The Global Structural Macroeconometric Modelling Project

Identifying global macroeconomic interdependencies using a revolutionised Global Vector Autoregression ***GVAR***

The aim of the project is to identify channels of macroeconomic interdependence and global synchronisation of financial markets, utilising a substantial sum of international data. A new modelling strategy is introduced based on the Global Vector Autoregression (GVAR) model pioneered by H. M. Pesaran and others, Pesaran (2004) atheoretical model is further upgraded in regional coverage and, more importantly, in providing detailed structural modelling incorporating theory-based channels of interdependence and cross country transmission mechanisms to be empirically tested and identified. With research outcomes interpreted in a policy formulation context.

The project serves as a baseline for prospective assignments within a Central Bank research department and forms as prospective PhD thesis.

Objectives (*Motivation*)

- **Provide a Long Run Structural Modelling of Key Economic Regions.**
- **Testing the Validity of Long-Run relations suggested by economic theory.**
- **Modelling macroeconomic interdependence and transmission mechanisms at a global scale.**
- **Incorporating global geopolitical constraints, financial and political events.**
- **Examine Oil Price hikes and Stock Market Synchronisation.**

Intended Outcomes

- **Contribute to the literature in a ‘pure research’ context (prospective PhD dissertation).**
- **Informing Policy formulation through usage of the new "Stylized Facts" & Improving Forecasts.**
- **Developing specialised Central Banking software for Macroeconometric policy modelling.**

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The increased process of globalisation of the world economy has several implications on policy formulation undertaken by the Central Bank of a Small Open Economy (SOE) as it is further exposed into global inevitable shocks and fluctuations, this research aims to reveal the existing uncertainty on the nature of macroeconomic interactions and its policy implications, providing the literature and policy makers with a modernised realistic econometrically investigated model of the global economy using the maximum available actual national and international data, implementing an updated Global Error Correction Model by using an underlying Global Vector Autoregression GVAR.

The central question

The main problem in which this research is based on could be simply put in the form of

"What are the effects of policy actions and non-policy shocks of economy X on the economy of Y and the rest of the world?"

this is answered mainly through the GVAR post-estimation construction of an Impulse Response Functions IRF, yet the research covers wide aspects of macroeconometric modelling and the methodology could be applied into various applications of international macroeconomics and finance; from the investigation of the Long Run equilibrium of the IS-LM-BP model, exchange rate dynamics and the Long Run relations of PPP,UIP, the various income, monetary and relative price macroeconomic transmission mechanisms, the global transmission of the interest rates and the contagion effects of currency crisis.

Our contribution to the previous literature is twofold; firstly this research provides an updated extension of a GVAR model that overcomes the shortcomings of the GVAR model developed by Pesaran et al (2004), the approach leads to providing meaningful impulse response analysis and also extends the literature on multivariate models incorporating structural change tests and possibly Non-linearity tests. Secondly, we contribute to the empirical literature on macroeconometrics and macroeconomic interdependence by applying the GVAR methodology to model the interactions within the global economy; the findings of the research are expected to provide valid implications for policy formulation and international policy co-ordination.

The Motivation

The motivation of this research is to reveal some of the existing uncertainty on the nature of the macroeconomic interactions between economies in a quantitative assessment of the causal relationships in the contemporary global economy, through the proposed global macroeconometric modelling of the GVAR, the interdependence of the industrial economies and the spillovers of policy and non-policy shocks in the major industrial economies and its consequences on developing and emerging markets economies under the increased -voluntary or compulsory- trend of integration into the world economy, applying Small Open Economy SOE analysis that targets policy formulation, the research outcomes has a current significant policy implications for Central Banks of SOEs under growing exposure to global shocks, additionally the research methodology of implementing the modified GVAR and its outcomes could also advise policy of International Organisations.

Summary of the research objectives

- Provide a detailed long run structural analysis of individual key economies and regions/country groups, improving the atheoretical GVAR model pioneered by Pesaran et al (2004) by imposing and testing long run relations suggested by economic theory following the methodology of Garrat et al (2003).
- Investigate the dynamic properties of the macroeconomic interactions through the development of GVAR and measurement of persistence of shocks and impulse response analysis, emphasising on the likely spillovers of policy and non-policy shocks and transmission mechanisms among interdependent economies.
- Provide a framework for modelling several transmission mechanisms at a global scale (the international transmission of inflation, the phenomena of global interest rate transmission and the contagion of currency crisis).
- Incorporating oil price and stock market indices as a representation of global political and financial events respectively, as well as allowing for geographic and geo-political constraints.
- To obtain new facts reflecting significant implications for policy including the conduct of monetary policy, the exchange rate regime and to design of the foreign currency basket adjustment peg for SOEs.

