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RESEARCH PAPER

The Optimal Level and Demand for International Reserves in Iran: An Optimization Formula and Monetary Disequilibrium

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Abstract

Due to the role of international reserves in eliminating disequilibrium in the balance of payments and the foreign exchange market, and their interaction with the money market, we try to answer two main questions regarding international reserves by focusing on the precautionary and monetary approaches. For this purpose, the paper is divided into two sections. In the first section, adapted to the Iranian economy, we present an optimization model based on utility maximization to calculate the optimal level of international reserves against sudden stops in capital inflows. Based on annual data for 1974–2021, the optimal ratio is about 10.5% of GDP per year in the basic scenario. In the second part, we examine the determinants of international reserves (IR). Applying the Autoregressive Distributed Lag (ARDL) technique, the results confirm that an excess of money demand (supply) causes an inflow (outflow) of IR, as postulated by the monetary approach to the balance of payments. According to the precautionary approach, adjustment costs and external debt positively affect the demand for IR. Furthermore, due to the conditions of the Iranian economy and the central bank's intervention in the foreign exchange market, as the exchange rate increases, the volume of IR decreases.

Keywords: balance of payments, international reserves, monetary approach, monetary disequilibrium, pre-cautionary approach.
JEL Classification: C22, C61, E41, F.

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Introduction

The discussion on foreign reserves has developed substantially since the collapse of the Bretton Woods system in 1973, because many countries became vulnerable to shocks in capital inflows, defined by Calvo (1988) as the Sudden Stop Syndrome. Therefore, foreign reserves held by central banks have grown significantly over the last three decades, especially in developing and emerging-market countries (Bianchi et al., 2018). For example, after the East Asian crisis of 1997–1998, countries tried to hold larger volumes of international reserves to manage sudden stops in capital inflows, which can be explained by self-insurance and precautionary motivations (Lee, 2018; Aizenman and Rhee, 2007; Aizenman et al., 2007; Gerlach et al., 2006). Following a relatively stable period in which the ratio of reserves to GDP was close to 10% since 1987, developed economies have been reducing their reserves relative to GDP, while developing economies have increased this ratio to a level exceeding 25% and, in some countries, even 30% (Pina, 2015). The reason may be that, after financial and currency crises, central banks in developing economies realized that a stronger reserve position would increase economic stability against shocks related to the balance of payments (Abdul-Rahaman and Yao, 2019; Vacaflores et al., 2012). In addition, these countries usually find themselves at risk of rising real interest rates in developed countries and try to protect themselves from the risks of capital flight or capital outflows and their effects, such as decreasing economic growth (Pina, 2015).

However, some studies, such as Sula and Oguzoglu (2021), argue that the impact of an increase in international reserves on economic growth is unclear, depending on the economic situation. For example, China and Japan are the two largest reserve holders, with approximately 23% and 10% of total global reserves in 2018. But since 1990, the average economic growth of China has been 11.9%, the highest rate among emerging-market countries, while in the same period, the average economic growth of Japan has been only about 0.7%, the lowest among developed nations. Many factors determine economic growth in different countries, and the analysis of similar countries does not establish a positive causality between the level of reserves and economic growth. Although holding foreign reserves has some benefits, it has an opportunity cost like any other asset, reflected as lost income from higher-yielding foreign and domestic investments (Benecka and Komarek, 2018; Aizenman and Sun, 2012; Rodrik, 2006). Most studies consider the opportunity cost as the cost of holding IR, but Steiner (2017) emphasizes inflationary effects. According to the quantity theory of money, the accumulation of reserves might result in inflationary pressures if the resulting monetary expansion is not sterilized and exceeds money demand growth.

So, depending on economic conditions, the balance between the benefits and opportunity costs of holding IR can differ across countries. Thus, central banks need to hold a level of international reserves that, on the one hand, is appropriate for repaying foreign debt and covering the risk of currency crises and imbalances in the BOP, and, on the other hand, strengthens income, export, and investment flows. Therefore, according to the above considerations, central banks have various reasons and motivations to hold foreign reserves, such as adjusting short-term imbalances in the BOP, when the exchange rate is fixed, paying foreign debt, and controlling the foreign exchange rate.

