Sharif University of Technology

Industrial Engineering Department

Money Supply Dynamic Modeling in Iran's Banking System

Systems Analysis I Project Report

Authors

Erfan Amani Bani

Mahan Pourhosseini

Mohammad Taghi Dehghan Nezhad

Taha Jafari

Supervisor

Prof. Shahram Shadrokh

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2.1 Dutch Disease

Revenue generated from the sale of oil and gas constitutes a significant influx of foreign exchange income for the country. This influx enters the economic distribution cycle, leading to an increase in liquidity. Subsequently, this heightened liquidity boosts domestic demand, particularly for non-tradable goods and services, fostering an environment of economic buoyancy within the country. This increased demand elevates domestic price levels, thereby diminishing the purchasing power parity of the national currency for traditional export commodities. As a consequence, a decline in the exportation of these sectors ensues, precipitating a recessionary trend characterized by job losses and the shuttering of production units within these sectors. Consequently, this dynamic facilitates an increased reliance on imports, substituting domestic production and precipitating inflationary pressures on the national currency. Specifically, in a scenario where the country operates under a fixed exchange rate regime and the central bank endeavors to maintain the domestic currency's value constant against a benchmark foreign currency (mirroring the situation in Iran), the conversion of foreign currency inflows into the domestic currency exacerbates liquidity, thereby accelerating inflation rates. The escalation of inflation diminishes the domestic currency's value against the benchmark currency, culminating in the depreciation of the national currency.

2.2 Unbridled Liquidity

In Iran, the structural governance mechanisms ensure that liquidity, or more accurately, the money supply, is determined endogenously, with the central bank having limited influence over monetary volume. When prices escalate within the nation, economic mechanisms are triggered that inherently support the expansion of the money supply. A primary consequence of increased liquidity is a surge in the inflation rate, impacting the cost of both consumer and capital goods. In response to rising inflation, the government often resorts to augmenting imports to temper price inflation through enhanced supply. This sequence of events—initiating with price and inflation hikes followed by an expanded money supply—contradicts conventional economic theories. The escalation in prices necessitates a higher monetary value for transactions, indicating a need for more money to facilitate transactions, thereby increasing nominal money demand. This increased demand typically leads to a rise in interest rates, prompting central bank intervention to align the interest rate with the expanded money supply. Contrary to the notion of central bank autonomy in controlling money volume, the observed growth in money supply is endogenously driven and influenced by economic activities. Central bank efforts to manage interest rates inadvertently contribute to both an increase in money volume and inflation, yet these outcomes are not solely dictated by independent central bank decisions.

2.3 Chronic Swelling

The relationship between tax revenue and nominal income growth is not linear, indicating that tax revenues do not increase in direct proportion to income growth. Consequently, during periods of inflation, although nominal incomes rise, tax revenues fail to match this increase equivalently. This discrepancy often results in a governmental budget deficit, which traditionally has two primary financing options:

1. Direct borrowing from the central bank, leading to an expansion of the monetary base, subsequently escalating liquidity and inflation.
2. Issuing debt securities, which can lead to a reduction in the securities' prices and a rise in interest rates.

Increased interest rates can deter investment, placing the private sector in a predicament of financial scarcity. Given that interest rate management is a critical function of the central bank, it is compelled to address rising interest rates. The central bank's intervention typically involves open market operations and the implementation of a contractionary monetary policy. This includes purchasing the bonds previously sold to the public, which paradoxically augments liquidity more than initially, thus fueling further inflation.

This cycle underscores a scenario where inflation initiates a chain reaction—beginning with a government budget deficit that necessitates measures resulting in monetary expansion and further inflation. Each compensatory strategy for addressing the deficit, whether through direct borrowing or issuing debt, inadvertently catalyzes liquidity growth, illustrating the complex interplay between fiscal policy, monetary policy, and economic stability.

3 Dynamic Hypotheses

In Iran, the increase in bank deposits has historically led to a surge in total investment, subsequently boosting the Gross Domestic Product (GDP) through an enhancement of the capital component. This GDP growth often empowers the government to exceed its fiscal constraints, resulting in an expanded government size and increased expenditure. However, this expansion in spending frequently outpaces revenue, creating a budgetary deficit. To bridge this gap, the government typically leverages oil revenue and borrows from the central bank, further inflating the government's debt and the country's liquidity. This scenario highlights the critical impact of government fiscal policies on economic stability, where GDP growth, driven by consumption, investment, government spending, and the net trade balance, plays a pivotal role in the broader economic landscape of Iran, irrespective of the oil sector's contribution.

The enduring sanctions on Iran, particularly targeting its oil exports, have significantly impacted its economy by reducing government revenue and exacerbating the budget deficit, a scenario that inherently leads to increased liquidity due to constrained fiscal capabilities. This situation is further compounded by sanctions that limit exports and complicate financial transactions, diminishing export volumes and contributing to the Dutch disease—a phenomenon where reliance on oil revenues hampers the broader economy, as detailed in earlier discussions. In attempts to mitigate these effects, the government's strategy of injecting oil revenues into the currency market to stabilize the national currency inadvertently suppresses domestic production and decreases GDP. Moreover, the government's reliance on subsidies to bridge fiscal gaps only deepens the budget deficit, prompting increased borrowing from the central bank and thereby expanding the monetary base and liquidity through the monetary multiplier effect, illustrating the complex interplay between sanctions, fiscal policy, and economic stability in Iran.

In the Iranian economy, a notable dynamic is the persistence of double-digit inflation, primarily fueled by the growth in liquidity outlined in previous discussions. As liquidity increases, bank deposits and the general money supply within the economy expand. According to the principle of supply and demand, an augmented money supply leads to a devaluation of currency, precipitating a rise in price levels. This escalation in price levels, in turn, triggers high inflation rates across the economy. As inflation climbs, the real interest rates offered by banks diminish, undermining the attractiveness of bank deposits for savers. Consequently, individuals are more inclined to withdraw their funds from banks, leading to a reduction in bank deposits. There exists an inverse relationship between bank reserves and the money multiplier coefficient; thus, as bank reserves dwindle, the money multiplier coefficient escalates. This increase in the coefficient amplifies liquidity by leveraging the monetary base, perpetuating a vicious cycle that exacerbates the unchecked growth of liquidity and further fuels inflationary pressures, demonstrating a complex interplay between monetary supplies, inflation, and banking behavior in Iran's financial ecosystem.

4 System Description

The liquidity increase in Iran represents a protracted crisis that serves as a precursor to several other economic challenges, notably inflation and the Dutch disease. This analysis delves into the intricate dynamics of liquidity by scrutinizing its interactions with critical subsystems: inflation, Gross Domestic Product (GDP), and the mechanisms of money creation. The primary focus is on the segments of the nation's banking system, its GDP, and the inflation rate. Additionally, the model incorporates other subsystems, such as the labor force population and the active population, which, although not of economic origin, significantly influence the system's dynamics; these are currently treated as exogenous variables for the purpose of this analysis.

Table 1 elucidates the variables under consideration, detailing their representation in diagrams, their classification as either rate or state variables, and their designation as exogenous or endogenous, thereby offering a comprehensive overview of the system's components and their interrelations. The delineation of the system's boundary is confined to the contours of Iran's economy, with the exogenous variables in Table 1 aptly illustrating this demarcation. The Iranian banking system, noted for its complexity, is only partially accounted for in this liquidity modeling effort, due to its intricate nature.

The temporal scope of this study spans from the year 1360 to 1410, as per the Iranian calendar, providing a long-term perspective on the evolution of liquidity and its ramifications. Subsequent sections will elaborate on the specific loops and subsystems under examination, culminating in a detailed cause-and-effect diagram that maps out the liquidity system's dynamics. This approach aims to unravel the multifaceted relationship between liquidity and its impact on Iran's economic stability, emphasizing the interplay between banking practices, GDP growth, and inflation trends.

Variable Name	Exogenous/Endogenous	Type
Export	Endogenous	Auxiliary
Import	Endogenous	Auxiliary
GDP	Endogenous	Auxiliary

Non-Oil GDP	Endogenous	Auxiliary
Sanctions	Endogenous	Auxiliary
Exchange Rate	Endogenous	Auxiliary
Oil Income	Exogenous	Auxiliary
Oil Price	Exogenous	Auxiliary
Consumption	Endogenous	Auxiliary
Savings	Endogenous	Auxiliary
Tax	Endogenous	Auxiliary
Population	Endogenous	Stock
Net Birth Rate	Endogenous	Rate
Government Costs	Endogenous	Auxiliary
Government Incomes	Endogenous	Auxiliary
Capital Stock	Endogenous	Stock
Price Level	Endogenous	Auxiliary
Inflation Rate	Endogenous	Auxiliary
Real Interest Rate	Endogenous	Auxiliary
Nominal Interest Rate	Endogenous	Auxiliary
Liquidity	Endogenous	Stock
Monetary Base	Endogenous	Auxiliary
Money Multiplier	Endogenous	Auxiliary
Bank Reserve Ratio	Endogenous	Auxiliary
Deposits	Endogenous	Auxiliary
Total Investment	Endogenous	Rate
Budget Deficit	Endogenous	Stock
Net Change in Budget	Endogenous	Rate
Oil Income	Endogenous	Auxiliary
Government Debts to Banking System	Endogenous	Auxiliary
Liquidity Change	Endogenous	Rate

Table 1: Table of system variables

5 Policies

5.1 First Policy: Eliminating the Government Budget Deficit

Addressing the government's budget deficit in Iran necessitates a strategic overhaul of three pivotal areas: subsidies, the inefficiency of the tax system, and government spending. These reforms are critical for stabilizing the economy and mitigating fiscal imbalances:

