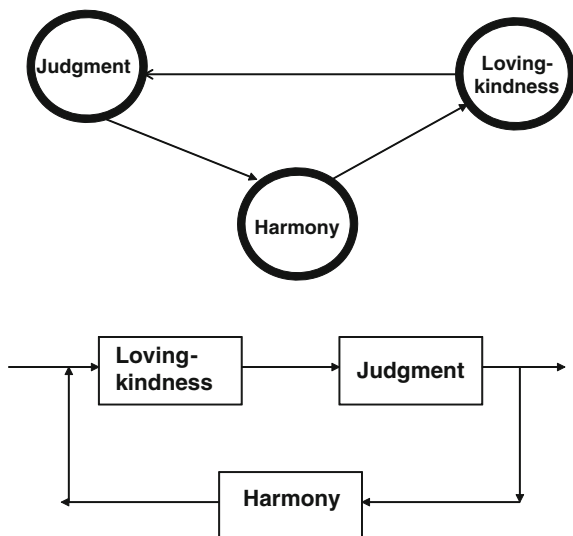


Fig. 1 The structure of the Tree of Life of Kabbalah model with 10 sefirot plus sefira Knowledge and the Cognitive (ChaBad or CBD), Emotional-Behavioral (ChaGaT or C'GT) and Action (NHY) triadic levels. Each sefira is described by its own similar sub-Tree of Life structure

The Tree of Life can also be seen in terms of the configurations, sets of sefirot (partzuf, singular, or partzufim, plural in Hebrew, Aramaic). For example, the five sephirot around Harmony plus sefira Harmony itself (Lovingkindness, Judgment, Endurance, Majesty, Foundation and Harmony itself) form the configuration of Harmony (Small configuration or Zeir Anpin in Hebrew, Aramaic).

Fig. 2 The Tree of Life Emotional triad Lovingkindness-Judgment-Harmony (Chesed-Gezurah-Tiferet in Hebrew or ChaGaT denoted C'GT) as a feedback control system



3 A Kabbalah System Theory: Hierarchical Feedback Control Systems in the Tree of Life

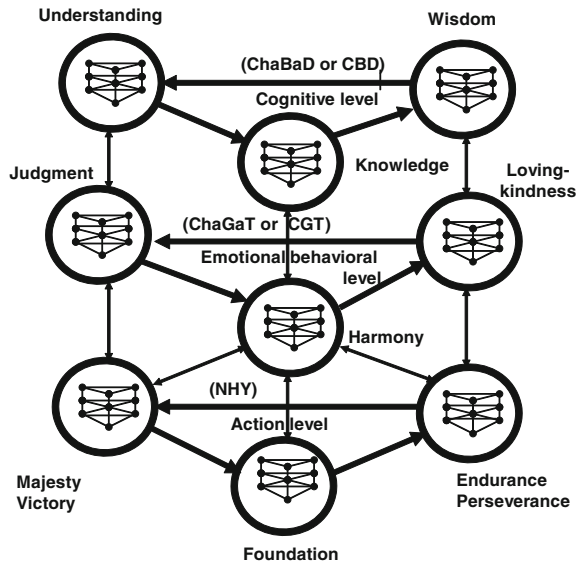
The three sefirotic triads of the Tree of Life can each be modeled by a feedback control system as we showed in [6].

For example (see Fig. 2), the sefirotic triad made of Lovingkindness-Judgment-Harmony (abbreviated as ChaGaT or CGT from the initials Chesed-Gezurah-Tiferet of the corresponding Hebrew words), functions as an emotional level feedback control system with Harmony as feedback control helping Lovingkindness to regulate Judgment and viceversa. We have seen before how Lovingkindness and Judgment have opposing though complementary functions. Harmony is known in Kabbalah to represent the sefira of the middle equilibrium line that helps maintain the balance between Lovingkindness and Judgment and the intuition of feedback loops was there for a long time [3, 11]. In specific human and social system applications, Lovingkindness and Judgment can each be described by their own 10 sub-sefirot as we discussed earlier.

Based on the above, we proposed a three level hierarchical feedback control system model for the Tree of Life, made of hierarchically interconnected feedback control system models of knowledge-cognitive level, emotional level and action level (see Fig. 3).

In the Tree of Life of Kabbalah, flow of information goes both ways between sefirot. However, for simplicity, we represent in Fig. 3, only one sense of arrows in the CBD, C'GT, NHY levels compatible with the feedback control structure of these levels but one should bear in mind that flows of information at these levels are much more complex and can also go in the opposite sense to the one represented in Fig. 3.

