Novelty Production and Evolvability In Digital Genomic Agents: Logical Foundations and Policy Design Implications of Complex Adaptive Systems

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Forthcoming Chapter Prepared for: Complex Systems in the Social and Behavioral Sciences: Theory, Method and Application

Edited by Euel Elliot and L. Douglas Kiel, Michigan University Press

Abstract

Novelty, innovation and surprises are ubiquitous in evolution and human social systems,with the adaptive immune system (AIS) and capitalism being respective exemplars. While novelty production embodies the hallmark of complex adaptive systems (CAS), as yet there is no consensus on what produces the 'smarts' that allows for innovative behaviours. Markose (2017) has shown how the Gödel-Turing-Post (**G-T-P**) digital machinery necessary to encode the Gödel sentence, is instrumental in genomic novelty and human proteanism. With evidence that genomic evolution acquired the mirror systems with the AIS and also in cognitive mirror neurons,the necessary **G-T-P** conditions for Self-Ref (self-reference) and Self-Rep (self-representation) were in place to encode the *Liar* qua hacker in the Gödel sentence. The latter allows a digital entity to self-report it is under attack and it becomes the trigger for the elimination of the *Liar/hacker*. Failing that, the Nash equilibrium entails a co-evolutionary arms race of innovations from which unilateral withdrawal spells failure. This represents undecidable structure changing dynamics wherein predictable formal rules may suffer demise. The idea that predictability can lead to system failure and policy ineffectiveness has a long provenance in Kantian principles based end-neutral coercive laws, and in the more recent intuitively held positions of the Lucas Critique on the need for surprises and also Goodhart's Law. The serial collapse of currency pegs and the massive system failure in the 2007 Great Financial Crisis were the consequence of a paradigmatic blind spot:pre-commitment to formal rules by authorities effectively eliminated 'surprises' on their own part by withdrawing from the co-evolutionary arms race and gave rule breakers (the Liar) free reign to game the system.

Keywords: Mirroring; Self-reference; Contrarian; Simulation; Immuno-Cognitive System; Genomic Digital System; Strategic innovation; Novelty; Surprises; Red Queen type arms race; Lucas Critique; End Independent Rules

JEL Classification : A12, C70, C79, B40

[1]Acknowledgements: I'm grateful for discussions with Bud Mishra, Will Casey and Yang Cai who invited me to give a Keynote Speech at the 2019 Bio-Inspired ICT Conference at Carnegie Mellon University. This gave me an opportunity to explore further the evidence and conjecture that the G-T-P logic is almost exactly hard wired in the immuno-cognitive systems of advanced eukaryotes, equipping them for novelty production and complex interactions. I'm grateful to Mikhail Prokopenko for seconding me that much of this is exactly like it says on the tin of Recursion Function Theory. The longstanding influences on me have been listed in Markose (2017) and will not be repeated here, Roman Frydman being an exception.

1. Introduction

There have been extensive surveys on what many have purported to be complexity economics and complexity sciences (Holt et. al.,2011, Colander et.al. 2000). However, few if any of them have singled out novelty production and 'surprises', as in radical disruption of structures and uncertainty of outcomes that exceed a known set of outcomes, as being significant to complex phenomena.[2] Some of the exceptions here are Casti (1994), Albin(1988), Witt(2008), Foster (2005) and Baumol (2002, 2004). Baumol (*ibid)*, in keeping with the Schumpeter (1934) vision of 'creative destruction'[3], has extensively discussed and documented the role of the relentless Red Queen[4] type strategic arms race in innovation by firms of products and processes in capitalism, which he claims is not addressed in mainstream economics. Witt (2008) states that "the emergence of novelty is a driving agent in evolution.... and ..the backbone of (economic) development and growth. Despite its central importance, the emergence of novelty is largely a blind spot in economic theory".

The theoretical impasse on novelty production has not been confined to economics.The problems, however,of not addressing what many regard to be the über and Machiavellian intelligence behind novelty production in economic systems, is that it has severe pragmatic consequences. These manifest as radical disruption evidenced in aspects of socio-economic systemic failure from regulatory arbitrage and gaming of the system with innovative rule breaking strategies and also structure changing dynamics from technological arms races with winners and losers. In a recent 2000 page volume on the foundations of behavioural economics

[2] The following characteristics have typically been listed as being pertinent for complexity sciences: non-linear dynamics, power laws and fat tailed extreme events, socio-economic interconnectedness and network models, fractality, self-organization and emergence. A large class of spectacular phenomena can only emerge or self-organize such as pattern formation in shoals of fish or flock of birds and even racial segregation, as in the Schelling (1971) model. There is, no doubt, that it is important to understand tipping points and sudden phase transitions in non-linear models.

[3] The Schumpeterian view (ibid) is that the "perennial gale of creative destruction," in capitalism during which new products and processes dislodge old ones, is a far more important force than optimization within extant set of technologies and the Neoclassical model of efficiency with price competition among existing firms and products.

[4]The Red Queen, the character in Lewis Carol's *Alice Through the Looking Glass*, who signifies the need 'to run faster and faster to stay in the same square' has become emblematic of the outcome of competitive co-evolution for evolutionary biologists in that no competitor gains absolute ground. Baumol (2002) shows how Red Queen type arms race in product or process innovation is undertaken by firms to ward off erosion in market share due to competitors.

(Dhami, 2016), that is encyclopaedic in its scope on extant models on economic behaviours, while trust, cooperation and defection strategies are discussed at length in standard game theory frameworks, there is no mention of how agents 'think outside the box', pursue creative behaviours, such as strategic innovation or arms races in novelty. Romer (2016) in having critiqued the multitude of exogenous random shocks that typically model 'surprise' or innovation in the mainstream macro-economic framework, has compared the model of white noise shocks to the discredited phlogiston theory of fire. This is arguably no different from the pre Barbara McClintock (1984) state of gene science, which had to resort to random mutations as the sole basis of diversity in evolution. McClintock (1984),in her Nobel prize winning discovery of transposable elements of viral software in the genome that perform basic recursive/digital operations of scissor paste and copy paste, [5] has ushered in the notion of the dynamic genome that creatively responds with exaptation of already extant functional gene codes to produce viable and novel solutions under conditions of stress. This along with recent advances in molecular biology have dislodged the view that random mutation in the form of replication or transcription errors form the primary basis of diversity and genomic change in evolution (Noble 2017, Shapiro 2013,2017, Amaral et. al. 2008,Mattick 2011, Ben-Jacob1998).

The objective of this chapter is to follow the long legacy of the so called Wolfram-Chomsky schema (see, Markose2004, 2005, 2017) to reboot the *sine qua non* for complex adaptive systems (CAS) in terms of the production of novelty and surprises. This coincides with the Type IV structure changing undecidable dynamics. Type's I-III dynamics do not produce novelty, and in sequence, they achieve limit points, limit cycles and chaotic dynamics.

[5] McClintock (1984) described the genome "as a highly sensitive organ of the cell, monitoring genomic activities and correcting common errors, sensing the unusual and unexpected events, and responding to them, often by restructuring the genome".

Recent work of Prokopenko et. al. (2019)[6] and Markose (2017) show that only systems with digital agents, operating on encoded information, that have achieved what can be called the conditions of computational universality associated with the epochal work of Gödel (1931),Turing (1934) and Post (1944) (**G-T-P** hereafter) can produce this tall order of Type IV dynamics that endogenously produce novel objects and/or phenotypes that are not previously there. The constructive or syntactic generation of the novel objects can be contrasted with statistical white noise as the model of innovation or surprise. The former is characteristic of complex systems like evolution and capitalism, respectively, with signature phenotypical and technological Red Queen type arms races in innovations. In keeping with Wigner's famous quip (Wigner 1960) on the unreasonable effectiveness of mathematics, Markose (2019) has given evidence, some of which will be reviewed here, of how the following **G-T-P** conditions are found to be ubiquitous in digital genomic systems, acquired over the course of evolution and form the foundations of intelligence.

The **G-T-P** conditions needed for novelty production are:

(i) Recursive operations[7] on encoded information, include the machine execution of codes and also their generation and storage with each encoded unit of information indexed by unique alpha-numeric identifiers.

(ii) There is a distinct domain of offline recordings and simulation in a formal Gödel meta-mathematics, organized in a tuple of a code centred self and the other. There is a bijective mapping between the off line 'mirror' system and the online machine executions of the same codes. This mapping of the mirror system will be called the **Self-Rep** for self-representation and

[6]Digital systems capable of Type IV dynamics, famously have been given a visual representation in theWolfram Rule 110 for cellular automata (CA), with irregular structure changes and novel patterns that do not repeat periodically.Prokopenko et. al (2019) associate such novelty generation with Gödel undecidability and incompleteness results. The authors state: "while the key role played by self-reference in proofs of undecidability in various computational frameworks is beyond doubt, its precise use in dynamical systems, and CAs specifically, has not been demonstrated explicitly". They aim to reconstruct the key element of a self-referential format of the negation/inverter machine in a Gödel type proof for CAs that are capable of novelty producing Type IV dynamics.

[7]General recursive functions include all elementary arithmetic, logical operations and also functions obtained from substitution, iteration and recursion. In the latter, functions call on themselves and use inputs that are outputs from previous calculations. See, Cutland (1980) and Rogers (1967), which are well known text books on this.

so called diagonal operations, which involve machines running their own codes are called **Self-Ref** or self-referential recursive operations.These terms were popularized by Hopstader (1999).

(iii) The identification of the logical archetype of the Liar, involving the negation operation on what can be predicted. This is encoded in a self-referential syntax of the famous Gödel sentence.

Markose (2017) lays the ground work to show how these are the three **G-T-P** conditions necessary for novelty production in what can be called a Genomic Nash equilibrium. What may be considered to be esoteric concepts in the foundations of mathematics are ubiquitous in the immuno-neural cognitive system, and hence have applicability far beyond the context in which they were originally developed. In Markose (2017), the discovery of mirror neurons by the Parma group (see, Gallese et. al. 1996, Rizzolatti et. al. 1996, Fadiga et al. 1995), relating to parallel expression or encoding in an offline environment in the cognitive neurophysiology of the brain of online machine executions from the motor and sensory cortex, has been identified with the **G-T-P** condition (ii). The Parma group identifies this mirror system as the basis of social cognition in that recognition of action of others is facilitated by the reuse of codes from neuronal firings from agent's own motor activity. I show how the well known textbook exposition of Rogers (1989) for the **G-T-P** condition (ii) utilizes a 2-place Gödel substitution function,which provides a setting that can incorporate the self and the other as a means of achieving social cognition and social interaction based on the reuse of codes from machine executions of motor activity by self. The experiments of Scott Kelso and his group (Tognoli et. al. 2007, Naeem et. al.2012) that discovered offline encoding of negation of predicted actions as part of the mirror neuron system were cited in Markose (2017) as providing key evidence for the necessary **G-T-P** logical condition (iii) in the cognitive-neural system to achieve the capacity to 'think outside the box' and be capable of novelty production.

It was in Markose (2019),[8] that for the first time evidence is given for how, since the Big Bang of Immunology (Janeway et. al. 2005) associated with the adaptive immune

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[8] Since about 2014, I had become familiar with the discoveries of the Parma Group on the mirror neuron system and the relevance of **G-T-P** condition (ii) for social cognition and the mutual mentalizing model, thereof . However, the

system (AIS) some 500 million years ago in the lineage starting with jawed fish, the immuno-cognitive machinery in genomic systems acquired the latter two **G-T-P** conditions necessary for novelty production. Note, the first **G-T-P** condition is a given with the digitization of inheritable information for life. The major implication of the fact that inheritable information is code based with an almost universal 4 letter base of known genomic systems is that while relatively error free digital copies can be produced, the Achilles heel of such digital systems is that they can be hacked by other biotic digital agents. Thus, in genomic digital systems, the Gödel archetype of the Liar can be identified as the hacker. All formal systems that have rules with predictable outcomes can likewise be destroyed. What is of significance here is the discussion on how **G-T-P** logic throws light on the very unique intelligence of biotic gene based digital systems.

It is known that with the adaptive immune system,which led to the eukaryote and mammalian radiation, the methods of immune defence added cyber security to detect malware that attacks the genomic software. This is over and above the extensive analog defences[9] in place with the innate immune system. There is now ample evidence that the Thymus Medulla remarkably expresses copies, in an *offline* environment, of about 85% of the genome (Danan-Gotthold et. al. 2016) that involves codes of programs that halt in the ribosomal self-assembly of somatic and regulatory domains, viz. are 'theorems' in the system. Expression of tissue specific gene codes in an off line environment of the Thymus Medulla in self-referential form often called promiscuous gene expression (Kyewski and Klein 2006), will be shown to be a text book case of Gödel formal systems, in particular, **G-T-P** condition (ii). The large scale recombinant recursive machinery called the **V-D-J** (variable-diversity-joining) of the adaptive immune system permits an extensive search in the domain of possible reactive pathogen software to the gene codes, presented in a self-

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presence of the mirror system in the Thymus Medulla of the adaptive immune system became known to me only about late 2017. This got incorporated in the Keynote talk I gave at the 2019 Bio-inspired ICT (BICT) Conference at Carnegie Mellon. It was in a conversation with Bud Mishra of the Courant Institute in November 2018, that I coined the epithet 'Genomic Nash Equilibrium' to underscore the point that endogenous novelty production that is ubiquitous in code based genomic systems, is also unique to them. In other words, to date, the endogenous novelty production of genomic systems that is **G-T-P** based is not yet a property of Artificial Intelligence.

