Towards a General Complex Systems Model of Economic Sanctions with Some Results Outlining Consequences of Sanctions on the Russian Economy and the World

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Abstract:
The main purpose of this paper is to present a complex nonlinear modelling approach to analyzing mixed capitalist economic systems. An application of a more elaborate version of this model is to explore the consequences of sanctions on the Russian economy and evaluate the model's predictive successes or failures. Furthermore, the formal expanded nonlinear model presented in the appendix may be seen as an initial step to put the analysis of economic sanctions within a formal complex socio-economic systems framework. The results obtained from this structural complex multisectoral model so far seem fairly accurate in terms of agreement with measured values of observable economic variables. The political consequences are uncertain and are to be explored separately in a companion paper and ultimately in a book length treatment. Methodologically, the paper also presents the case for using Social Accounting Matrix (SAM)-based models for understanding problems of analyzing sanctions in an economywide context. Linear as well as Nonlinear models are presented in the appendix. The nonlinear modelling approach might prove to be especially relevant for studying the properties of multiple equilibria and complex dynamics.

1. Introduction

The main purpose of this paper is to explore a complex nonlinear modelling approach to mixed economic systems of advanced economies. A policy-relevant application of this approach is found in tracing the consequences of economic sanctions on the Russian economy and the world which takes rational responses in a modern game theoretic context seriously. Furthermore, the formal expanded nonlinear model presented in the appendix may be seen as an initial step to put the analysis within a formal complex socio-economic systems framework that is amenable to empirical implementation. This formal nonlinear model may thus be seen as an exercise in policy relevant constructivist mathematical modelling that is amenable to advanced computational algorithms.[1] In this sense, the theoretical approach here is aligned with the recent move towards an evolutionary complex systems framework for economic and political economy analysis within the constructivist mathematical analytical tradition(Ansperger 2008; Antonelli 2008; Colander 2000; Jia and Kenney 2021; Khan 1998, 2002,2011a-d, 2012a,b, 2013,2014,2017, 2021a-d,2022; Jiang and Khan 2017;Khan et. al. 2023;Togati 2006).

In the economic analysis of sanctions literature, many contributions have tried to examine the effectiveness of sanctions in achieving their intended objectives.[2] The general conclusion from this literature is that sanctions most of the time fail to be effective. An oft cited cross sectional study found that only 34% of sanctions were effective in attaining their intended policy goal (Hufbauer et al, 1990, 2007). However, some have pointed out that even this modest estimate of effectiveness can be questioned. For example, most of these success cases occurred together with other confounding but causally relevant factors including military interventions. After taking these confounding factors into account, the success rate can drop to 5 per cent. Pape (1997) argues that once one controls for these other factors, the success ratio falls to as

[1] Earlier pioneering work of Khan in formal modeling of economic sanctions in an economywide setting was carried out in a multisectoral linear setting and applied to South Africa. For a comprehensive book length analysis, see Khan(1989).Khan(1987,1988,1990,1991) papers explore different specific facets of trade and investment sanctions

[2] Rodríguez (2022) presents several case studies and cites some of the relevant literature though it omits the--- admittedly scant--- formal economy wide modeling literature.

low as 5%. Other scholars are less pessimistic but still derive success ratios well under 50 percent. Morgan, Bapat, and Kobayashi. (2014)., Biersteker and van Bergeijk (2015), Biersteker and Hudáková (2015), Bapat and Morgan (2009), Bapat, Heinrich, Kobayashi, and Morgan. (2013), Weber and Schneider (2019), and Felbermayr et al. (2020) present empirical approaches including cross-sectional data sets that show that economic sanctions are very crude policy instruments in Tinbergen's terms. Other relevant findings since Khan's (1987, 1988,1989,1990,1991) pioneering economy wide modeling works also support his original argument that sanctions are more likely to succeed when their targets are limited and not overly ambitious (such as regime change) and when the economic cost imposed by the sanctions is significant if not crippling. (Khan 1989;Dashti-Gibson et al, 1997; Letktzian and Souva 2007; Hufbauer et al, 2007; Kavakli, Tyson and Hatipoglu 2020).The more complex nonlinear economywide modelling work presented here generally confirms these points; but it also presents results that are derived more rigorously and raises deep questions about political and ideological motivations.

2. Towards a General Complex Systems Theory and Model of Economic Sanctions

Writing in 1926, in a biographical essay on Edgeworth, Keynes underlined some of the problems of complex human systems:

> We are faced at every turn with problems of organic unity, of discreteness, of discontinuity--- the whole is not equal to the sum of the parts, comparisons of quantity fail us, small changes produce large effects, the assumptions of a uniform and homogeneous continuum are not satisfied.[3]

If anything the world economy today shows to even a greater degree the kind of complexity captured in Keynes's words above. Fortunately, systems theory and economic theory have both made some progress since those dark days. Although we are far from a genuinely complete theory of complex economic systems, efforts are

[3] Keynes(1971-9), Vol. X, p. 261

underway that have already borne some interesting fruit in several limited areas.[4] There are many facets of complex mixed capitalist economies --each with its own sub-systemic characteristics to be sure, but there are also some common strategic features. The purpose of this paper is to partly synthesize from a strategic perspective--- to the extent it is possible to do so--- and present a general nonlinear model that can handle both real economic and financial economic sanctions. We now turn to this task.

3. An illustrative model of the complexity approach during the fourth industrial revolution that incorporates the innovation system with AI sectors with a material basis in advanced semiconductors

3.A. Economic and Technological Systems as Complex Structures

During the fourth industrial revolution currently underway, the key strategic question for economic and technological systems concerns the prospects for long-term economic growth with equity. Ultimately, it is the ecologically sustainable growth that will determine the wealth that can be distributed among personal consumption, investment, government spending on infrastructure and public services, etc.

Therefore, it is the creation of an augmented (complex) national innovation system or ANIS that will determine the viability of any large mixed economy such as the US, Russian or Chinese economy. Clearly, economic sanctions can halt this temporarily. On the other hand, for a large resource rich economy with adequate human resources such as Russia, sanctions can mobilize political will to channel resources towards maintaining the ANIS. Unfortunately, in an environment of great power rivalry, this will most likely expand the military industrial complex(MIC) at the expense of other sectors. We need a multisectoral model of complex economic systems to capture this aspect.

Furthermore the process of building an innovation system is very much an evolutionary and path-dependent process. The central idea is that the provision of appropriate types of capital, labor and forms of organization for high value-added industries will lead to rapid productivity increases. However, to sustain such an increase, this innovation system must create a positive feedback loop or a virtuous cycle of innovations. For China's semiconductor industry and AI sectors these positive feedback loops will generate both increasing returns to scale and further innovation capabilities.

The formal technical problem is the existence of multiple equilibria in complex economies. A positive feedback loop leading to a virtuous cycle of growth and technology development is one particular sequence of equilibria in this context. In general, such a sequence also involves increasing returns. In the remainder of this section a theoretical exploration of innovation with increasing returns and multiple equilibria will be undertaken.

Technically, economic processes exhibit non-convexities -- violating the generic assumption of competitive equilibrium economics. In PRC, we find that the process has been a complex state-market interaction. Furthermore, distributional concerns can also be better analyzed in a model of a complex and adaptive social and political economy.

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[4] See for example, Khan(2004a,b, 2003a,, 1998,1997) and the references therein.

3.B. A Non-linear Model of Complexity

At any single point in time, the model can be presented as a Social Accounting Matrix (SAM) representation of the socio-economic system. The key distinction here is the explicitly non-linear nature of the economy-wide functional relationships. The key theorem shows the existence of multiple equilibria. Some further considerations of complexity and increasing returns show that multiple equilibria are indeed the natural outcomes in such models. Thus, there would seem to be some role for domestic policy in guiding the economy to a particular equilibrium among many.

The virtue of an economy-wide approach to an advanced economy with its advanced technology systems is the embodiment of various inter-sectoral linkages. In a SAM, such linkages are mappings from one set of accounts to another. In terms of technology systems, the production activities can be broken down into a production (sub-) system and a set of innovative activities thus both separating and linking the AI sectors as a network with all the economic activities in the complex economic-technical system.

One major component of the entire innovation system is, of course, the expenditures on R&D. In the SAM for Russia for example, this can appear either as an aggregate expenditure along the column labeled R&D, or as a set of disaggregated expenditures. In the latter case these may be specified according to productive activities (e.g., construction, electrical equipment, etc.) or by institutions (e.g., private R&D expenditures, government R&D expenditures, etc.). It should be emphasized that the dynamic effects of R&D on the economy can be captured only in a series of such SAMs over time. This approach is still at the conceptual stage, but appears to be quite appealing. One can contrast the possible policy experiments that can be undertaken within such a framework with the apparently ad hoc science and technology policies in many developing countries. In particular, the impact over time of a ANIS can be traced by building and maintaining such SAMs.

Choice of new technology in a country like Russia is affected by research and development in at least three different ways. Such a country can attempt to develop new technology through R&D, as mentioned previously. This ultimately requires a positive feedback loop innovation system in order to be self-sustaining. Another alternative is to adapt existing technology. This too requires a production system geared towards innovation in a limited way. A third alternative is to import technology or to acquire it through attracting foreign direct investment. In practice, all these different forms may be combined. The abstract model embodies all these different possibilities. However, the first option requires, among other things, a presence of multiple equilibria. In a unique equilibrium world, the competitive equilibrium (under the assumption of complete markets) will always be the most efficient one. The presence of increasing returns usually destroys such competitive conditions.

We begin with a number of productive activities reflecting the existing technological and financial structure with high technology sectors including AI sectors marked off by specific superscripts with subscripts giving nonlinear *technological coefficients functional* on a function space. Thus these activities are defined on the input-output subspace of the general and abstract mathematical space X along with all other economic activities. In addition to the values of inputs and outputs, points in this space could also represent household and other institutional income and expenditure

accounts. We also incorporate the possibility of R&D as a separate productive activity. Formally, it is always possible to break R&D down into as many finite components as we want. The key relationship in this context is that between the endogenous accounts (usually, production activities and technologies, factors and households) and the exogenous ones. It is this relationship that is posited to be *non-linear* and this together with some assumptions on the relevant mathematical space can lead to the existence of multiple equilibria.

Although the existence theorems for these multisectoral models provide some structure for the equilibria as sequences of fixed points in the socio-economic structure with evolving technology systems, it is not specified a priori which equilibrium will be reached. The idea behind a ANIS can now be stated somewhat more formally. It is to reach a sequence of equilibria so that in the non-linear models of the entire economy the maximal fixed points that are attainable are in fact reached through a combination of market forces and policy maneuvers over time. It is also to be understood that path-dependence of technology would rule out certain equilibria in the future. Thus, initial choices of technologies can matter crucially at times.

3. C. The Model on a Lattice

Define X as a vector lattice over a subring M of the real field R.Let $x_+ = \{x \mid x \in X, x \geq 0\}$

A non-linear mapping N is defined such that $N : X_+ \to X_+, N_0 = 0$. Given a vector of exogenous variables d, the following non-linear mapping describes a simultaneous non-linear equations model of an economy, E:

$$x = Nx + d \qquad (1)$$

for a given $d \in X_+$.

This non-linear system represents a socio-economic system of the type described previously. In order to specify the model further, the following assumptions are necessary.

1. X is order complete
2. N is an isotone mapping
3. $\exists \hat{x} \in$ such that $\hat{x} \geq N\hat{x} + d$

In terms of the economics of the model, the non-linear mapping from the space of inputs to the space of the outputs allows for non-constant returns to scale and technical progress over time. The 3 assumptions are minimally necessary for the existence of equilibrium. Assumption 3 in particular ensures that there is some level of output vector which can be produced given the technical production conditions and demand structure.