In the Iranian economy, a significant part of foreign reserves is affected by external shocks related to oil exports because oil revenues finance a significant part of the public budget. Therefore, foreign reserves increase in the case of a positive oil shock due to the impossibility of investing in foreign markets, but a negative shock sharply reduces the volume of foreign reserves. Also, in recent years, especially after the monetary crisis in 2017–2018, to control expectations and widespread demand for foreign exchange, the Central Bank has tried to prevent depreciation of the national currency and capital flight by supplying foreign exchange reserves to the market. In addition, trade restrictions, lack of flexibility in the foreign exchange regime, control of capital flows, and insufficient access to international financial markets are among the most significant problems of the Iranian economy that can affect IR. Changes in international reserves affect the dynamics of macroeconomic variables, especially the demand side, liquidity, and inflation. Therefore, neglecting their proper management increases the possibility of BOP imbalances and negative consequences that can spread through the economy and expose it to systematic risks. For this reason, considering the importance of international reserves and the factors affecting them, this study tries to answer the following questions:

- According to the conditions of the Iranian economy, what is the optimal level of foreign reserves in terms of GDP?
- What is the relationship between the level of reserves held by the central bank and other macroeconomic variables in the Iranian economy?

Considering the research questions, we organize the remainder of the paper as follows. Section 2 reviews the literature on IR. Section 3 presents the optimization model. Section 4 describes the theory of demand for IR and the econometric methodology. Section 5 concludes.

Literature Review

As stated in the previous section, the IR-to-GDP ratio in developing countries has increased faster than in developed countries over the last three decades. Although holding IR can have significant economic benefits, it also has opportunity costs because of the lost income from high-yield investments. This issue encourages central banks to use cost-benefit approaches to determine the optimal level of IR. Around the mid-1960s, researchers began to study the incentives of central banks to hold IR, for example, Machlup (1966) and Heller (1966). According to Machlup's "wardrobe theory," IR holding is not the result of the central bank's rational behavior; rather, it is caused by the insatiable desire of central banks to hold more reserves. In contrast, the optimizing approach, pioneered by Heller (1966), postulates that central banks behave rationally and determine their reserve level by trading off the opportunity costs and benefits of holding reserves. The opportunity cost of holding reserves is, in fact, the income that the government or the central bank could obtain from investing in domestic and foreign markets, but this income is forgone by holding reserves (Benedict and Souster, 2014). Prior to Heller (1966), researchers examined only the qualitative nature of reserves, but he provided a formula for determining the optimal level of reserves and the deviation of observed values from it. Frenkel and Jovanovic (1981) presented this issue dynamically, including the inventory-theoretic approach based on Baumol's approach to the demand for money. According to this theory, the central bank should solve the problem of minimizing the cost of holding reserves. Therefore, the optimal level of IR depends inversely on the opportunity cost and directly on adjustment costs, which are the core of buffer-stock models and precautionary approaches to holding foreign reserves. Developing countries try to maintain larger reserves as a tool to implement adjustment policies and manage imbalances in the BOP (Mulapo, 2016). Therefore, the greater the fluctuations or costs of adjusting the balance of payments, the larger the volume of IR held by the central bank to implement adjustment policies.

The stocks of reserves might be regarded as precautionary savings intended to prevent and manage future economic crises and to reduce output volatility (Aizenman and Lee, 2007), so IR plays a prominent role as a buffer stock or anti-shock mechanism against sudden stops in capital inflows (Padhan et al., 2021; Bianchi et al., 2018). When the economy experiences a sudden stop in capital inflows, the cost of financing through external debt will increase. Therefore, holding foreign reserves as an insurance tool will cover such costs (Aizenman et al., 2020; Hur and Kondo, 2016; Durdu et al., 2009). As a prudential tool, it increases the flexibility of the financial system in the face of private over-borrowing. In other words, reserve accumulation leans against the wind and significantly reduces exposure to financial crises (Arce et al., 2019). Furthermore, in countries where the private sector has less access to international financial markets and cannot insure itself against external shocks, the role of foreign reserves as an insurance and precautionary tool is greater than in other countries (Jeanne and Sandri, 2020). Although this situation was more prevalent under the Bretton Woods system than today, as discussed by Monnet and Puy (2019), it remains relevant for developing countries with low levels of international financial integration (Jeanne and Sandri, 2020). Other related empirical work addressing the precautionary motive for reserves includes Calvo et al. (2013), Bussiere et al. (2013), Frankel and Saravelos (2012), Obstfeld et al. (2010), Mendoza et al. (2009), Carroll and Jeanne (2009). In addition to managing imbalances in the BOP, some empirical studies consider external debt repayment in line with a precautionary motive. Especially in developing countries, the first and easiest way to repay external debt is to use the international reserves held by the central bank. Therefore, as external debt increases, the central bank holds more reserves to repay debt and ensure financial stability. Foreign reserves hedge the government's fiscal position and enhance its credibility (Bocola and Lorenzoni, 2017). According to the Greenspan–Guidotti rule, the central bank must hold foreign reserves up to the amount of external debt with one-year or less maturity. Some authors, such as Aizenman et al. (2020), Zhu et al. (2018), Schröder (2017), Vacaflores et al. (2012), and Bankole et al. (2011), confirm the positive relationship between the level of external debt and IR.