[9] Analog defences of the innate immune include setting up barriers, toxicity, raising temperature by inflammation and ingestion by phagocytes.

referential way, to simulate putative attacks or changes to the gene codes. Markose (2019) finds that the recursive machinery that underpins the mirror systems with self-referential mappings for the identification of the other, especially of hostile agency given in **G-T-P** conditions (ii and iii) above is identical for the adaptive immune system and the cognitive mirror neuron system.[10]

Thus, we have growing evidence that the **G-T-P** conditions, in particular the Gödel sentence, far from being a funky and esoteric construction in the foundations of mathematics, is ubiquitous in the immuno-cognitive code based genomic systems. Effectively, the Gödel sentence allows for a code in a **G-T-P** based immuno-cognitive system to self-report that it is under attack or being hacked. In the absence of this, 'thinking outside the box', strategic innovation and an arms race in novelty production are not possible. In the context of extended phenotypes, to use a term coined by Dworkin (1989) to refer to artefacts developed external to the organism, humans equipped with cognitive **G-T-P** machinery will both embrace the Liar strategy and identify the same in others as they aim to falsify or negate predictable/computable rules and are primed with the 'smarts' for protean and innovative behaviours. This, as will be shown, has far reaching implications for the vulnerability of predictable rules and formal systems.

The main point of departure between the **G-T-P** games with Genomic Nash Equilibria (Markose 2017) and standard game theory is that in the latter the action set is fixed and given and it is asserted that there is no Nash equilibrium that generates surprises or novelty.[11]The question that Binmore(1987) seminally asked comes to the forefront: Whether the scope of strategic behaviour can be restricted to a system that is logically closed and complete in view of the Gödel archetype of the Liar or contrarian? The flawed foundations of extant game theory is that there is no option of exiting from given action/choice sets and in the absence of inherent

[10] There is a long legacy at least since Irun Cohen (1992) on the so called cognitive immune system theories of intelligence in which internal self-image is the basis of the 'other'. Many like Nataf (2017), Kipnis (2017), Kipnis et. al (2012) and others, make the link between how the immune system became 'smart' and the possible similarities in bio-molecular processes underpinning neural activities relating to cognition, communication and signalling, social cognition and even behavioural traits (Lopes 2016). Miller (2018) goes further and characterizes all biotic elements to be cognitive components imbued with self-referential sensory perception of the 'other'. Ofcourse, what is missing in the above narratives is the precise **G-T-P**recursive machinery at work.

[11]Bhatt and Camerer (2005) succinctly state this: "in a Nash equilibrium nobody is surprised about what others actually do, or what others believe, because strategies and beliefs are synchronized, presumably due to introspection, communication or learning."

Gödel incompleteness in the socio-cognitive machinery with putative novelty that lies outside listable action sets, the only indeterminism is randomization between known alternatives. In **G-T-P** games, radical indeterminism in the form of Gödel incompleteness follows in a Nash equilibrium with surprise strategies that map outside extant action sets to avoid logical inconsistency and strategic failure.

In fact, failure of a player in a 2 person adversarial **G-T-P** game only occurs when the Liar qua hostile agent wins *out of equilibrium* as the formal structure of the game involving the Liar is not acknowledged by the other player, viz there is a false belief. In other words, a record of being attacked is not sufficient, the self-referential record of the hostile agency of the other is also needed, viz. for a code to self-report that it is under attack. This yields a diagonal formulation for which the machinery of the Second Recursion Theorem (Rogers, 1967) is needed to determine the Nash equilibria of the game as fixed points of recursive strategy functions being used by the **G-T-P** players. The important point is that where the encoding of such fixed points involving the Liar can be achieved, their undecidabilty is a theorem in the **G-T-P** cognitive machinery. The recursive best response functions, thereafter, can only take the form of Emil Post (1944) productive function which implements novel objects that map outside of all listable sets, yielding a surprise strategy in the Nash equilibrium of the game.This has an inherent 'productive' structure of an arms race in innovation which permits co-existence of adversarial agents as part of the Nash equilibrium in **G-T-P** games.

Further, what is significant is that, the incompleteness of the system that permits endogenous novelty production in the form of new syntactic objects implies that the code based information processing is strictly in accordance with Gödel formal systems (see Smullyan 1961). The latter implies that in the absence of logical consistency, incompleteness is not possible. With the organizing principle behind endogenous novelty production being logical consistency, this rules out the position of those who focus solely on recursive recombinant machinery for variety (Bienhocker1961, Holland1995). The partial adoption of the recursive or computation framework typically dispenses with the stock in trade features of code based dynamics of self-reference (**Self-Ref**), self-representation (**Self-Rep**), the necessity of Liar like viral software, recursive function fixed points and incompleteness with the productive function (Post, 1914) based arms race in novelty production.

Doyens like Gregory Chaitin (2012, 2013) have underscored the role of code based models as opposed to equation driven ones for evolutionary innovation. However, being wedded to the pre-McClintock (1984) era of gene science and evolution, the Chaitin metabiology[12] purports to model random mutation in software as sole driver of new forms. Hence, Chaitin, despite making the digital basis of DNA central, dispenses with the ingredients of **G-T-P** to do with Self-Rep/Self-Ref as being essential to novelty production and incompleteness. The prototypes of this in genomic evolution are the mirror systems in the Thymus Medulla and the mirror neurons in the brain.

Sections Two and Three will elucidate further the above outlined **G-T-P** logic behind novelty production in genomicadaptive immune systems and in the human mirror neuron system. Section Fourwill discuss some implications of **G-T-P** logic driven über intelligent agents for regulator-regulatee arms races and policy design in general. Here one is confronted by those, like Foster (2005) [13], who are interested in novelty production but shows a disinclination to invest in **G-T-P** logic and computation theory. Durlauf (2012), who surveys complexity economics in the context of policy, acknowledges his lack of knowledge of the **G-T-P** logic behind novelty production and hence is not familiar with the archetypes of **G-T-P** logic to do with self-reflexive mappingsand the challenges posed by contrarian/Liar like negation to predictable trends andformalistic rules. Also, despite his survey of some agent based stock market models (that purport to generate boom-bust cyclical dynamics), Durlauf(*ibid)* is silent about what can be

[12]Chaitin's critics have noted that in terms of implementation, the so called 'creative' aspects of the accretion of new and different software ends up being teleological in that only improvements to a n-bit Busy Beaver Function are sought (see, Siedlinksi 2016).

[13] Foster (2005) stated: "Contributors to this literature have developed a 'meta-mathematics' that can be used to generate models with evolutionary properties, i.e.,a capacity to generate 'surprises' (Casti 1994). However, although these mathematical developments seem to be fundamentally important, they tend to be only loosely connected with less formal ideas and insights in evolutionary and institutional economics that have been around for decades."

regarded to be Complexity Economics 101, which is the seminal insight of Arthur (1994) that in many real world games, like stock market games, contrarian anti-herding strategies that go against predictable trends and, being in the smallest minority, producethe best winning strategies. This contrarian payoff structure, analogous to the Liar in **G-T-P** logic, results in the impossibility of a unique computable rational expectations, which leads to heterogeneity of meta-models for prediction and with it endogenous cyclic dynamics that follow.

The far reaching and deleterious consequencesof a four decade long macro-economic policy orthodoxy displays this blind spot on **G-T-P** logic for CAS that if the rule breaking Liar like agents cannot be eliminated then predictable rules are vulnerable and regulators should be prepared to coevolve, innovate and 'do running repairs'[14]. Thus, despite the highly influential thesis by Robert Lucas (1972,1976) on the necessity of surprises in policy in view of the Liar like negation of what is predictable and problems of meta measurements with the econometrics of identifying behaviourally altered structure changes, the similarity of the Lucasian postulates with **G-T-P** logic for CAS was missed. Further, remarkably, given the pivotal role of surprise strategies[15] in the Lucasian thesis for avoiding policy failure, the special case envisaged by Lucas of a policy surprise was to embedded it in surprise inflation and modelled as prediction errors. As surprise inflation clearly seems untoward for a policy maker to do, the extensive literature that subsequently developed on the basis of the papers by Kydland and Prescott (1977) and Barro and Gordon(1983) aimed at vitiating surprises by an advocacy of pre-commitment to predictable rules. Apart from Goodhart (1994), nobody queried how predictability can be prescribed as a norm in policy when the first Lucas premise is that predictability can lead to policy failure. Effectively, the hacking game in which the hacker punishes predictability was ousted from economic policy design.

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[14] This is a phrase coined by Paul Tucker (2011) in a speech https://www.bis.org/review/r110704e.pdf. The notion of running repairs to regulation illustrates the erstwhile pragmatism of common law countries like the UK.

[15]The notion of a surprise strategy appears in the so called Lucas surprise supply function often defined as follows: $y= y^{*} + b(\pi - \pi^{e}) + \varepsilon$. This says that output, y, will not increase beyond the natural rate, y*, unless there is 'surprise' inflation, $(\pi - \pi^{e})$ which is the prediction error from expected inflation, π^{e}. The idea here is that the private sector contravenes the effects of anticipated inflation, viz. the neutrality result. Hence, it is intuitively asserted that authorities who seek to expand output beyond the natural rate need to use surprise inflation.

The Lucas thesis on policy ineffectiveness and the necessity of policy 'surprises' along with Goodhart's Law on indeterminism and policy failure will be shown to have a close bearing on A.O Hirschman's (1991) famous rhetoric of reaction based on futility, perversity and jeopardy arguments for why expedient policies aiming to achieve specific outcomes narrowly justified could suffer these categories of failure. The Kant (1965) and Hayek (1960, 1967) thesis on the primacy of end-neutral legal rules on avoiding coercive imposition of socio-economic laws that fulfil predetermined outcomes will be briefly reviewed here.

I will outline the serial failure of monetary and macro-economic institutions that were predicated on a pre-commitment to fixed policy rules to vitiate the Lucas surprise strategy. Thus, first was a serial collapse of currency pegs in the 1980's and then the exclusive focus on an ad hoc inflation target. In many cases the latter was imposed by statute and aimed at tying the hands of regulators in Western central banks, Markose (2013). This led to an almost near collapse of the global financial system with the 2007 Great Financial Crisis. Regulators were alarmingly oblivious of the financial arms races, Haldane (2012), many triggered by Basel banking regulation, when over $16 Trillion of securitized assets and $60 Trillion of credit derivatives were strategic innovations for purposes of gaming the system. The latter triggered self-reflexive forces of financial behaviours that would spell system failure. I argue that this was the consequence of blind spots in mainstream game theory and policy framework that are oblivious of the über **G-T-P** intelligence behind endogenous strategic innovation.

Section Two GTP Logic Condition (ii) and Evidence from Genomic Evolution of Self-Ref and Self-Rep

Arguably, evidence for and understanding of **G-T-P** condition (i) (see Introduction)as the model of computation, is most widespread. There is extensive evidence starting with the Nobel prize winning work of Günter Blobel on the prevalence of unique identifiers for biotic elements. The latter feature, in 21 st century nomenclature, can be described as self-assembly of digitized materials in the ribosomal machine execution of gene codes to produce 3-D prints of the somatic and regulatory structures, Gershenfeld(2012). Further, the Turing Machine models of bio-molecular computing evidenced in ribosomal RNA are well known (Shapiro 2012, Verghese et. al.2015) and the literature abounds with many metaphors regarding the digitalization of inheritable information. In contrast, what appears to be less well understood is how the **G-T-P** conditions of (ii) and (iii) are fundamental to evolution of genomic systems and how they were acquired in the course of evolution.

In this section, I elucidate the **G-T-P** condition (ii) that is key to bio-intelligent digital systems that is seen in the Thymus Medula of the adaptive immune system and in the cognitive mirror neuron systems. It is not without reason that the former is called the Big Bang of Immunology and the latter, the Great Leap Forward by Ramachandran (2000). The recursive machinery of the immuno-cognitive system will be shown to entail **Self-Rep** and **Self-Ref** operations which build Gödel incompleteness into the immuno-cognitive machinery.

The paradigm shifting nature of the so called promiscuous gene expression in the thymus, which "*mirrors virtually* (italics added) all tissues of the body" , Kyewski and Klein (2006),is a view that is widely held.[16]The next section will show how the mirror system permits the cognitive system to identify the *other*, and in particular the Liar/hacker or the hostile agent, in terms of a self-referential mapping.

2.1 *Online* Self-Assembly with Self-Ref, Machine Execution and *Offline* Self-Rep in Immuno-Cognitive Systems

The focus here is on how the recursive function mirror operations in the two key genomic neural cognitive and adaptive immune systems take place involving self and other in what is effectively a digital game. The self agent will be denoted as the host (h) and the antigen as the parasite (p), with the two protagonists strictly being confined to using (total) recursive functions as strategy functions. Thus, expressions of the tissue specific gene codes in the Thymus Medulla epithelial cells (m-**TEC**s) relate to the Gödel meta-mathematics that can organize encoded information in

[16] See, Derbinski et al. (2001), Danan-Gottholdet. al. (2016).

off-line domain based on ribosomal machine executions of the same. In Markose (2017), an identical recursive machinery is shown to be at work in the cognitive mirror neuron system that records information from the online action related operations in the motor and sensory/optical cortex. This basal digitized information in the respective immuno-cognitive systems will be shown to be 'theorems' of the systems and define the objective of the genomic game as one in which hosts have to retain the genomic identity and somatic integrity of the basal codes in terms of the phenotypes or the outputs generated from them.