Fig. 3 The Tree of Life as a hierarchical three level feedback control system: Cognitive (Wisdom-Understanding-Knowledge (CBD)), Emotional-Behavioral (Lovingkindness-Judgment-Harmony (C'GT)) and Decision Making-Action (Endurance-Majesty or Victory-Foundation (NHY))



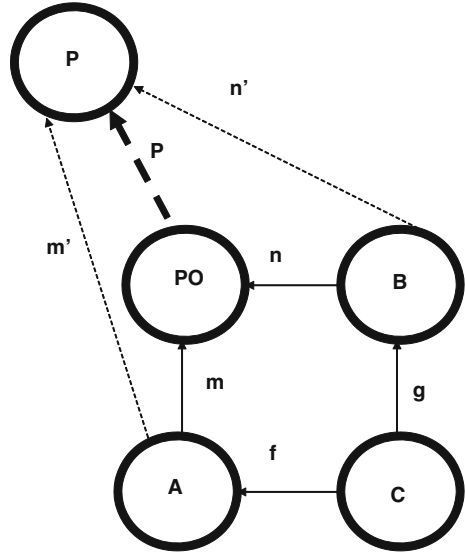
This hierarchical feedback control system in Fig. 3 is in fact a complex of horizontal and vertical, short and long feedback loops, descending and ascending, providing a range of feedback types in particular for complex economical and financial systems with behavioral and knowledge factors.

4 An Algebraic Combinatorial Modeling Framework for Kabbalah System Theory Based on Category Theory and Algebraic Topology

The Tree of Life with its 10 sefirot as nodes and its 22 directed edges or arcs connecting the sefirot defines a graph. What makes this graph special is the existence of three hierarchic levels in it corresponding to cognition, emotion and action, the symmetry left-right between the side of Lovingkindness and the side of Judgment with a middle axis of Harmony moderation between them. If we now consider the structure of each sefirot with its sub-Tree of Life, we do get a very specific Tree of Life graph indeed having an inter-inclusive structure, a graph of graphs, where the graph in each node has the same shape as the large overall graph. The arcs connecting two sefirot can be interpreted as transformations between their sub-structures modeled by graphs. This indicates that the Tree of Life, according to category theory [24, 26, 41], is in fact best described by a commutative diagram in the category of graphs.

The category of graphs is made of graphs as objects and graph transformations as morphisms including the possible compositions of such morphisms. Such graph morphisms or transformations between graphs are a model for the dynamic transitions

Fig. 4 The category theoretic commuting diagram definition of the pushout PO of objects A and B over C including the universality property (stability, robustness) of PO with respect to any other P



of a graph structure in time and hence for the dynamics of the Tree of Life graph. Graphs form a special type of category called “topos” [41] which has many useful properties for system theory modeling among which is the existence of pullbacks and pushouts which we define next for the case of a general category. For category theory and topos theory introduction see [24, 27].

Definition 1 The pushout of objects A and B over object C in a category containing objects A, B, C connected by the morphisms $g: C \rightarrow B$, $f: C \rightarrow A$, is an object PO of that category together with morphisms $n: B \rightarrow PO$ and $m: A \rightarrow PO$ in the category morphism set such that (i) the diagram in Fig. 4 commutes $m \circ f = n \circ g$ (where “o” denotes morphism composition) and (ii) PO has the universality property meaning that for any other object P in the category and morphisms $m': A \rightarrow P$ and $n': B \rightarrow P$ that satisfy the commutativity of the diagram in Fig. 4 $m' \circ f = n' \circ g$, there exists a unique morphism $p: PO \rightarrow P$ such that $p \circ m = m'$ and $p \circ n = n'$ (see Fig. 4).

We introduce next a concept dual to pushout in category theory, pullback, obtained by reversing the morphism arrows in Definition 1.

Definition 2 The pullback of objects A and B over object C in a category containing objects A, B, C connected by the morphisms $g: B \rightarrow C$, $f: A \rightarrow C$, is an object PB of that category together with morphisms $n: PB \rightarrow B$ and $m: PB \rightarrow A$ such that (i) the diagram in Fig. 5 commutes $f \circ m = g \circ n$ where “o” denotes morphism composition and (ii) PB has the universality property meaning that for any other object, P, in the category and morphisms $m': P \rightarrow A$ and $n': P \rightarrow B$ that satisfy the commutativity of the diagram in Fig. 5 that is $f \circ m' = g \circ n'$, there exists a unique morphism $p: P \rightarrow PB$ such that $m \circ p = m'$ and $n \circ p = n'$ (see Fig. 5).