Theoretical Background behind the GVAR modelling

The macroeconomic interdependence transmission mechanisms provide theoretical justifications for a set of identification schemes reflecting different aspirations could be investigated to reveal which mechanism hold in the long run, the macroeconomic interdependence mechanisms are typically categorised as:

Resulting from the trade account of the balance of payments; the higher is the openness of the economy (the proportion of the country's trade to GDP) the more important these linkages are expected to be.

Monetary Impulses

Monetary impulses are transmitted via their effects on the Interest rates and the capital account of the BOP, e.g. *beggar-thy-neighbour policy* as a transmission of monetary policy impulses. These effects depend on the degree of integration between the real and financial sectors of the economy and on the degree of capital mobility.

Relative price adjustments

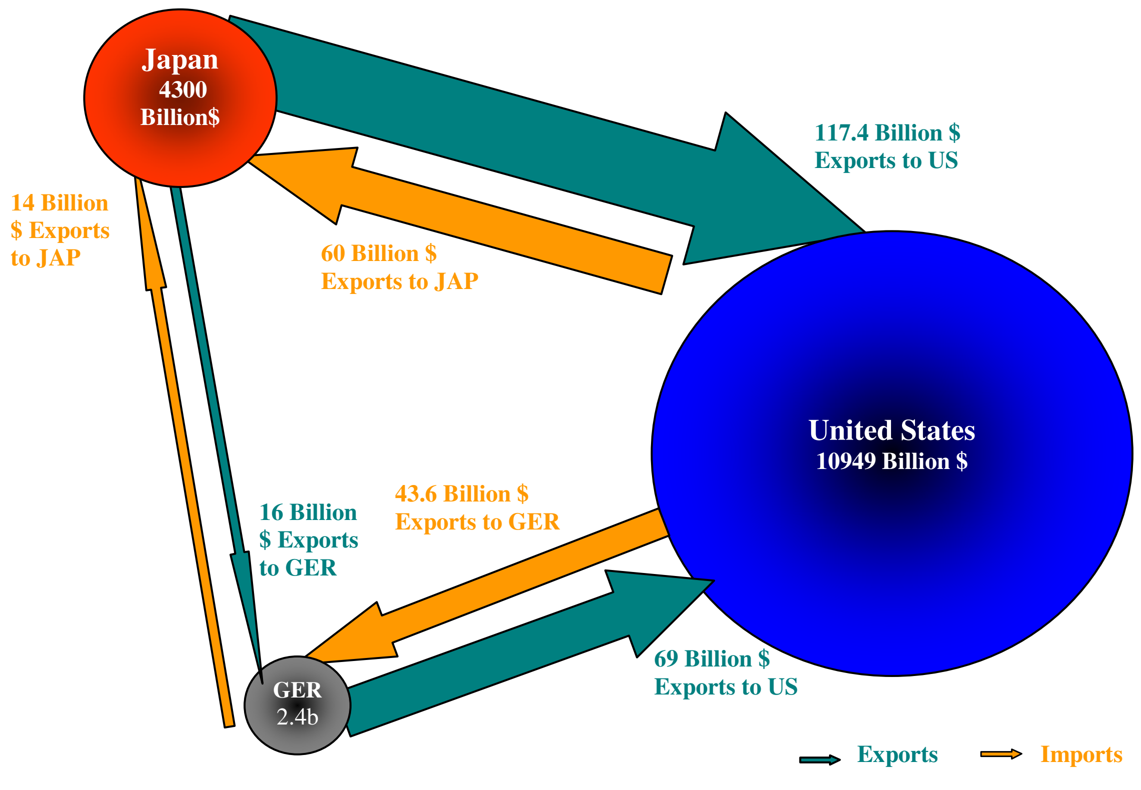
Changes in prices have an effect on Terms of Trade (TOT) and this is the mechanism of how economies affect each other, the speed of such an adjustment will depend on the degree of price flexibility and on the country's wage-price nexus.