1. **Subsidy Reform:** Historically, the Iranian government has attempted to maintain price stability by controlling prices through subsidies. This approach, while aimed at protecting consumers, perpetuates a detrimental cycle that exacerbates the budget deficit. Gradual subsidy removal, particularly on energy carriers, is essential for breaking this cycle. Although such measures may provoke significant social resistance due to rising costs, they are anticipated to curb the government's expansionary fiscal policy, subsequently reducing inflation. This transition requires careful planning and implementation to mitigate adverse impacts on the population.
2. **Tax System Overhaul**: Reforming the country's tax structure to enhance revenue is another critical step. The focus should be on implementing a progressive Personal Income Tax (PIT) system, lowering Corporate Income Tax (CIT) rates to bolster business investment, and increasing taxes on dividends and bank deposits to stimulate production. However, the path to reform is fraught with challenges due to the powerful influence of political and economic interests within the country's tax affairs organization and legislative bodies. Navigating these obstacles requires a balanced approach that considers the socio-economic implications of tax reforms.
3. **Curbing Government Expenditure:** The practice of increasing government spending to secure votes, as observed at the end of Ahmadinejad's first term, reflects a broader issue of fiscal irresponsibility preceding elections. Instituting a robust supervisory mechanism or integrating such practices into conflict of interest legislation could prevent future occurrences. This measure would not only enhance fiscal discipline but also foster a more transparent and accountable governance structure.

5.2 Second Policy: Reducing Bank Interest

The decline in bank profits affects depositors dependent on interest income and companies in need of financing. To mitigate these impacts:

1. **For Depositors:** To address potential protests from those reliant on bank interest, educational initiatives through digital platforms can highlight the negative

consequences of high bank interest rates. Subsequently, guiding these individuals towards the stock market and sectors directly contributing to economic growth can offer alternative income opportunities, aligning personal financial gains with broader economic productivity.

2. **For Companies Seeking Financing:** The reduction in bank deposits and lending necessitates a shift towards equity financing. Companies are encouraged to attract investment through the stock market by offering pre-emptive shares. If this approach proves challenging, alternative strategies such as seeking foreign investment or block share transfers can provide the necessary capital, ensuring sustained operations and growth.

These approaches aim to navigate the challenges posed by reduced bank profits, fostering a more resilient and growth-oriented economic environment.

5.3 Third Policy: Structural Reforms of the Banking System

To address the complexities and challenges within Iran's banking system—a hybrid of liberal and Islamic principles—structural reforms are essential for managing liquidity. These reforms aim to overhaul the supervision and operational frameworks, mitigating risks and enhancing the overall financial stability. The key reforms include:

1. Implementing Precautionary Measures for Bank Balance Sheet Growth
2. Enhancing Loan Granting Supervision
3. Strengthening the Interbank Market
4. Vetting Borrower and Credit Recipient Qualifications
5. Ensuring the Central Bank's Independence

These structural reforms are aimed at reinforcing the foundations of Iran's banking system, addressing vulnerabilities, and enhancing its capacity to manage liquidity effectively. By implementing these changes, the banking system can better support economic growth and stability, reducing the risk of financial crises and improving the overall financial landscape.

6 Proposed Model

In this section, we undertake the modeling of the money creation system in Iran, concentrating on the interactions between GDP, inflation, and liquidity within the banking framework. The methodology unfolds in a structured manner: initially, the model's principal loop is delineated, serving as the backbone of the analysis. Subsequently, this is expanded through the development of additional loops and subsystems, illustrated via open and causal diagrams. These expansions are rigorously aligned with the dynamic hypotheses introduced in Section 3, ensuring a coherent and theoretically grounded approach. Through this process, the model aims to offer a comprehensive representation of the intricate dynamics at play, facilitating a deeper understanding of the economic phenomena under study.

6.1 First Module

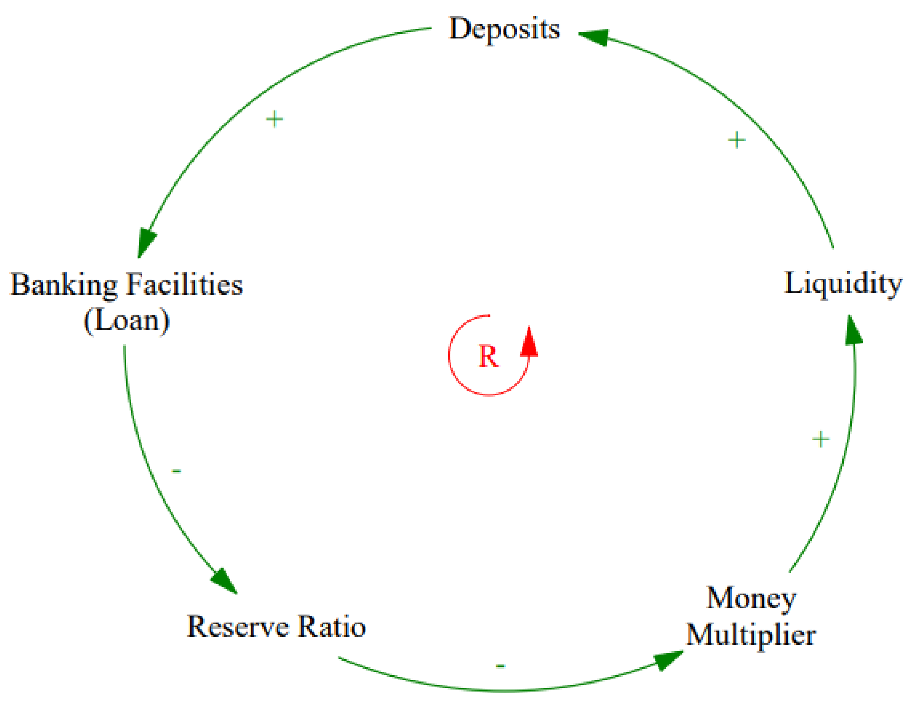

Figure 1: Cause and effect diagram of module 1, the main loop of money creation in Iran's economy

The liquidity variable stands as the central focus within the system under investigation, typically quantified in thousands of billion tomans (hemat), highlighting a pivotal dynamic within Iran's economy. This positive feedback loop reveals a critical aspect: under scenarios where Iran experiences positive economic growth, there is a tendency for government expansion. This phenomenon was particularly evident during the 10th government, coinciding with periods when global oil prices exceeded $100 per barrel. Government expansion leads to escalated expenditures and, consequently, a pronounced budget deficit, serving as a primary source of liquidity generation in the Iranian economy. A key strategy employed by the Iranian government to address this deficit involves borrowing from the banking sector, thereby increasing its indebtedness to this system. The influx of funds into the banking system, supported by the monetary multiplier mechanism, fosters liquidity growth. A substantial portion of this liquidity remains within the banking system as deposits, which in turn facilitates investment growth through loans extended to the populace. This surge in total investment, a crucial GDP component, further stimulates economic growth, illustrating a cyclical .interconnection between government spending, liquidity, and GDP growth in Iran

Second Module 6.2

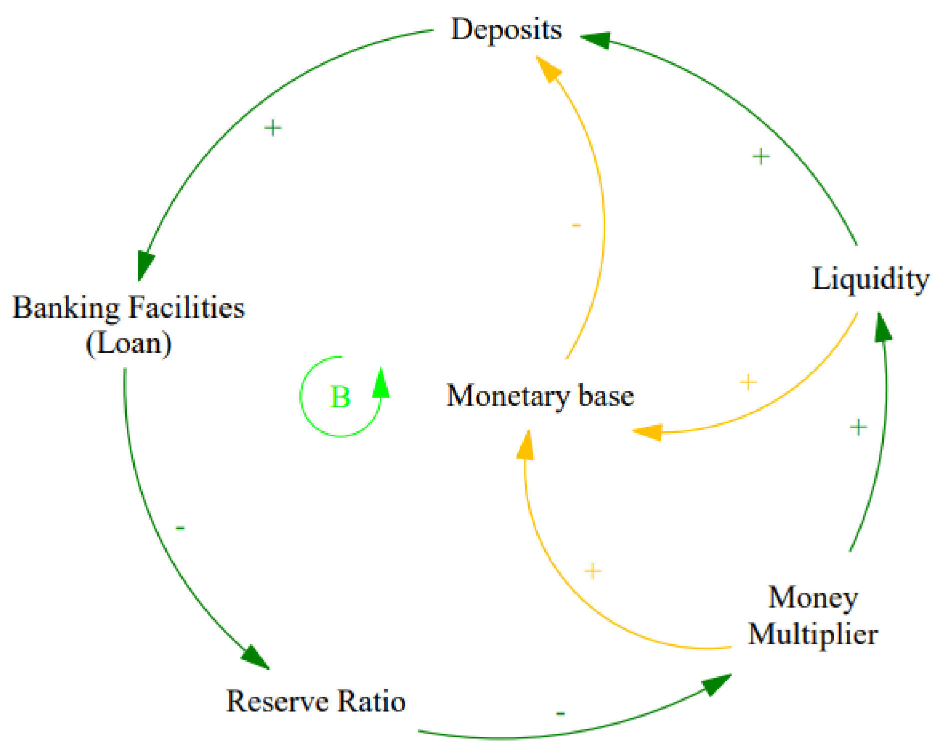

Figure 2: Cause and effect diagram of module 2, swelling loop next to the main loop in the first module

In Iran's economic framework, the unceasing escalation of liquidity, fueled by the government's expansionary monetary policies, precipitates a complex cycle of chronic inflation. This cycle is exacerbated by the direct correlation between increased liquidity and the devaluation of the national currency, leading to higher general price levels and inflation, as captured by the Consumer Price Index (CPI). The Fisher equation highlights this phenomenon, showing that rising inflation reduces real interest rates, prompting withdrawals from the banking system and subsequently lowering bank reserves. Unlike in many developed countries where interest rates are market-driven, Iran's fixed interest rate policy, dictated by the Credit Money Council, further complicates this dynamic. This reduction in bank reserves inversely boosts the monetary multiplier, perpetuating a cycle of unbridled liquidity growth—a significant positive feedback loop that underscores the intricate relationship between government policy, inflation, and liquidity in Iran's economy.