Using the well-known system of Gödel numbers (g,ns), integers can uniquely identify gene codes based on the near universal alphabet of the genome.The set of genes codes representing both protein coding and non-coding (n.c) ones is denoted as

$$\mathbf{G} = \{g_1 , g_2, \ldots\ldots , g_{\#}\}. (1.a)$$

Any gene code will be generically denoted as g, and # denotes some finite cardinal number. The digital encoding of the finite set of states under which the genes are transcribed is denoted by ***S***, with $s \in \boldsymbol{S}$ is an element in a finite and countableset of states and other archival information.[17] The set of online action related data from the motor cortex and sensory optical neuronal firings will be denoted by set **A**,

$$\mathbf{A} = \{a_1, a_1, a_1, \ldots\ldots, a\# \}. (1.b)$$

In the following, while the narrative is primarily in terms of the tissue specific gene codes in set **G**in (1.a) for the mirror system in the adaptive immune system, as the graphics in **Figure 1** show, on replacing this by set **A** in (1.b), we have an identical mirror system for the cognitive mirror neuron system.

Self- Ref Machinery:

In order to represent the online self–assembly of the ribosomal RNA or the non protein coding transcription machinery, the following notation from Rogers (1967) is used to represent the online machine execution of the gene code:

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[17]Note, analog measurements of state variables, such as chemical concentration, temperature etc, have to converted into digital code in order for this to be processed by a digital agent.

$$\phi_{\phi_g(g)}(s) = q \;.\;\; (2)$$

Here, the $\phi_g(g)$ in the subscript of the recursive function ϕ that outputs q underscores the online self-assembly or **Self-Ref** process (typically denoted as Diag (g) = $\phi_g(g)$) such that the gene encodes a program *g* that effectively runs its own code. The output *q* in (2) that follows from the full transcription / translation process produces, respectively, a protein in the case of a coding gene, or a RNA regulatory phenotype based on a non-coding(nc) gene.

Self-Rep Mirror System:

The famous *offline* Gödel Meta-Representation system in Thymus Medulla can be given the following format from Rogers (1967, p. 202-204):

$$\phi_{\sigma(g,g)}(s) \cong \phi_{\phi_g(g)}(s)=q, \text{ iff } \phi_g(g) \downarrow .(3)$$

Here, the diagonal operation of **Self-Ref** in (2) when a machine runs its own code and halts, denoted by $\phi_g(g) \downarrow$, is bijectively represented in **Self-Rep** format as in σ(g,g) for the genome in (3). The LHS function σ(g,g) modelled along the lines of the Gödel 2- place substitution function (see, *ibid*) has the feature that it names or 'signifies' in the off-line recording in the Thymus Medulla epithelial cells, m-**TEC**s, the one-one bijective mapping of the machine execution of the gene codes $\phi_{\phi_g(g)}(s)=q$. That is , when the self-assembly machine executions that halt and proceed to output q, the meta system also faithfully predicts the outcome is q. In Markose (2017), this is taken to be baseline point of the game when the pathogen does not disrupt host gene codes.

In general, the two place Gödel substitution function σ(x,y) has place-holders from the perspective of self on status of self and status of non-self vis-à-vis self:

σ (*status of self*, *status of non-self vis-à-vis self*).

Thus, in the σ(g,g) notation in (3), in the 1st place from the left, is the record of host's gene code and an identical g in the 2nd place implies that the host has identified that there has been no alteration of this gene code by the non-self antigen or pathogen, aka Liar. In other words the agency of the other is calibrated self-referentially, viz. in terms of self-codes. The diagonal elements σ(x,x), in general, have great significance in the *offline* meta system organized in matrix form. As discussed in Markose (2017), only diagonal elements demonstrate Nash equilibria when both status of self and self's identification of non-self status are in sync, with false beliefs and undetected deceit being ruled out. These will be contrasted with off-diagonal elements σ(x,y) or σ(y,x). In general, as one substitutes different values σ(x,y) for a given state s, the whole space of potential genomic outcomes implementable by recursive functions can be explored. There is an important theorem here (see, Rogers 1967)[18]that the *g.ns representing σ(x,y) in the meta-system can always be obtained whether or not the partial recursive function* $\phi_x(y)$ *on the right-hand side of (3) which executes programs halts.*

The significance of this bijective offline recording device of m-**TEC**s for tissue specific genes has led Derbinski et al.(2001) to note that " m-**TEC**s may indeed represent an immunological homunculus, in that they mirror and anticipate the peripheral self". Markose (2019) gives the bio-informatics in terms of the recursive function operations of the **V-D-J** recombinant machinery which enables the adaptive immune system to identify putative attacks on the gene codes, $g \in \boldsymbol{G}$ by a self-referential process. Some key elements of this are outlined in the next section as to how the **V-D-J** recursive machinery trains T-cell receptors to identify malware alterations of the basal gene codes.

In the case of the mirror neuron system and the motor-sensory cortex mappings pertaining to actions, $a \in \boldsymbol{A}$ in (1.b) denotes a generic action code that belongs to the set of actions $\boldsymbol{A}$ that cause canonical neurons to fire with action execution by self (self-codes, for short). This gives immediate and unerring action prediction and inference relating to the other by embodied *offline simulation* of the self-codes as in (3) and discussed further in Markose (2017). In particular, I will argue that unless there is an exhaustive listing of basal self-codes as in the

[18] It is well known by what is called the SMN Theorem or the Parameterization Theorem (Rogers, 1967) how new g.ns for recursive operations on extant g.ns can be mechanically generated.

genomic m-**TEC**s and in the cognitive mirror system of motor-sensory activity, the anticipation of algorithmic alterations of self-codes by the other, malware detection in the case of m-**TEC**s and intentionality of the other in cognitive systems are not feasible.

There is growing evidence for and many non-mathematical accounts of the mirror mapping in the adaptive immune system of the tissue specific gene codes. There is an even more elaborate description of mirroring of online motor and sensory cortex activity[19] with the discovery of the mirror neuron system (MNS) by the Parma Group in the 1980's. Gallesse (2009), Gallese and Sinigaglia (2011) have characterized the MNS as a common neuronal platform for conducting *offline embodied simulations* for action prediction in the other based on a parallel set of neurons that fire during action execution by one-self.[20] In fact, Ramachandran (2000) made pronouncements that have been regarded to verge on hyperbole: "mirror neurons would do for psychology what DNA did for biology by providing a unifying framework and help explain a host of mental abilities that have hitherto remained mysterious and inaccessible to experiments… And that the emergence of a sophisticated mirror neuron system set the stage for the emergence, in early hominids, of a number of uniquely human abilities such as proto-language (facilitated by mapping phonemes on to lip and tongue movements), empathy, 'theory of other minds', and the ability to 'adopt another's point of view'." I, ofcourse, fully concur with these views though my position is that without the **G-T-P** framework, much of this may remain mysterious and controversial. Indeed, despite so called computational frameworks for cognitive biology (see, Fitch 2014)[21] or computational neuroscience, apart from Tsuda (2014), there has

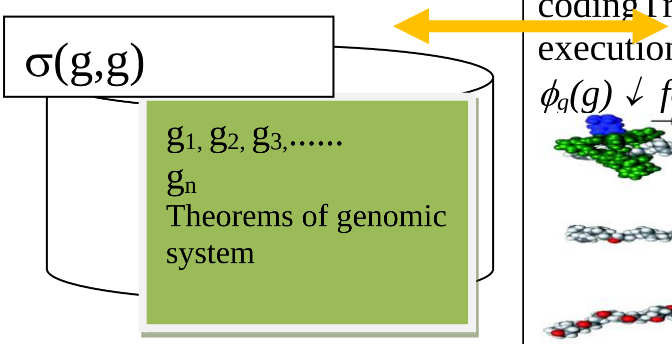
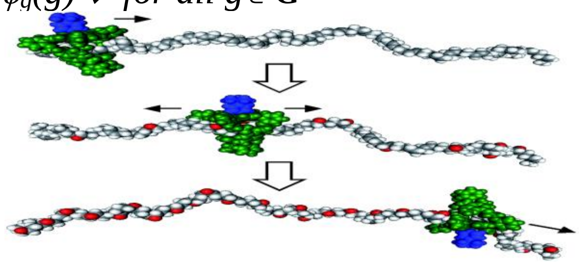
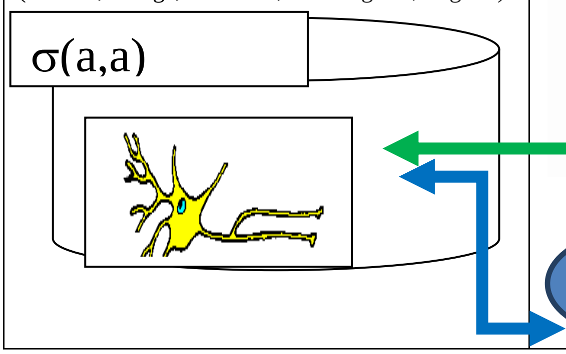
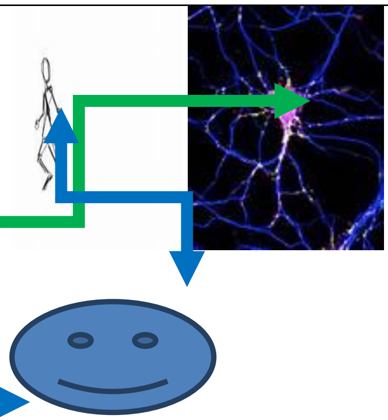
[19] The neurons that fire with actual action execution by are called *canonical neurons* (Arbib and Fagg (1998)) and correspond to on-line machine executions by self in the **G-T-P** logic.

[20]Ramachandran (2000) describes this as follows: "It's as if anytime you want to make a judgement about someone else's movements you have to run a VR (virtual reality) simulation of the corresponding movements in your own brain and without mirror neurons you cannot do this."

[21]Many computational cognitive models rely on Bayesian learning. As stated in Fitch (2014) the recordings from the sensory-visual and motor cortex constitute "a large, complex and ancient set of Bayesian priors (visual, sensory, motor) that constrain inference in any mammalian brain, and are equally operative in the human brain". Bayesian inference is statistical and is a far cry from inference by embodied offline simulation in the **G-T-P** cognitive system, which also permits novelty generation. See **Table 1** for further differences between the **G-T-P** cognitive system and Bayesian and other mainstream decision theories.

Figure 1:Gödel Meta-representation(Rogers,1967) and Mirror Systems in Immuno-Cognitive Systems

Note: ***Offline*** Mirror Systems in Medulla Thymus (**Panel A, Left**) and ***Offline*** Cognitive Mirror Neuron System (**Panel B, Left**) and respective Bijective Map of ***Online*** Gene Transcription (**Panel A, Right**) and ***Online***Action Execution in Motor–Sensory Cortex (**Panel B Right**)

Offline Recording/Simulation Equation (2) (LHS) Self-Rep Notation $\phi_{\sigma(g,g)}(s)$	***Online Machine Execution Right Equation (2)(RHS) Self-Ref Notation*** $\phi_{\phi_g(g)}(s)=q,$
Panel A (Left) **Medullary Thymus Epithelial cells (m-TECs) Mirror Mapping** of tissue specific genes/peptides of ~85% of genome	**Panel A (Right)** **Baseline Machine Execution of Coding and nc-Genes modelled as a self-assembly of digitized biotic elements of gene codes in set G**(see, equation (1.a))
Baseline : With no malware 	Ribosomal and non-codingTranscriptionmachine executionswhich halt: $\phi_q(g)\downarrow$ *for all* $g \in$ **G** 
Panel B (Left) **Mirror Neurons (Yellow) For Social Cognition (see, Markose, 2017)** **For action prediction with self and other**	**Panel B (Right)** **Canonical Neurons (Pink on black)Firing Based on Motor Cortex (eg'self'-walking,Green Arrows)and Sensory/Visual Cortex as observer byself of'other' walking(Blue Arrows)**
Discovered by Parma Group '90s (Gallese, Fadiga, Rizollatti,Di Pellegrino, Fogassi) 	

been no explicit discussion of the role of the genomic mirror systems and the recursive information processing in **G-T-P** computational model in equation (3).

Tsuda (2014) identifies how neural systems which need to process a self-referential description use the mirror neuron system as in the mathematics of the Gödel's incompleteness theorem: "When neural systems process a self-referential description, they may first have to make a copy of the object of self-reference and then refer to this copy. This two-stage formulation can be realized mathematically in the proof of Gödel's incompleteness theorem through the processes of projecting mathematical statements to natural numbers and of referring to meta-mathematical statements by providing mathematical statements about such numbers. The presence of mirror neurons in animal brains or mirror neuron systems in human brains may also be a realization of the above two- stage formulation in brains, because mirror neurons, or mirror-neuron systems, can be activated, not only by behavior in others similar to one's own behavior, but also by one's own behavior." However, Tsuda (2014) does not utilize the mirror system for a model of cognition capable of implementing novelty production.