Fig. 5 The category theoretic commuting diagram definition of the pullback PB of A and B over C including the universality property (stability, robustness) of PB with respect to any other P

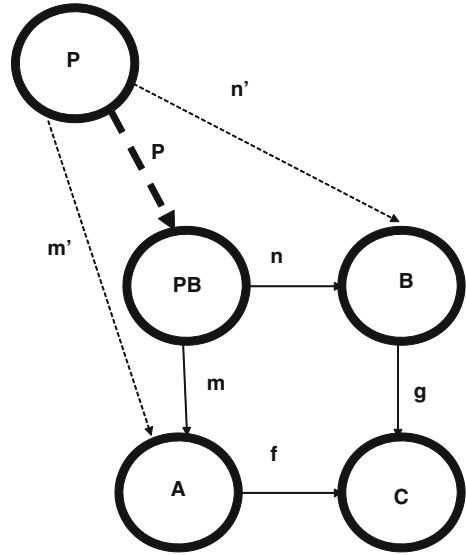
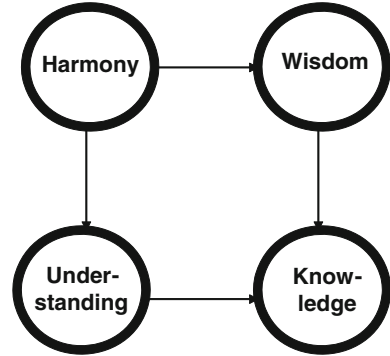


Fig. 6 In the Tree of Life, sefira Harmony is built through the pullback of wisdom and understanding over knowledge



Goguen [15, 16] showed how general system theory can be formulated within the algebraic framework of category theory and how pullback is a model for input-output behavior of systems while pushout is a model for system interconnections, couplings, feedbacks. Negoita [32, 33] and Negoita and Ralescu [31], based on Goguen, introduced pullback in expert systems and human system management models.

For example, in Burstein and Negoita [6] it is shown in great detail how in the Kabbalah of Tree of Life, Harmony is built through a pullback of Understanding and Wisdom over Knowledge (see Fig. 6). To be precise, according to Kabbalah, the cognitive subsystem CBD (brain or mochin in Hebrew) of Configuration of sefirot around Harmony, Zeir Anpin (ZA), is created as a pullback of Wisdom CBD and Understanding CBD over Knowledge.

We will generalize this further here to involve more sefirot at all levels and multiple limits or nested limits (limits of limits).

Pullback and pushout are two particular cases of the more general concepts of limits and colimits in a category [26, pp. 62–72]. These are defined similarly as in Figs. 4 and 5 except that instead of two objects A, B mapped into a third object C , an arbitrarily complex commuting diagram \mathbf{D} of objects and morphisms between them is used instead. The limit for example, the multidimensional generalization of pullback, is given by an object and morphisms from it to each of the objects of the diagram \mathbf{D} such that the overall diagram commutes and the limit object has universality property defined as a multidimensional generalization of the universality property in Definition 2 (we say that we have a limit or limiting cone for diagram \mathbf{D}). Similarly we have colimits or limiting cocones..

The Tree of Life has more than just nodes and arcs, it also has triads or triangles as higher dimensional faces like CBD, C'GT, NHY and each sefira has its own sub-triads or sub-triangles as shown in Fig. 1. If we ignore for the moment the sub-Trees of Life that make up each individual sefirot, the Tree of Life can be seen as an abstract simplicial complex, a concept from algebraic topology and its category theory formulation [14, 29] which we introduced in complex dynamic system theory modeling [5, 7, 8]. The Tree of Life is made of 0-dimensional simplices, the sefirot, 1-dimensional simplices or faces, the arcs, and 2-dimensional simplices or faces, the triads or triangles. An abstract simplicial complex is a multidimensional generalization of graphs as it allows faces (simplices) of higher dimensions.