6.3 Third Module

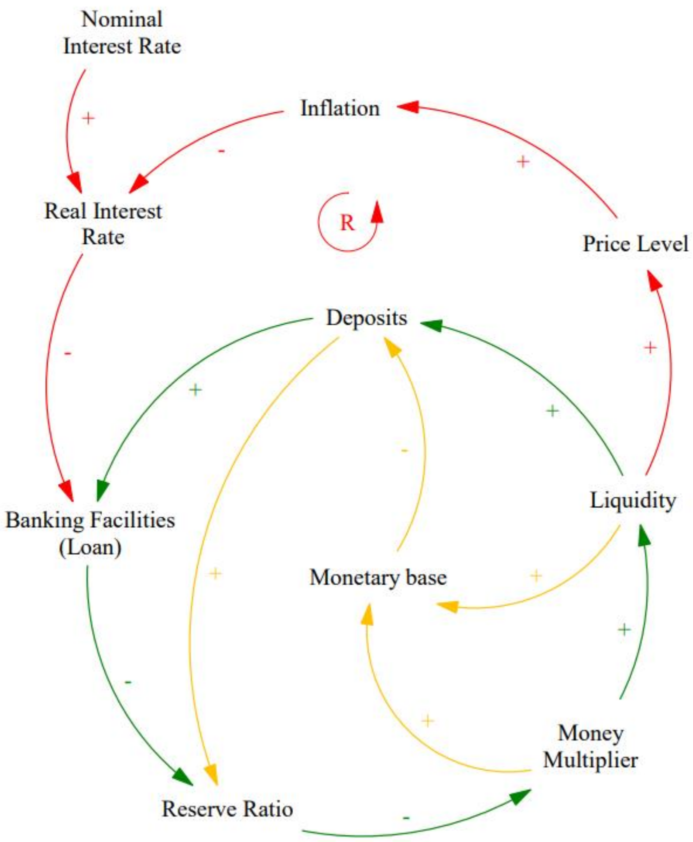

Figure 3: Cause and effect diagram of module 3, addition of Dutch disease dynamics to module 2

In Iran, a portion of oil revenues is routinely allocated to the central bank by the government. The central bank, often acting upon government directives and hampered by its lack of autonomy from the executive branch, engages in the practice of injecting oil dollars into the market. This intervention aims to lower the free market currency price to appease public sentiment. However, this strategy proves to be counterproductive, creating a lose-lose situation. By diminishing the dollar's market value against the Rial, it inadvertently disincentives exporters, leading to a decline in overall export volumes. Simultaneously, the reduced dollar rate against the Rial makes importing certain goods, which have domestic counterparts, more economically viable. This influx of imports can stifle domestic production, indirectly suppressing it and contributing to a reduction in Gross Domestic Product (GDP). While the government may view the exchange rate reduction as beneficial for curbing inflation—given the Iranian economy's reliance on imported production inputs and the direct impact of currency valuation on the prices of both domestically produced and imported goods—this policy inadvertently fosters a hidden suppression of production, undermining economic growth and stability.

6.4 Fourth Module

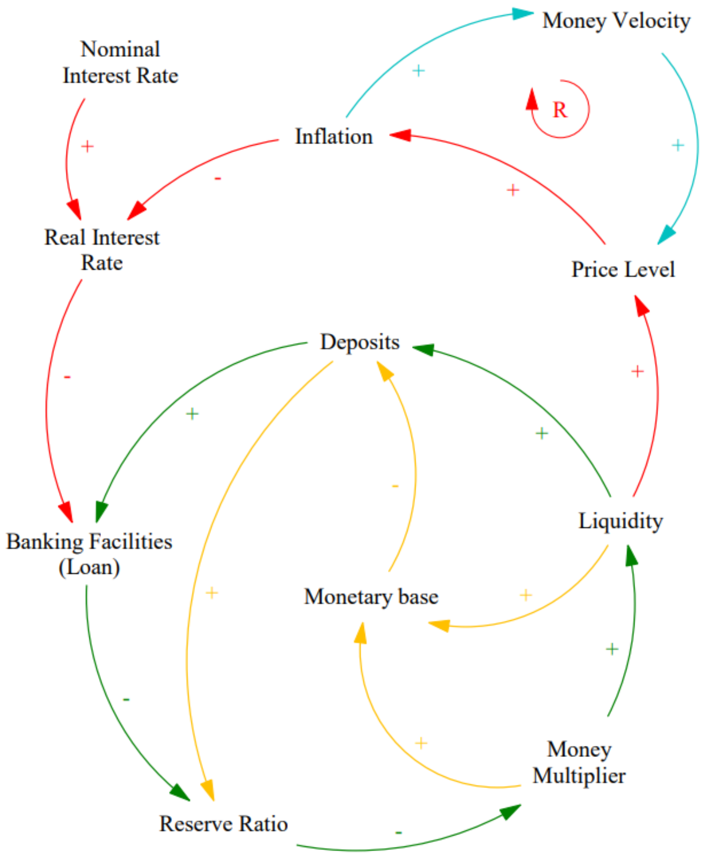

Figure 4: Fourth module

6.5 GDP Subsystem with Population Effect

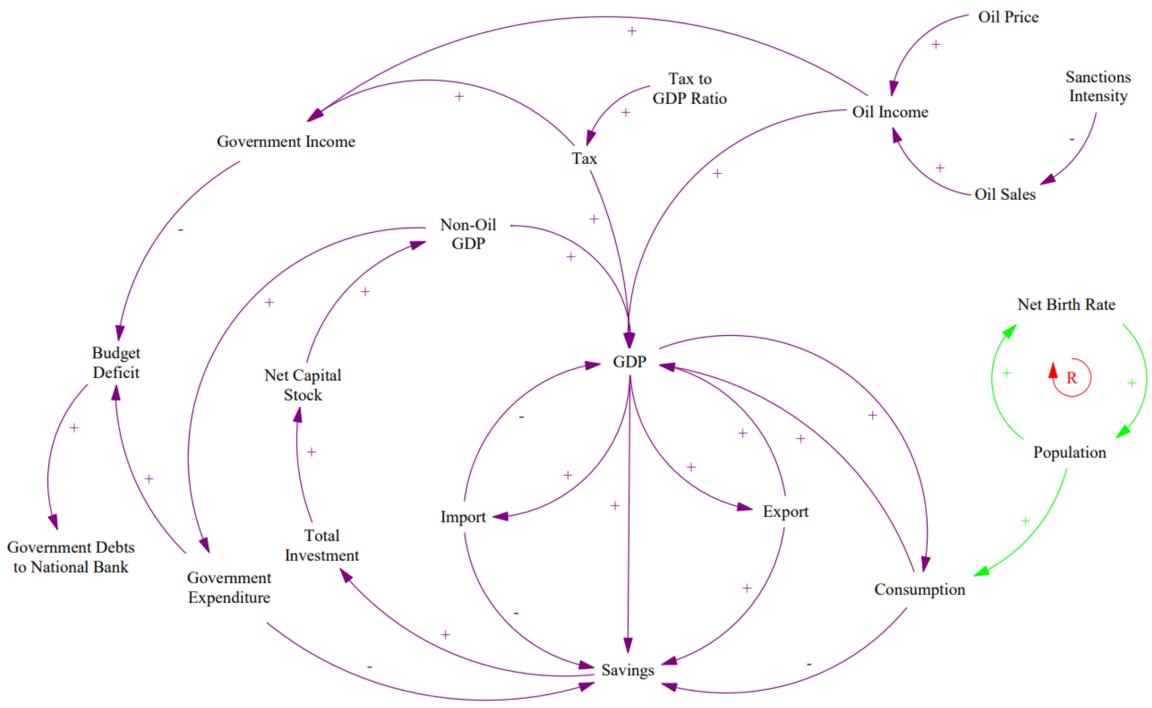

Figure 5: Completed cause and effect diagram of GDP subsystem on module 3

Gross Domestic Product (GDP) is fundamentally composed of consumption, total investment, government spending, and net exports, with net exports representing the differential between exports and imports. Each of these elements is intrinsically linked to GDP, fostering bidirectional positive feedback loops that underpin the economic cycle. An increase in GDP not only elevates consumption and savings due to the interplay of economic dynamics but also enhances national savings as a direct consequence of increased consumption. In macroeconomic terms, the equivalence of total savings and total investment suggests that an uptick in savings, typically channeled through bank deposits, proportionally boosts total investment. This relationship underscores the essential role of the capital stock concept, as defined by the Central Bank of Iran, in elucidating the investment facet of GDP and the pivotal interactions between savings, investment, and economic growth mechanisms.