The graphics in **Figure 1**, are useful to show an identical recursive machinery based on **G-T-P** condition (ii) given in equation (3) that is at work both in the mirror system of the m-**TEC**s of the adaptive immune system (**Panel A**) and for the cognitive mirror neuron system (**Panel B**). The, respective, self-referential online machine executions (RHS) **Figure 1** are mapped 1-1 to offline **Self-Rep** that permits meta-inference on self and the other. There are, ofcourse, interesting differences in the processes by which information on the other is conveyed via visual-sensory cortex to the mirror neuron system when external phenotypes are involved in the set **A** (equation (1.b)) and in the case of peripheral antigen receptors and those antigen receptors in the m-**TECs**. Some details of the latter are given in the next section.

Section Three GTP Logic Condition (iii): The Liar Strategy/Malware, Contrarian Structures and Who Do You Need To Surprise ?

3.1 Self-Halting Machines and Theorems of the Systems

The starting point here is to note thata halting computation is proof by construction. The domain of halting self-referential machines constitutes theorems, in the genomic immune and cognitive systems, respectively, given by the basal setsg $\in \boldsymbol{G}$ and a $\in$ **A**.

The sets ***G*** and ***A*** can be shown to be the subset of the archetypal creative set **C**[22](see, Cutland, 1980, p.133). The latter is a listable set of all self-referential machine calculations that halt with any $x \in \aleph$, where $\aleph$ is the set of integers. Set **C** is central to Post (1944) set theoretic proofs for Gödel incompleteness and **Figure 2** gives what Cutland (1980, 148) calls the miniature form of the Gödel Incompleteness Theorem, adapted for our case. Thus, in the case of set **G** of gene codes, we have self-halting codes where the downward arrow denotes halting Turing machines (TMs)**:**

$$\boldsymbol{G} = \{\, g \mid \phi_g(g) \downarrow ;\ TM_g(g) \text{ halts} ;\ g \in \boldsymbol{W}_g ,\ \text{for all } g \in \boldsymbol{G} \} \ . \ (4.a)$$

In some formal systems which are consistent, for every $g_i \in \boldsymbol{G}$, a negation symbol on g_i, as in $g_i^{\neg}$ will suffice to produce a listable set of non-theorems in the system. The latter set denoted as $\mathbf{G}^{\bullet}$, is disjoint from the set **G** and in **Figure 2**, $\mathbf{G}^{\bullet}$ displays the *known* listable set containing 'forbidden' and altered malware infected gene codes. A halting machine execution of $g_i^{\neg}$ will imply the destruction of specific somatic/tissue of $g_i \in \boldsymbol{G}$ and the phenotype associated with it.

$$\mathbf{G}^{\bullet} = W_{\sigma_n^{\neg}} = \{ g^{\neg} \mid \phi_{g^{\neg}}(g^{\neg}) \uparrow ;\ TM_{g^{\neg}}(g^{\neg}) \text{ does not halt} \leftrightarrow g \in \boldsymbol{W}_g ,\ \phi_g(g) \downarrow \}. \ (4.b)$$

The listable set $\mathbf{G}^{\bullet} = W_{\sigma_n^{\neg}}$ is a subset of the set $\boldsymbol{C}^{\sim}$(see, footnote 21 and **Figure 2**) and has the property explained in Markose (2017) **Lemma 3,** that its index $\sigma_n^{\neg}$ entails a recursive

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[22]Set **C** that represents the 'diagonal' set contains the g.ns of those recursively enumerable sets, $\mathbf{W}_x$, that contain their own indexes (see Cutland , 1980, 123, Rogers, 1967, 62): $\boldsymbol{C} = \{\, x \mid \phi_x(x) \downarrow ;\ TM_x(x) \text{ halts} ;\ x \in \boldsymbol{W}_x \}$.
The complement of **C**, represents the ' anti-diagonal' set, which is different from every listable set $\boldsymbol{W}_x$ all x:
$\boldsymbol{C}^{\sim} = \{\, x \mid \phi_x(x) \uparrow ;\ TM_x(x) \text{ does not halt} ;\ x \notin \boldsymbol{W}_x \}$.

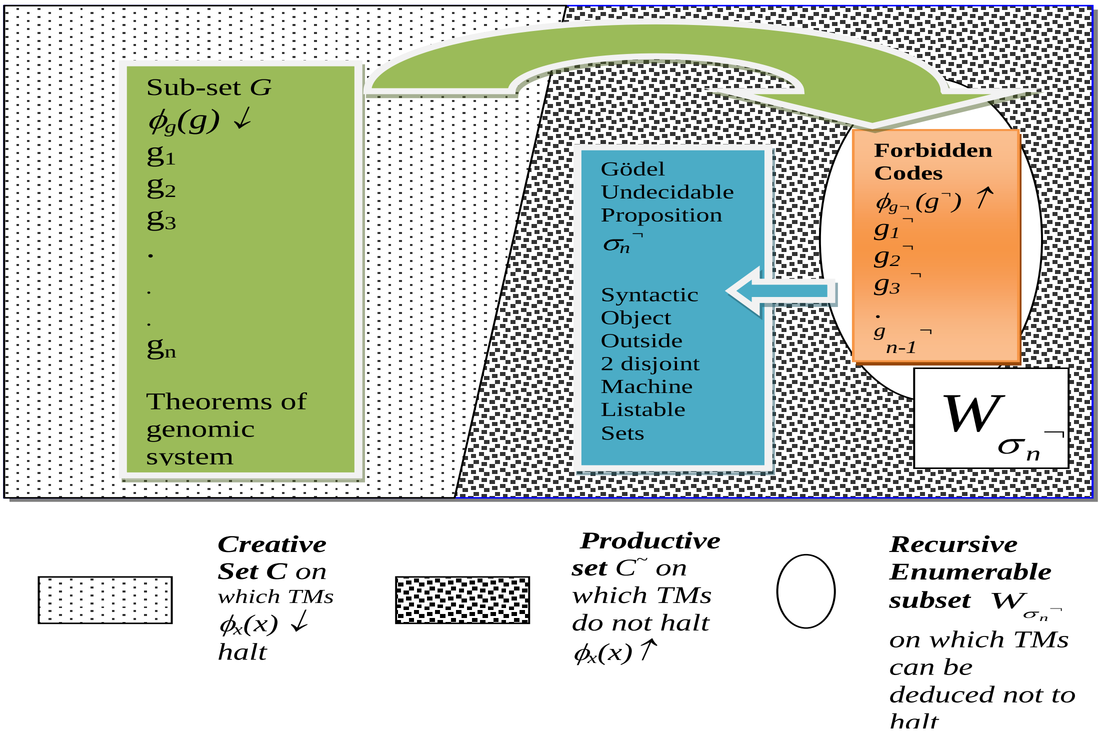
enumeration function $\tau(g_n^{\neg}) = \sigma_n^{\neg}$ such that nth element $g_n^{\neg}$ indexed as $\sigma_n^{\neg}$ can only be added to the listable set $W_{\sigma_n^{\neg}}$, but, cannot belong to $W_{\sigma_n^{\neg}}$.

Figure 2 illustrates how the listing in the Thymus Medulla of the self-halting tissue gene codes of the halting ribosomal machinery are identical to the listing of theorems in a formal system. The listing of non-theorems of the system, which are the so called 'forbidden' codes are those that should not be executed online in the genomic system as it will produce outcomes antithetical to the original gene codes or theorems of the genomic system. Hence, the forbidden codes belong to the set of non-halting codes, disjoint from the gene codes or theorems of the system.

Figure 2 Gödel Incompleteness Result in Miniature: An Illustration of Mirror Mapping in Thymus Medulla of Gene Codes that are Theorems in Genomic System

Gödel undecidable proposition $g_n^{\neg}$ lies outside the listable sets **G** and $W_{\sigma_n^{\neg}}$, viz. $\sigma_n^{\neg} \notin \mathbf{G} \cup W_{\sigma_n^{\neg}}$.

Note $\sigma_n^{\neg} = g_n^{\neg}$.



What is important to note is that the list of forbidden gene codes cannot be exhaustively listed in the set $\mathbf{G}^{\bullet} = W_{\sigma_n^{\neg}}$. The point being here in the miniature formulation of Gödel incompleteness, is that there will be an altered gene code which is undecidable in the formal system, viz. it is not decidable whether it is a 'theorem' or not in the system. With the productive function for set $\mathbf{C}^{\sim}$ in Post (1944) being the trivial identity function of the index of the set $W_{\sigma_n^{\neg}}$, $\tau(g_n^{\neg}) = \sigma_n^{\neg}$ is the

Gödel undecidable proposition and this lies outside the listable sets **G** and $W_{\sigma_n\neg}$, viz. $\sigma_n\neg \notin \boldsymbol{G} \cup W_{\sigma_n\neg}$ as shown in **Figure 2**. In the next section, I will give details of how malware detection is conducted by the adaptive immune system such that the encoding $g_n\neg$ can be derived.

3.2 Malware/ Liar Strategy Function and V-D-J based T-Cell Detection of non-self pathogens

We need to bring in the agency of the pathogen qua hacker who can alter the basal gene codes using software. It is useful to assume that the strategy functions for the host and the parasite f_i ,$i \in (h,p)$ that can alter the basal information in sets ***G*** and ***A*** are total computable functions such that *g*.ns of f_i, $i \in (h,p)$ are contained in set $\mathfrak{R}$,

$$\mathfrak{R} = \{\, m \mid f_i = \phi_m \,,\ \phi_m \ \textit{is total computable}\}. \quad (5)$$

The set $\mathfrak{R}$ of all total computable functions, is not recursively enumerable or capable of being listed by an algorithm. The proof of this is standard, see, Cutland (1980, p.127). Representing known members of set $\mathfrak{R}$ based on sets **G** and **G•,** collectively denoted as **G*,** the g.ns in set $\mathfrak{R}$**-** ***G**** present countable infinite number of ways for new technologies or phenotypes that can be formed and hence also the potential malware alterations to gene codes. Note, from Markose (2017), the best response Post (1944) productive function is also the surprise strategy function:

$$f_i = f_i^{!} = \phi_m \text{, such that } m \in \mathfrak{R}\text{-}\boldsymbol{G}^*,\ i \in (h,p)\ . \quad (6)$$

Markose (2017) has proved that the best response surprise strategy function given by the Post (1944) productive function that maps outside extant listable sets into $\mathfrak{R}$-***G**** is a Nash equilibrium when this is triggered by a fixed point of the recursive function of the negation or Liar or malware strategy $f_i\neg$, $i \in (h,p)$, defined in (7.a). Only such innovations will be accorded with the status of strategic innovations. I will show how the **G-T-P** logic can give a plausible model for how the adaptive immune system of the host using **V-D-J** operations identifies new code centric threats by pathogens and the resulting somatic hyper-mutation (Noia and Neuberger 2007) associated with novel ways of countering antigenic attacks in terms of surprise strategies.

In order to understand how T-cells that are released into the periphery from the offline environment of the m-**TEC**s are selected and how they can detect malware using the **G-T-P** logic, it is useful to define the Liar Strategy or the non-self malware attack, which occurs online in the periphery. The Liar Strategy or malware $f_p{}^{\neg}$ aims to change a tissue specific code of gene self-assembly machine Diag(g)= ϕ_g (g) which produces output q and recorded accordingly in the m-**TEC** mirror system as $\phi_{\sigma(g,,g)}(s) = q$. As the malware $f_p{}^{\neg}$ occurs in the online peripheral tissue specific code with the code change in g_n denoted as $g_n{}^{\neg}$, note the real time offline mirror recording is in the *peripheral* **MHC** (Major Histocompatibility Complex) antigen receptors.

The Liar/ Malware Strategy $f_p{}^{\neg}$

$$\phi_{f_p{}^{\neg}Diag(g)}(s) = \phi_{\sigma(g_n^{\neg},\ g)}(s) = \phi_{\phi_{g_n^{\neg}}(g_n)}(s) = \neg\,\phi_{\sigma(g,g)}(s) = q^{\neg} \text{ iff } \phi_{\sigma(g,,g)}(s) = q. \quad (7.a)$$

Thus, the halting online self-assembly machinery as a result of the malware $f_p{}^{\neg}$ in (7.a) is:

$$\phi_{g_n^{\neg}}(g) = f_p{}^{\neg}\text{Diag}\ (g_n). \qquad (7.b)$$

In (7.a), the effect of taking the malware altered gene code $g_n{}^{\neg}$ with input g_n, is to change the output of self-assembly machine Diag (g_n) (on the R.HS of (7.a)) in the following way : on the L.H.S of (7.a) we have $\neg\phi_{\sigma(g,g)}(s) = q\neg$ if and only if $\phi_{\sigma(g,g)}(s) = q$. Here, ¬ is the 'not' or negation symbol. Thus, the malware $f_p{}^{\neg}$ in (7.a) produces the opposite of the host's desired outcome.

As noted in Markose (2017) with regard to the Liar strategy, here also the malware/pathogen succeeds only out of equilibrium in (7.a). The malware $f_p{}^{\neg}$ alters the gene code to $g_n{}^{\neg}$ under conditions when the host has not yet updated the second place g_n in σ ($g_n{}^{\neg}$, g_n) to reflect self-identification of the agency of the hostile other. On the flip side, from the perspective of pathogen, the success of $f_p{}^{\neg}$ requires that the host is deceived. As is well known, the adaptive immune system can take four to seven days to respond to a tissue code specific attack by a pathogen. How is this done ?

For this the T-cell receptor must also have g.n g_n¬ obtained during the training received in the offline m-**TEC** simulation environment and from which the fixed point of the reactive malware software f_p¬ on the gene code g_n is obtained.