Existence of Multiple Equilibria:

Theorem: Under the assumptions 1 - 3, there exists $x^* \in X_+$ so that x^* is a solution of

$$x = Nx + d$$

Proof: Consider the interval $[0, x] = \{\hat{x} \mid \hat{x} \in X_+, 0 \leq \hat{x} \leq x\}$ where $\hat{x}$ is defined as in assumption 3. Take a mapping F.

$$F : x \in X_+ \to Nx + d$$

F is isotone and maps $[0, x]$ into itself.

Define a set $D \equiv \{x | x \in [0, x], x \geq Fx\}$.

By assumption 3, D is non-empty.

We now show $x^* \equiv \inf D$ is a solution to $x = Nx + d$. $x^* \equiv \inf D$; therefore $x^* \leq x, \forall x \in D$. F is isotone; therefore $Fx^* \leq Fx \leq x$ for each $x \in D$ implying.

$$Fx^* \leq x^*$$

From (2) we have $F(Fx^*) \leq Fx^*$. Thus $Fx^* \in D$; hence $x^* \equiv \inf D \leq Fx^*$ so, $Fx^* \leq x^* \leq Fx^*$. Therefore $x^* = Fx^*$.

This is an application of Tarski's and Birkhoff's theorem. The key feature to note here is that the equilibrium is not necessarily unique. It should also be noted that under additional assumptions on space X and the mapping N the computation of a fixed point can be done by standard methods (e.g. Ortega and Rheinboldt).

3.D. Multiple Equilibria on Banach Space:

In this section the results for multiple equilibria are extended to functionals on Banach Space. We can define the model again for monotone iterations, this time on a non-empty subset of an ordered Banach space X. The mapping $f : X \to X$ is called compact if it is continuous and if $f(x)$ is relatively compact. The map f is called completely continuous if f is continuous and maps bounded subsets of X into compact sets. Let X be a non-empty subset of some ordered set Y. A fixed point x of a map $N : X \to X$ is called minimal (maximal) if every fixed point y of N in X satisfies

$$x \leq y (y \leq x)$$

Theorem: Let (E, P) be an ordered Banach space and let D be a subset of E.

Suppose that $f : D \to E$ is an increasing map which is compact on every order interval in D. If there exist y, $\hat{y} \in D$ with $y \leq \hat{y}$ such that $y \leq f(y)$ and $f(\hat{y}) \leq \hat{y}$, then f has a minimal fixed point x. Moreover, $x \leq y$ and $x = \lim F^k(y)$. That is, the minimal fixed point can be computed iteratively by means of the iteration scheme

$$x_0 = y$$

$$x_{k+1} = f(x_k) \qquad k = 0,1,2,....$$

Moreover, the sequence (x_k) is increasing.

Proof: Since f is increasing, the hypotheses imply that f maps the order interval $[\bar{y}, y]$ into itself. Consequently, the sequence (x_k) is well-defined and, since it is contained in $f[\bar{y}, y]$, it is relatively compact. Hence it has at least one limit point. By induction, it is easily seen that the sequence (x_k) is increasing. This implies that it has exactly one limit point $\bar{x}$ and that the whole sequence converges to $\bar{x}$. Since f is continuous, $\bar{x}$ is a fixed point of f. If x is an arbitrary fixed point in D such that $x \geq \bar{y}$, then, by replacing y by x in the above argument, it follows that $\bar{x} \leq x$. Hence $\bar{x}$ is the minimal fixed point of f in $(\bar{y} + P) \cap D$. It should be observed that we do not claim that there exists a minimal fixed point of f in D.

We can also show that if $F : x \in X_+ \to Nx + d$ is an intersecting compact map in a non-empty order interval $[x, \hat{x}]$ and $x \leq Fx$ and $F\hat{x} \leq \hat{x}$ then F has a minimal fixed point x^* and a maximal fixed point x^{**}. Moreover, $x^* = \lim F^k(x)$ and $x^{**} = \lim F^k(\hat{x})$. The first of the above sequences is increasing and the second is decreasing.

Complex Dynamics and Out-of-Equilibrium Behavior:

Complex Adaptive Systems (CAS) are dynamic systems that can evolve with a changing environment. In CAS evolutionary trajectories there is no separation between a system and its environment in the sense that a system does not necessarily passively adapt to a changing environment. On the contrary, we have a system closely linked with all other related systems making up an ecosystem. In this larger ecosystem, change is necessarily that of co-evolution with all other related systems, rather than as adaptation to a separate and distinct environment.

As is well known, nonlinear dynamic systems can display a wide range of dynamic behaviors. Dissipative systems with a big enough perturbation can move to a new basin of attraction with much disorganization during transition. Also, even with bifurcations, we do not know for certain the expected path. Furthermore, catastrophic singularities are also possible.

My argument can now be summarized in terms of, dissipative systems dynamics in a world of multiple equilibria. Instead, a neoliberal global economy may simply go through cycles of instabilities. In Russia it is possible to set up a new capability enhancing system of production and distribution during the 4th industrial revolution

Technically, the "micro-macro" linkages can also be addressed through agents-based modelling and evolutionary game theory.

It should also now be clear that initial western claims about the effectiveness of sanctions were either based on intuitive and misinformed guesses, or very simplistic models that gave misleading results about damages to Russia and ignored the possibility of damaging the European economies and those of the global south. The expanded and detailed SAM-based nonlinear model in Appendix 3 with extensive nonlinearities in both the real and financial sectors gave results as early as March 22, 2022 that captured much more accurately the effects that we are observing now.[5]

Russia's Priority Areas:
Advanced Storage Technologies
Alternative and Renewable Energies
Biotechnology/Genetics
Electronic Components
Environmental Technologies
Integrated Circuits/Semiconductors

[5] I gave a Zoom presentation organized by Bradford University,UK on 22 March, 2022 for an international audience where I presented some of these results.The powerpoints are available upon request.

Manned Space Exploration
Materials Technology
Nanotechnology
Network and Communication Technologies
Optical and Biological Computing
Software and Related Services

According to American Electronics Association (AeA), which carried out a synthetic assessment of the Russian plan, the Plan's goals are ambitious, but not unrealistic. Russian industry in ANIS has a leadership mainly composed by engineers, who are in a favourable position to understand the nature and the strategic centrality of research and technology, and such leadership has already built up remarkable elements of strength in the S&T and R&D area. For instance, it has been pouring huge societal investments into higher education and research once again(state financing for higher education more than doubled since 2014).Large SOEs are once again investing heavily in technological upgrading and human capital formation, and there are a number of start-up innovative firms in IT and AI areas.

Yet, Russia also faces a number of challenges. Its high-tech industries are growing extremely fast, but many are still usually concentrated on low value-added stages in the value chain. Another key area of concern is constituted by weak IPRs protection . Under sanctions, this can cause difficulties and can only be overcome through channeling human and nonhuman resources to these sectors quickly. Since March 2022, Russia has done quite a bit in this arena.

However, it is also urgent to take decisive measures to reform allocation of capital, encourage risk taking, and let ideas flow more freely, to stimulate truly innovative thinking and research. As the APEC (2005) workshop on this topic has made clear, the convergence of information technology, biotechnology and nanotechnology (the so-called super convergence) might be the most significant technological event of the 21st century (see Khan 2005). The process of convergence is already underway. All the major national and regional players including USA, EU and Japan have already taken significant steps in order to maintain and gain further advantage in these technologies. Russia is a latecomer except for high technology in MIC, particularly missile, tank, artillery and aviation technologies. What can Russia do in order to be in the same league as the other major powers ?

Taking into account the challenges posed by a very competitive international environment where the other major powers still hold a significant advantage, Russia can achieve super convergence only through the creation of a self-sustaining innovation system that can move forward over time, This paramount strategic goal must be properly seen as the logical evolution of the present S&T strategy, basically centered around perfecting Russia’s ANIS, towards a qualitatively superior, self-propelling innovation system. The 15-year Plan, if successful, will complete the catch up process by 2025. Between 2025 and 2050, the strategic goal

should be to build up autonomously advanced technological capabilities in the three crucial areas, with a view towards moving towards super convergence. Regional cooperation with China, Iran and India can play an important role in this strategy. Increasing the number of competent staff in the areas of planning for high technology development is being given serious consideration. In Khan (2008a,c, 2004a, 2002,1998) the overall planning framework is presented as part of a system-wide effort to create a positive feedback loop for innovation, which is at the same time distributionally progressive, equitable,and environmentally sustainable. The term used later by Khan to refer to such a mechanism is that of nonlinear social capabilities enhancing complex innovation system, or SCENIS[6]. Clearly, under sanctions the fossil fuel dependence of Russia will present serious obstacles for meeting the ecological sustainability requirement for ANIS. One can only hope that the forced departure from neoliberalism will create circumstances that will lead to increasing efficiency and pursuing equity to get consent from below.

The SCENIS framework to evaluate the impact of economic sanctions on Russia can be applied through quantitative economy-wide modeling techniques, in order to analyze the challenges for transition from now to 2030 and
then from 2030 to 2050.

The SCENIS approach to economic sanctions is based on a somewhat novel theory of innovation in the economy wide setting. Its first and most important feature is that the analysis of a SCENIS can be thought of as part of the institutional turn in economic theory.

However, in contrast with much institutional literature, its propositions can also be expressed in a formal language, through models that can be estimated quantitatively for both rigorous, empirical scientific testing and for policy making purposes. The starting point of the SCENIS theory is the creative destruction process at the firm and industry level. However, an extension to an economy-wide setting requires the explicit theorization of the role of the state as well as an interacting nonlinear market process. The direction in which the theory leads is a complex interaction between state policies and market processes that influence the decisions taken by specific firms in particular areas of innovative activities. The key concept that is developed in this context can be called a Managed Creative Destruction (MCD) process. In a national (or regional) MCD, the creative destruction process characterizing innovation is structured more consciously by the state (or the states in a particular region). It can be argued that China is now going through this process. Following Schumpeter, we assume that innovation in specific firms can have economy-wide effects. As models based on this approach have multiple equilibria, the concept of a Complex sustainable capabilities enhancing innovation system or SCENIS is formalized by picking an appropriate sequence of equilibria over time. It can be also shown that SCENIS has

[6] See Sen (1999) and his other writings for pioneering work on human capabilities as the most appropriate set of measures of well-being. See also Khan(1998,2014,2017 and 2020) for social embeddedness of capabilities. My most recent work also incorporates intersectionality extending the reach of capabilities theory further.

empirical relevance by applying the formal model to an actual economy. Ultimately, technological transformation — in particular the creation of a SCENIS - is what makes the difference between sustained growth and gradual or sudden decline.

In addition to the system wide approach to innovation over time, the SCENIS theory offers two other distinct advantages. One is the linkage between micro and meso or macro levels. One can start with firm level data on innovation activities and link these to sectoral and intersectoral information flows. In this way, what happens at the firm level can be seen from a larger, economy wide perspective. At the same time, the impact of firm level activities on overall level and pace of innovation can also be ascertained qualitatively and quantitatively.

The third aspect of SCENIS is distributional. Since the complex system dynamics of SCENIS is holistic, it integrates production with distribution. Thus the distribution of value added in production at both the factorial and household levels can be formulated as part of a general equilibrium (or, under circumstances of internal or external shocks, disequilibrium) frame work. Given the levels and distribution of income among households, the consumption patterns and effective demand feedback mechanisms complete the formulation of a system wide model.