Beyond the above transmission mechanisms and the theory of the long run equilibrium of IS-LM-BP the modelling strategy is built on firstly; the existing theoretical doctrines in international macroeconomics and finance, and furthermore; the philosophy behind the modelling strategy is inspired by an original fact-based hypothesis introduced in this research explained in the following theoretical propositions:

The Gravitation Hypothesis

The likely spillover effects of policy actions and non-policy shocks originating in the trading partners of a small open economy SOE are often expected to be larger due to the 'relative importance' of the foreign economy, the spillover effect relies according to this hypothesis is to be of higher significance depending on two factors; the size of the economy of the trade partner and the SOE trade volume with that trading partner, a relatively larger economy trading partner would affect the SOE under consideration more severely than another trading partner of a relatively equal or smaller size, the magnitudes of spillovers effects –whatever its nature- on one or all the macroeconomic variables has the direction of 'large to small economies', from another perspective the relative size gravitation proposition could be illustrated by the fact that a large economy like the US pursuing an expansionary monetary policy at a given point of time leading for a growth of 1% in output (the own country effect), this excess of economic activity represents a high proportion of another economies or even larger than some SOEs and the US would demand more imports boosting the exports of the SOE and the relative importance of the US in the international trade of the considered SOE would increase substantially as the US becomes (and usually is) a major exporting market and hence its straight forward how the spillovers of the US would rather be of massive importance.

Figure 1: Trade Volumes between the Largest Three Economies in The World



Sources:
Data on GDP from the World Bank's [Quick reference Tables](#).
Data on International Trade Flows are from the IMF *Direction of Trade Statistics* **DOTS**, using ESDS International data

This hypothesis motivates the specification and the construction of the modelling strategy, it could also employed explain some economic phenomenal and their policy implications for example, the phenomena of the global transmission of the interest rates, further discussed below. This application has also a theoretical concern for further investigation of the Uncovered Interest

Parity (UIP) and the Real Interest Parity (RIP) empirically investigated by Cumby and Mishkin (1984) and Mishkin (1984).

The relative size gravitation proposition is an analogy of the gravity laws in physics as the "gravitation" between two objects is from the object with a larger mass to the lower mass, a similar pattern is expected to be weakly applicable among economies where trade barriers act as "resistance to gravity forces".

Integration into the Global Economy: Two propositions

The aim of the Global macroeconometric modelling is to inform policy formulation of central banks of SOEs by identifying macroeconomic interdependencies and the impacts of the foreign shocks and global macroeconomic fluctuations on the SOE, on the mechanism of the domestic policy correspondence to such shocks under increased integration with the global economy, two propositions arise for having 'Best Response': the *"Lock 'n' Key"* and the *"Induced fit"* propositions, in an analogy to the mechanism of the enzymes in biology, the Lock 'n' key proposition suggests an optimal means of integration; into a particular foreign economy as a trading partner, in specialising in a specific exporting sector or in having an optimal policy rule (reaction function), a set of policy instruments as exchange rate regimes, tariffs and trade barriers optimised to domestic policy targets forming a 'key' in locking the process of integration. On the other hand the *'induced fit'* shares the view that for every foreign shock a there exist a structural adjustment of the home economy in one or all of the monetary, fiscal and exchange rate policies that enables the economy to internalise the adverse effects of exogenous inevitable shocks to the SOE or to enhance a positive spillover caused by a trading partner or by a global phenomena.

The phenomena of the global transmission of the interest Rates

The flexible methodology of the GVAR would also allow to examine in a global setting the phenomena of international transition of the interest rate, the increased comovements in real interest rates in the long run observed and provided in the literature by Fukao and Hanazaki (1986), and recent empirical evidence provided in Chin & Frankel (1995) Frankel et al (2000), (2004) showing that only US, Japan and Germany can independently set their interest rates, in which these economies are the largest three economies in the world and also the major trading partner in both imports and exports representing the majority of the export market for many economies.

The research of Frankel et al (2000), (2004) could be further investigated and linked with the monetary impulses transmission mechanisms of the macroeconomic interdependence through the effect of interest rates on monetary aggregates following the monetary policy interpretation of Sims (1992), this phenomena indicates an important policy implication regarding the independence of monetary policy for an SOE, and the doubtful question that whether monetary policy should address only the domestic business and financial developments, this analysis is also relevant to the discussions of the propositions of integrating with the global economy.