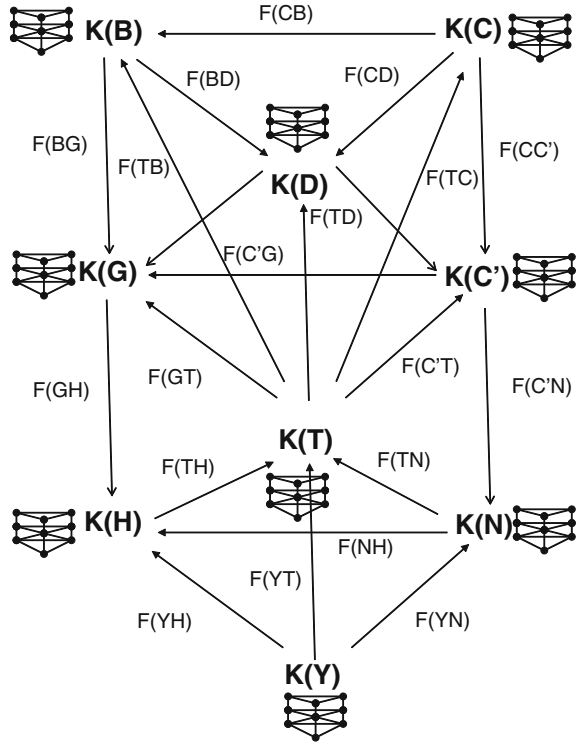
Considering each sefirot modeled by its own simplicial complex structure as above, the Tree of Life becomes a commutative diagram in the category of abstract simplicial complexes. This is not a topos as was the category of graphs but, nevertheless, has finite limits and colimits, pullbacks and pushouts [20]. In this category, abstract simplicial complexes are the objects and simplicial maps between simplicial complexes are the morphisms. Simplicial maps map faces into faces or simplices into simplices. Simplicial maps can model dynamic transitions in The Tree of Life.

In Burstein and Nicu [7] and Burstein et al. [8] a simplicial dynamic system theory was introduced on abstract simplicial complexes (such as the Simplicial Tree of Life in Fig. 1), using multidimensional simplicial vector fields and their flows on simplicial complexes.

We have now all ingredients to assemble the category theoretic and algebraic topological combinatorial model of the Tree of Life to be used in our Kabbalah system theory (see Fig. 7).

Each sefira is represented by its 2-dimensional abstract simplicial complex (sub-Simplicial Tree of Life model) as in Fig. 3 (2-dimensional because we consider each sefira as having its own CBD, C'GT, NHY triads as 2-dimensional simplices). We denote these abstract simplicial complexes by $K(C)$, $K(B)$, $K(D)$... in Fig. 7 for each of the sefira C, B, D, \dots . Simplicial maps between the simplicial complexes of sefirot, mapping simplices of one sefira into simplices, of the other sefira are used in Fig. 7 as algebraic model for the connections between sefirot in terms of their constituent sub-simplices. We denoted these simplicial maps by $F(CB)$, $F(BD)$, $F(CD)$...corresponding to the sefirot which are linked.

Fig. 7 The category theoretic and algebraic topological combinatorial modeling framework for the Tree of Life hierarchic system in Fig. 3: each sefira is represented by an abstract simplicial complex $K(C)$, $K(B)$, $K(D)$... and sefirot are connected by simplicial maps that map simplices into simplices, $F(CB)$, $F(CD)$, $F(BD)$ The overall diagram must commute and so does any sub-diagram, as diagrams in the category of abstract simplicial complexes. All limits and co-limits (pullbacks and pushouts) of any sub-diagram do exist in the category of simplicial complexes



The diagram in Fig. 7 with simplicial complexes and simplicial maps in the category of simplicial complexes must be commutative including any sub-diagrams of it. All the limits and colimits (pullbacks and pushouts) of sub-diagrams in Fig. 7, do exist indeed in the category of simplicial complexes [20]. In the Tree of Life, as we said, the flow of information goes both ways between two sefirot which amounts in fact to the existence of two arrows both ways between each two sefirot in Fig. 7. However, for simplicity, we only represent the arrows that will be used in the behavioral and knowledge based economics and finance modelling and focus on Limits but bear in mind that dual arrows exist too and so do colimits of these.

In addition, we can assume $K(T)$ to be equal to the limit (pullback multidimensional generalization) of the diagram $(\text{Lim}(K(C), K(B), K(D)), K(C'), K(G))$ which exists in the category of simplicial complexes and where $\text{Lim}(K(C), K(B), K(D))$ is the limit of diagram $(K(C), K(B), K(D))$ which exists. Given the universality property of $\text{Lim}(K(C), K(B), K(D))$, there exists a morphism from $K(T)$ to this limit and hence $\text{Lim}(\text{Lim}(K(C), K(B), K(D)), K(C'), K(G))$ is well defined in the sense that $K(T)$ can form indeed a limiting cone for $(\text{Lim}(K(C), K(B), K(D)), K(C'), K(G))$. The assumption on $K(T)$ can be considerably relaxed using the universality property of $\text{Lim}(\text{Lim}(K(C), K(B), K(D)), K(C'), K(G))$ which implies the existence of a morphism from $K(T)$ to $\text{Lim}(\text{Lim}(K(C), K(B), K(D)), K(C'), K(G))$ which exists.