4.Some Results on The Impact of Economic Sanctions on Russia and Beyond from Applying the Structural-Financial Complex Systems Model:

The model in appendix 3 has an expansive number of sectors, factors and household types. I used mainly OECD data and socio-economic statistics on labor force and household income and consumption fro other international sources and surveys. Disaggregation gave much more detail on output in subsectors, employment and income generation. Thus SAMs were built to address disaggregated level question.The 250 plus equations could thus be expanded several times.In principle, as more data become available, even more disaggregation can be usefully carried out. It is worthwhile to mention that following the methodology described in Khan(2006), the well-being impact on ordinary Russian citizens is captured by using a Beta-distribution and using the sanctions shock. Surprisingly, being self-sufficient in basic food items and because the poor use locally processed and manufactured goods or imports from China and India, the countervailing policies to protect the standard of living of ordinary people has by and large succeeded, particularly away from Moscow and St. Petersburg.But without this simple policy response and coordinated response, the people in poorer oblasts would have suffered much more grievously from these sanctions including withdrawal of investments.

But before discussing some of key findings taking into account Russian countermeasures, let me present the key activities of Russia in the field of Artificial Intelligence (AI). AI is already an important part of the revolution in military affairs and will be increasingly in ISR and networked combined arms warfare. Here,too, surprisingly, the western sanctions have not made any dent in economic activities in

AI-related activities. Here is my fairly extensive list based on the latest information I could gather:

A detailed list of AI-related technologies in Russia:
Clearly, with an adequate industrial base in high technology, Russia can catch up and become a leader in many areas of AI. Russia has made rapid progress in catching up and is either at the frontier or already dominant in the following AI areas:

- Brain models, Brain mapping, Cognitive science
- Natural language processing
- Fuzzy logic and soft computing
- Expert systems
- Decision support systems
- Automated problem solving
- Knowledge discovery
- Knowledge representation
- Knowledge acquisition
- Knowledge-intensive problem solving techniques
- Knowledge networks and management
- Intelligent information systems
- Intelligent web-based business
- Intelligent agents
- AI and evolutionary algorithms
- Distributed AI algorithms and techniques
- Neural networks and variations, including: Deep Learning
- Heuristic searching methods
- Constraint-based reasoning and constraint programming
- Intelligent information fusion
- Learning and adaptive sensor fusion
- Search and meta-heuristics
- Integration of AI with other technologies
- Social intelligence (markets and computational societies)
- Social impact of AI
- Emerging technologies
- Applications (including: computer vision, signal processing, military, surveillance, robotics, medicine, pattern recognition, face recognition, finger print recognition, finance and marketing, stock market, education, emerging applications, ...)

MACHINE LEARNING; MODELS, TECHNOLOGIES & APPLICATIONS:
- Statistical learning theory
- Unsupervised and Supervised Learning
- Multivariate analysis
- Hierarchical learning models
- Relational learning models
- Bayesian methods

- Meta learning
- Stochastic optimization
- Heuristic optimization techniques
- Neural networks and variations (eg. Deep Learning)
- Reinforcement learning
- Multi-criteria reinforcement learning
- General Learning models
- Multiple hypothesis testing
- Markov chain Monte Carlo (MCMC) methods
- Non-parametric methods
- Graphical models
- Bayesian networks
- Cross-Entropy method
- Time series prediction
- Fuzzy logic and learning
- Inductive learning and applications
- Graph kernel and graph distance methods
- Graph-based semi-supervised learning
- Graph clustering
- Graph learning based methods
- Motif search
- Aspects of knowledge structures
- Computational Intelligence
- General Structure-based approaches in information retrieval, web authoring, information extraction, and web content mining
- Latent semantic analysis
- Aspects of natural language processing
- Intelligent linguistics
- Computational Neuroscience

- ALGORITHMS FOR BIG DATA:
  Data and Information Fusion
  Algorithms (including Scalable methods)
  Signal Processing
  Data-Intensive Computing
  High-dimensional Big Data
  Multilinear Subspace Learning
  Sampling Methodologies
  Streaming

- BIG DATA FUNDAMENTALS:
  Novel Computational Methodologies
  Algorithms for Enhancing Data Quality
  Models and Frameworks for Big Data
  Graph Algorithms and Big Data

- INFRASTRUCTURES FOR BIG DATA:
  Cloud Based Infrastructures (storage & resources)
  Grid and Stream Computing for Big Data
  Autonomic Computing
  Programming Models and Environments to Support Big Data
  Software and Tools for Big Data
  Emerging Architectural Frameworks for Big Data
  Paradigms & Models for Big Data

- BIG DATA MANAGEMENT AND FRAMEWORKS:
  Database and Web Applications
  Federated Database Systems
  Distributed Database Systems
  Knowledge Management and Engineering
  Novel Data Models
  Data Preservation and Provenance
  Data Protection Methods
  Data Integrity and Privacy Standards and Policies
  Scientific Data Management

- BIG DATA SEARCH:
  Multimedia and Big Data
  Social Networks
  Web Search and Information Extraction
  Scalable Search Architectures
  Cleaning Big Data, Acquisition & Integration
  Visualization Methods for Search
  Graph Based Search and Similar Technologies

- PRIVACY IN THE ERA OF BIG DATA:
  Cryptography
  Threat Detection Using Big Data Analytics
  Privacy Preserving Big Data Collection
  Intrusion Detection

- DATA MINING/MACHINE LEARNING TASKS:
  Regression/Classification
  Segmentation/Clustering/Association
  Deviation and outlier detection
  Explorative and visual data mining
  Mining text and semi-structured data
  Temporal and spatial data mining

- DATA MINING ALGORITHMS:
  Artificial Neural Networks / Deep Learning
  Fuzzy logic and rough sets

Decision trees/rule learners
Evolutionary computation/meta heuristics
Statistical methods
Collaborative filtering
Case based reasoning
Ensembles/committee approaches

- DATA MINING INTEGRATION:
Mining large scale data/big data
Data and knowledge representation
Data warehousing and OLAP integration
Integration of prior domain knowledge
Metadata and ontologies
Legal and social aspects of data mining

- APPLICATIONS and Further Research Areas:
Bioinformatics, Medicine Data Mining, Business/Corporate,
Industrial Data Mining, Direct Marketing, Database Marketing,
Engineering Mining, Military Data Mining, Security Data Mining, ...
- Data to Information to Knowledge Mapping
- Knowledge Mining
- Business Intelligence
- Information Retrieval Systems
- Knowledge Management and Cyber-Learning
- Database Engineering and Systems
- Data and Knowledge Processing
- Data Warehousing and Datacenters
- Data Security and Privacy Issues
- Information Reliability and Security
- Information and Knowledge Structures
- Knowledge and Information Extraction and Discovery Techniques
- Knowledge and Information Management Techniques
- Knowledge Extraction from Images
- Knowledge Representation and Acquisition
- Large-scale Information Processing Methods
- Intelligent Knowledge-based Systems
- Decision Support and Expert Systems
- e-Libraries (Digital Libraries) + e-Publishing
- Ontology: Engineering, Sharing and Reuse, Matching and Alignment
- Agent-based Techniques and Systems
- Workflow Management
- Content Management
- Data and Knowledge Fusion
- Global Contextual Processing and Management Implementation
- Data/Information/Knowledge Models
- Managing Copyright Laws

- Interoperability Issues
- Transaction Systems
- Ontologies and Semantics
- Object-oriented Modeling and Systems
- Case-based Reasoning
- Classical Aspects of Information Theory
- Applications (e-Commerce, Multimedia, Business, Banking, ...)
- Natural Language Processing
- Information Integration
- Multi-cultural Information Systems
- Domain Analysis and Modeling
- Metamodeling

Theoretical, mathematical, empirical and experimental aspects of cognitive computing, including:

- Bio Inspired Cognitive Algorithms
- Improving Cognition in machine learning systems
- Modeling Human Brain processing systems
- Multimodal learning systems
- Reinforced learning
- Cognitive evolution
- Cognitive inferential systems
- Cognitive improvement in deep learning networks
- Advancements in Neural Networks
- Multiscale Learning systems
- Fractal based learning and decision support systems
- Application of chaos Engineering in machine intelligence
- Dynamical learning systems
- Application of Information Theory in Machine Intelligence
- Application of linear and nonlinear optimization theory in ML
- Self-Adaptive and Self Organizing Systems
- Manifold and Metric learning
- Cognitive Modeling, Visualization and Analytics of Big Data
- Graph Theoretic approaches in dimensionality reduction
- Information and Knowledge retrieval and searching algorithms
- Big data knowledge mining
- Mathematical modeling of Big Data and Artificial Intelligence
- Cognitive Signal Processing
- Rough Set Theory
- Agent Based Modeling in Machine Learning Systems
- Information Processing and Decision Making Systems
- Big Data Fusion and Information Retrieval
- Time and Space Analysis in Machine Learning
- New application of classical stochastic and statistical analysis for big data machine learning
- Nature inspired cognitive computing algorithms

- Cognitive Feature Extraction
- Extraction of latent semantics from big data

It should be clear from the existing state of R&D in the above area that Russia is the more advanced of the two countries the US DoD 2017 white paper identified as the competitors for global dominance.However, publicly the US policymakers constantly present Russia as a backward country. This probably explains why there is such shock regarding the advanced state of hypersonic and cruise missiles of Russia and its space based ISR capabilities.

I now turn to empirical results.I discuss first the trade and investment sanctions and then financial sanctions taking into account Russian responses. I then discuss the possible impacts on Europe, Germany in particular. I then turn to the collateral damage to the global south. It is perhaps not surprising that both the US and PRC are net gainers from these sanctions---particularly energy sanctions.It is also not surprising that Iran benefits as well. But India's gains are results of ingenious policy reversals showing flexibility with alacrity. China, India and other BRICS gain also from financial sanctions which have hastened dedollarization and other related alternatives. I have argued for hybrid global financial architecture(HGFA) with important regional groupings. It does appear that such a structure of HGFA is taking shape in front of our very eyes today.[7]

But first let us recall some basic propositions regarding the economics and political economy of sanctions from Khan(1987,1988,1989,1990 and 1991):

- Objective of imposing sanctions (usually collateral damage on vulnerable other parties not considered)
  - *Policy Change favored by sanctioning entities(mainly US, UK and EU)*
  - *Change in Leadership/regime change*
- In case of Russia: Which agents can accomplish such changes?
  - *Putin & Russian State Apparatus including the Army*
  - *Oligarchs*
  - *Financial markets/People/Media*
- Time Frames ---short-, intermediate-, and long-run
- Non-Linearity in sanctions and complexities
  - *Effect of small sanctions is different from large*

Interactions among different types of sanctions

It is noteworthy that after almost a year and many rounds of many different kinds of trade and financial sanctions by and large the sanctions have failed in the short run. This still leaves the question of whether these sanctions can succeed in the medium term(2-3 years) or long run (beyond 3 years). Unless some factors within Russia and in Russia's relations with PRC and the global south change drastically to Russia's detriment, there is very little chance of medium or even long run success of western sanctions. Let us look at the impacts more carefully using our model-based results. We