Although the precautionary approach is the prevailing view in the literature, another important approach to holding IR is the mercantilist approach, which focuses on the country's exports and argues that reserve accumulation may be a by-product of industrial policies promoting exports in the presence of growth externalities (Korinek and Serven, 2016; Rabe, 2016; Michaud and Rothert, 2014; Benigno and Fornaro, 2012; Rodrik, 2008; Aizenman and Lee, 2007). If there is a significant positive relationship between exports and the level of IR, policies that increase production and exports can be more effective than adjustment policies in increasing the level of IR. On the other hand, under a floating exchange-rate regime, the accumulation of IR and the non-entry of foreign exchange into the market will increase the exchange rate, which in turn can help strengthen export incentives and increase IR. According to this approach, a more flexible exchange-rate regime allows more automatic market adjustments and eliminates imbalances in the balance of payments (Dolly et al., 2003). The imbalance in the BOP can then be reduced endogenously without the need for adjustment policies (Aizenman and Lee, 2007). In developing economies such as Iran, however, where the exchange rate is recognized as one of the most important factors in shaping expectations, the central bank targets the exchange rate (its level or fluctuations) to control inflation expectations and prevent excessive depreciation. The central bank uses foreign exchange reserves to intervene in the market and deal with sudden shocks of exchange-rate appreciation and capital outflows (Sola and Agazoglu, 2021; Frommul and Medilich, 2021; Rob, 2016). In such circumstances, if the exchange rate increases relative to the level desired by the central bank, the amount of foreign exchange reserves injected into the market increases, and the volume of reserves decreases. Hossain and Ahmed (2009) found low relative exchange-rate volatility from 2006 to 2008, indicating active intervention by Bangladesh Bank in the foreign exchange market during this period. Krugman (1979), in first-generation models of monetary crises, argues that high reserves only delay the onset of a crisis and cannot prevent it.

An Optimization Formula for the Level of IR: JR Model

In this section, we present a formula that measures the optimal level of IR, considering the economic conditions of Iran, such as the dependence of capital inflows on external factors, including the global oil market and international sanctions. Some related empirical work using an optimization framework includes Bianchi et al. (2018), Zhou et al. (2018), and Jovanovikj and Andonova (2017). Here, the model is taken from Jeanne and Rancière (2011), which is suitable for small open economies (SOEs) and has formed the basis of many studies since the 2008 crisis. This model is based on utility maximization and a buffer mechanism, in which BOP and domestic absorption changes are considered when the economy faces a capital inflow shock. In this model, the optimal level of IR is regarded as an insurance tool. The economy is on a long-term stable path, and the only source of uncertainty or negative shock is related to capital flows (a sudden stop). Time is assumed to be discrete and infinite, and only one good is available at home and abroad. The economy is divided into the government and the private sectors. The private sector includes a continuum of atomistic, identical, infinitely lived consumers with an intertemporal utility defined by

$u_t = E_t[\sum_{i=0}^{\infty}(1+r)^{-i}u(C_{t+i})],$ (1)

where the flow utility function has a constant relative risk aversion (CRRA):

$$u(C) = \frac{C^{1-\sigma}}{1-\sigma} \quad \sigma \geq 0;\ \sigma \neq 1, \qquad (2)$$
$$u(C) = \log(C) \quad \sigma = 1$$

Consumers maximize their welfare subject to the following budget constraint:

$C_t = Y_t + L_t - (1+r)L_{t-1} + Z_t,$ (3)

where Y_t is domestic output, L_t is external debt and Z_t is a transfer from the government. The interest rate *r* is constant, and the representative consumer does not default on her external debt. Another constraint that borrowers face is the existence of a prudential tool that determines the proportion of domestic income that they are allowed to borrow. In the literature on prudential tools in the financial markets, this constraint is called the loan-to-income ratio, which is defined as follows:

$(1+r)L_t \leq \alpha_t Y_{t+1}^n,$ (4)

where the debt is fully repaid in period t+1 and α_t is a time-varying parameter that captures the pledgeability of domestic output to foreign creditors. We assume that both α_t and $Y_t$are known in period t, implying that debt issued in t is default-free if condition (4) is satisfied. Thus, the lower the α_t value, the fewer capital inflows and the lower the possibility of a shock. This parameter can be influenced by domestic and foreign economic conditions, expectations, and the penalty imposed on domestic defaulters (Broner and Ventura, 2011), which is assumed to be exogenous for simplicity and according to the purpose of this study. The economy can be in two states: the normal – or non-crisis – state (denoted by *n*), or in a sudden stop (denoted by *s*). In normal times output grows at a constant rate *g* and the private sector can pledge a constant fraction of output.