Capital stock encompasses the aggregation of capital goods and non-financial assets produced within a country, quantifiable through gross fixed capital formation figures. These assets are instrumental in the production of goods and services and the generation of income. As per the standard system of national accounts, the capital balance reflects the net cumulative value of capital formation, adjusted for the useful life of these assets. Consequently, the inventory of non-financial capital assets is comprised of the total value of various categories such as "buildings and facilities", "machinery and equipment", "research and development", "exploration of mines", and "other fixed assets produced". These components are essential for the production process or have potential utility in generating economic value.

Under the defined framework, an escalation in total investment directly contributes to an augmentation of the capital stock. This increase in capital stock, in turn, boosts non-oil GDP, signifying that enhancements in the production of goods and services outside the oil sector positively impact the overall Gross Domestic Product. Thus, a rise in non-oil gross production inherently leads to an uplift in GDP, highlighting the integral role of capital investment in fostering economic growth and diversification.

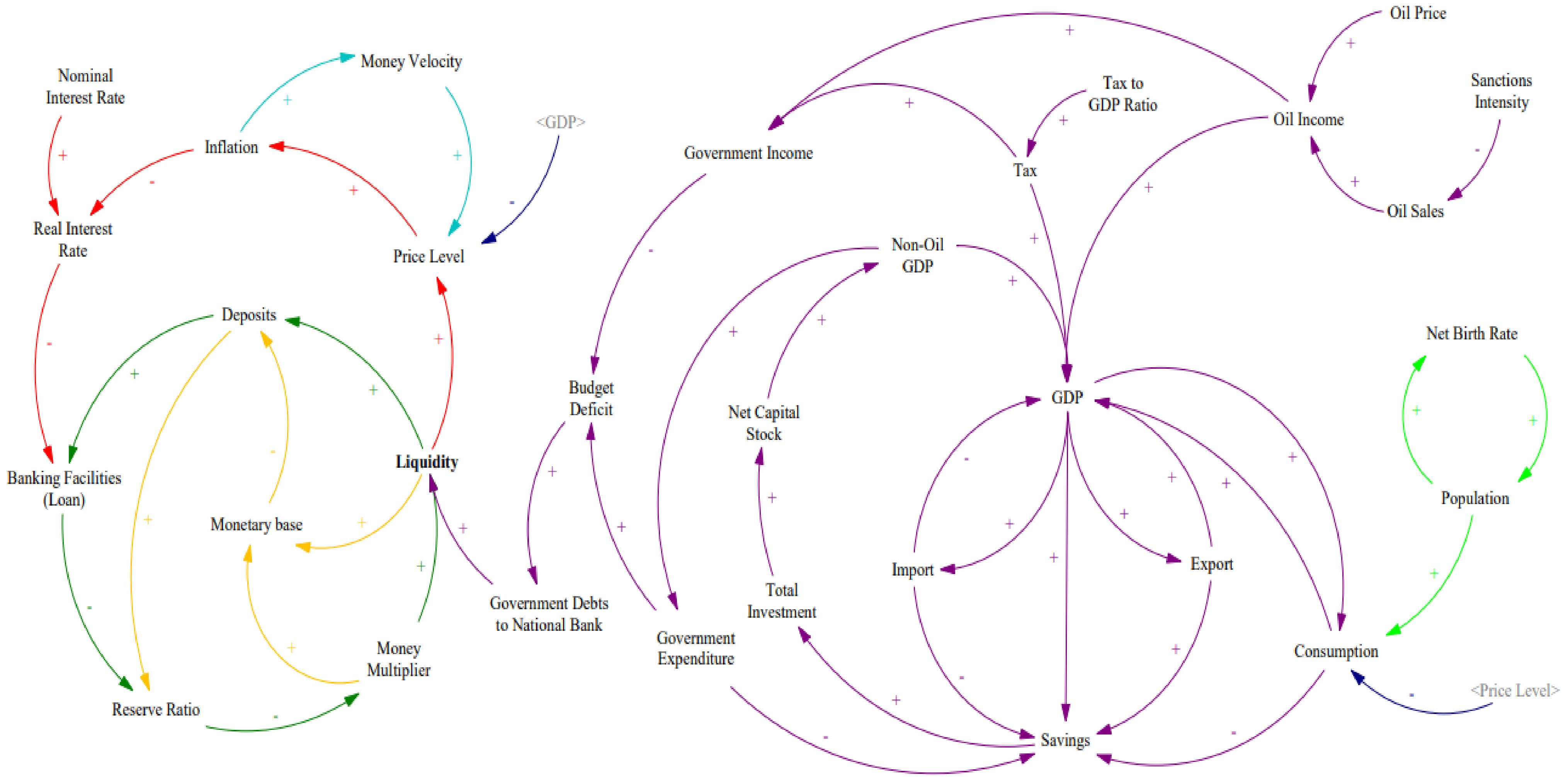

Figure 6: Final version of Causal Loop Diagram (CLD) - Modular

6.6 Complementary Relationships

In this section, we examine the impact of auxiliary and external variables on Iran's economy, notably the preferred currency policy up to this year, which significantly affects imports. We consider the preferred currency an external variable, where its increased application or value typically reduces imports. This underscores how currency policy influences trade and illustrates the broader economic strategy's effect on import patterns.

A portion of Iran's oil revenues funds development, while another part covers the government's budget deficit. Increased oil-related foreign exchange earnings enhance government income, helping to reduce the deficit. Yet, higher foreign exchange income often leads to bigger government size and higher costs. Additionally, higher taxes boost government revenue but may also burden individuals, making savings more difficult. This situation highlights the intricate balance between government income sources, spending, and the wider economic effects of fiscal policies.

Two exogenous variables significantly impact liquidity in Iran's economy: net foreign assets and banks' debt to the central bank. Both factors positively influence liquidity, with increases in either net foreign assets or banking sector indebtedness to the central bank leading to a rise in liquidity levels. These relationships underscore the role of external financial positions and banking dynamics in the liquidity equation.

The impact of exports and imports on the general price level is a crucial aspect of economic dynamics. Naturally, an increase in exports coupled with a reduction in imports tends to elevate the general price level. Furthermore, the general level of foreign prices, considered an exogenous variable, directly influences domestic price levels. This highlights how international trade and global price trends play a significant role in shaping domestic inflation and price stability.

In Iran's economy, the active population is distinctly defined as individuals aged between 16 and 60 years. This demographic is considered an exogenous variable, with its size directly influencing the working population within the economy. A larger active population correlates with a higher potential workforce, which, in turn, positively impacts economic growth and GDP (excluding oil revenues). Furthermore, considering the previously discussed definition of capital stock, it's evident that an increase in the active or working population also beneficially affects the economy's capital stock. This relationship underscores the critical role of human capital in driving economic development and enhancing productivity.

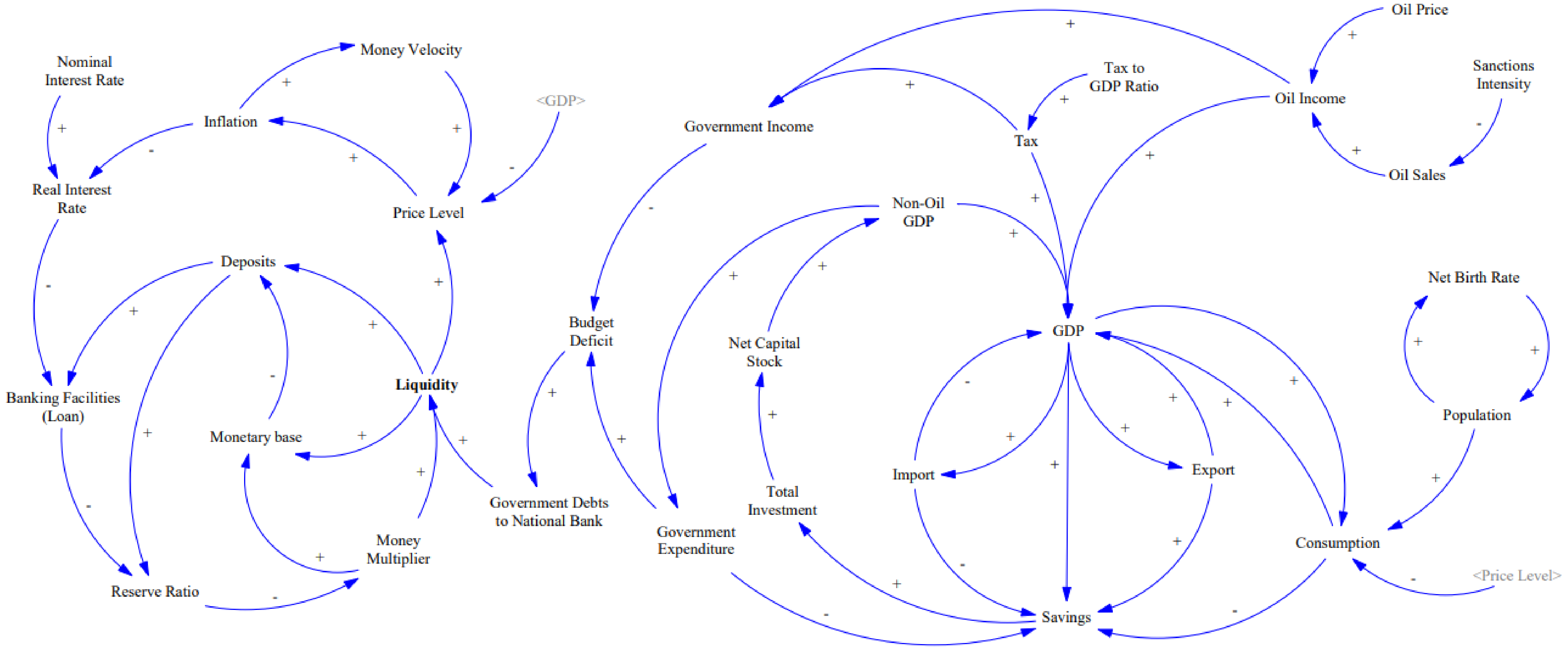

Figure 7: Final version of Causal Loop Diagram (CLD)

7 Relationships In The Model

Central bank data reveal a linear relationship between nominal GDP and net capital stock, illustrated in figure 8. This relationship highlights the direct impact of capital stock on economic output, indicating an increase in nominal GDP with a rise in net capital stock, showcasing the integral role of capital investment in economic growth.