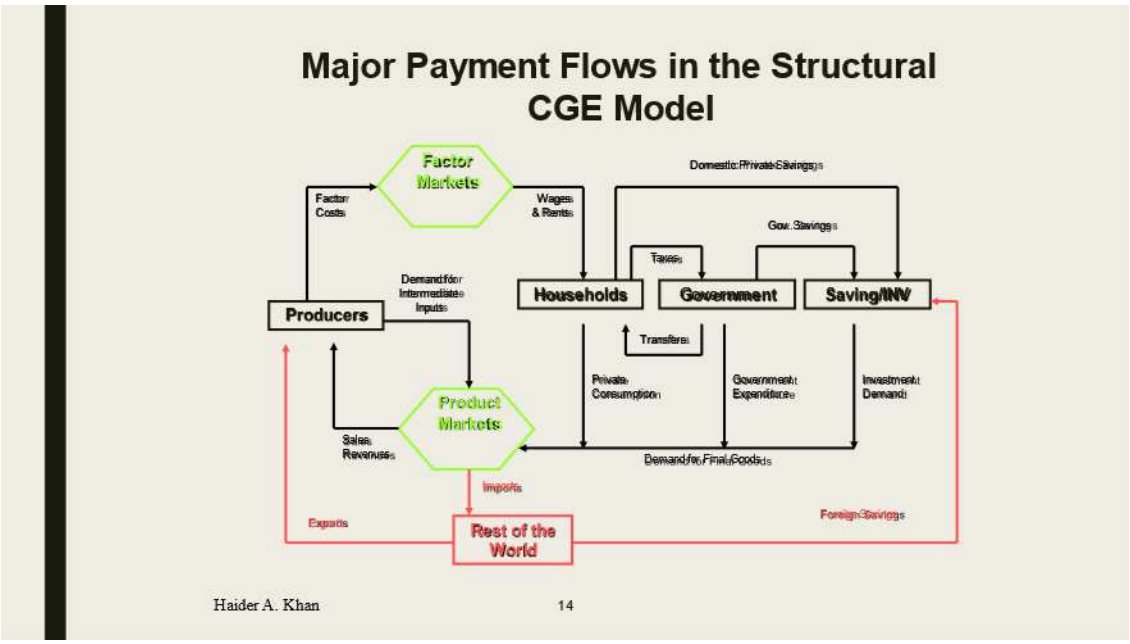
[7] See Khan(2004b, 2013, 2014, 2017, 2021a-d, 2022 and Khan et.al. 2023)

should acknowledge that Russia needed to be flexible in responding to the needs of the global south which except for a few countries like India, China and a few oil producing countries would be and indeed have been affected adversely. So we begin with the need for rational response in a game theoretic strategic framework.

The following three points are important to grasp:

- Russia must have known it would face significant financial blowback from its invasion of Ukraine. Therefore, does it follow that sanctions will only adversely impact Russian civilians instead of halting Russian military operations? **Yes, with some qualifications.**
- Investment banks such as Goldman Sachs and JPMorgan chase have been reported to be buying up cheap Russian corporate debt, is it right for private companies to attempt to profit from this (or any) conflict? **Morally, NO. legal part is quite technical--- economics will depend on how the secondary markets for such debt function within the legal constraints. But it is now clear that even with near complete financial blockade these sanctions have failed.**
- Because Least Developed Countries are so disproportionately affected from external economic shocks, could strategic price controls help protect the Least Developed Countries from the shocks and global inflation resulting from the Russia-Ukraine conflict? **Absolutely necessary esp. for Africa. But more important are strategic reserves, esp. of food, food aid and supplying these in time. Even DCs like Egypt, Turkey, India and Bangladesh will be affected adversely. Russia wisele made accommodations particularly with respect to the African countries and Turkey.**

Turning now to specific model-based analysis, we note the structure of the economic flows in the Russian economy given by figure one below.



We note both the domestic production structure and the open economy relations. A feature apparently overlooked by western analysts is the relatively closed and self sufficient production structure except the energy exports and luxury goods imports. If we keep this in mind, the following numbers from the model without and with rational responses are sensible ones. Since our complex systems model has non-Walrasian adjustment , the following points should be kept in mind:

• Asset markets.
  – Equilibrium in asset portfolios but also nonlinear complex dynamics.
• "Financial" variables:
  – Money, debt, equity.
  – Domestic and foreign assets.
  – Interest rate, inflation, equity prices, nominal exchange rate.

The simplistic approaches when used---and only rarely if at all--- by the western analysts ignored these complexities and the possibilities for alternative policy responses by Russia with cooperation from PRC, India, Iran and other countries from the global south.

Also, the following two points are important:

- Sanctions can limit/eliminate inflows from The West
  - *Impossible/difficult to convert rubles into dollars---successful so far---eventually Russia was forced to go on ruble payments only with longterm dedollarization becoming a real possibility.*
  - *Bank runs from rushing to withdraw rubles---Initial panic but now under control*
  - *Rushing to buy extra goods and services: hyper-inflation? Not yet; could prevent this and keep inflation moderate if real resources are mobilized to increase supply of necessities*
  - *Destroy confidence in financial system/increase financial fragility---need capital controls and reining in big private capitalists(oligarchs)*
- Capital Controls can avoid further outflows of capital. This has been done successfully.
  - *Maintaining confidence in financial system requires liquidity provision---It happened quickly. RCB deserves credit for this optimal timely response.*
  - ***Dedollarization (intermediate and long-term)***
  - *RCB led competently by* Elvira Nabiullina who is a professional central banker

It should be acknowledged that western sanctions against Russia have been maximal and unremitting. I mention just a few prominent features:

- Russian banks subject to blocking or asset freeze sanctions in at least one Western jurisdiction include: VEB, PSB, VTB Bank, Bank Otkritie,

Sovcombank, Novikombank, Bank Rossiya, Black Sea Bank For Development And Reconstruction, Genbank, and IS Bank.

- The prohibitions of the Russia-related CAPTA(Correspondent Acct. or Payable-through Acct.)Directive take effect beginning at 12:01 a.m. eastern daylight time on March 26, 2022.
- Russia's largest lender Sberbank and other banks have been sanctioned so that customers would be unable to transfer funds in certain foreign currencies to accounts at other banks, both in Russia and abroad.This has led to making alternative non-SWIFT based messaging and interbank operations.
- Moscow and Beijing worked together to establish cooperation between their respective financial messaging systems. Russia's SWIFT alternative, the System for Transfer of Financial Messages (SPFS), has allowed and further enabled the flow of domestic interbank traffic.
- On the important oil and gas sanctions, the European Union's foreign ministers initially disagreed on oil and gas sanctions.But under Us prodding, they did go through with these sanctions eventually but only to see adverse effects on their own economies. Germany after the destruction of Nordstream pipelines now has to pay 4 to 6 times as much for oil and gas.

It should be kept in mind that our model has been constructed in such a way that sanctions-induced financial and real economic crises are possible , and anticipating and responding to this in a timely manner is crucial. Thus if Russia responds in the optimal or near-optimal way according to the game-theoretic logic using some fuzzy logic version of backward induction, the risks can be mitigated,. What has happened? Briefly, with some simplification, no response or the uncoordinated responses on the part of Russia indeed would have been disastrous. GDP would have contracted by 20 per cent or even more. Main banking system would have collapsed. None of these happened. Only luxury goods consumption in main cities decreased. Foreign travel was adversely affected.But ordinary Russians remained largely unaffected. With the recent social policy announcements particularly in health, education, pension and housing sectors the citizens---particularly the more vulnerable segments will be further protected. Ironically, post-soviet, freewheeling crony capitalist Russia has been forced now to adopt some quasi-socialist policies to enhance the social capabilities of its ordinary citizens.

Here are some model based multipliers ---first without countervailing response and then with near-optimal responses:

Some Sanctioned Sectors---Impact factors ranging from 1.5 to 2.5 at the given level of sanctions:

- **Food**
- **Accommodation and food service activities**
- **Textile products**
- **Leather and footwear**

- **Beverages and tobacco**
- **Agriculture**
- **Basic metals and other by products for high tech (e.g. neon used for microchip prod., palladium, etc.)**
- **Motor vehicles, trailers and semi-trailers**
- **Financial and insurance activities**
- **Real estate activities**
- **Professional, scientific and technical activities**
- **Arts, entertainment and recreation**

Our model gives further intrasectoral disaggregated results; but this will suffice. What happens with near optimal countervailing measure? Here is the general picture for the same sectors. On the whole , contraction could be limited to below 5 per cent. This has indeed happened. Paricularly in necessities from food to essential services, production has not contracted. Overall contraction has been limited to about 3 per cent. How could this happen?

Briefly, consider the following:

- Real sectors are more important for well-being of all citizens;Fiscal policy and sectoral policies---keeping the purchasing power of citizens esp. on fixed incomes intact through tax relief and transfers;
- Supply side policy for increasing the production and distribution of necessities---do without luxuries---only the elite have suffered.
- Non-sanctioning partners---Key: India and China---Mexico is non-sanctioning also.
- Sanctioning the non-sanctioning partners---a fraught problem and so far ineffective.

I finish this brief excursion of model results with a quick look at the longer term prospects (beyond 3 years):

- **Autarky**
  - *Similar to USSR but directed mixed state-market capitalist economy Current account surplus, March 2022 more than $200bn; but now less exports----Redistribution of assets and income can revive domestic demand---need to increase supply (reduce excess capacity and unemployment)---politically feasible?*
  - *Decoupling of production processes---EU retreats*
    - Example: auto production: VW local value added is ~70%
    - Ukraine occupation (like 1980s Afghanistan?)---foolish choice
- **China Cooperation/Life-Line---long-term growth may depend on this**
  - *Create liquid Rubles-Renminbi(CNY) market*
    - RMB replaces $
    - US can sanction Chinese banks (put on "Specially Designated Nationals" list---see US treasury page). But this will not be

effective because of bilateral arrangements with Russia and other countries of BRICS and the global south.

The upshot is that US hegemony is not going to be seriously threatened for at least another decade. But seizing Russia's assets has made China in particular anxious. Alternative payments systems and dedollarization have accelerated .But further institutionalization of these trends will require at least another decade. We will see a fully bifurcated hybrid global financial architecture(HGFA) by 2040. It is taking shape in front of our very eyes right now. [8]

5.Summary and Conclusions: The Future of Economic Sanctions

To summarize, let us look at the most important model predictions from March 22, 2022:

- Immediately both Russia and the Europeans---esp. Germany---will suffer economically. Germany will have to find another way of paying for Russian oil and gas, or do without it and pay higher prices for US and US-negotiated Qatari-Saudi oil and gas. Russia will sell to PRC but that may not work in the long run unless long-term 10-20 year contracts can be arranged to avoid market volatility and exchange rate risks. These predictions have largely been borne out with some inevitable geopolitical nuances. Germany is substantially worse off and China and India have profited handsomely.
- Together with the development of digital currencies by China, Russia and other central banks, and alternatives to SWIFT messaging network which China, Russia and Iran are pioneering, de-dollarization will be accelerated.This , too, has been confirmed; but unlike some unscientific amateur enthusiasts, the pace is much slower than their "predictions".Thus the model predictions are more reliable than these wild dedollarization enthusiasts' leap into the future.
- Therefore, my final conclusion is that by 2030-35, the US financial hegemony in the global economy will end. It will not be as bad as the end of British financial hegemony economically for the US unless more foolish imperialist wars are fought by the US; but given US arrogance at all levels, it will be even more traumatic for the US elites than it has been for the UK elites.
- Further on financial sanctions: The main effect will come from the sanction on central bank. Inflation will increase as ruble falls. But with tighter monetary policy and increased trade that is ruble-based, these tendencies could be reversed. Also, even in the worst case scenario, this will hardly bring about the fall of govt. which is what the western media (which shows little grasp of either

[8] The analytical shortcomings and slipshod use of data (when the data are used at all) of most writing on sanctioning Russia should by now be clear. As an example, we can look at the recent January article by two Yale University Business School professors that claim without any evidence and contrary to IMF and other analyses that Russian economy is in serious trouble. See Jeffrey Sonnenfeld and Steven Tian(2023).

economics or politics) claims. If Cuba, Venezuela and Iran could withstand such sanctions, a much richer country which has more than 650 billion dollars in reserve and getting more everyday will hardly be affected politically. Notice that no serious Western economist has supported the journalistic speculations with serious economic analysis.Technically, with capital controls instituted quickly and controlling the few oligarchs who buy dollars and send them out of the country, the problem of devaluation can be tackled. If food(Russia is a food surplus country now, at least partly in response to earlier sanctions), housing, education, healthcare prices are put under control(it is possible to control prices during war time, as people who know US history during WW2 will recognize), this will cushion the general public and retirees who unlike the oligarchs don't speculate in money markets and pass their ill-begotten wealth to Swiss, EU and US banks. By and large, Russian policy response has been as game theory would predict, and such response has succeeded in mitigating the effects of these sanctions.