Bio-informatics of T-Cell Training : Extensive Horizaon Scanning

In Markose (2019), it is conjectured that the recombinant **V-D-J** system of the adaptive immune system imprints the $5x10^7$T- cells that are known to be generated on a daily basis (Kyewski and Klein, 2006) with a stochastic selection of g.ns based on the universal genomic alphabet. This is the most spectacular horizon scanning search process within the set ***ℜ-G**** for codes of software that will help the T-cell receptors in their training in the *offline* or virtual environment of the m-**TEC**s. This offline training of the T-cells is for the detection and elimination, in the online environment that immunologists call peripheral tissues, of malware software (non-self antigen) that is reactive to tissue specific gene self-codes and their known antigens. The T-cells have to achieve this[23]without attacking self-codes, resulting in autoimmune disease. Extensive discussions are about the so called elimination of self-reactive T-cells in m-**TECs** to avoid autoimmune disease. As noted by Wu et. al. (2009), there has been little or no focus on how T-cell training [24]equips T-cells for "self-non-self discrimination..that ..continues in the periphery after thymic negative selection, ..this is an enigma."

Markose (2019) claims that in the positive selection of T-cells imprinted with the **V-D-J** generated g.ns, only those that are derived from the **Self-Rep** formatted self-codes in set **G** are retained and the others are eliminated. These include g.ns generated from **V-D-J** for diagonal and off-diagonal terms (of the matrix of meta information, see Markose 2017) not derivable from the g.ns in the set **G***. In the negative selection, partially trained T-cells that generate g.ns for

[23] Of the $5x10^7$ T- cells that are known to be generated on a daily basis, it is estimated that $1–2×10^6$ mature T cells are actually released daily into the circulation. "The loss of over 95% of thymocytes reflects the stringent selection processes that shape the developing T cell repertoire" Kyewski and Klein (2006) .

[24] As stated by Michael Lotz in his **BICT** 2019 Keynote, while almost 99.9% of genes are the same for humans, only 6% of T-cell repertoires of different humans are the same. Hence, while some can combat new pathogens others may not and hence succumb to them.

putative malware that is reactive to the g.ns in set **G*** as in (7.a) are eliminated.[25] Partially trained T-cells have signatures like σ ($g_n^{\neg}$, g) in (7.a) and represent machine halting assembly programs being executed by the malware and hence are dangerous if released online as they will accomplish the negation of the tissue specific gene code g_n as shown in (7.a).

The partial training arises from the fact that the host is under false belief that there will be no malware attack when there could be one (in the online environment) and has not identified the function $f_p^{\neg}$, that is the identity of other as the hacker/Liar. For the T-cell training to be complete in the m-**TEC**s, the T-cells must determine fixed point of $f_p^{\neg}$ and match this with the encoding in the peripheral **MHC** antigen receptors, in real time, should there be an actual attack of the tissue specific gene codes by this specific pathogen.

In other words, the host's immuno-cognitive system must encode the Gödel sentence in (8), which uses the Second Recursion Theorem for the T-cell identification of the malware function $f_p^{\neg}$ on the R.H.S of (8) with the peripheral **MHC** antigen receptor for the same on the L.H.S of (8). Once, the host has 'synced' with the malware/Liar strategy σ ($g_n^{\neg}$, g) in (7.a,b) , set v to be the g.n of Diag ($g_n^{\neg}$) $= \sigma$ ($g_n^{\neg}$, $g_n^{\neg}$) $= \phi_{g^{\neg}}(g^{\neg})$. Then, on using the updated version of (7.b) in the 4th equality in (8) below, by construction, v is the fixed point of the malware/Liar function. This yields,

The Gödel Sentence:

$$\phi_v = \phi_{\sigma(g_n^{\neg},\, g_n^{\neg})}(s) = \phi_{\phi_{g_n^{\neg}}(g_n^{\neg})} = \phi_{f_p^{\neg}\sigma(g_n^{\neg},\, g_n^{\neg})}(s) = \phi_{f_p^{\neg}(v)} \quad .(8)$$

The index σ ($g_n^{\neg}$,$g_n^{\neg}$) is a very precise self-referential statement of which gene code is under attack and the biotic identity of the pathogen that is attacking it. Further, by construction, this is

[25]It is interesting to note that all **V-D-J** T-cell codes that are the result of reactivity to known antigen codes in **G•** are virtual clones of more virulent forms of extant pathogens.

not a computable fixed point as it will produce a contradiction,[26]and hence in (8) the output of the game is not predictable. At this juncture, whether the pathogen or host will win is undecidable, once the host has identified the hostile agency of the other and this is mutual. This implies, the Post (1944) productive construction of the set in (4.b) and **Figure 2** follows in that the index for $g_n^{\neg}$ will lie outside two listable or recursively enumerable disjoint sets, respectively, for the 'theorems' of the system and the known list of 'non-theorems'.

In summary, the syntactic fixed point in (8) permits the tissue specific gene code of the host to self-report that it is under attack by a non-self antigen (the hostile other), and this plunges the genomic system into a state of radical uncertainty in the form of undecidability. At this point, the adaptive immune system of the host is geared toward countering the malware. For this a new anti-body has to be produced and then applied enmasse.[27]The host is compelled by **G-T-P** logic of the Gödel sentence σ *(*$g_n^{\neg}$, $g_n^{\neg}$) to adopt the *only* best response function logically permitted by the **G-T-P** framework, which is the Post (1944) productive recursive surprise function, $f_h^!$ defined in (6). The latter will exit known listable sets and adopt an innovative anti-body specific to the information in $g_n^{\neg}$, viz. in accordance with the tissue specific gene code ,g_n , and the nature of the malware attack on it.

It is worth pointing out that this is where extant game theory models that have adopted the computability framework misconstrue the power of the **G-T-P** results.[28] Incompleteness requires a constructive generation of a 'witness' for an undecidable proposition

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[26] On updating (7.a) and (7.b) the Liar/Malware strategy $g_n^{\neg}$ now operates on itself, we have $\phi_{\phi_{g_n^{\neg}}(g_n^{\neg})}$ = $\neg\phi_{\phi_{g_n^{\neg}}(g_n^{\neg})}$, which is a contradiction.

[27] It is beyond the scope of this chapter to give the detailed recursive bio-informatics behind the somatic hyper mutations (Noia and Neuberger 2007) on B-cells that follow from this point in the host adaptive immune system. The same is the case on how retrotransposon activity can change the germline.

[28] For instance, consider the Nachbar and Zame (1996) conclusion that "for a large class of discounted repeated games (including the repeated Prisoner's Dilemma) there exist strategies implementable by a Turing machine for which *no* best response is implementable by a Turing machine". The Post(1944) set theoretic proof of the Gödel incompleteness result shows that that from fully deducible non-computable fixed points of a game as in the Gödel sentence in (8), the *only* (italics added) best response strategies that can be implemented by total recursive functions, viz. Turing machines, are those that satisfy the property of productive functions that syntactically produce objects that lie outside given recursively enumerable sets.

(see, Smullyan 1961, Chapter 5), which has to utilize a recursive function for this that can be proven to map outside of all extant recursively enumerable sets (of gene codes for actions/phenotypes) in that system. This is in keeping with the laymen's intuition about 'thinking outside the box', as an innovation cannot be confined within extant action/phenotype sets (see, Markose 2017).

In Markose (2017, **Lemmas 3** and **5**), it is shown how a non-trivial recursive reduction function from the indexation of the undecidable proposition from the Gödel sentence in (8) given as $g_n = \sigma_n$ in **Figure 2**, will produce a Nash equilibrium novelty producing recursive surprise function $f_h^!$. In the case of the adaptive immune system, this takes the form of new antibodies. Corresponding to the set $W_{\sigma_n^{\neg}}$ in **Figure 2** , the recursive reduction that implements the surprise strategy function will be indexed as $\sigma_n^!$ such that the surprise strategy set $W_{\sigma_n^!}$ satisfies the consistency requirements of the basal information in **Figure 2**, viz. $\sigma_n^!$ can only be added to $W_{\sigma_n^!}$ and cannot belong to $W_{\sigma_n^!}$. This is shown in the structure of a co-evolutionary arm race with innovative antibodies that can ensue as a Nash equilibrium in which both host and pathogen coexist. It can be conjectured that the endogenous recursive reduction operations modelled here govern all RNA regulatory networks so that relays of digital on-off switches satisfy the original basal organization of listable 'theorems' in set **G** and from the online genomic machine executions and the non-theorems there-off.

The arms race in the immune system is exactly that- the immune system is primarily evolving its defensive tactics against software hackers, which aim to 'highjack' the original gene codes to do their bidding. Genomic identity and conservation of some gene codes, which has continued over the millennia is the remarkable consequence of the immuno-cognitive system being able to put in place a code centric cyber security. The spectacular horizon scanning done by the adaptive immune system and the decentralized nature of biotic cyber defence are other notable features of the system.

Even though, prior to Markose (2017), there has not been an explicit cognitive model for meta-representation, deception, detection of deception and so called social proteanism, a substantial literature addresses this. Many (see, Sperber 2000) hold the capacity for meta-representations is *the* prime faculty in humans and adduce from this much credence for the hypothesis of an evolutionary arms race in higher order meta-representational abilities that has been called 'Machiavellian intelligence' by Bryne and Whiten (1988), Whiten and Bryne (1997). The evolution of deception in animals and primates in environments with conflicting goals and the detection of falsity have been identified as an important landmark of meta-representational competence in humans (see, Baron-Cohen 1995).[29] Miller (1997) has catalogued deceitful behaviour to combat situations with the potential for conflict as follows: deceit takes the form of hiding intentions, the deliberate spreading of misinformation and finally the development of *protean* strategies based on unpredictable adaptive behaviour to escape from hostile agents or rivalrous conspecifics. Miller (1997) and Grammar et. al. (2002) cite a co-evolutionary arms race in foundational social interactions such as human courtship where deception and proteanism feature.

. Further, it can be conjectured that when the cognitive neuronal system implements the mutual recognition of hostility, negation or deceit, this places the meta-representational system of each agent in a state of chaos corresponding to non-converging calculations elicited by neuronal mappings. Such implications for novelty recognition and production have been cited in Korn and Faure (2003). Remarkably, Korn and Faure (2003) who investigate the role of chaotic dynamics in the neuro-physiology of the brain, review the work of Freeman and his collaborators (Skarda and Freeman, 1987) and conclude that "chaos confers the (neural) system with a deterministic 'I don't know state' from which new activity patterns can emerge… chaotic states… are well designed for preventing convergence and for easy

[29] There is evidence that autistic individuals have difficulty in passing the so called Sally-Ann test on ascribing false beliefs to others. It has been found that this group has dysfunction in their mirror neuron system and ,irrespective of high IQ, they have trouble with mind reading or with making out intentions of others and hence social and strategic skills.

'destabilization' of their activity by a novel input .. . they are ideally fit for accommodating the neural networks with a new and still unlearned stimulus".

Section Four Extant Strategic and Regulatory Frameworks Relating to Contrarian Oppositional Structures and Innovative Rule Breaking

In this section, I will briefly survey the perceived lack of a framework in economics and in political economy, in general, to deal with the logic of opposition or the contrarian, the strategic use of deceit, surprises and rampant technology and strategic arms races in socio-economic interactions.The interesting point is that many notions from Gödel logic are used intuitively in economic discussions and in popular culture[30]. However, without the investment in the requisite mathematics for the novelty production, the status of these discussions has been hampered by a flawed paradigm of social cognition and strategic interaction dominated by optimization within extant choice sets where the cognitive wherewithal to exit from extant choice sets and innovate is not possible (Binmore,1987).

It is useful here to summarize in **Table 1**the main differences between **G-T-P** immuno-cognitive systems and mainstream cognitive/decision theories. Notions such as reflexivity and self-reference, the contrarian or the Liar and the necessity to exit from extant lists of phenotype and technologies under conditions of radical uncertainty of undecidability are simply missing in mainstream decision and game theory models. This creates serious blind spots in policy related institutions that have led to severe consequences in the last 30 years, especially in the macro and monetary regulatory institutions of advanced Western economies.

A propos game theory on strategic behaviours relating to deceit and surprise, Crawford (2003) begins with the elaborate subterfuge involved in the D-Day Allied landings of World War II in order to surprise and wrong foot the enemy. However, Crawford (2003)

[30] In Joseph Heller's *Catch 22*, Major Major who aims to avoid the squaddies, adopts the Liar strategy. He can 'win' against any visitor whose arrival is expected or preannounced by simply maintaining that he is not in. The only Nash equilibrium strategy of this game for those who want to see him is to surprise him as did madman Yossarian who ambushes the Major. Those squaddies who are rule abiding, viz. fall in with Major's rule that they turn up announced, have given up on seeing him. The only person who is waiting in the ante-chamber to see the Major is a rookie, Appleby, who has not worked out that the Major is the Liar: an *out of equilibrium* situation, as to turn up announced is simply not rational for anybody who wants to see the Major.

concludes that to date , economic "theory lags behind the public's intuition"... and "we are left with no systematic way to think about such ubiquitous phenomena". As can be seen, the right hand side column (marked with #) of **Table 1,** which covers mainstream cognitive and decision theories, the very concept of a surprise strategy as a Nash equilibrium of a game is missing.