Beggar-thy-neighbour policies

The methodology of the GVAR allows to econometrically investigate scenarios of 'beggar-thy-neighbour' policy, where an expansionary monetary policy in the US for example by lowering the Federal Fund Rate would first lead to an expansion in the US money supply leading to an increase in the US output and price level, the increased income reflected by the rise in output and the relative price effects would attract importing from abroad increasing the *marginal propensity* *to import*, for which for a large economy like the US this would have a severe international consequences, as the export-oriented economies (like South east Asia) would boost its exports leading to a domestic expansion in output putting pressure on the domestic interest rate to rise, given the current high capital mobility, the expected capital outflow from the US to these economies, the Balance of Payments surplus of the US will result into a depreciation in the value of the US dollar and appreciate the domestic currencies of the export-oriented economies leading to domestic inflation reducing the competitiveness of these economies and substitute consumption away from their goods and services lowering economic activity, and hence this reveals how the US expansionary policy is beggaring other economies as the US expansion of output lead to a reduction output of its trading partners.

Biased Capital Mobility

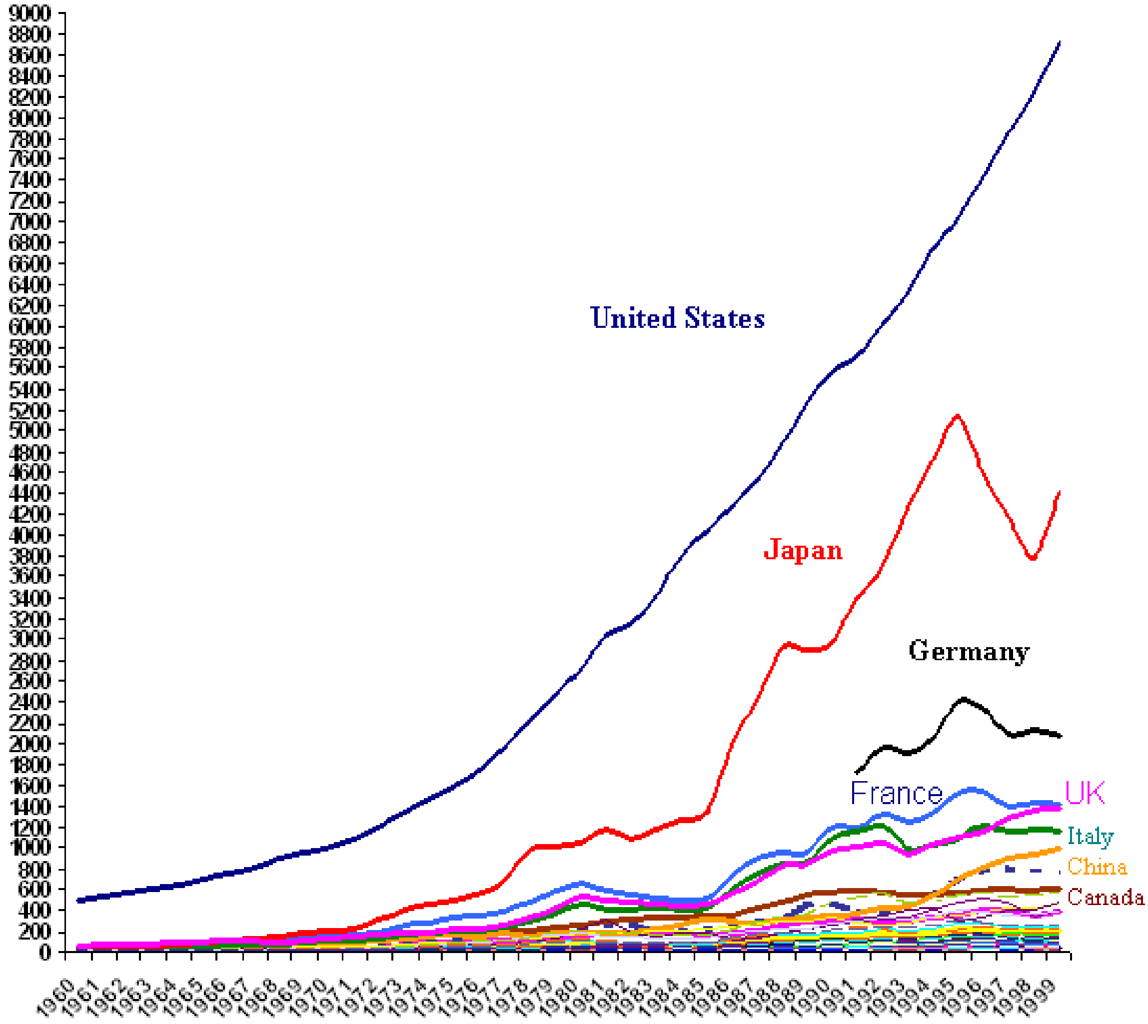
Another "pure" theoretical proposition related to the latter two and is inspired by some facts from the past experiences of the conduct of monetary policy, as raising the interest rates failed in attracting foreign capital flows opposite to the textbook-like obsolete models of the macroeconomy. Despite the undisputed massive increase in capital mobility globally in the last two decades, still the response of capital flows to the SOEs outside the OECD is low in magnitude or painfully slow, while in the opposite case the capital flow is instantly significant and often dangerous as a "Capital Flight" being in some cases one of the factors causing currency crisis, such an asymmetry is caused directly by legal capital flows and non-floating exchange rate regimes or indirectly because of factors as the level of financial system development, informational imperfections and risk aversion of international financial agents and lastly political disorders and similar 'signalling' effects.