- Operation of Marshall-Lerner condition will ensure that the BOT and BOP (esp. with capital controls) will continue to show surplus accumulating reserves that will act as a further cushion for the economy.With trade diversion away from EU and UK, the trade with new partners seemingly fulfils these conditions and again policy responses so far have been successful.
- Oil and Gas Ban: Europe was not on board initially, but did fall in line gradually. The US is scrambled to replenish its own supply from Saudi Arabia, UAE, Venezuela and Iran. EU , and Germany in particular, by following the US line, have essentially cut their own economic throats.

For a realist, economic and other sanctions are here to stay. Clearly, even in the nuclear age wars between NATO-US and Russia or China are conceivable. But short of proxy or even direct wars, sanctions are going to be used symbolically and also at times substantively. The actual war most probably will call forth what at least one side thinks are substantive sanctions. But in game theoretic terms many refined Nash equilibria will exist.[9] Where the world ends up will depend on a number of complex factors. Hence, there will be good reasons for modeling sanctions in a complex systems framework.

The models presented in the text and the appendices demonstrate that complexities can be handled rigorously through constructive analytical tools that allow actual computation of fixed points to be carried out. The empirical results derived through such constructive analyses show the need for careful gathering of data and integrating data from various sources in a consistent manner in a SAM framework.

The failure of many aggregate models of sanctions to predict with any degree of accuracy the impact of sanctions against Russia shows how serious the problem of disaggregation in a consistent framework is. In the case of Russia, there has been much

[9] We allow for departures from equilibria in "perturbed games" and consider trembling hand perfect equilibria as well. Thus off-the-equilibrium plays are also allowed.

wishful and dogmatic claims. The earlier bold and overly optimistic western "analysis' ignored the resource endowments of Russia, its modern innovation system, MIC and connections with alternative markets. At the same time, Russian partisans dogmatically denied Russian vulnerabilities. Both were wrong. In fact, such irrational and dogmatic claims and counterclaims demonstrated a saying attributed to Napoleon: The first casualty of war is truth.

While I would not claim too much for the complex systems models I have constructed and tested, it is clear from their relative predictive success that we need to keep in mind both causal complexities and recursive game theoretic interactions on the strategy and pay off spaces and attempt the most rigorous modeling possible mathematically. But there is no magic bullet in modeling. We can only think in terms of successive approximations and constant testing for further improvement. Apart from the relevance of sound data and modeling, the work presented here carry the message that such methodology when pursued carefully will lead to progressively better approximations. This is the promise of steady scientific work which requires patience, humility and modesty in addition to the mastery of a set of complex modeling and data gathering and synthesizing skills as well as the ability to offer proofs from the perspective of computability in the best tradition of constructive mathematics.

Furthermore, in the age of climate change, our modelling of sanctions should also address the effects on ecological sustainability. Thus integration of ecological factors in a model of sanctions can be critical. In my related work(Khan et. al.(2009)) I have attempted to do this. This work shows that sanctions can indeed be integrated with ecological impacts modeling for the BRIC(South African detailed data was not available for the econometric work) as a group. Thus a sanctions model can also investigate the relation between rapid economic growth or slowdown and environmental degradation in the BRIC economies. It utilizes environmental, macroeconomic and financial variables coupled with Kyoto Protocol indicators based on panel data from 1992 to 2004.In keeping with the goal of examining long run sustainability, the long-run equilibrium relationship between economic growth and energy consumption is examined. *Feasible general least squares* procedure (FGLS) is employed to estimate the environmental degradation caused by increases in energy consumption. *Pooled regression analysis* is used to estimate the relationship between energy consumption and growth variables. The impact of excessive economic growth rates on energy consumption levels is studied by means of *threshold pooled ordinary least squares* (POLS) method. Moreover, this analysis takes into account the legitimate econometric criticism of the Environmental Kuznets Curve highlighted by Stern (2004). The findings reveal that higher energy consumption leads to increased CO_2 emissions in the countries under consideration.It is also found that rapid economic growth further inflates energy consumption levels in the emerging BRIC economies. The results of cointegration analyses also confirm these findings. Finally, the inclusion of the US and Japan as the world's largest energy consumers does not significantly alter the results of our study.

The implications of the study of impact of sanctions on Russia's energy and innovation systems environment are quite clear. The crucial question is: what kind of transformations in the global and local economic environment and development discourse will influence the policies of the Russian economy in the right direction. A related question is: how can the resource rich economies of the world like Russia play an enabling rather than a predatory role in furthering sustainable industrialization and development in all the countries including the LDCs? Sadly, the impact of sanctions against Russia seems to have been largely ecologically destructive.

Appendix 1:Economic Sanctions: Output, Employment and Household Income and Cosumption as wellas Growth impacts of the industrial and non-industrial sectors – a simple SAM-based Model

Fixed price modelling in a SAM-based framework

In this section of the appendix, the social accounting matrix is presented as a data-gathering framework as well as an analytical tool for studying the effects of the energy sectors on growth. Appendix 2 presents the methodology for estimating the impact of growth generated by both the industrial and non-industrial sectors on poverty alleviation. The origins of social accounting can be traced as far back as Gregory King's efforts in 1681, but more recent work stems from the attempts by Richard Stone, Graham Pyatt, Erik Thorbecke, and others.[10]

In the methodological framework of this study, the SAM is used for mapping production and distribution at the economy-wide level. In this section, first a general SAM is described. Then it is shown how the method for studying the effect of growth within this framework follows logically from its structure. The model used is a simple version of a class of SAM-based general equilibrium models.[11] It summarizes succinctly the interdependence between productive activities, factor shares, household income distribution, balance of payments, capital accounts, and so on, for the economy as a whole at a point in time. Given the technical conditions of production, the value added is distributed to the factors in a determinate fashion. The value added accrued by the factors is further received by households according to their ownership of assets and the prevailing wage structure. In the matrix form the SAM consists of rows and columns representing receipts and expenditures, respectively. As an accounting constraint receipts must equal expenditures.

As is elaborated further in Khan and Thorbecke (1988), the SAM framework can be used to depict a set of linear relationships in a fixed coefficient model. For deciding the question of determination, the accounts need to be divided into exogenous and endogenous ones. For instance, in the China SAM, there are three endogenous accounts.

These are factors, households and production activities, leaving the government, capital and the rest of the world accounts as exogenous.[12]

For key SAM accounts where y is endogenous income, x is exogenous accounts and t is leakages, we can see immediately that

$$y = n + x \tag{1}$$

$$y = 1 + t \tag{2}$$

---

[10] For a description of SAM as a data-gathering device, see Khan and Thorbecke (1988). Khan (1997) also has a chapter on this alone.

[11] In Walrasian general equilibrium models the flexible price vector determines the equilibrium. In a Keynesian (dis)equilibrium model in the short-run the quantities vary while the price vector remains fixed.

[12] See Khan and Thorbecke (1988: ch. II) for more theoretical details and empirical examples. The presentations here follow the cited work closely.

Now if we divide the entries in the transactions matrix T_{nn} by the corresponding total income (that is, y_n), we can define a corresponding matrix of average expenditure propensities. Let us call this matrix A. We now have:

$$y = n + x = Ay + x \tag{3}$$

$$y = \left(1 - A\right)^{-1} x = Mx \tag{4}$$

M has been called the matrix of accounting multipliers by Thorbecke, for these multipliers, when computed, can account for the results (for example, income, consumption, and so on) obtained in the SAM without explaining the process that led to them. Let us now partition the matrix A in the following way (Khan and Thorbecke).

$$A = \begin{bmatrix} 0 & 0 & A_{13} \\ A_{21} & A_{22} & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix} \tag{5}$$

Given the accounts factors, household and the production activities, now we see that the income levels of these accounts (call them y_1, y_2, y_3, respectively) are determined as functions of the exogenous demand of all other accounts. In this respect, what we have is a reduced-form model which can be consistent with a number of structural forms. This is quite satisfactory as far as tracing the effects of a certain injection in the economy is concerned or for prediction purposes when the structural coefficients are more or less unchanged.

One limitation of the accounting multiplier matrix M as derived in equation (4) is that it implies unitary expenditure elasticities (the prevailing average expenditure propensities in A are assumed to apply to any incremental injection). A more realistic alternative is to specify a matrix of marginal expenditure propensities (C_n below) corresponding to the observed income and expenditure elasticities of the different agents, under the assumption that prices remain fixed. The C_n matrix can be partitioned in the same way as the A matrix above. The most important difference between the two partitioned matrices is that $C_{32} \neq A_{32}$. Expressing the changes in income (dy) resulting from changes in injections (dx), one obtains

$$\mathrm{d}\, y_n = C_n\, \mathrm{d}\, y_n + \mathrm{d}\, x \tag{6}$$

$$= \left(I - C_n\right)^{-1} \mathrm{d}\, x = M_c\, \mathrm{d}\, x \tag{7}$$

M_c has been called a fixed price multiplier matrix and its advantage is that it allows any nonnegative income and expenditure elasticities to be reflected in M_c. In particular, in exploring the macroeconomic effects of exogenous changes in the output of different product-cum-technologies on other macroeconomic variables, it would be very unrealistic to assume that consumers react to any given proportional change in their incomes by increasing expenditures on the different commodities by exactly that same proportion (that is, assuming that the income elasticities of demand of the various socioeconomic household groups for the various commodities were all unity). Since the expenditure (income) elasticity is equal to the ratio of the marginal expenditure

propensity (MEP_i) to the average expenditure propensity (AEP_i) for any given good i, it follows that the marginal expenditure propensity can be readily obtained once the expenditure elasticity and the average expenditure propensities are known, that is,

$$y_i = MEP_i/AEP_i \tag{8}$$

$$MEP_i = y_i\, AEP_i \tag{9}$$

and

$$\sum_i MEP_i = 1 \tag{10}$$

Thus, given the matrix A_{32} of average expenditure propensities, and the corresponding expenditure elasticities of demand, y_i the corresponding marginal expenditure propensities matrix C_{32} could easily be derived.[13]

[13] See Khan and Thorbecke (1988) for some examples.

Appendix 2: Economic Sanctions: Innovating and Other (including Energy) sectors, growth, distribution and poverty

Multiplier decomposition, growth and poverty alleviation sensitivity

Since poverty in the present context is measured by identifying a poverty line in monetary terms, incomes of the various household groups are the crucial variables. In particular, sectoral growth generated by the energy sectors must be linked to incomes of the various households in order to determine the exact extent of the alleviation of poverty through growth. The exact effect of income growth on poverty, of course, depends on the sensitivity of the adopted poverty measure to income. In this paper the P_α class of additively decomposable poverty measure is selected for this purpose. For α = 0, 1, *n* this measure becomes the headcount ratio, the poverty gap and a distributionally sensitive measure that gives specific weights to each poor person's shortfall, respectively.