Table 1: Methodological Differences: G-T-P Immuno-Cognitive Systems vs. Mainstream Cognitive Decision Theories

Immuno-Cognitive Systems with Inbuilt Gödel Incompleteness and Novelty Production	**#Mainstream Cognitive/Decision Models (Primarily Bayesian)**
(1.a) Basal information from gene codes and motor-sensory cortex: mapped into *offline* mirror systems for meta-analysis on self and other. **(1.b)** Recursion is centre stage with **Self-Ref** and **Self-Rep** Operations **(1.c)** Inference by embodied offline simulations that come from reuse of code based computations **See equation (3) and Figure 2**	**(1.a#) Firth (2014)**, The recordings from the sensory-visual and motor cortex constitute " a large, complex and ancient set of Bayesian priors (visual, sensory, motor) that constrain inference in any ... brain," **(1.b#)** No notion of operations of **Self-Ref** and **Self-Rep** **(1.c#)** Bayesian inference : Statistical
(2.a) Formalistic and Predictable outcomes can be subjected to hostile Liar strategy, viz. predictability can be punished and Liar wins out of equilibrium (**2.b**) Non-computability of fixed points with Liar/Contrarian: Undecidability and source of heterogeneity	**(2.a#) No archetype of the Liar/Contrarian** Instead, game scenarios such as matching pennies used to model opposition **(2.b#)** No notion of undecidability; Indeterminism takes the form of randomization over known actions
(3) Novelty and Surprise manifest as new syntactic objects outside extant listable sets of phenotypes/technology **(3.a)** Post (1944) constructive generation of innovation that can be added to a listable set but cannot belong to it **(3.b)** Novelty and Surprise: Nash equilibrium in **G-T-P** games with arms races in innovation utilizing the above productive set construction	**(3#) Noveltyand Surprises: Prediction error** **(3.a#)** The definition of Bayesian surprise "as the distance between the posterior and prior distributions of beliefs over models", Itti and Baldi (2009); ●Random Technology Shocks (Romer,2016) ●Surprise Inflation (Lucas, 1976) **(3.b#)** Categorically deny the existence of a surprise as a Nash equilibrium strategy, Bhatt and Carmerer (2005)
(4) Theory of Mind relies on recursive mirror structure of Self-Ref/ Self-Rep. **(4.a)** Agency of other is inferred via recursive function fixed point methods. Meta recording of **Self-Ref** takes the other to concur with self **(4.b)** To process deceit, at most 2nd order self-referential mapping needed: highest level of computational intelligence with horizon scanning for threats **(4.c)** Organizing principle of encoded information is consistency, without which there cannot be endogenous incompleteness.	**(4#) Theory of Mind: No/Optional mirror structures** **(4.a#)** k-level reasoning is step by step rather than by circular reasoning **(4.b#)** Notion of low level self-referential thinking according to Coricelli and Nagel (2008) is when self disregards the other.

In Section 4.1, I will discuss the Arthur et. al. (1997) model of self-reflexive price formation in stock markets that makes homogenous rational expectations an impossibility result.The Markose et. al (2004) agent based model is used to show how only when the payoff function rewards those that are contrarian and anti-herd in terms of their decision to buy or sell stock will the price show endogenous cyclical up and down movements. This raises the intriguing prospect that the contrarian structure, well known in the foundations of mathematical logic, is the source of heterogeneity due to epistemic incompleteness, viz. the logical necessity to agree to disagree. Likewise, the seminal inclusion of the necessity of surprise by Lucas (1972) in a policy context in response to regulatees who can contravene predictable policy will be compared to the **G-T-P** logic in **Table 2** Section 4.2. In Section 4.3, I will discuss the widespread and costly failures that characterize Western regulatory institutions due to the doctrinaire way in which pre-commitment to predictable 'rules' were instituted starting with the currency pegs in the 1980's on the grounds that they provide an inflation anchor.

4.1 Self-Reflexive Stock Market Games, Arthur (1994), and Contrarian/Minority Payoff Structures, Arthur et. al (1997)

In Arthur et. al.(1997) the reflexive nature of prices in asset markets was mooted. The best known example of reflexivity, often written about in the popular press, is that of stock market prices:

$$P_{t+1} = g(\sum_{i=1,..N} \beta_{it}(\hat{m}_{it}(P_{t+1}))). \quad (9)$$

Here, P_{t+1} is *the price at t+1* is determined by the strategies β_{it} (to buy or sell)of investors indexed by i= 1,2,.. N, based on their respective beliefs, $\hat{m}_{it}$, *of the price at t+1* . The market price determination function g(.) is the function that maps from the aggregate net demand (total buy orders less sell orders) at time t. A lucid statement of the problem of self-reference in asset markets can be found in Arthur *et. al* (1997) : "In asset markets, agents' forecasts create the world that agents are trying to forecast. Thus, asset markets have a reflexive nature in that prices are generated by traders' expectations, but these expectations are formed on the basis of anticipation of others' expectations. This reflexivity, or self-referential character of expectations, precludes expectations being formed by *deductive means* (ibid, italics added), so that perfect rationality ceases to be well defined”**.**

Spear (1989) was the first to show that rational expectations involving the belief or forecast function $\hat{m}_{it}$ corresponds to inductive identification by trial and error of the fixed point, a, for the market price function g(.), as in $\phi_{g(a)}(s) = \phi_a(s)$ where *s* is an encoding of past historical data and other archival information and a is an algorithm for the market price determination function.

Further, pointing out the inherent contrarian or minority nature of the stock market game where payoffs to pure speculative investors are at their maximum if they sell when majority are buying and vice versa, Arthur (1994) over turned traditional ideas of rationality and showed that it is logically impossible for all investors to have an identical/homogenous rational expectations.[31] The contrarian need not only appear in the agency of a player. It can arise from the structure of the payoffs of a game where a player wins only if his actions diverge from that of a majority of co-players.

Arthur (1994) noted that asset markets have a contrarian pay-off structure, rewards tend to accrue to those agents who are contrarian or in the minority. That is, if it is most profitable to *buy* when the majority is selling and *sell* when the majority is buying, then if all agents act in an identical homogenous fashion having made predictions from the same meta-model, they will fail in their objective to be profitable. In a minority wins pay off function, a unique homogenous model for prediction for how many will buy, for example in the case of 100 traders, will produce the following outcomes; if 50 or more are predicted to buy, then *all* will sell and they will fail to be in a minority and win the game. And vice versa, if less than 50 are predicted to buy, then all will buy and again fail to be in a minority. Any trend movements in prices will be broken down

[31] Formally, assume that there is an unique homogenous forecast function $\forall i$, $\hat{m}_{it} = \phi_a(s) = P_{t+1} \uparrow$, ie. a price rise is predicted. Then, the contrarian strategy denoted as $\beta_{it}^{\neg}$ kicks in for all investors, leading them to sell. This results in the market price function to output a price fall $\phi_{g(a)}(s) = P_{t+1} \downarrow$. In other words, this fixed point is not computable Rationality, in the presence of minority pay off structures generates endemic heterogeneity in strategies.

by contrarians who will arise endogenously from untagged agents, Arthur et.al. (1997). The lack of effective procedures to determine winning strategies in games with contrarian payoff structures and the impossibility of homogenous rational expectations, cleverly identified by Arthur (1994) in the above informal statement of this problem in stock markets is typically called the Minority or El Farol game. So unlike the traditional Milgrom-Stokey no trade results and a cessation of trade under conditions of homogenous rational expectations, there is instead heterogeneity of beliefs and myriad technical trading strategies that endogenously bring about the boom and bust dynamics seen in asset markets.

In Markose et. al.(2004), a simple agent based model in which the stock market game is stripped down to its basics was devised to test whether it is the contrarian/minority pay off structure that induces self-equilibrating up and down swings in the stock prices.[32] Firstly, we use the concept of radical decoupling from Foster and Young (2006), in that traders have no direct way of knowing how to win the game. Agents only have knowledge of payoffs, viz whether they have won (+1 reward) or lost (-1 loss) when they buy or sell 1 unit of the stock at each time step.There is no constructive way of mapping between individual actions and the winner determination function, which notifies them if they receive a payoff of +1 or -1. Hence, traders seek to learn how to win from neighbours in a social network. Agents differ only in memory and those with zero memory give random advice, using a toss of a coin,on whether to buy or sell and hence have an inherent capacity to give the 'best' advice to win the minority game. Agents with longer memory give trend following advice.[33]

I report simulation results from these two payoff or winner determination functions: when being in a majority wins the game versus being in a minority wins. The punch

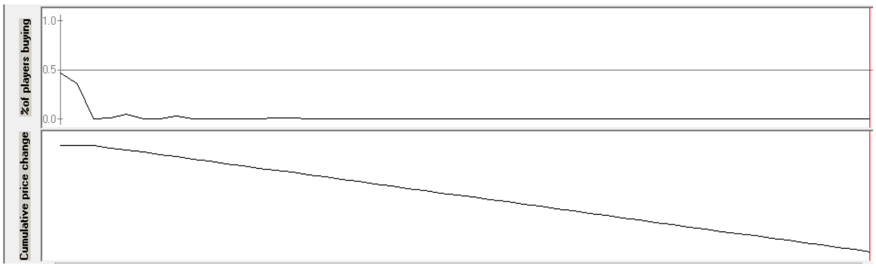
[32] This agent based model on the significance of the contrarian pay off structure is given in the first lecture by me in the module called Computational Market Micro-Structure and Complexity Economics for an MSc Computational Economics at the University of Essex. The link to the simulator of the contrarian payoff game can be found at: http://www.acefinmod.com/simulators/ .

[33] Agents use reinforcement learning and incrementally break away from those who give bad advice and randomly find new advisors till all agents learn to play the minority or majority game, appropriately, when each of these winner determination rules is in operation. Interesting core-periphery network formations emerge. In the minority game the 'gurus' in the hub from whom most traders are taking advice are zero memory agents. In a majority game, those with long memory become gurus and traders chase trends in one way markets.

line is that only in a minority pay off game structure, **Figure 3 Panel B**, does the asset price show self-equilibrating up and down dynamics as the contrarian anti-herding kicks in when price trends form, picking the price up from the trough and bringing the price down from a peak. When the majority wins payoff function is in place, agents relentlessly follow trends and one way markets get entrenched as in **Figure 3 Panel A**. This simple model of Markose et. al.(2004) is intended to show that contrarian structures, integral to the Gödel logic, are vital in endogenously generating cyclical stock market dynamics.

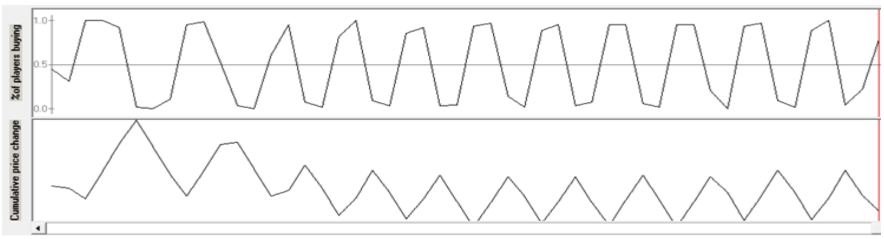
Figure 3Price Trends and Winner Determination Rule

A: Majority Wins Rule



A.When majority wins rule applies: the price (bottom panel in **A**) shows a one way market, either increasing or decreasing. In this case, price is decreasing since everyone is selling (top panel).

B: Minority Wins Rule



B:When minority wins rule applies: Price (bottom panel in **B**) experiences equilibrating up and down swings rather than one way markets.

4.2 Lucas (1972)Thesis on Surprise Policy Strategy and Widespread Policy Failure

A loose amalgam of the three following postulates is well known in the Lucas (1972, 1976) thesis on policy design and these can be seen to correspond closely with issues raised above.

First, policy objectives may be rendered ineffective by strategic behaviour of private agents if they can anticipate (viz. have rational expectations) or know outcomes of policy. This postulate corresponds to the Liar strategy in **G-T-P** logic in equation (7.a) when agents can negate what they can predict/compute. See also Table 2 item 1.

Second, when faced by a private sector with rational expectations, it is deemed necessary for authorities to use surprise strategies to achieve policy objectives. This corresponds to the Nash equilibrium in a **G-T-P** game in which the only response in the presence of the Liar is to exit from extant action set and generate novelty.

Third, in what is called the Lucas Critique, Lucas (1976) raised the problem of a lack of structural invariance of optimal behavioural equations due to strategic responses to anticipated policy events that may cause predictive failure in econometric models for purposes of policy evaluation.[34] Typically, mainstream macro-economists do not consider the Lucas Critique to be logically connected to the first two postulates. In contrast,in a **G-T-P** game the undecidable dynamics for which there is no finite halting machine that can determine the outcome of the game with the contrarian and with innovations changing structuresis the logical consequenceof postulates (1) and (2).

Many cite similarities between the Lucas thesis on policy failure and Goodhart's Law. Goodhart's Law claims that *"any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes"* (Goodhart, 1981). Goodhart's Law is basically an empirical rather than theoretical exegesis of what followed when the Tory chancellor in the mid 1980's attempted to achieve preannounced nominal monetary targets. As per Goodhart's Law, these monetary variables became more volatile in the period after they were the object of much concerted effort to control/target them than in any period before that. Fischer (1994) has given Goodhart's Law a wide enough theoretical berth to suggest that any formalistic monetary rule will suffer eventual breakdown. Thus, the general intuition of Goodhart's Law parallels the Lucas Critique (Lucas 1976) in that meta/prediction models suffer problems of reflexivity when the outputs of prediction are no longer computable as the actions based on the prediction will alter outputs.