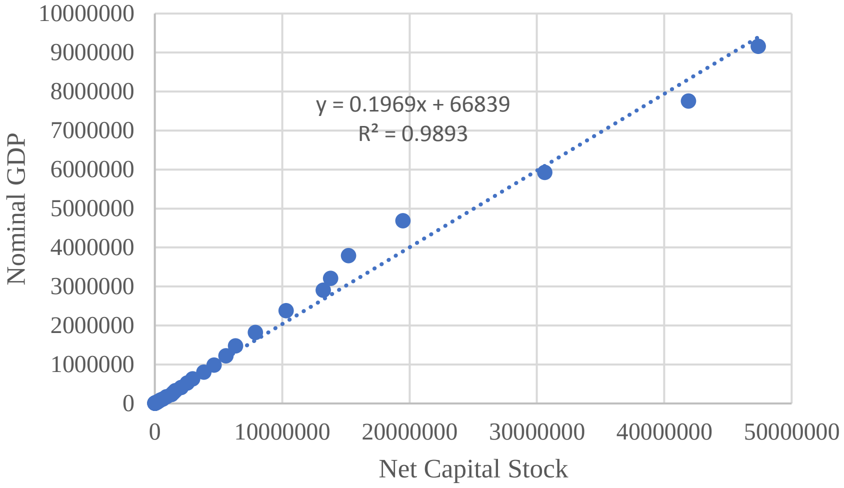

Figure 8: Scatter plot of nominal GDP and net capital stock

Government spending data, sourced from the Statistics Center website, and GDP data from the Central Bank are represented in a dot chart, revealing a linear regression relationship with a high correlation coefficient of 0.99. This strong correlation underscores the significant impact of government expenditure on GDP, highlighting the direct and substantial influence of fiscal policy on economic output.

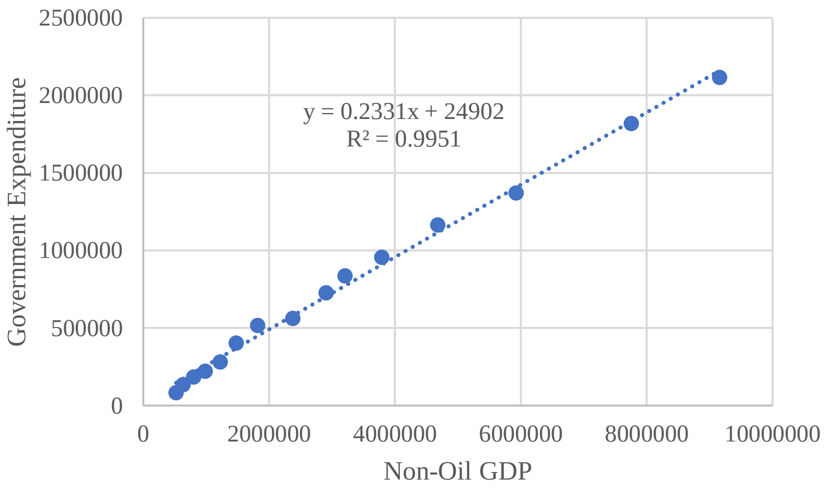

Figure 9: Scatter plot of government spending and oil GDP

The connection between inflation levels in the country and the intensity of sanctions exhibits a relatively strong linear relationship, with a correlation coefficient of 0.61. This relationship is visually depicted in diagram 12, showcasing the interaction between these two variables through a dot diagram. Furthermore, macroeconomic theory posits an equilibrium relationship among liquidity (M), the velocity of money circulation (V), real gross output (Y), and the general level of prices (P), highlighting the interplay between monetary factors and economic outcomes.

$$MV = PY \ \rightarrow V\Delta M = \Delta(PY) = P_2Y_2 - P_1Y_1$$

$$Price\ level_t = \frac{V\Delta M + (GDP_{t-1})(Price\ level_{t-1})}{Nominal\ GDP_t}$$

$$Price\ level_{t-1} = Delay(Price\ level_t, 1, Price\ level_{1379})$$

$$GDP_{t-1} = Delay(GDP_t, 1, GDP_{1379})$$

$$Inflation_t = Max\left(\frac{Price\ level_t - Price\ level_{t-1}}{Price\ level_{t-1}}, a \times Sanctions\ Intensity + b\right)$$

In the linear regression analysis of inflation, a represents the slope, showing how inflation changes with sanctions, while b is the y-intercept, indicating initial inflation when sanctions are absent.

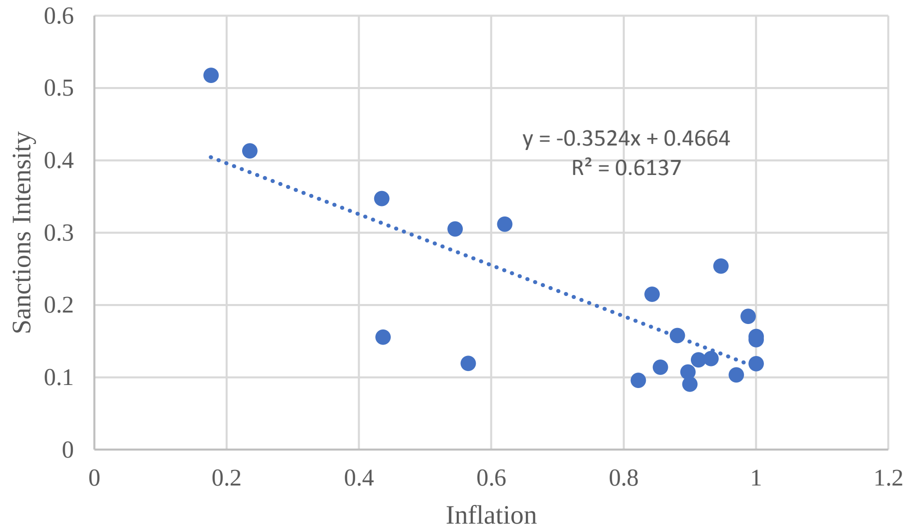

Figure 10: Scatter plot of inflation and sanctions intensity

The oil GDP is determined using the linear relationship depicted in diagram 10, where nominal GDP encompasses the sum of gross oil production and oil sales. Thus, the GDP formula integrates these components, allowing for the calculation of the total GDP based on the outlined relationships and the specific contributions of the oil sector to the economy.

$$GDP = Consumption + Investment + Government\ Expenditure + Export - Import$$

Utilizing historical data from the World Bank on the proportion of each GDP component, average percentages were derived to quantify the contribution of each to GDP, detailed in a relationship table. For instance, imports accounted for an average of 22.5% of Gross Domestic Product over the period 1379 to 1400, illustrating their economic impact. Investment, distinct from other components, is understood to equal savings in equilibrium conditions, guiding the modeling of the savings relationship accordingly. This approach ensures a comprehensive analysis of each component's role within the GDP, except for investment, which is analyzed through its equivalence to savings.

$$Savings = GDP\ -\ Consumption\ -\ Government\ Expenditure\ -\ Export\ +\ Import$$

The model incorporates trends of input variables depicted in graphs 11 to 15, which showcase the progression of variables such as the intensity of sanctions, oil price, the exchange rate of the dollar to the Rial, and the monetary multiplier. Notably, the severity of the embargo, a qualitative variable, has been quantified for this model by calculating the ratio of the average annual oil sales to the maximum yearly sales within the period from 1379 to 1399. This approach yields a variable ranging between zero and one, providing a measurable scale for the sanctions' intensity. The corresponding data for this calculation, along with the data for other variables and their computations, are detailed in the attached Excel file, facilitating a comprehensive analysis of the inputs shaping the economic model.