If we apply Kakwani's decomposition to the P_α measure for specific sectors and households *i* and *j* respectively, the change in $P_{\alpha ij}$ can be written as follows:

$$\mathrm{d}\,P_{\alpha ij} = \frac{\partial P_{\alpha ij}}{\partial \overline{y}_i} + \sum_{k=1} \frac{\partial P_{\alpha ij}}{\partial \theta_{ijk}} \mathrm{d}\,\theta_{ijk} \tag{11}$$

Here $P_{\alpha ij}$ is the P_α measure connecting sector j to household group *i*, y_i is the mean per-capita income of household group *i*, and θ_{ijk} is the income distribution parameter. Under the unrealistic but simplifying assumption of distributional neutrality:

$$\frac{\mathrm{d}\,P_{\alpha ij}}{P_{\alpha ij}} = \eta_{\alpha i}\left(\frac{\mathrm{d}\,\overline{y}_i}{\overline{y}_i}\right) \tag{12}$$

where $\eta_{\alpha i}$ is the elasticity of P_{ij} with respect to the mean per capita income of each household group *i* resulting from an increase in the output of sector *j*. $\mathrm{d}\,\overline{y}_i$ on the right hand side is the change in mean per capita income of household group *i*. This can be written as (by considering the fixed price multiplier matrix)

$$\mathrm{d}y_c = m_{ij}\,\mathrm{d}x_j \tag{13}$$

where $\mathrm{d}x_j$ is the change in the output of sector *j* on a per capita basis for group *j*. We can now rewrite the average change in poverty measure as

$$\frac{\mathrm{d}\,P_{\alpha ij}}{P_{\alpha ij}} = \eta_{\alpha i} m_{ij}\left(\frac{\mathrm{d}\,x_j}{\overline{y}_i}\right) \tag{14}$$

By aggregating across the household groups we can arrive at the overall poverty alleviation effect

$$\frac{\mathrm{d}\,P_{\alpha j}}{P_{\alpha j}} = \sum_{i=1}^{m}\left(\frac{\mathrm{d}\,P_{\alpha ij}}{P_{\alpha ij}}\right)\left(\frac{\eta_i}{\eta}\right) = \sum_{i=1}^{m}\left(\frac{\mathrm{d}\,P_{\alpha ij}}{P_{\alpha ij}}\right)\left(\frac{P_{\alpha ij}}{P_{\alpha j}}\right) \tag{15}$$

Since we are considering a P_α measure

$$\frac{\mathrm{d}P_{\alpha j}}{P_{\alpha j}} = \sum_{i=1}^{m}\left(\frac{\mathrm{d}P_{\alpha ij}}{P_{\alpha ij}}\right)\left(\frac{\sum\left(\left(z-y_k\right)/z\right)^{\alpha}}{\sum\left(\left(z-y_1\right)/z\right)^{\alpha}}\right) \tag{16}$$

where q_i is the number of poor in the ith group and the total number of poor $q = \sum_{i=1}^{m} q_i$

Let $s_{\alpha i}$ be the poverty share of household group i (naturally $\sum_{i=1}^{m} s_{\alpha i} = 1$)

$$s_{\alpha i} = \sum_{k=1}^{q_i}\left(\frac{z-y_k}{z}\right)^{\alpha} \Bigg/ \sum_{l=1}^{q}\left(\frac{z-y_l}{z}\right)^{\alpha} \tag{17}$$

We can further rewrite the expression for the average change in overall poverty alleviation.

$$\frac{\mathrm{d}P_{\alpha j}}{P_{\alpha j}} = \sum_{i=1}^{m}\left(\frac{\mathrm{d}P_{\alpha ji}}{P_{\alpha ij}}\right)s_{\alpha i} \tag{18}$$

Combining Equations 14 and 18, we now have

$$\frac{\mathrm{d}P_{\alpha j}}{P_{\alpha j}} = \sum s_{\alpha i}\eta_{\alpha i}m_{ij}\left(\frac{\mathrm{d}_{xj}}{\overline{y}_i}\right) \tag{19}$$

We can separate the income increase via the modified multiplier effect from the sensitivity of the poverty measure formally in Equation (19) by defining the following two entities:

- $m'_{\alpha ij} = s_{\alpha i}m_{ij}$ gives the modified multiplier effect in terms of income of a poor group.
- $q_{\alpha ij} = \eta_{\alpha i}(\mathrm{d}x_j/\overline{y}_i)$ represents the sensitivity of the poverty index to the change in income. I adopt their terminology and call this the poverty sensitivity effect.

But each multiplier m_{ij} can be further decomposed:

$$m_{ij} = \eta_j d_{ij} \tag{20}$$

where n_j gives the (closed loop) interdependency effects and d_{ij} the distributional effects of a change in demand for the product of sector j on household group i.
Thus

$$\frac{\mathrm{d}P_{\alpha j}}{P_{\alpha j}} = \sum m'_{\alpha ij}q_{\alpha ij} \tag{21}$$

$$= \sum_{i}^{m}\left(r_{\alpha ij}\right)\left(s_{\alpha ij}\,\mathrm{d}_{ij}\right)\left(q_{\alpha ij}\right) \tag{22}$$

The d_{ij} on the right hand side can be further decomposed by multiplicatively decomposing the total distributive effects. Given the structure of C_n matrix:
$D = D_3D_2D_1$ where $D_3 = (I - C_{22})^{-1}$; $D_2 = C_{21}C_{13}$, and $D_1 = (I - C_{33})^{-1}$
The particular element for each household i and sector j can be selected from these three matrices.
Thus the contribution of an increase in output of a particular sector i to poverty alleviation can be decomposed multiplicatively into its two components: (i) the contribution due to the change in mean income of the poor across all groups and (ii) the sensitivity of the particular poverty measure to this change in average income of the poor.

Appendix 3:

A Financial- Structural Model of Liberalization and Economic Sanctions(FSCGE): The SCENIS approach and an illustrative model

The model was developed for applying to financial liberalizations and economic sanctions. However, with some modifications this can be applied to many other policy experiments/simulations as well. The most striking aspect of the model is the possibility of a financial crisis that results directly from the forces unleashed by the moves to liberalize finance quickly. This happens because of the weaknesses in the Banking/Financial sector which cannot cope with the demands arising from sudden liberalization. Significantly, such crises can occur even in a flexible or `managed float' regime. The persistence of the crisis in Asia during 1997-98 as well as the 2008 global crisis and its aftermath suggest that `structural' factors rather than fixed exchange rates were the underlying causes of the crisis. For sanctions, this model can test whether a more self-sufficient economy in the real sectors with limited financial openness fares better than a completely liberalized economy which then faces sudden and severe real and financial sanctions. Note that for production, finance and households as well as factors each equation can be expanded to many more; so given data availability, an

implementable model will have more than the 233 shown here. Typically, with the steady secular increase in computational power following Moore's law, we can implement 500-1000 eqn. or even larger models easily in the 2020s.

Equations of the FSGGE Model:

I. HOUSEHOLD AGRICULTURE (HAG)

1. $NW_{HAG}(t) = KAS_{HAG}(t-1) + DSB_{HAG}(t-1) + DPB_{HAG}(t-1) + P_Z(t)Z_{HAG}(t-1) + P^K_{HAG}(t)K_{HAG}(t-1) + S_{HAG}(t)$

Household net worth at eop (end of period) is = cash + initial deposit at private, state bank + the value of stock held at eop + value of capital, which is the amount of capital at the beginning of period multiplied by price at eop to account for capital gain + saving.

NOTE: Household Position is a net position. The assumption is that the households do not engage in borrowing activity. Household is a recipient of wages/salary, interest from deposit, and firm's profit. It does not borrow for consumption. A household may borrow for investment in a venture, however, once it takes a loan of this kind, then it no longer is classified as household. Depending on the type of business the household will be classified under a certain type of firm.

2. $QA_{HAG}(t) = NW_{HAG}(t) - P^K_{HAG}(t)K_{HAG}(t)$

Quantity of financial Assets of household Agriculture is equal to household net worth minus the value of physical capital at eop.

NOTE: Physical capital of household at eop -- $K_{HAG}(t)$ includes investment made during the year. See equations 11, 22, and 33.

3. $q_{HAG} = A^{HAG}_{SB}(i_{sb}/\bar{i}_{sb})^{\sigma_{HAG}-1} + A^{HAG}_{PB}(i_{pb}/\bar{i}_{pb})^{\sigma_{HAG}-1} + A^{HAG}_{Z}(r/\bar{r})^{\sigma_{HAG}-1} + A^{HAG}_{KAS}$

Agriculture households try to maximize the utility of return q_{HAG}, which is formulated using CES type harmonic mean return.

A^{HAG}_i = Distribution parameter

i_{SB}, i_{pb}, and r = interest rate at private, state bank and rate of return on capital (profit) respectively

$\bar{i}_{SB}, \bar{i}_{pb}$, and $\bar{r}$ = normal yield on bank (private and state bank) deposits and company's capital.

σ_{HAG} = elasticity of substitution

The agriculture household asset returns consist of interest from State Bank, Private Bank, the share of the firm's profit, and cash. Government security is not available for households to buy. Therefore there is no return from government security.

4. $\varnothing_{SB}^{HAG} = A_{SB}^{HAG} \dfrac{(i_{sb} / \bar{i}_{sb})^{\sigma_{HAG}-1}}{q_{hag}}$ → Share of deposit on state bank

5. $\varnothing_{PB}^{HAG} = A_{PB}^{HAG} \dfrac{(i_{pb} / \bar{i}_{pb})^{\sigma_{HAG}-1}}{q_{hag}}$ →Share of deposit on private bank

6. $\varnothing_{Z}^{HAG} = A_{Z}^{HAG} \dfrac{(r / \bar{r})^{\sigma_{HAG}-1}}{q_{hag}}$ → Share of equity

7. $\varnothing_{KAS}^{HAG} = A_{Z}^{HAG} \dfrac{A_{KAS}^{HAG}}{q_{hag}}$ → Share of Currency

The sum of $\varnothing_{sb}^{HAG}, \varnothing_{pb}^{HAG}, \varnothing_{Z}^{HAG}, \varnothing_{KAS}^{HAG}$ must equal to one

8. $D_{HAG} = \varnothing_{sb}^{HAG}(QA_{HAG}) + \varnothing_{PB}^{HAG}(QA_{HAG})$

Total Agriculture-households Deposit for each type of HH is equal to share of household deposit in state bank multiplied by total financial assets plus the share of household deposit in private bank multiplied by total financial assets.

9. $Z_{HAG} = \varnothing_{Z}^{HAG}(QA_{HAG})$

Total Agriculture-household stock/equity is share of stock x total financial assets

10. $KAS_{HAG} = \varnothing_{KAS}^{HAG}(QA_{HAG})$

Total Agriculture-household cash is share of cash x total financial assets

11. $K_{HAG}(t) = K_{HAG}(t-1) + I_{HAG}(t)$

Total Capital owned by Agriculture-household = initial capital + total investment at end of period.

II. HOUSEHOLD NON-AGRICULTURE (HNAG)

12.
$$NW_{HNAG}(t) = KAS_{HNAG}(t-1) + DSB_{HNAG}(t-1) + DPB_{HNAG}(t-1) + P_Z(t)Z_{HNAG}(t-1) + P^K_{HNAG}(t)K_{HNAG}(t-1) + S_{HNAG}(t)$$

13. $$QA_{HNAG}(t) = NW_{HNAG}(t) - P^K_{HNAG}(t)K_{HNAG}(t)$$

14. $$q_{HNAG} = A^{HNAG}_{SB}(i_{sb}/\bar{i}_{sb})^{\sigma_{HNAG}-1} + A^{HNAG}_{PB}(i_{pb}/\bar{i}_{pb})^{\sigma_{HNAG}-1} + A^{HNAG}_{Z}(r/\bar{r})^{\sigma_{HNAG}-1} + A^{HNAG}_{KAS}$$

15. $$\varnothing^{HNAG}_{SB} = A^{NHAG}_{SB}\frac{(i_{sb}/\bar{i}_{sb})^{\sigma_{HNAG}-1}}{q_{hnag}}$$ → Share of deposit on state bank

16. $$\varnothing^{HNAG}_{PB} = A^{NHAG}_{PB}\frac{(i_{pb}/\bar{i}_{pb})^{\sigma_{HNAG}-1}}{q_{hnag}}$$ → Share of deposit on private bank

17. $$\varnothing^{HNAG}_{Z} = A^{HNAG}_{Z}\frac{(r/\bar{r})^{\sigma_{HNAG}-1}}{q_{hnag}}$$ → Share of equity

18. $$\varnothing^{HNAG}_{KAS} = A^{HNAG}_{Z}\frac{A^{HNAG}_{KAS}}{q_{hnag}}$$ → Share of Currency

The sum of $\varnothing^{HNAG}_{sb}, \varnothing^{HNAG}_{pb}, \varnothing^{HNAG}_{Z}, \varnothing^{HNAG}_{KAS}$ must equal to one

19. $$D_{HNAG} = \varnothing^{HNAG}_{sb}(QA_{HNAG}) + \varnothing^{HNAG}_{PB}(QA_{HNAG})$$

20. $$Z_{HNAG} = \varnothing^{HNAG}_{Z}(QA_{HNAG})$$

Total Nonagricultural-household stock/equity is share of stock x total financial assets.