[34] Lucas (1076) states : "any change in policy will systematically alter the structure of economic models . . . for the question of short- term forecasting, or tracking ability of econometric models . . . this conclusion is of only occasional significance . . . [but] for issues involving policy evaluation, in contrast, it is fundamental".

Table2, items 1-4, show that the trio of Lucas postulates correspond to the conditions that result in the Gödel incompleteness result and a co-evolutionary Nash equilibrium in which novelty and surprises follow.

Table 2: Gödel Logic on Liar like structures (the agent who negates what can be predicted), Surprise Strategy and Undecidable Dynamics vs Lucas (1972,1976) on Policy Ineffectiveness, Strategic use of Surprise and Lucas Critique

Postulates of Gödel Logic	**Lucas Postulates on Policy**
(1)The Liar Strategy : Agent who negates what can be predicted. Equation (7.a) states how only what is predicted can be negated.Liar strategy succeeds only out of equilibrium when the identity of Liar is not acknowledged.	**(1#)Agents with Rational Expectations of policy can render it ineffective by negating what can be predicted.** The idea that the private sector contravenes the effects of anticipated policy is called the neutrality result.
(2) Markose (2017) and in equation (8) the two place meta-model records the Gödel sentence in a fixed point of the policy game as one where regulator identifies that the policy has been negated by Liar.	**(2#)** When faced by regulatees who can negate what can be predicted, it is deemed necessary by Lucas (1972) for authorities to use 'surprise' strategies to achieve policy objectives.
(3)**Novelty and Surprise as syntactic constructions** The Nash equilibrium strategy function that maps from (2) is a surprise one in that no recursive function can remain within the listable set of actions. The Post (1944) production function produces a constructive syntactic object outside of listable sets as in equation (6).	(3#)**Strategy Surprise as Surprise Inflation in Lucas (1972)** Lucas couched surprise policy strategy in terms of 'surprise' inflation $y= y^* + b(\pi - \pi^e) + \varepsilon$, This says that output,y, will not increase beyond the natural rate , y*, unless there is 'surprise' inflation, $(\pi - \pi^e)$ or prediction error from expected inflation, π^e.
(4)Undecidable structure changing Type IV dynamics implies that no finite meta model with a halting algorithm can list/enumerate the innovation in advance.	**(4#)Lucas Critique states**: No econometric model can identify innovation based structure changes that follow from regulatory arbitrage[35]
(5) Markose (2017) and also equation (7.a) show that Liar wins out of equilibrium, only if Liar has not been identified. For this extensive horizon scanning is conducted by immuno-cognitive systems. If Liar/ rule breaker cannot be eliminated, either the predictable transparent rule has to be abandoned or the host has to be involved in a Nash equilibrium of novelty production.	**(5#)**Consequence of Lucas surprise inflation in (iii), led to the most widespread error of logic and strategy in mainstream macro-economics. Authorities pre-committed to a fixed rule, abandoned horizon scanning, failed to identify Liar/rule breakers and unilaterally withdrew from co-evolution arms races

[35] As stated in Lucas (1976): "any change in policy will systematically alter the structure of economic models . . . for the question of short- term forecasting, or tracking ability of econometric models . . . this conclusion is of only occasional significance . . . [but] for issues involving policy evaluation, in contrast, it is fundamental".

Table 2 item (5) indicates, a longstanding misunderstanding by macro and monetary economists of the notion of a 'surprise' policy strategy in the Lucas thesis on policy design. If the surprise policy and strategic indeterminism followed to counter regulatees who negate what they can predict, how is it possible that leading economists concluded that systemic stability of the macro-economy can be achieved by pre-committing to a fixed rule designed to control inflation ?

Most economists show scant awareness of the role of countering Liar like rule breakers whose success is guaranteed precisely because the regulatory authorities are committed to a fixed formalistic rule and in some cases the predictability of these yield free lunches, as we will see in the case of the currency peg debacle to control inflation.

Since the 1990's there has been a bandwagon effect of a class of models called monetary game theory models that set aside the Lucas policy postulates and advocate its exact opposite for the conduct of monetary policy. The dichotomous application of the Lucas surprise dictum to policy objectives pertaining to real and nominal sides of the economy is the prominent feature of monetary game theory models that dominated discussions on policy design. Goodhart (1994)[36] was the only economist who smelt a rat and raised the alarm. For real side objectives the famous Lucasian categories of 'dust, ambiguity and uncertainty' (*ibid.* p.110) are deemed necessary to achieve policy outcomes. For nominal variables such as the price level and the rate of inflation, these models hold that commitment to transparent monetary rules such as that of currency pegs or preannounced inflation targets involving interest rate adjustment will lead to greater credibility and success in inflation control.

A vast literature called the credibility and transparency literature developed to find means of "tying the hands" and preventing the authorities from using 'surprise' inflation. While Rogoff (1985) spoke of the use of reputation without explicit rule, Krugman (1996) argued for a crisis proof fixed exchange rate lay "with a high cost to abandoning the peg, for

[36]Goodhart(1994), in the format of an open letter to the Governor of the Bank of England, reviews Cukierman (1992). Goodhart suggests that it may be "*silly"* (italics in original, *ibid*.p144) that these models have diametrically opposite policy recommendations for policy objectives on real and nominal variables.

e.g, a very strong public commitment.” The complexity and **G-T-P** perspective espoused here challenges policy prescriptions of this genre of monetary game theory models summarized in the words of Cukierman(1994,1440) : “Precommitment of monetary policy to a pre-announced course is a device for reducing inflation expectations .... . A central bank ... with an unequivocal mandate to focus on price stability, is one institutional device for committing monetary policy. Another device is the maintenance of a fixed parity with the currency of a country that puts high priority on stable prices”.

4.3 Pre-commitment To Fixed Rule to Vitiate Surprise Inflation: The Serial Collapse of Currency Pegsand the Soros Liar Strategy

It is interesting to note the dramatic demise of the £-Sterling tethered to the European Exchange Rate (ERM) currency peg was brought about by George Soros in 1992 who has openly claimed that fundamental insights from mathematical logic relating to self-reflexivity[37] and the Cretan Liar have served as an inchoate, though powerful, guide to his successful career as a currency speculator (see, Soros1995, 69, 213).

The structure of the currency peg will be seen to provide a classic example of a transparent rule for which the Liar strategy that certifies a no win for the authorities can be given as formalizable propositions. **Figure 4**, which encapsulates facts on the structure and collapse of ERM currency pegs gives some credence to the view in Obstfeld(1996) that analyses on currency crises should focus on the ‘logic’ or abstract structure of the game in place rather than just catalogue the diverse circumstances in each case.

- **Figure 4** is useful to state the rules of the ERM currency peg. As shown in **Figure 4**, the exchange rates of the pegged currencies were only allowed to fluctuate between ± 2.5 %. A central bank inevitably stakes its reputation on its capacity to maintain the parity of the exchange

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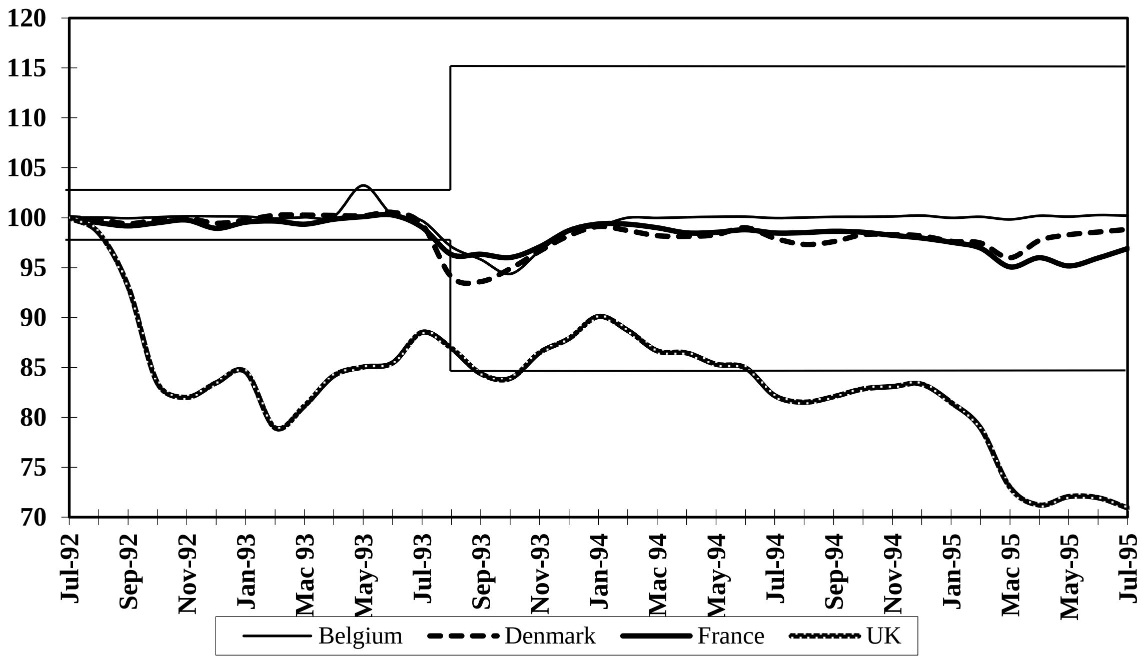
[37] Indeed, it was a chance meeting with Roman Frydman at C.V Starr Centre of NYU soon after the Soros debacle of the £-Sterling in 1992, that eventually helped me crack the key element of Gödel logic as to what or who is the Liar. Frydman asked me, since I purport to know so much about Gödel logic, “Why did George Soros claim that he was using the Liar Strategy in his heist on the Bank of England?” The Liar negates and wins from what is predictable/computable, see equation (7.a). Needless to say, the Institute of New Economic Thinking that Soros claimed he was setting up to study reflexivity and the Liar like complex social phenomena, among other heterodox ideas, has shown little or no advance in this direction. After Frydman quizzed me on the Liar Strategy and having acknowledged the Binmore (1987) seminal insight, my critique (Markose, 2001) of Velupillai (2000) focuses on his silence regarding the Liar.

rate of its currency, especially, in regard to the lower bound. At that point, taking the case of £-sterling, the authorities were duty bound to use foreign reserves to buy sterling and/or raise the interest rate and push the exchange rate above the peg.

- The stark reality is that currency pegs have not survived and every failed currency peg was defended *and* suffered speculative attacks.

- What **Figure 4** shows is that the state of the fundamentals relating to the long term viability of the parity was neither necessary nor sufficient for speculative attacks. U.K with a 20% overvalued currency sustained attacks as did the other ERM currencies whose parities appear to be virtually unchanged within the pegged regime and when it effectively floated.

Figure 4 : The Structure of the European Exchange Rate Currency Peg Exchange rates against the Deutschemark for the Belgian franc, French franc, Danish krone and British pound sterling July 1992-July 1995 (index).
Source: *Eurostatistik*, April 1993, 1994, 1996, August and October 1995.



- The only material difference in the case with the widening of the bands from ± 2.5 % to ± 15% was that it rendered the rule dead letter and when the conditions of a defence were made ambiguous, the speculative attacks ceased dramatically. This contradicts popular models at the time, that speculators attack when they believe that authorities will *not* defend, (Eichengreen and Wyplosz, 1993, Morris and Shin 1998). This is in stark contrast to the Liar strategy in (**L.1**, **L.2**).

Liar/Speculator= | **Sell forward**   **If Authorities Defend peg and e-rates go up** **(L.1)**
No attack   **Otherwise**   **(L.2)**

From condition **(L.1)**, the Liar Strategy attacks took place *after* the authorities had intervened in the forex markets and bought the home currency forward pushing the forward rates up (see, Fung *et al* 2000). If the authorities did not buy sterling and defend it, the forward prices will fall and then the Liar/Speculator strategy is no longer profitable.

Signs that the structure of the game with the Liar was not understood by the authorities are now well recorded. Schooled in the doctrine of transparency and commitment, authorities involved with failed currency pegs without exception followed in the footsteps of Norman Lamont, the UK Chancellor, who in the ill-fated defence of the £-sterling in the summer of 1992 worked to remove "any scintilla of doubt' about the intentions of the government ...that he and the government were 'going to maintain sterling's parity and ...do whatever is necessary ", Stephens (1996) (as quoted in Eichengreen1999). Indeed, greater the defence effort by authorities, the greater are the potential profits for the currency short seller as the forward price at which he sells forward is high and also the depletion of central bank reserves *signals subsequent sharper devaluations* that enables the short seller to close out by buying back more cheaply than otherwise. In the standard credibility paradigm, as loss of credibility in the capacity of authorities to defend the parity is seen to be the driving force behind speculative attacks, show of strength and committed defence of the parity is upheld as the optimal strategy. In view of the Liar Strategy for shorting currency, a preannounced defence of the currency peg is never a Nash equilibrium strategy (see equation7.a).