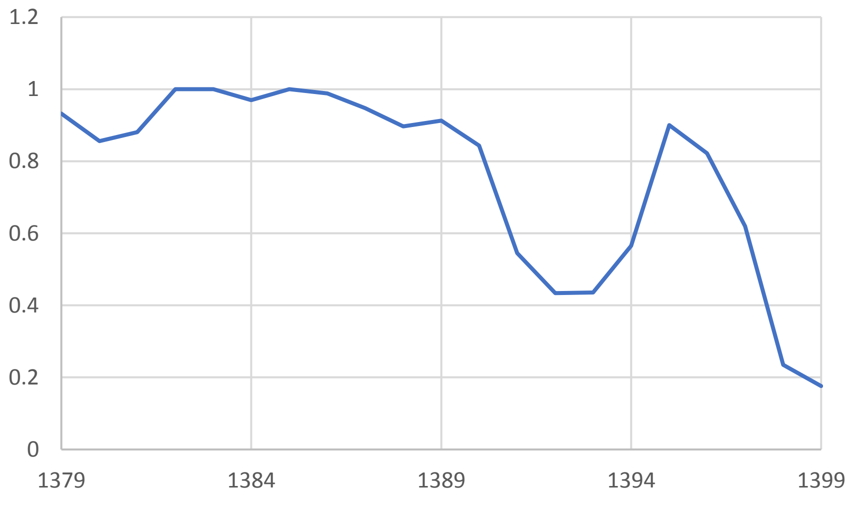

Figure 11: The trend of changes in the intensity of sanctions during the years 1379 to 1399

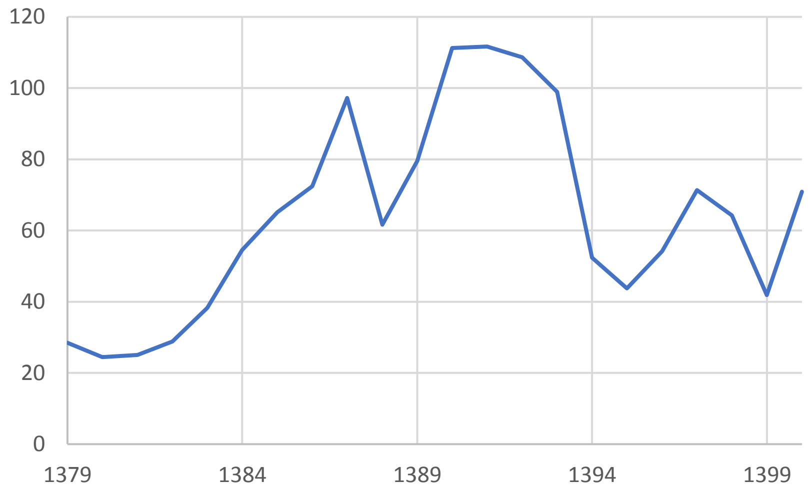

Figure 12: The trend of changes in oil price ($) during the years 1379 to 1400

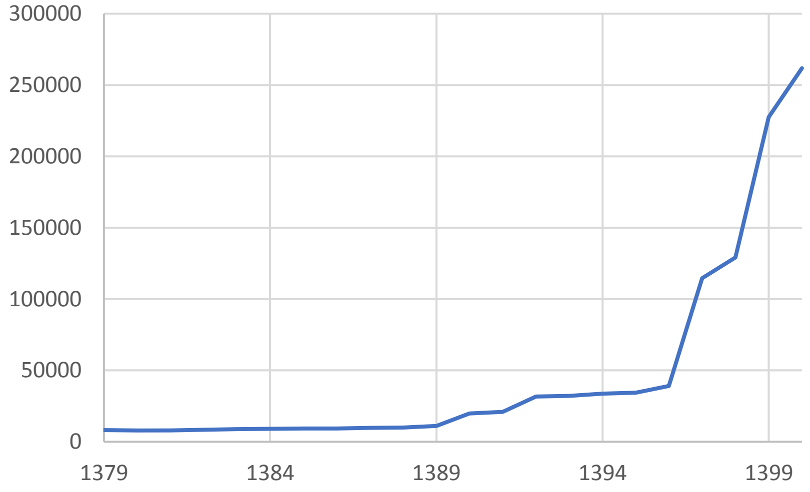

Figure 13: The trend of variable changes in the value of the Dollar to the Rial during the years 1379 to 1400

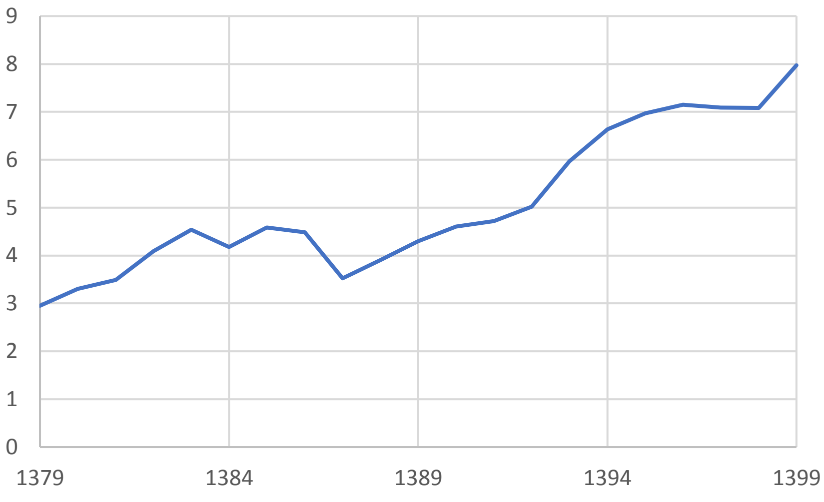

Figure 14: The trend of variable changes in the monetary multiplier during the years 1379 to 1400

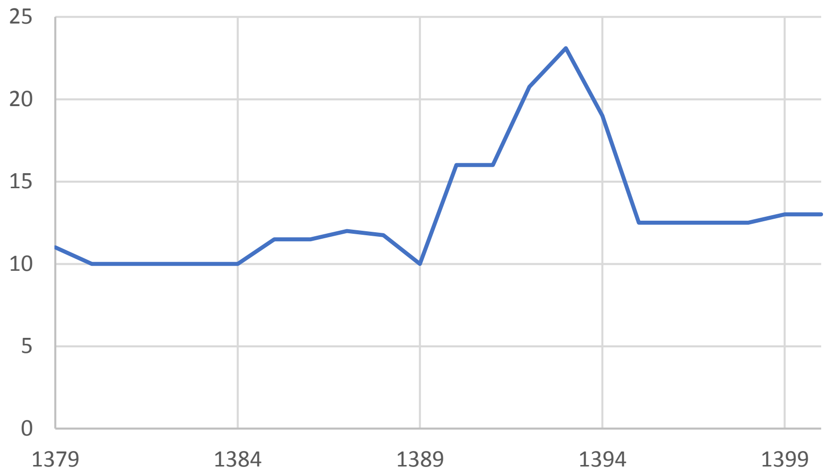

Figure 15: The trend of nominal interest rate variable changes during the years 1379 to 1400

8 Validation

We used the following statistics to verify and validate the data:

$$R^2 = \left(\frac{1}{n} \times (X_d - \bar{X}_d) \times \frac{X_M - \bar{X}_M}{S_M \times S_d}\right)^2$$

$$MAPE = \frac{1}{n} \times \sum \frac{|X_M - X_d|}{X_d}$$

$$MSE = \frac{1}{n} \times \sum (X - X_d)^2$$

$$U_M = \frac{\bar{X}_M^2 - \bar{X}_d^2}{MSE}$$

$$U_S = \frac{\bar{s}_M^2 - \bar{s}_d^2}{MSE}$$

$$U_c = \frac{2 \times (1 - R) \times S_M \times S_d}{MSE}$$

The results of the statistics for the main variable of the system (liquidity) are shown below.

Variable	$\mathbf{U_M}$	$\mathbf{U_S}$	$\mathbf{U_C}$
Liquidity	0.57	0.33	0.1

Table 2: Validation results of the model on liquidity variable

The U_M statistic is used to check the performance of the system compared to the real data, which is a number between 0 and 1. Considering that the output of the presented model is 0.57, we conclude that the graph has been slightly shifted up or down compared to the real data, which of course is clear in graph 13. The U_S statistic is also used to check the variance, according to the number 0.33, there is some difference in the correlation between the two graphs. The U_C statistic is also used to check the covariance, if two graphs have a time delay, this statistic takes a high value, but considering that it is 0.1 for us, it indicates that the relationships related to the delay it is well considered in modeling. For the final check, the sum of squared error statistic was used, and the number obtained was 0.97, and this indicates the fit of the simulation model with the real model.

Efforts to refine the model for enhanced accuracy and to avoid overfitting of regression relationships to the data have been consistently undertaken. This included meticulous attention to improving the precision of input data, particularly those influencing the calculation of oil prices. In the nonlinear analysis process, the model's outcomes were rigorously reviewed multiple times, leading to adjustments based on feedback. For instance, the average ratio of government borrowing from the central bank relative to the budget deficit was adjusted from 0.5, as indicated by historical data, to 0.3. This revision accounts for the compensation of a portion of government borrowing with oil dollars, suggesting the adjusted ratio more accurately reflects reality.

Moreover, the introduction of a "sanctions severity" variable significantly enhanced the model by incorporating the impact of sanctions on variables like inflation and oil revenue. Prior to this adjustment, the omission of sanctions' effects resulted in inaccuracies in the behavior of certain model variables, which were rectified by including the sanctions variable, thereby improving variable behavior predictions.

A third major revision involved reevaluating the relationship between non-oil GDP and the net stock of capital. Initially, this relationship was modeled using a fourth-degree polynomial to increase correlation, albeit without a logical basis, leading to overfitting. A shift to a linear relationship corrected this issue, aligning the main variable's behavior more closely with historical data, demonstrating the model's iterative refinement process aimed at achieving a balance between accuracy and representativeness.