21. $$KAS_{HNAG} = \varnothing^{HNAG}_{KAS}(QA_{HNAG})$$

Total Non-agriculture-household cash is share of cash x total financial assets

22. $$K_{HNAG}(t) = K_{HNAG}(t-1) + I_{HNAG}(t)$$

Total Capital owned by Non-agriculture-household = initial capital + total investment at end of period.

III. HOUSEHOLD TOTAL (h)

23. $NW_h(t) = NW_{HAG}(t) + NW_{HNAG}(t)$

24. $QA_h(t) = QA_{HAG}(t) + QA_{HNAG}(t)$

25. $qh = q_{HAG} + q_{HNAG}$

26. $\varnothing_{SB}^{h} = Q_{SB}^{HAG} + Q_{SB}^{HNAG}$ → Share of deposit on state bank

27. $\varnothing_{PB}^{h} = Q_{PB}^{HAG} + Q_{PB}^{HNAG}$ → Share of deposit on private bank

28. $\varnothing_{Z}^{h} = Q_{Z}^{HAG} + Q_{Z}^{HNAG}$ → Share of equity

29. $\varnothing_{KAS}^{h} = Q_{KAS}^{HAG} + Q_{KAS}^{HNAG}$ → Share of Currency

30. $D_h = D_{HAG} + D_{HNAG}$

31. $Z_h = Z_{HAG} + Z_{HNAG}$

32. $KAS_h = KAS_{HAG} + KAS_{HNAG}$

33. $K_h(t) = K_{HAG}(t) + K_{HNAG}(t)$

IV. FIRMS

34 - 37. $DEF = P_i^k I_i - S_i$ i = FAG, FMIN, FTS, FI

38-41. $Z_i(t) = Z_i(t-1) + \alpha_i + \beta_i\left[(DEF_i(t) / P_i^k(t)\right]$ i = FAG, FMIN, FTS, FI

42s-

45. $QL_i(t) = DEF_i(t) - P_z(t)\left[Z_i(t) - Z_i(t-1)\right] + LSB_i(t-1) + LPB(t-1) + LF_i(t-1)$
i = FAG, FMIN, FTS, FI

Another part of the deficit must be financed through borrowing. The required amount of total borrowing at time t ($QL_i(t)$ must be equal to the amount of deficit minus the value of outstanding equity increase at the end of period plus last year's outstanding loan from state bank, private bank, and foreign loan.

The firm's total loan comes from different sources. From the State Bank, Private Bank, and from foreign loan, with distribution parameter of A_x^i, and interest rate on bank loan of i_l, interest rate of foreign loan of i_f. Using CES specification, the firms try to minimize the cost function based on capitalized borrowing cost of $\bar{i}_{xi} / i_x$.

46.-49. $q_i = A_{sb}^i (\bar{i}_{li} / i_l)^{\sigma_i - 1} + A_{pb}^i (\bar{i}_{li} / i_l)^{\sigma_i - 1} + A_{fl}^i (\bar{i}_{fli} / i_{fl})^{\sigma_i - 1}$

i = FAG, FMIN, FTS, FI

q_i is the average of capitalized interest rates for each type of the firm.

NOTE: It is assumed that interest rate is not the key explanatory factor for the firm's decision to choose between state bank or private bank. The image of private bank includes having better service, faster and easier to deal with and that of state bank as safer, bigger, more helpful when a firm is in trouble. Firms borrowing from the State bank are restrained by many requirements and its reputation for inflexibility must be taken into account when one tries to find out why there are certain preferences toward one or another.

The share of loan from state bank, private bank, and foreign loan of each firm is given by equation 50-61. The sum of the share must equal to 1.

50-53. $\varnothing_{sb}^i = A_{sb}^i \dfrac{(\bar{i}_{Li} / i_l)^{\sigma_i - 1}}{q_i}$ i = FAG, FMIN, FTS, FI

54-57. $\varnothing_{pb}^i = A_{pb}^i \dfrac{(\bar{i}_{li} / i_l)^{\sigma_i - 1}}{q_i}$ i = FAG, FMIN, FTS, FI

58-61. $\varnothing_{lf}^i = A_{lf}^i \dfrac{(\bar{i}_{fli} / i_{fl})^{\sigma_i - 1}}{q_i}$ i = FAG, FMIN, FTS,FI

The demand for loan from each type of bank by each type of firm is given in equation 62 to 73.

62-65. $LSB_i = \varnothing_{lsb}^i QL_i$ i = FAG,FMIN,FTS, FI

Firm's demand for loan from state bank

66-69. $LPB_i = \varnothing_{lpb}^i QL_i$ i = FAG,FMIN,FTS,FI

Firm's demand for loan from private bank

70-73. $LF_i = \varnothing_{lf}^i Ql_i$ i = FAG,FMIN,FTS,FI

Firm's demand for loan from abroad

74. $L = \sum_{i=FAG}^{FI} LSB_i + \sum_{i=FAG}^{FI} LPB_i$

Total domestic loan = total loan from state bank and from private bank to all firms.

75-78. $K_i(t) = K_i(t-1) + I_i(t)$ $K_i(t) = K_i(t-1) + I_i(t)$

Total capital stocks held by firms at the end of period equal to capital stock at the beginning plus investment at the end of period.

V. GOVERNMENT (G)

79. $FL_G(t) = FL_G(t-1) + e(\Delta FL_G^{\$})$

Foreign Loan at time t (eop) = Outstanding Loan from abroad at the beginning plus New Loan from abroad in local currency. The additional loan amount is exogenous, valued at foreign currency (dollar) but converted into local currency by multiplication with exchange rate.

80. $QL_G = LPB_G(t-1) + LSB_G(t-1) + LCB_G(t-1) + P_G^k(t)I_G(t) - S_G(t) - e(\Delta LF_G^{\$})$

Government Demand for domestic credit = Govt. Investment + initial borrowing from the banking system (SB, PB, and CB), less Government Saving and Loan from abroad.

NOTE: The Government demand for domestic credit is a net position with loan payment included (if any). Any amount of loan repayment from the government to the banking system will appear as reduction in saving by the same amount. Government investment is exogenous.

81. $L_G = \left[\alpha_G^{SB} + \beta_G^{SB}(DEP_{SB})\right] + \left[\alpha_G^{PB} + \beta_G^{PB}(DEP_{PB})\right]$

Bank Credit to Government = initial claims of government, certain resources in SB and PB + statutory liquidity ratio β multiplied by Deposit of SB and PB.

82. $LCB_G = QL_{G-}L_G$

Central Bank Loan to Government; it is the government balance sheet residual i.e. the portion of total loan to government that is not fulfilled by commercial banking sector.

83. $K_G(t) = K_G(t-1) + I_G(t)$

VI. COMMERCIAL STATE BANK PORTFOLIO (SB)

84. $DSB = DSB_{HAG} + DSB_{HNAG}$

Deposits in the state bank come from household, agriculture and non-agriculture, at a fixed rate of deposit i_d.

85. $RR_{SB} = u_1^{SB} + u_2^{SB}(DEP^{SB})$

Reserve requirement in the central bank = marginal amount u_i + a fraction of deposits.

86. $QL_{SB} = DSB + ADVCB_{SB} - LSB_G - RR_{SB} + LIK_{SB}$

Domestically available resources or the total loan can be given from domestic resources = deposit + advances from central bank + liquidity credit from central bank - loan to Govt. - reserve requirement.

87. $DCB_{SB} = RR_{SB}\left[1 + \theta(i_{lsb} / \bar{i}_l)^{-\gamma}\right]$

The State Bank reserve at the central bank is always higher than the requisite reserve requirement. The excess reserve is a function of interest rate charged by the state bank for loan. The higher the rate the lower the excess reserves.

88. $LF_{SB} = \left(L_G^{SB} + DCB_{SB} + \sum_{i=FAG}^{FL} LSB_i\right) - (DSB - REDSCNT - NW)$

The state bank resources are deposits, rediscount from the central bank and net worth. The total resources available will be used to create loans to government; commercial loans to firms and some will be used as deposits to central bank. If the available resources are less than the loan created, then foreign loan is needed.

VII. COMMERCIAL PRIVATE BANK PORTFOLIO (PB)

89. $DPB = DB_{HAG} + DPB_{HNAG}$

90. $RR_{PB} = u_1^{PB} + u_2^{PB}(DEP^{PB})$

91. $QL_{PB} = DPB + ADVCB_{PB} - LPB_G - RR_{PB} + LIK_{PB}$

Available resources (domestic) = deposit + advances from central bank - loan to Govt. - reserve requirement + liquidity credit from central bank

92. $DCB_{PB} = RR_{PB}\left[1 + \theta(i_{lpb} / \bar{i}_l)^{-\gamma}\right]$

93. $LF_{PB} = \left(L_G^{PB} + DCB_{PB} + \sum_{i=FAG}^{FL} LPB_i\right) - (DPB - REDSCNT - NW)$

VIII. COMMERCIAL BANK TOTAL

94. $DEP = DSB + DPB$

Total deposit taken by commercial bank.

95. $RR = RR_{SB} + RR_{PB}$

Total reserve deposit at central bank.

96. $QL + QL_{SB} + QL_{PB}$

Total resources available domestically.

97. $i_L = \bar{i}_L\left[\frac{L(i / i_F)^{\in}(i_R / i_R)^{\phi}}{\alpha QL}\right]^{1/\delta}$

Market clearing interest rate i_L = Loan interest rate; i_F =Foreign Loan interest rate; i_R = Rediscount Interest rate.
$\in, \phi,$ and δ = loan supply interest rate elasticities, α = loan supply intercept.

98. $DCB = DCB_{SB} + DCB_{PB}$

Total deposit of commercial bank at central bank, including required reserve.

99. $LF = LF_{SB} + LF_{PB}$

Total residual items. The foreign loan needed by the domestic commercial banking sector to cover excess loan over domestic resources available.

IX. CENTRAL BANK PORTFOLIO

100. $FL = FL_{SB} + FL_{PB} + FL_{FAG} + FL_{MIN} + FL_{IS} + FL_I + FL_G$

101. $ADVCB = ADV_{CEL} + \varnothing_4\left[(FL_{SB} + FL_{PB}) - FL_{CEL}\right] - \gamma_4 (DEPCB - RR)$

Total advances available from central bank = ceiling for advances less state bank's and private bank's advances, less net deposit at central bank.