These assumptions on $K(T)$ generalize the construction of $K(T)$ as pullback of $K(C)$ and $K(B)$ over $K(D)$ detailed in [6] or the construction of $K(T)$ as limit of the commuting diagram $(K(C), K(B), K(D))$. All the above limits exist in the category of simplicial complexes subject to the commuting diagram in Fig. 7 and they are a model of system input-output behavior [15, 16]. We also assume $K(Y)$ to be the limit of $(K(T), K(N), K(H))$ commuting diagram and thus being equal to its input-output behavior. Alternatively, we can assume $K(Y)$ to be equal to the pullback of $K(H)$ and $K(N)$ over $K(T)$. Again, all the above assumptions and construction formulas can be relaxed by using the universality property of limits which yields for example a morphism from $K(Y)$ to $\text{Lim}(K(N), K(T), K(H))$ which exists.

The limit assumption $K(T) = \text{Lim}(\text{Lim}(K(C), K(B), K(D)), K(C'), K(G))$ means that the behavior of the Knowledge level control system $(K(C), K(B), K(D))$ can be calculated within the Tree of Life and is learned by $K(T)$ which internalizes Knowledge at the Emotional level aggregating it with emotional $K(G), K(C')$ in order to transmit this to Action level. Pullback and limits amount to aggregating and synthesizing behavior of systems at different levels.

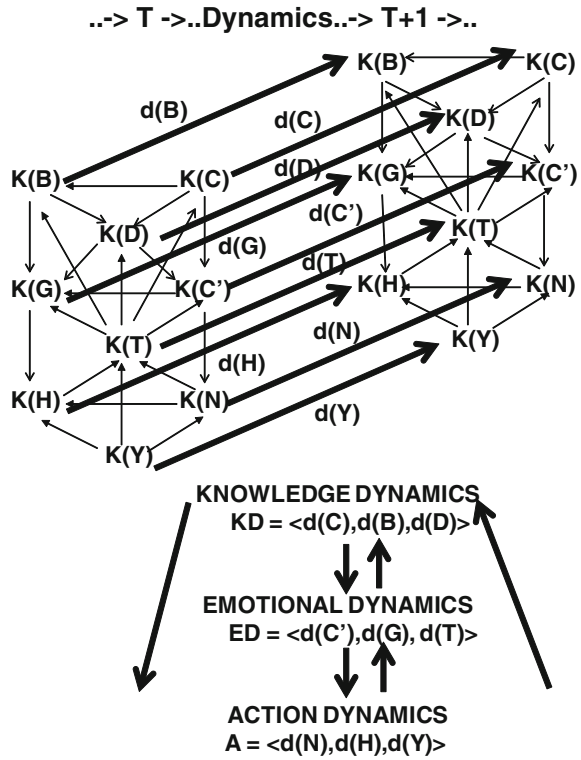
5 System Dynamics in Kabbalah System Theory

We will expand here the Kabbalah system theory framework created in [6] by developing a system dynamics model for the Tree of Life. In a category theory framework, the simplest model of discrete time dynamics for an object is an endomap or endomorphism from the object to itself [24, p. 137]. We consider simplicial endomaps $d(B), d(C), d(C') \dots$ for each of the simplicial complexes $K(B), K(C), K(C') \dots$ in Fig. 7, mapping each of the simplicial complexes to itself in the category of simplicial complexes through simplicial maps. This leads to 3 groups of dynamics:

KNOWLEDGE DYNAMICS	$KD = \langle d(C), d(B), d(D) \rangle$
EMOTIONAL DYNAMICS	$ED = \langle d(C'), d(G), d(T) \rangle$
ACTION DYNAMICS	$A = \langle d(N), d(H), d(Y) \rangle$

In order to get a model for the dynamics of the Tree of Life algebraic combinatorial model in Fig. 7 we impose that the diagram in Fig. 8 commutes meaning that this is also the case for all sub-diagrams in the category of simplicial complexes that can be made with any of the complexes $K(B), K(C), K(C') \dots$, any of the endomaps $d(C), d(B), d(D) \dots$ of these complexes into themselves and any of the simplicial maps $F(CB), F(CD), F(BD) \dots$ from the Tree of Life model in Fig. 7 (see Fig. 8). Figure 8 basically says that the Tree of Life connects Knowledge Dynamics, Emotional Dynamics and Action Dynamics between themselves in a way that is compatible with and influenced by the relation between sefirot in the Tree of Life. The dynamics of the Tree of Life is ultimately given by the three dynamics.