These notions of the asymmetry of capital mobility suggests a non-linear BP curve in modelling the macroeconomic interdependencies and such a 'Biased' mobility of capital has a strong implications on the transmission of the interest rate that gave this research more original insights and served as further motivation.

Output co-movements and the 'Myth' of Convergence

In output fluctuations there is also a secular trend that is often described as a 'common' trend, the fact that there is short run interdependence in output as a result of monetary impulses interdependence and interest rates linkages, apart from that, output are believed to be linked with independent technological shocks and that lead to a doctrine suggesting a form of 'Convergence' of the economies in the world, and by opening up the less developed and the small economies would chase-up the modern world, there are other views that the process of convergence is already taking its course, that is usually suggestively based on the rapid growth of some of the SOEs although the intuition is encouraging yet it takes a normative tune, jumping to conclusion of what should be instead of what is actually the case, with the current poverty on the global scale and looking at the data the evidence is not so encouraging and in positive terms, we have a strong evidence that convergence took no place in the last decades of the past century.

Figure 2: Current GDP (million$) for 91 Countries



The overall aim of this research falls centrally into those two propositions, seeking new evidence for deriving such a reactions to the global macroeconomic, financial and political shocks.

Methodology

The aim of the research is in constructing an updated realistic multi country Mundell- Fleming model, that reveals the uncertainty about macroeconomic interactions and spillover effects among interdependent economies, utilizing the advancements provided in the literature on the analysis of cointegrated variables, the operationalisation of the research extends the atheoretical GVAR framework of Pesaran et al (2004) providing a detailed long run structural modelling of country groups/regions of the world economy whereas theoretical economic doctrines, international trade and capital flows patterns and the contemporaneous structure of the world economy are allowed to play a role in suggesting the nature of the long run relationships among the interdependent economies through providing over-identifying restrictions on the cointegrating relationships, such a restrictions to be imposed and statistically tested as in the methodology of Garrat et al (2003), and Papaikonomou (2003).

The underlying intuition of the exogeneity or endogeneity of the foreign variables corresponding to a country or a region are pre-assumed suggested by economic theory, international trade patterns, regional monetary unions and relative economy's sizes, e.g: the output of the G7 economies is expected to be endogenous in the country-specific model of any G7 economy on the grounds that in the long run the G7 economies share co-movements responding to common technological shocks, or for another example, to the SOE of Korea the underlying assumption to treat all foreign variables as exogenous but treating the regional macroeconomic variables of South east Asia to be endogenous, given the structure of the financial markets of South East Asia, but for a much smaller economy then all variables including the regional variables to be all exogenous, on he other extreme a country like the US would all foreign variables possibly including the global exogenous oil price level all to be treated as endogenous, the oil price in the global model could alternatively be a '*self generating variable*' defined by Granger and Yoon (2001) all of these assumptions are tested in the process of constructing the structure of the GVAR and the model is estimated upon the country-specific and regional-specific tests.