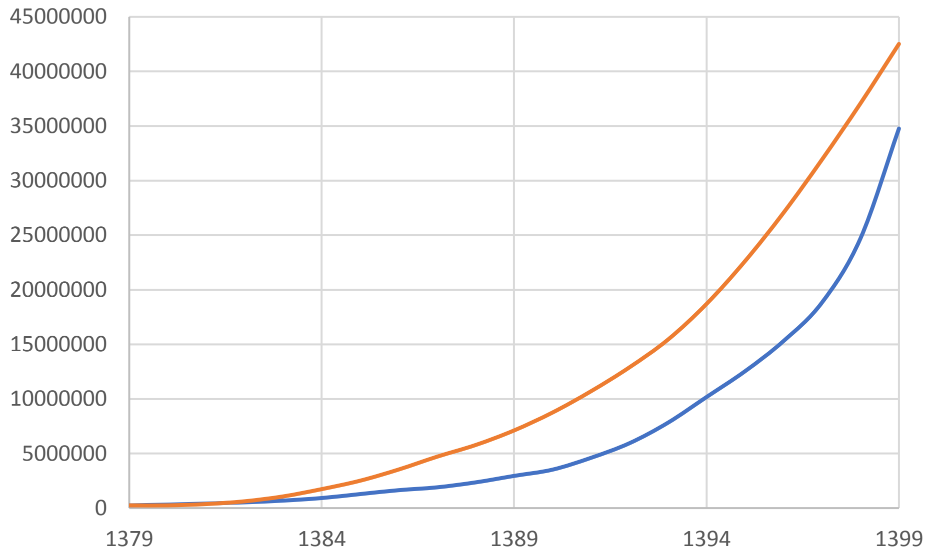

Figure 16: Comparison chart of model (orange) and real (blue) liquidity between 1379 and 1400

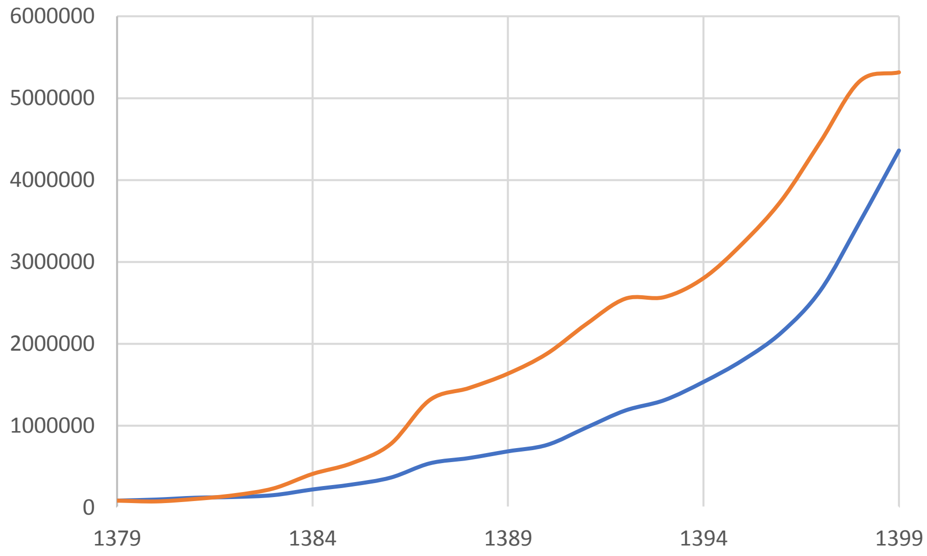

Figure 17: Comparison chart of model (orange) and actual (blue) monetary base between 1379 and 1400

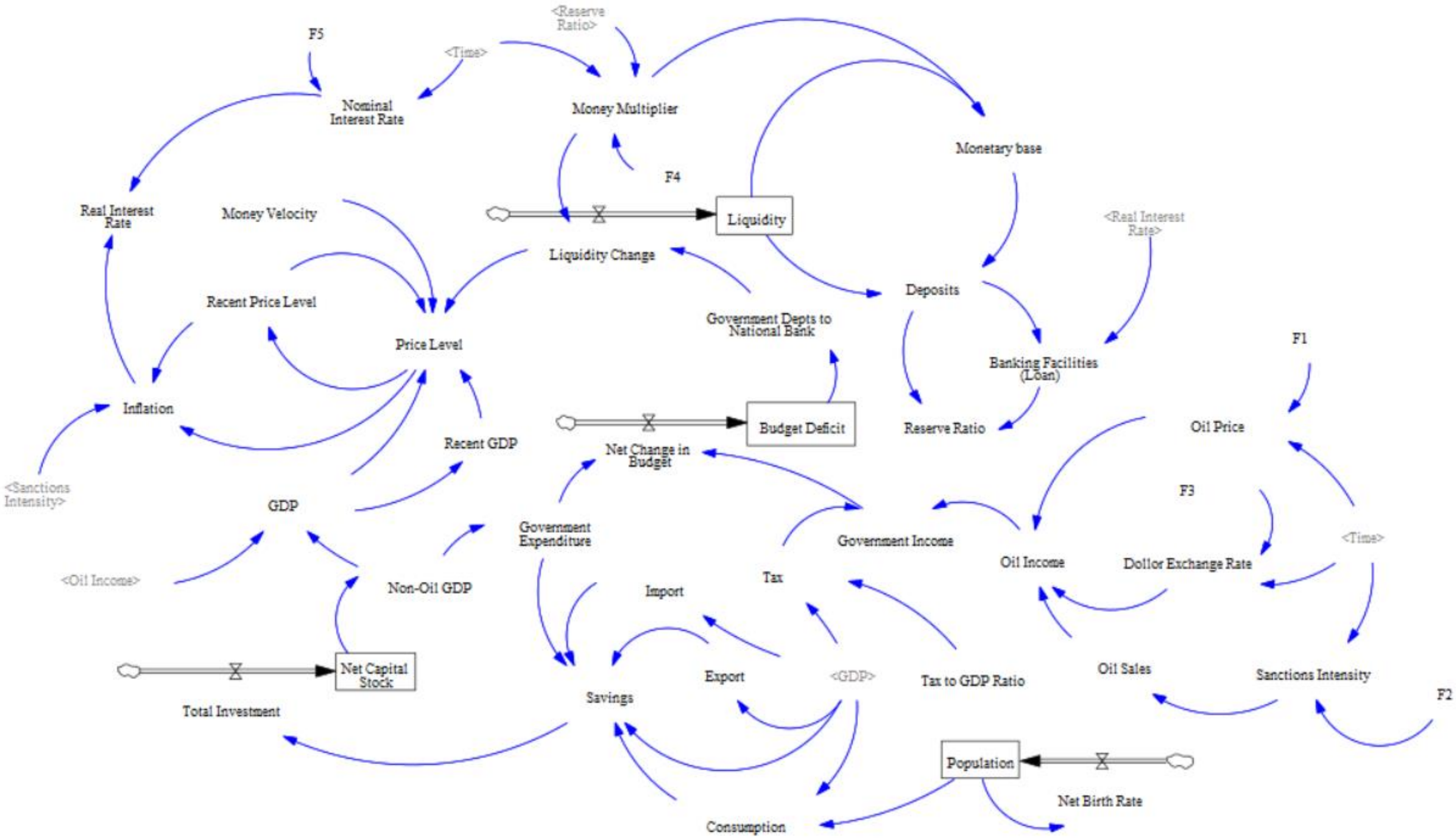

Figure 18: Stock flow diagram (SFD)

9 Developing Scenarios and Policy Making

First Policy

In the 6th development plan, the government's goal to diminish the budget deficit and enhance financing through taxation—to achieve a target where taxes constitute 30% of GDP—reflects ambitious fiscal reform. However, as detailed in section 5.1, while attainable, the structural intricacies of Iran's budget allocation system pose significant challenges to this objective. Given these complexities, a prudent approach would be to initially aim for a more modest increase in the tax-to-GDP ratio, from the existing 6% to 15%. This adjustment allows for an evaluation of the impact of such fiscal policy changes on the economy, enabling a gradual approach to reform that can be scaled based on observed outcomes and mitigating potential adverse effects associated with abrupt fiscal adjustments.

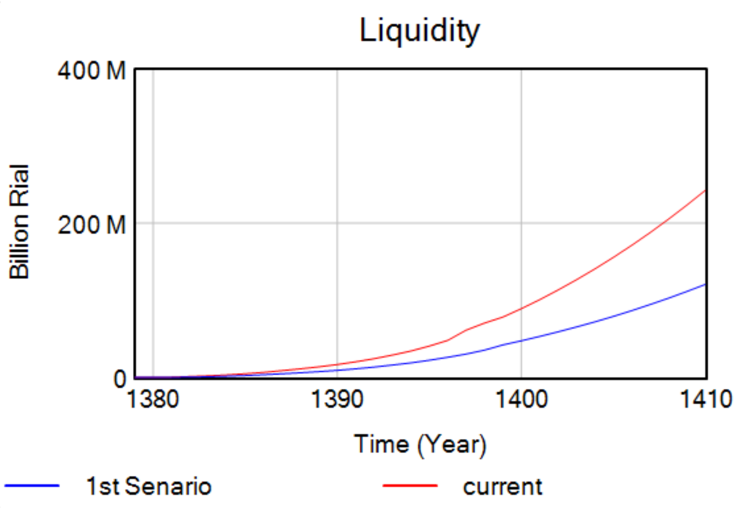

Figure 19: Liquidity changes during 1379 to 1410 under the current state and applying the first proposed policy

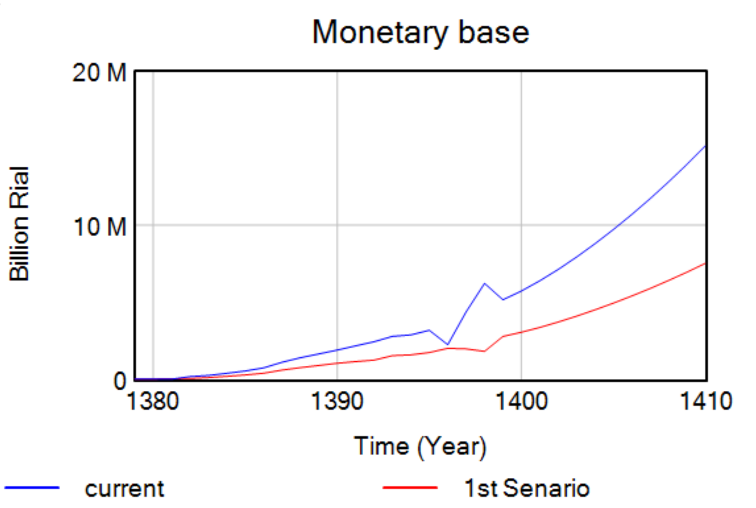

Figure 20: Monetary base changes during 1379 to 1410 under the current state and applying the first proposed policy

The data presented in graphs 19 and 20 illustrate that modifying the government's tax policy to increase the tax-to-GDP ratio from 6% to 15% could markedly decelerate liquidity growth in Iran over the subsequent nine years. Given that liquidity expansion is a primary catalyst for inflation, this reduction in liquidity growth is expected to significantly curtail inflation rates within the country. This outcome highlights the effectiveness of fiscal policy adjustments in managing macroeconomic variables, suggesting that strategic tax reforms can serve as a potent tool in stabilizing the economy by directly addressing the root causes of inflation.