Fig. 8 System dynamics model in the Kabbalah system theory of the Tree of Life given by a commutative diagram in the category of simplicial complexes. Simplicial endomaps or endomorphisms between each sefira simplicial complex and itself describe local dynamics at the level of each sefira. Commutativity of the overall diagram means that sefirof dynamics are compatible with and influenced by the relation between sefirof in the Tree of Life. The overall dynamics maps the Tree of Life algebraic combinatorial model in Fig. 7 into itself



6 The Kabbalah System Theory Modeling of Behavioral and Knowledge Based Economics and Finance

We can finally apply the Kabbalah system theory modeling framework, developed in the previous sections, to economics and finance. A hierarchical feedback control Tree of Life model like the one in Fig. 3 will be used to integrate together personal knowledge, emotional intelligence elements and elements of economics and finance theory (see Fig. 9).

The Cognitive, knowledge level of the economic and financial decision making process, can be adequately represented in terms of Polanyi personal or aggregated knowledge theory as a framework for dynamic knowledge [34, 35]. Tacit knowledge is the difficult to articulate, subconscious/unconscious knowledge based on experience [28]. Explicit knowledge is decoded, explained tacit knowledge, formalized, documented, organized, conscious etc. Once tacit knowledge becomes explicit knowledge, it is categorized or classified according to action and behavioral emotional frames so that it can be used by the next levels, the level of emotions and behavior and by the level of actions. Popper's objective knowledge theory also has three levels called "three worlds" and can be alternatively used here [37].

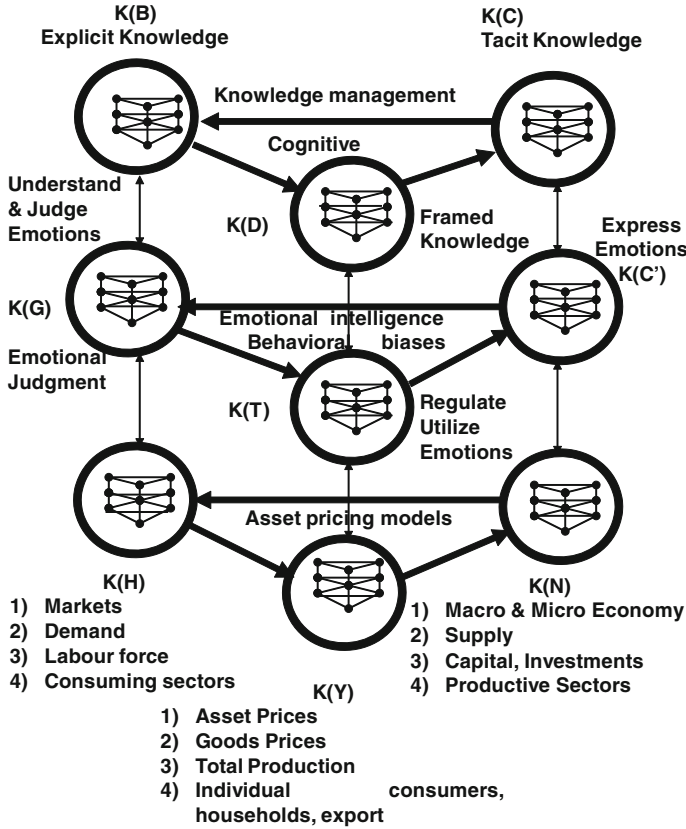


Fig. 9 Kabbalah system theory modeling for (1) behavioral and knowledge based asset pricing, (2) aggregate supply and demand behavioral and knowledge based model for goods prices, (3) knowledge based production models of Cobb-Douglas type linking invested capital, labor force and total production with knowledge and behavior and (4) knowledge based and behavioral economic sectorial balance models of Leontieff type linking productive sectors, consuming sectors, individual and household consumers and export

Emotional intelligence theory [17–19, 38] offers the ideal way to model the Emotions behavioral level in the Tree of Life structure in Fig. 8. The three components of the triad are expressing emotions, understanding and judging emotions and regulate/control and utilize them for action level.

The bottom triad of Action is the actual classical economics and finance processes level. Finance and classical economic theory [2, 13] can be used to obtain Tree of Life system models according to Fig. 9 for:

- (1) Behavioral and knowledge based asset pricing system modeling including macro and micro economic factors, asset market technical and quant factors and asset prices together with emotional and knowledge factors (select items labeled with (1) for each of the sefirot N, H, Y)

- (2) Aggregate supply and demand behavioral and knowledge based modeling for goods prices (by selecting items labeled with (2) for each of the sefirot N, H, Y)
- (3) Knowledge based production models linking invested capital, labor force and total production with knowledge and behavior giving knowledge based and behavioral Cobb Douglas theory for example (by selecting items labeled (3) for each of the sefirot N, H, Y)
- (4) Knowledge based and behavioral economic sectorial models linking productive sectors, consuming sectors, individual and household consumers, export giving knowledge based and behavioral static and dynamic Leontieff sector balance models (by selecting items (4) for each of the sefirot N, H, Y).