The approach of GVAR would depart with the lag order selection tests, followed by the Wald lag-exclusion test statistic then the analysis proceeds for post-estimation VAR tests of Lagrange Multiplier (LM) test of residual autocorrelation, and residual normality tests implementing Skewness, Kurtosis and Jarque-Bera test statistics, finally the cointegrating properties of the model are investigated as the cointegration rank tests of Maximum Eigenvalue and the Trace statistics are calculated and since the number of cointegrating relationships are determined then Vector Error Correction Model VECM is then estimated then the critical element of the research is in imposing over-identifying restrictions on the cointegrating equations or the "Long-Run relationships" suggested by the theoretical framework, then these over-identifying restrictions are empirically tested by the Log-likelihood Ratio test of over-identified cointegrated model.

This flexibility of the GVAR modelling allow for testing various theoretical economic doctrines such as PPP, UIP at a global scale as well as at a regional/country group level, as these doctrines form a set of over-identifying restrictions on the cointegrating long run relationships that could be statistically tested noting that -for example- PPP might only hold among the larges trading partners of an economy or among the same countries in its region but not necessarily to hold on a global scale, this flexibility also allow to consider the case of a single variable's cross-country interdependence; for example co-movements of output across a country group, then the outputs might be cointegrated, a more applicable phenomena is the synchronisation of stock market prices across financial markets, Kasa (1992) provides evidence on cointegrated stock market prices among G7 economies, similar evidence reported more recently in Sharma and Wongbangpo (2002) that showed long run relations among stock prices across ASEAN.

Country Groupings of World Economies

Brief review of current and past classification of world economies:

World Bank Classifications of Economies

WB Classification is based on **Geo-political**, **Income** & **Indebtness** basis:

Income Classification ***(using GNI per capita)***

1. Low income
2. Middle Income:
   - Lower middle
   - Upper Middle
3. High Income
   - non-OECD
   - OECD
   - European Monetary Union (EMU)

Regional Classification
(on Geo-political basis)

1. East Asia & Pacific.
2. Europe & Central Asia.
3. Latin America and the Caribbean.
4. Middle East North Africa, (MENA)
5. South Asia.
6. Sub-Saharan Africa.

Indebtness Classification
(based on present value of Debt Service to GNI or to Exports)

1. Severely Indebted
2. Moderately Indebted
3. Less Indebted
4. Not classified by debt

Other classifications of the WB

1. Heavily Indebted Poor Countries (HIPC)
2. Least Developed Countries *(UN classification)*

GVAR Country Grouping Classification

The Economies are grouped into "Regions" or "Groups" on the basis of:

[1] Size of the Economy.
[2] Openness of the Economy's International Trade.
[3] Contemporaneous Nature of the Direction of International Trade.
[4] Its function in the global economy (e.g. major oil exporter).
[5] History of contagion of economic crisis.
[6] Geographic and geo-political factors.
[7] Global distribution of Population density.
[8] Institutional factors.

On the above factors, the proposed GVAR model consists of the following 9 categories:

- **US**: Central Economy of the system, the ***reference economy***
- **EMU**: European Monetary Union [Euro Area].
- **RG7**: Canada, Japan, and UK.
- **ROECD**: Rest of the OECD.
- Large non-oil Developing Economies [China, India, Brazil & Russia].
- **DOEC** *(Developing Oil Exporting Economies)*: OPEC countries, major non-OPEC oil exporters including developed countries oil exporters (e.g.: Norway).
  Subgroups include:
  - OPEC countries:
    - The Gulf Cooperation Council GCC countries.
  - Major non-OPEC oil exporters
  - Developed countries oil exporters (e.g.: Norway)
- **Transition Economies**: ex USSR and ex Yugoslavian Union countries
- **Emerging Markets** (Asian tigers).
- **Marginalised Economies**; rest of developing world.

All about the Gs: A Guide to Committees, Groups and Clubs @ the IMF

Related Papers to the project:

- **'Biased Capital Mobility and the Non-linearity in the Global Transmission of Interest Rates'**
- **'Econometric Assessment of the Global Output Co-Movements and Common Technological Shocks'**
- **'Sacrifice Ratio and Conflicts in Monetary Policy: a Realistic Application of Game Theory'**
- **'Exogeneity of the Global Oil Price, Is Oil a "self-generating" variable?'**
- **'Modelling the Determinants of the Global Oil Price in the Long Run: Does the Market Mechanism work?'**

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