Second Policy

Iran's banking system faces numerous challenges, among which the inadequate oversight by the central bank over the facility distribution process, particularly in private banks, stands out. This lack of supervision has allowed for an intentional or unintentional reduction in banks' reserve ratios, contributing to an increase in the monetary multiplier and, consequently, liquidity growth. By implementing stricter regulations on the mechanism for allocating facilities, the government and the central bank can significantly reduce the ratio of facility allocation to current bank deposits from 0.84 to 0.6. Such a measure would effectively curb liquidity growth, addressing one of the critical aspects of the liquidity crisis. This approach underscores the importance of regulatory oversight in maintaining financial stability and highlights the central bank's role in mitigating systemic risks through policy interventions.

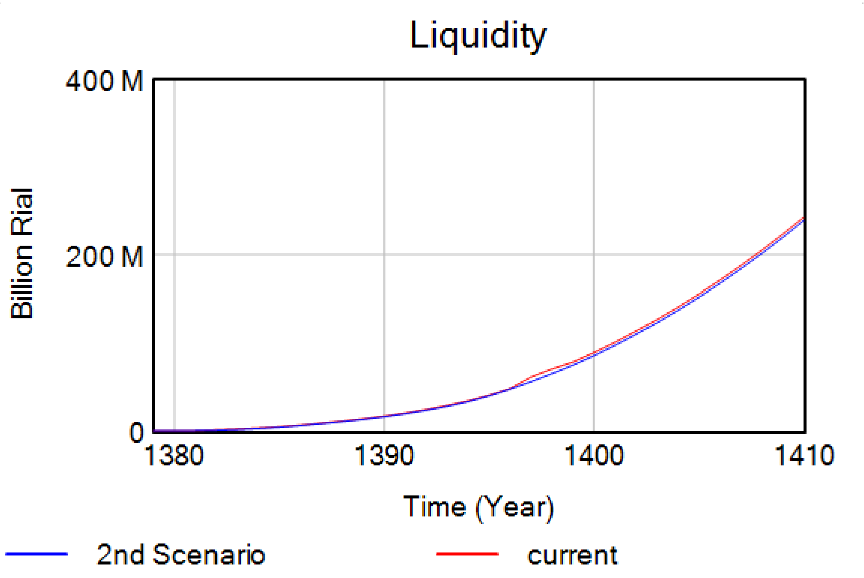

Figure 21: Liquidity changes during 1379 to 1410 under the current state and applying the second proposed policy

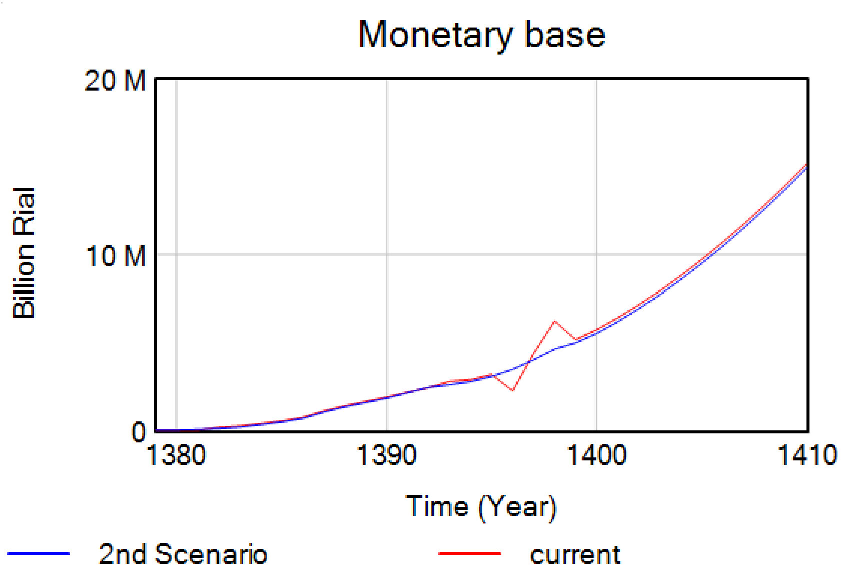

Figure 22: Monetary base changes during 1379 to 1410 under the current state and applying the second proposed policy

Charts 21 and 21, which juxtapose liquidity and the monetary base, reveal that the adjustments implemented under the second policy did not yield a marked deviation towards the desired state. This outcome is contrary to initial expectations, suggesting that the policy's impact on reducing liquidity growth and stabilizing the monetary base was less significant than anticipated.

Appendix

Variable	Equation	Unit
Total Investment	$Savings$	Billion Rials
Capital Stock	$\int_{1379}^{T} (Total\ Investment)dt$	Billion Rials
Non-oil GDP	$0.1669 \times Net\ Capital\ Stock + 66839$	Billion Rials
GDP	$"Non-Oil\ GDP" + Oil\ Income$	Billion Rials
Recent GDP	$DELAY1I(GDP, 1, GDP_{1379})$	Billion Rials
Inflation	$Max((\frac{Price\ Level - Recent\ Price\ Level}{Recent\ Price\ Level}), -0.3524 \times Sanctions\ Intensity + 0.4664)$	Dmnl
Price Level	$((Money\ Velocity \times Liquidity\ Change) + (Recent\ Price\ Level \times Recent\ GDP)) / GDP$	Dmnl
Recent Price Level	$DELAY1I(Price\ Level, 1, CPI_{1379})$	Dmnl
Nominal Interest Rate	$F5(Time) + SMOOTH(F5(Time), 2)$	Dmnl
Real Interest Rate	$Nominal\ Interest\ Rate - Inflation$	Dmnl
Money Velocity	$Average\ Money\ Velocity = 0.92$	$\frac{\text{Rial}}{\text{Year}}$

Monetary multiplier	$MIN(DELAY1I(\frac{1}{Reserve\ Ratio}, 1, Reserve\ Ratio_{1379}), F4(Time))$	$\frac{1}{\text{Rial}}$
Liquidity	$\int_{1379}^{T} (Liquidity\ Change)dt$	Billion Rials
Liquidity Change	$Government\ Depts\ to\ National\ Bank\ \times\ Money\ Multiplier$	Billion Rials
Government Debts to Banking System	$0.3\ \times\ Budget\ Deficit$	Billion Rials
Budget Deficit	$\int_{1379}^{T} (Net\ Change\ in\ Budget)dt$	Billion Rials
Budget Change	$Government\ Expenditure\ -\ Government\ Income$	Billion Rials
Government Costs	$(0.2331 \times "Non-Oil\ GDP"\ +\ 24902)$	Billion Rials
Tax	$GDP\ \times\ Tax\ to\ GDP\ Ratio$	Billion Rials
Export	$0.2426\ \times\ GDP$	Billion Rials
Import	$0.225\ \times\ GDP$	Billion Rials
Savings	$GDP\ -\ Consumption\ -\ Government\ Expenditure\ -\ Export\ +\ Import$	Billion Rials
Consumption	$(0.6\ +\ \frac{Population_t}{Population_{t-1}}) \times\ GDP$	Billion Rials
Government Incomes	$(Oil\ Income\ +\ Tax)$	Billion Rials

Monetary Base	$\frac{Liquidity}{Money\ Multiplier}$	Billion Rials
Deposits	$Liquidity\ -\ Monetary\ base$	Billion Rials
Banking facilities	$0.84\ \times\ (1\ +\ Real\ Interest\ Rate)\ \times\ Deposits$	Billion Rials
Savings rate	$2.3\ \times \frac{(Deposits\ -\ "Banking\ Facilities\ (Loan)")}{Deposits}$	$\frac{\text{Dmnl}}{\text{Year}}$
Oil Price	$F1(Time) + SMOOTH(F1(Time), 2)$	Dollar
Oil Income	$Oil\ Price\ \times\ Oil\ Sales\ \times\ Dollar\ Exchange\ Rate\ /\ 1e + 09$	Billion Rials
Oil Sales	$Sanctions\ Intensity\ *\ 2.25e + 06$	Barrels
Dollar Exchange Rate	$F3(Time) + SMOOTH(F3(Time), 2)$	Rial
Sanctions	$F2(Time) + SMOOTH(F2(Time), 2)$	Dmnl
Tax to GDP Ratio	0.061	Dmnl
Population	$\int_{1379}^{T} (Net\ Birth\ Rate)dt$	Person
Birth Rate	$0.01257\ \times\ Population$	$\frac{\text{Person}}{\text{Year}}$

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