102. $KAS_{CB} = KAS_H$

103. $NWCB(t) = NWCB(T-1) + DISCR$

DISCR = Accounting discrepancy of state owned firms

104. $CBREV(t) = FL(t) - FL(t-1) - SF(t) + CBRES(t-1)$

Central Bank's reserve = net foreign loan at eop less foreign saving plus reserve at the beginning of the period.

105. $NWRES = CBLG + ADVCB + CBRES - KASCB + DEPCB - NWCB$

X. OTHER FINANCIAL BALANCE

106. $P_Z = \dfrac{ZZ_H}{(Z_{FAG} + Z_{MIN} + Z_{FTS} + Z_I}$

107. $INT = \left(A_{SB}^H + A_{PB}^H + i_L L_{SB} + i_L L_{PB}\right) + \left(A_{CB}^{SB} + A_{CB}^{PB} + i_L L_{SB} + i_L L_{PB}\right)$

Interest payment.

XI. PRODUCTION AND PRICE FORMATION

108 - 114. $P_i^k = \xi_4 P_4 + \xi_7 P_7$` i = 1,2,3,4,5,6,7

P_i^k = Price indexes for each sector's capital stock; capital goods come from the industrial sector and from import.

115 - 121
$$P_{i0}^* = [(\Theta_{1i})^{\sigma_i^{int}} (P_1)^{1-\sigma_i^{int}} + (\Theta_{2i})^{\sigma_i^{int}} (P_2)^{1-\sigma_i^{int}} + (\Theta_{3i})^{\sigma_i^{int}} (P_3)^{1-\sigma_i^{int}} + (\Theta_{5i})^{\sigma_i^{int}} (P_5)^{1-\sigma_i^{int}} + (\Theta_{6i})^{\sigma_i^{int}} (P_6)^{1-\sigma_i^{int}} + (\Theta_{7i})^{\sigma_i^{int}} (P_7)^{1-\sigma_i^{int}}]^{1/(1-\sigma_i^{int})}$$

i = 1,2,3,4,5,6,7; P_{i0}^{*} = cost indexes for sectoral intermediate uses, input output coefficient = a_{ji}^{*} and constant elasticities of substitution among intermediate inputs = σ_i^{int}

122 - 128. $a_{ji}^{*} = \left[\frac{P_i^{*} \Theta_{ji}}{P_j} \right]^{\sigma_i^{\text{int}}}$ j = Sector ; i = Market participant HAG - FI

a_{ji}^{*} = Input Output Coefficient.

129 - 135.

$$P_i^c = \left[(\Theta_{Li})^{\sigma_i^{FIN}} (W_i)^{1-FIN} + (\Theta_{Ki})^{\sigma_i^{FIN}} (r_i + \delta_i)(P_i^K)^{1-FIN} \right]^{1/(1-\sigma^{1-FIN})} + (\Theta_i^{*})^{\sigma_i^{FIN}} (P_i^{*})^{\sigma_i^{FIN}}$$

CES Cost function = labor cost + fixed capital cost + cost of intermediate goods used

i = sector/commodity 1-7

σ_i^{FIN} = Elasticities of substitution

136 - 142. $L_i = (P_i^c \Theta_{Li} / W_i)^{\sigma_i^{FIN}} X_i$ i = Hag - FI

Level of employment.

143 - 149. $r_i(t) = \frac{1}{P_i^K(t-1)} \left[P_i^c(t) \Theta_{Ki} \left(\frac{X_i(t)}{K_i(t-1)} \right)^{1/\sigma_i^{INT}} \right] - \delta_i$

Sectoral rates of profit are determined by output level X and incoming capital stocks $K_i(t-1)$

i = HAG - FI

150. $r(t) = \frac{r_{HAG}(t) P_{HAG}^K(t) K_{HAG}(t-1) + \cdots r_{FI}(t) P_{FI}^K(t) K_{FI}(t-1)}{P_{HAG}^K(t) K_{HAG}(t-1) + \cdots P_{FI}^K(t) K_{FI}(t-1)}$

Average rate of profit (used for household portfolio decisions) depends on sectoral rate of profit

151 - 157. $X_{ji} = a_{ji}^{*} \left[\frac{P_i^c \Theta_i^c}{P_i^c} \right]^{\sigma_i^{FIN}} X_i$ j = Commodity 1 - 7

I = Mkt Participant HAG - FI

Intermediate goods flow using a^{*}_{ji} coefficient of input output defined with regard to the intermediate aggregate. (Flow of goods j (sector j) to market participant i; i.e. demand of good j by market participant i).

158 - 164. $Mi = \left[\frac{P_i \Theta_{0i}}{e(1+t_0)P_0} \right]^{\sigma_i^{FIN}} X_i$

i = Sector 5, 6 & 7 (Import Mining and Import other)
Mi = Derived demand for import

165 - 171. $P_i = P_i^c (1 - t_i)$ i = 1-7

After tax prices for each sectors/commodity

XII. INCOME GENERATION AND SAVING

172. $W = w_{HAG} L_{HAG} + \cdots w_{FI} L_{FI} + W_{fh} - W_{hf}$

173 - 179. $\Pi_i(t) = r_i(t) P_i^K(t) K_i(t-1) + \Pi_{fi} - \Pi_{if}$

i = HAG, HNAG, SB, PB, FAG, FMIN, FTS,FI.

Profit income flows.

180 - 185. $OS_i = (1 - \upsilon_i)\Pi_i + SUB$ i = SB, PB, FAG, FMIN, FTS,FI.

Operating surplus of firms i is part of profit after the household share of υ
Government owned firm (Bank) receives subsidy SUB

186 - 191. $S_i = (1 - d_i - t_i^{dir}) OS_i$ i = SB, PB, FAG, FMIN, FTS,FI

Saving of the firm, equal to operating surpluses less dividend d payment less direct taxes t_i^{dir}.

192. $Y_{HAG} = W_{HAG} + d_{SB}^{HAG} OS_{SB}^{HAG} + \cdots d_{FI}^{HAG} OS_{FI}^{HAG} + v_{SB}^{HAG} \Pi_{SB}^{HAG} + \cdots v_{FI}^{HAG} \Pi_{FI}^{HAG} + TRAN_{gHAG} + TRAN_{fHAG}$

Household AG income = wages +dividend + share of profit +transfer from G and abroad.

193. $Y_{HNAG} = W_{HNAG} + d_{SB}^{HNAG} OS_{SB}^{HNAG} + \cdots d_{FI}^{HNAG} OS_{FI}^{HNAG} + v_{SB}^{HNAG} \Pi_{SB}^{HNAG} + \cdots v_{FI}^{HNAG} \Pi_{FI}^{HNAG} + TRAN_{gHNAG} + TRAN_{fHNAG}$

194. $Y_h = Y_{HAG} + Y_{HNAG}$

Total HH income is the sum of HAG Income and HNAG income

195. $D_{HAG} = D_0^{HAG} + (1 + s_{HAG})Y_{HAG} - TRAN_{HAGf} - t_{HAG}^{dir} Y_{HAG} - (A_5^h + i_L L_5) + Y_{HAG} NW_{HAG}$

Consumption demand = initial /basic consumption + consumption - transfer abroad - direct taxes

196.
$D_{HNAG} = D_0^{HNAG} + (1 + s_{HNAG})Y_{HNAG} - TRAN_{HNAGf} - t_{HNAG}^{dir} Y_{HNAG} - (A_5^h + i_L L_5) + Y_{HNAG} NW_{HNAG}$

197. $D = D_{HAG} + D_{HNAG}$

198. $S_{HAG} = Y_{HAG} - TRAN_{HAGf} - t_{HAG}^{dir} Y_{HAG} - (A_f^{HAG} + i_L L_5) - D_{HAG}$

199. $S_{HNAG} = Y_{HNAG} - TRAN_{HNAGf} - t_{HNAG}^{dir} Y_{HNAG} - (A_f^{HNAG} + i_L L_5) - D_{HNAG}$

200. $S_h = S_{HAG} + S_{HNAG}$

201. $Y_g = \sum_{i=1}^{4} t_i P_i^c X_i + et_0 P_5 M_5 + et_0 P_6 M_6 + et_0 P_7 M_7 + t_h^{dir} Y_h + \sum_{i=SB}^{FI} t_i^{dir} OS_i + \sum_{i=1}^{4} t_i^{\exp} P_i^c E_i$
t

Government income consists of the sum of indirect taxes from all sectors + domestic currency of import indirect taxes + direct taxes from household + the sum of direct taxes of firms + export taxes.

202. $S_g = Y_g - \sum_{i=1}^{7} P_i G_i - TRAN_{gh} - (A_5^g + i_l L_g)$

203. $S_f = \sum_{i=1}^{7} \Pi_{if} + W_{hf} + \sum_{i=5}^{7} eP_i M_i + TRAN_{hf} + TRAN_{gf} - \sum_{i=1}^{4} (1 + t_i^{\exp}) P_i^c E_i - W_{fh} - \sum_{i=1}^{4} \Pi_{fi} - TRAN_{fg} - TRAN_{fh}$

Current Account Deficit in foreign currency terms is converted to domestic currency, with export tax rate of $t_i^{\exp}$

XIII. FINAL DEMAND DETERMINATION

204. $\tilde{D} = \sum_{i=1}^{7} \Theta_i^{dem} P_i$ i = 1-7

205 - 211. $C_i = \Theta_i^{dem} + (\alpha_i^{dem} / P_i)(D - \tilde{D})$

i = 1-7

212 - 215. $I_i(t) = \left[I_{0i} + \omega_i \left\{ r_i(t) - i_l(t) \right\} \right] K_i(t-1)$

i = firms ;FAG - FI.

Investment demands of firms depend positively on rate of profit r_i and negatively on loan interest rate i_l. The firm investment parameter is ω_i.

216 - 217 = $I_i(t) = \left[I_{0i} + \omega_i \left\{ r_i(t) \right\} \right] K_i(t-1)$ i = SB and PB

State bank and private bank demand for investment depend positively on the rate of profit. As observed, investment demands of firms depend positively on rate of profit r_i and negatively on loan interest rate. However, a simultaneous increase in the loan and deposit rate will net a zero effect. The decisive factor in this case is the spread between loan - deposit rate. But the spread will correlate with rate of profit thus the spread effect on investment demand has been reflected through the inclusion of r_i.

218. $I_{HAG} = I_{0HAG} + \omega_{HAG}^{i} i_l + \omega_{HAG}^{y} (Y_{HAG} / P_{HAG}^{k})$

219. $I_{HNAG} = I_{0HNAG} + \omega_{HNAG}^{i} i_l + \omega_{HNAG}^{y} (Y_{HNAG} / P_{NHAG}^{k})$

220. $I_h = I_{HAG} + I_{HNAG}$

Household demand for investment is a function of interest rate (with investment parameter ω^i) and real income (investment parameter W^y).

221. $I_g = I_{0g}$

222 - 225. $E_i = E_{0i} \left[\frac{e P_f^E}{(1 + t_i^{Exp}) P_i^c} \right]^{\eta}$

Export depends on the ratio of price of foreign goods and domestic border price, the elasticity is η. i = 1-4

XIV. COMMODITY BALANCES

226 - 232. $Xi = \sum_{j=HAG}^{FI} X_{ij} + C_i + G_i + \xi_i \left(\sum_{j=HAG}^{FI} I_j \right) + p_i \left[\sum_{i=1}^{7} \delta_i K_i(t-1) \right]$

i = Commodity 1-7; j = HAG - FI

p_i = sectoral composition of depreciation

XV. SAVING - INVESTMENT BALANCE

233. $$SI = \sum_{i=HAG}^{FI} S_i + S_f - \sum_{i=HAG}^{FI} P_i^k I_i$$

Saving of all sectors (excluding the G) plus foreign saving less investment of all sectors (foreign saving not included) will be zero if overall macroeconomics balance is to be maintained.

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