This way, Fig. 9 displays together four possible behavioral and knowledge based models for four categories of economic or financial topics within the Tree of Life hierarchical feedback control systems as in Fig. 3.

Although supply, demand, consumption, investments, production seem clearly objective economic variables, they are all subjected to behavioral elements such as fear. We already learned after September 11, 2001 and after the 2008 financial crisis, that consumer fears and investor fears can trigger behaviorally induced economic slowdowns despite any objective signs of early economic recovery.

Kabbalah system theory expanded in the previous section (see Figs. 7 and 8) can be used to create the mathematical computational models for Fig. 9 according to the commuting diagram with limits and colimits (pullbacks and pushouts) in Figs. 7 and 8.

In this framework, we can approach the knowledge sensitivity of demand and goods prices pioneered in [28] based on Polanyi personal knowledge theory [34, 35]. We consider choice of items (2) in Fig. 9: Supply-Demand-Goods Prices. The knowledge based dynamics of supply and demand affecting prices and vice-versa via feedbacks, can be described by the corresponding model in Figs. 7 and 8 for the Tree of Life system model in Fig. 9, choice (2). Based on the assumptions/constructions on $K(Y)$ and $K(T)$ made in the discussion after formulating the commuting diagram model in Fig. 7, goods prices appear as a multiple limit (multidimensional generalization of pullback) involving Supply, Demand, Explicit and Tacit knowledge, Framed knowledge, and the expressed and judged/understood emotions given by $K(C')$ and $K(G)$ as follows:

Goods Prices = $\text{Lim}(\text{Supply}, \text{Demand}, \text{Lim}(\text{Lim}(\text{Tacit K}, \text{Explicit K}, \text{Framed K}), \text{Express Emotions}, \text{Judge/Understand Emotions}))$.

As we explained above, limits of diagrams in categories represent input output behavior of systems described by those diagrams [16]. Calculating the above limit opens the door to simulating input-output behavior of the knowledge based behavior of goods prices.

Given that $K(T)$ in choice (2) of Fig. 9, represents regulating and using emotions in decision making and actions of supply and demand processes, the $K(T)$ limit assumption/construction over knowledge level limit and over expressed and understood/judged emotions, shows algebraically how emotional intelligence, the regulator of emotions is using decoded and emotionally categorized personal knowledge.

Cobb-Douglas production functions and Leontieff sector balance models can be formulated in Fig. 8 with choices (3) and respectively (4) from Fig. 9. Total production appears as limit of Labor force, capital and investments but also explicit, tacit and framed knowledge filtered through our emotional intelligence.

Behavioral finance cognitive and emotional biases and heuristics [36, 40] create market mispricings at stock price and stockmarket index levels. Behaviorally biased interpretation of company microeconomic factors (earnings results) and stock price moves is not the only source of mispricings, there is also macroeconomic information which is behaviorally interpreted causing macroeconomic mispricings such as those arbitrated by the global macroeconomic arbitrage introduced in [4] and analysed by Werner de Bondt, one of the pioneers of behavioral finance [12]. Using choice (1) in Fig. 9 and the corresponding category theoretic simplicial complex system dynamics given by the commuting diagram in Fig. 8 for the complexes in Fig. 9, we obtain the dynamics for behavioral and knowledge based asset pricing (BKAP):

KNOWLEDGE DYNAMICS	$KD = \langle d(C), d(B), d(D) \rangle$
EMOTIONAL DYNAMICS	$ED = \langle d(C'), d(G), d(T) \rangle$
BEHAVIORAL AND KNOWLEDGE BASED ASSET PRICING DYNAMICS	$BKAP = \langle d(N), d(H), d(Y) \rangle$

Based on Fig. 9 we have the following Kabbalah behavioral, knowledge based asset pricing model:

$$\begin{aligned} \text{Asset prices } K(Y) &= \text{Lim } (K(H), K(N), K(T)) = \\ &= \text{Lim } (K(H), K(N), \text{Lim } (\text{Lim } (K(B), K(C), K(D)), K(C'), K(G))) \end{aligned}$$