In 1999, after a decade long serial collapse of currency pegs at great economic cost,[38] Eichengreen (1999), finally sought to break ranks with the official IMF intellectual credo

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[38] Pegged currency regimes, instituted on grounds of providing an inflation anchor, that have suffered systematic speculative attacks leading to currency crisis and/or economic collapse are the following. Jamaica,1990, 1992 ERM crises involving the £-sterling, lira, franc, krona, punt and others, the 1994 peso crisis, the Thai baht (the second wave of attacks on it), the Malaysian ringit and the Indonesain rupiah, 1997. In January 1999, the IMF package of

of which he was formerly a part of. Eichengreen(1999) with hindsight calls into question what was considered *de rigueur* on the basis of a very large and influential literature on the conduct of monetary policy which advocated pre-commitment to a transparent formalistic institution such as the currency peg. In contrast to the prescribed resoluteness by central banks to expend extensive foreign currency reserves in the maintenance of a preannounced parity for the currency at a prespecified discrete point in time, Eichengreen (1999) recommends flexible bands at the first whiff of trouble 'before the crunch' comes. To this, Charles Goodhart is reputed to have said: "If at the first whiff of trouble whilst managing a pegged regime, the best response is to preemptively declare a float : Why Peg ?"

I have argued that the dismal theorizing on part of economists on formalistic predictable rules comes from the fact that the most prolific and ubiquitous Liar strategy is a closed book to them as this foundational logical framework is not known to them.

4.4 Kant, Hayek and Hirschman: Rules, Principles and Discretion

We are faced with a situation in which economists appear to place their eggs in the one basket of a formalistic rules based system with little understanding of the vulnerability of formalism to Liar like gaming that could destroy the system. From Sections 2 and 3, we saw that genomic identity and somatic coherence requires that the basal informationin sets **G** and **A** (in equations 1.a and 1.b) are offline recording of predictable rules, respectively, from the ribosomal machine execution of gene codes and the neuronal activity in the motor-sensory cortex. In biotic systems, the model in Sections 2 and 3 indicate that these code based predictable rules are given primacy as 'theorems' with consistency as a (non-constructive) organizing principle. The biotic system is regulated in a rigorous way in which Liar like threats are identified by wide spread simulation based and offline horizon scanning in the adaptive immune system and where the Liar/pathogen

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$41bn. was lost in the defence of the dollar peg with the Brazilian real. What constitutes a 'successful' speculative attack is contentious. For instance, Krugman (1996, 356) refers to the speculative attack on the krona which netted what appears to be the largest amount of bank reserves of the ERM currencies to speculators as "an attack that failed when the Swedish government proved ready to defend the currency with very high interest rates" of around 500%. Surely, the speculator does not judge his success by whether or not the parity is broken but by how much is netted from the attack and to count on its use as a money pump in the future.

cannot be eliminated, the biotic system shows the capacity for innovation based co-evolutionary arms race with the hostile agent. This arms race is a Nash equilibrium in which neither party can unilaterally withdraw without facing destruction of their objectives. However, as I have already noted, as game theory is silent about ubiquitous activities like these; this is also missing in any discussion about policy design in mainstream economics.

It is admittedly less obvious what rules are 'theorems' in man-made regulatory systems. Legal formalism and the ideal of the rule of law and not of men, are meant to put a brake on arbitrary discretion that arises from excessive leeway on having to interpret the application of the law. But this is predicated on self-evident truths that are 'universalizable', Kant (1965). These, as in the case of the American constitution can betaken to be foundational axioms, which are more in the form of juridical principles of a formal legal system. Expectation of equal application without discrimination engenders decentralized litigation initiated by individual litigants who challenge rules for their inability for general implementation. Indeed, rules can be taken down as being 'arbitrary' if they encroach on a prior set of libertarian principles of autonomy. These observations lend credence to the hypothesis that in market societies decentralised control characterised by the autonomy of the individual decision maker is achieved by the evolution of a specific kind of legal system that constitutes an end-independent system of rules. The fundamental idea that the autonomy of private decision making, the freedom associated with market relationships, can only be achieved by a coercive application of those legal rules that are themselves end-independent and universalizable is a Kantian one. In the words of Kant (1965, 25), in order to develop a deeper understanding of the legal system that co-ordinates actions of autonomous individuals, one must be able to:

(i) ascertain how a legal rule qualifies for universal legislation (see also *ibid.,* 34),

(ii) gauge 'the great and manifold consequences that can be drawn from this law', and

(iii) overcome our astonishment at 'its simplicity (of structure) ... and its authority to command without appearing to carry any incentive with it'.

This Kantian agenda of furthering our understanding of the fundamental rules that coordinate and control market relationships, receives the most brilliant and consistent exposition in the work of F.A. Hayek. Hayek, in having hypothesized that markets and the libertarian ethic associated with the system, is the outcome of the development of a system of control and co- ordination that is (a) informationally decentralized, (b) evolutionary and (c) possessing non-purposive characteristics of an open-ended system, has undoubtedly challenged the predominant bastions of utilitarian, rationalistic and centralized theories of control.The question is why should we abstain from using the coercive powers of the state to achieve predetermined outcomes? In Markose (1991), I offer a preliminary investigation of how Kantian end neutral rules operate to govern market societies. I argue that the expectation of universalizable rules or non-discriminatory application will set in motion a decentralized litigious process in which parties challenge an unjust law.

Hayek's defence of autonomy of action is primarily an epistemic one and indeed based on his view of cognitive incompleteness (Hayek 1952,1967) in the Gödel sense. As we possess more knowledge than what can be formalized, especially the uncountable infinite capacity to innovate (see, equation (5)), much of this knowledge is tacit and will be lost to the world without autonomy of action. In classical liberalism, this is what causes tension between the autonomy of the individual and the coercive rules of the state.

The Kantian end-neutral rules do not offer person/place specific predetermined outcomes and hence Liar like rule breaking is also not possible. Likewise, rules such as traffic rules about keeping within speed limits only permit limited opportunities for protean regulatees to game them. Such traffic rules can be enforced by a system of monitoring. In contrast to Kantian end-neutral rules and traffic rules, economic and financial regulatory rules have specific predicable outcomes and yield economic incentives for regulatees to break them. It is a sign of our times, that ad hoc rules like the currency peg and inflation targets have been elevated to the status of being ‘universal’ and change or reform to these is considered to be exercising discretion, which is used in the pejorative sense.

In Markose (2017), in the context of a game between regulator and regulatees, regardless of the foundational aspects of the regulatory rules, the latter are considered to be a set of formal rules, which if they can be run with regulatees being rule abiding (viz. analogous to no malign hacking) produce desirable outcomes for the regulator. However, the status of the Liar as a malign force is problematic in man-made rules based systems.

The role of contrarian Liar strategies in bringing down financial systems should not be underestimated. The prominent contrarian strategies that have netted vast profits in the context of institutionalized free lunches of the ERM currency peg and the Credit Default Swaps carry trades in the run up to the 2007 crisis (Markose et. al. 2012) have been, respectively, that of George Soros in 1992 and the protagonists of the ‘Big Short’ who also include Paolo Pelligrini and John Paulson in the 2007 crisis. Good institution design should vitiate such opportunities. In fact, the regulatory rules of Basel Banking Committee that invited such self-reflexive destabilizing forces when regulatees game the system (see, Fatouh et. al 2019) have been criticized. In the words of Kane (2010), we must avoid “official definitions of systemic risk that have left out the role of government officials in generating it.”

There is, ofcourse, a long line of literature as in the classic work of Hirschman (1991), where Lucas type critiques have aptly been called ‘futility, perversity and jeopardy’ arguments against institutional building, which deliberately aim to bring about specific and predetermined outcomes in society. Such objectives when pursued at a collective level, according to this thesis, will result in unintended consequences for society that may nullify the original intent of public action (the futility argument); it may bring about consequences, that are opposite from those being proposed (the perversity argument); and finally it may ‘destabilize’ the system as a whole (the jeopardy argument). Despite, Hirschman’s original intent to pillory the above as *the rhetoric of reaction*, he redresses his position and advices policy makers to minimize “the vulnerability of policy proposals on perversity, futility or jeopardy grounds" (Hirschman 1995, 61). The idea here is that the rules that aim to stabilize the system, self-reflexively[39] end up destroying it.

Needless to say, the dominance of the view that macro-stability lies in maintaining a fixed inflation rule has forestalled any scientific advances in the study of the stability of the economic system as a highly interconnected co-evolving one in which policy rules have to be carefully designed to avoid unintended perverse consequences. Interestingly, Eichengreen (2010) now concludes :"fundamentally, the (2007) crisis is the result of flawed regulations and perverse incentives in financial markets ". Further, in the context of the events leading to the 2007 crisis, Jones (2000) noted a lack of interest in the study of regulatory capital arbitrage entailed in securitization and other financial innovations regarding which he said "absent measures to reduce incentives or opportunities for regulatory capital arbitrage over time such developments could undermine the usefulness of formal capital requirement as prudential policy tools". In the absence of simulation models in the tool kits of most economists, Jones (2000) concluded that it was a lack of data for econometric modelling that prevented academic or regulators from keeping track of activities that undermined stated policy objectives in the Basel II banking regulation.

Slowly, in the post GFC era, a case is being made at regulatory institutions for simulation based stress testing policy in terms of the efficacy of the proposed fixed rule before implementation. Questions are being asked about the wisdom of authorities who rely on a fixed rule for inflation for stability of the monetary and economic environment when state supplied money in retail transactions are almost fully being replaced by digital payments media and a commensurate low inflation in cashless economies.

[39] Reflexivity of the legal system, is enjoying a resurgence of interest, see, Deakin (2015), Rogowski and Deakin (2011).

5. Conclusion

This chapter has given evidence that the capacity for endogenous novelty production is not just an artifact of famous Gödel meta-mathematics (Prokopenko et. al. 2019, Casti 1997). It is integral to the immuno-cognitive systems of eukaryotes and reaches its apogee with humans with their über intelligence, sometimes called the Machiavellian brain (Ramachandran, 2000,Bryne and Whiten, 1988). The Big Bang of Immunology (Janeway et.al, 2005) and the so called Great Leap Forward (Ramachandran, 2000) characterize immuno-neuronal brain functioning that manifest explicit code centric digital self-referential mirror systems that permit complex interactions between self and the other. This includes the detection of hostile agency and arms races in novelty production. The key mirror systems that implement **Self-Ref** and **Self-Rep** in immuno-cognitive systems have been illustrated in **Figure 1**. Further, the advances in molecular biology on the production of variety in evolutionary genomic systems in the post Barbara McClintock era have revolutionized our thinking that random mutation may not be the primary source of variety in evolution. It is my view, first articulated in Markose (2019), that it is necessary to modify the proposition popularized by Dobzhansky (1973) that "nothing in biology makes sense except in the light of evolution". My take is that, nothing in the biotic evolution of complexity makes sense without taking the digitization of inheritable information in the genome seriously. Evidence outlined in Sections **Two** and **Three**, indicate that intelligence as found in biotic immuno-neuronal systems takes an elaborate form of distinguishing self and other in an unique framework in which the **G-T-P** logic is hardwired for decentralized cybersecurity aimed at genomic identity and somatic coherence.

I have sought to summarize (see, **Table 1)** the methodological differences between mainstream cognitive decision theories and the **G-T-P** immuno-cognitive systems. The former do not have the wherewithal to exit outside of given choice sets and novelty or innovation is typically modelled as white noise prediction error within a statistical framework. **G-T-P** immuno-cognitive systems utilize code based embodied simulations and have Gödel incompleteness inbuilt for evolvability and with it the capacity to recursively exit from listable sets. Radical uncertainty in the form of undecidability follows self-referential identification of the contrarian/Liar/hacker hostile agency to a baseline action and marks the exit points with the arm race in innovation being a Nash equilibrium with both host and pathogen being able to co-evolve. Thus, the cognitive base of the recurring pursuit-evasion type contests that entail arms-races in new behaviours that are diverse as they are spectacular, have been given a new framework.

A key aspect of complex adaptive systems is the capacity of interacting agents to show über intelligence with strong proclivities for contrarian rule or trend breaking behaviour and the production of structure changing novelty and 'surprises'. This takes the co-evolutionary form of a Red Queen type arms race in innovation. I have argued regulator-regulatee arms race (no different from a parasite-host dynamics) involves monitoring and production of countervailing new measures (comparable to the production of anti-bodies) by authorities in response to regulatee deviations from rules due to perverse incentives or loopholes in place. As noted, the blind spots in extant game theory and decision theories have led to spectacular self-reflexive policy led institutional failures in Western economies. Axelrod (2003) cites system failure in networks, or their lack of robustness, to arise from a situation in which "c*oevolution is not anticipated*". While Axelrod has in mind the arms race between hackers and network developers, I have shown that a fatal oversight in system design is not to take on board the need to constantly address this factor of Liar/hacker like onslaughts for which simulation based and real time horizon scanning are vital. It must be clear to many how my analysis of the dismal failure of mainstream economics in having precipitated disastrous systemic failures in Western economies is considerably different to that of other heterodox economists such as Helbing and Kirman (2013), Collander et. al (2009). These critiques of mainstream economics remain silent about the blind spots relating to novelty production and the digital foundations of über intelligence.

Perhaps, with the 4th Industrial Revolution driven by code based digital systems imbued with advanced AI, there may be some added urgency among economists to take digitization and computation theory seriously. Finally, the spelling out of the immuno-cognitive foundations of novelty production in a ubiquitous strategic setting suggests many rich investigative lines for empirical neuro-physiological experiments, extending issues covered in Camereret. al. (2005) and Bernhiem (2009). The urgency for these lines of investigation arises from the fact that extant models of strategic behaviour cannot account for protean behaviour which is ubiquitous in evolutionary arms races and in socio-economic systems.

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