where we used in the above formulas

$$K(T) = \text{Lim } (\text{Lim } (K(B), K(C), K(D)), K(C'), K(G))$$

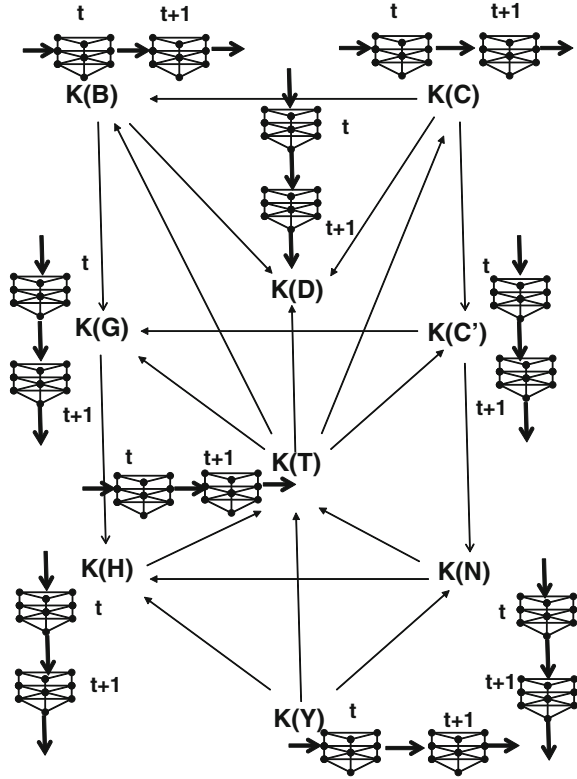
as discussed after introducing the commuting diagram model in Fig. 7.

This model is static. In order to get the dynamic model, we replace all simplicial complexes by their corresponding “simplicial complex in time” presheaves and morphisms of presheaves of simplicial complexes in functor categories or categories of presheaves (see [27, pp. 25, 36] for presheaves in time concept). We get commuting diagram of presheaves of simplicial complexes in time in Fig. 10.

Alternatively we can use the dynamics $ED = \langle d(C'), d(G), d(T) \rangle$ and $BKAP = \langle d(N), d(H), d(Y) \rangle$ defined in Fig. 8 in order to propagate and map in time $K(Y) = \text{Lim } (K(H), K(N), K(T))$ and $K(T) = \text{Lim } (\text{Lim } (K(B), K(C), K(D)), K(C'), K(G))$ through the commuting diagram in Fig. 8.

In this framework we can model the dynamics of emotional and cognitive biases and heuristics influence on asset prices:

Fig. 10 Kabbalah system theory model for behavioral and knowledge based asset dynamics of the Tree of Life in Fig. 9, case (1). This is a commutative diagram in the category of presheaves of simplicial complexes in time. Each sefira is described by a presheaf of simplicial complexes in time and the maps between sefirot are morphisms of presheaves of simplicial complexes in time. Commutativity of the overall diagram means that sefirot dynamics are compatible with and influenced by the relation between sefirot in the Tree of Life



- overconfidence bias is the excessive faith in one's cognitive abilities. This is modeled within the framework of Fig. 7 described in the previous section: $K(Y)$, representing asset prices, is modeled as a limit or limiting cone (multidimensional generalization of pullback) of $K(H)$, $K(N)$, $K(T)$ commuting diagram representing respectively markets, macroeconomic and microeconomic company factors and explicit $K(B)$ and tacit $K(C)$ knowledge filtered through our emotional intelligence
- conservatism bias is due to fixation in previous personal knowledge to the detriment of processing and acknowledging new economic, markets and company information. This leads to prices in $K(Y)$ to underreact to new market and economic information in $K(H)$ and $K(N)$ and rather to price in excessively previous explicit knowledge $K(B)$ framed as $K(D)$
- optimism bias is an emotional bias, while the biases defined above were cognitive. It is the bias according to which investors, based on their emotional structure, are over-optimistic about markets and economic situation. This can be explained in our model of Fig. 7 by the algebraically aggregated effect of the emotional judgment ($K(G)$) component of emotional intelligence and the emotionally categorized explicit knowledge in $K(D)$.

Conclusions

We have developed here a Kabbalah system theory approach to behavioral and knowledge based economics and finance. This allowed us to integrate elements of classical economic and finance theory with Kabbalah, personal knowledge theory and emotional intelligence theory to create a modeling framework.

The Tree of Life of Kabbalah is ideal for this framework since it has three interconnected levels: cognitive, behavioral and action. We developed here system structure and dynamics models for the Kabbalah system theory of the Tree of Life reflected in Figs. 7, 8, 9 and 10 based on category theory and algebraic topology.

Pullback and pushout (limit and colimit) in category theory were used to model system behavior and respectively, system interconnection.

We focused particularly on formulating behavioral knowledge based asset pricing models and cognitive and emotional biases in this Kabbalah system theory modeling framework.

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