$Y_t^n = (1+g)^t Y_0,$ (5)

$\alpha_t^n = \alpha_0,$ (6)

but if there is a sudden stop, output falls by a fraction γ below the trend, and the foreign sector does not pay any loans to the private sector.

$Y_t^s = (1-\gamma)^t Y_t^n$ (7)

$\alpha_t^s = 0.$ (8)

To ensure that the consumer can repay all her debt in a sudden stop, we assume $\alpha + \gamma < 1$ We assume $r > g$ to keep the consumer's intertemporal income finite. In the real world, capital can take more than one year to flow back to a country after a sudden stop. Thus, we assume that it takes a specific number of periods θ for the economy to return to its path after a sudden stop. If a sudden stop happens at time *t*, the economy stands back in state *n* at time $t+\theta+1$. According to the above interpretations, the dynamics of the economy and foreign debt in this time interval will be as follows:

$$Y_{t+\tau}^{s} = [1-\gamma(\tau)]Y_{t+\tau}^{n}, \qquad \tau = 0,1,\dots,\theta \tag{9}$$

$$\alpha_{t+\tau}^{s} = \alpha(\tau), \tag{10}$$

where $\gamma(.)$ and $\alpha(.)$ are exogenous and non-negative functions, respectively decreasing and increasing in τ. Also, in $\tau = 0$, we have $\gamma(0) = \gamma$ and $\alpha(0) = 0$ and in $\tau = \theta$ we have $\gamma(\theta) = 0$ and $\alpha(\theta) = \alpha$. It is further assumed that at the end of the sudden stop episode the consumer has regained the same level of access to external credit as before the sudden stop, $\alpha(\theta) = \theta$. In this model, the only source of uncertainty is the capital inflow shock or risk of a sudden stop. The probability of sudden stop occurrence is denoted by π. These shocks reduce consumer welfare in two ways: On the one hand, consumption declines to a lower level than its trend, decreasing the consumer's welfare if her intertemporal substitution of consumption elasticity is finite, and on the other hand, by reducing production and domestic income, the intertemporal income will decrease if there is no transfer payment from the government. Therefore, in this model, the role of the government is to insure the consumer against the shock of capital inflows smooth her consumption path by joining a 'reserves insurance contract' with foreign investors. It is assumed that the government pays the premium X_t at time t to the insurer and instead receives a payment R_t from the insurance company if the economy is faced with a shock.

The government simply transfers the cash flows resulting from the contract to the domestic consumer, which implies Equation (11) as long as the economy stays in state n, and Equation (12) when the economy moves into state s.

$$Z_t^n = -X_t, \tag{11}$$

$$Z_t^s = R_t - X_t, \tag{12}$$

Thus, the government must relinquish some of the resources in normal times to keep the economy on a stable path. Such a decision would impose the opportunity cost of these resources on the economy. Finally, we need to specify the price at which the foreign insurers provide the reserves. We denote by μ_t the marginal utility of funds (or pricing kernel) for the insurers at time t and assume that it is higher if the domestic economy is in a sudden stop. The difference between μ_t^s and μ_t^n determines the cost of insurance for the small open economy.

For simplicity, it is assumed that the price of a non-crisis dollar in terms of a crisis dollar is constant and denote it by

$\vartheta = \frac{\mu_t^n}{\mu_t^s} \leq 1.$

The foreign insurers are perfectly competitive, and their discount rate is the same as the domestic consumer. The present discounted value is denoted by:

$$\sum_{t=1}^{\infty} \beta^t (1-\pi)^{t-1} [(1-\pi) X_t \mu_t^n - \pi (R_t - X_t) \mu_t^s] \geq 0 \tag{13}$$

A Formula for the Optimal Level of Reserves

The government chooses the paths $(X_t . R_t)_{t=1.2....}$ to maximize domestic welfare (1) subject to the (3), (4), (11), (12), and (13). The Lagrange can be written as:

$$\mathscr{L} = \sum_{t=1}^{+\infty} \beta^t (1-\pi)^t \{(1-\pi) u(C_t^n) + \pi (C_t^s) + \varphi[(1-\pi) X_t \mu_t^n - \pi (R_t - X_t) \mu_t^s]\},$$

where φ is the shadow cost of constraint (13). By solving the problem of maximization, the consumption paths in the normal and sudden stop periods, X_t, and R_t are obtained as follows:

$$C_t^n = Y_t^n + \frac{\alpha}{1+r} Y_{t+1}^n - \alpha Y_t^n - X_t, \tag{14}$$

$$= Y_n^t \left(1 - \frac{r-g}{1+g} \lambda\right) - X_t,$$

$$C_t^s = Y_t^s - \alpha Y_t^n + R_t - X_t, \tag{15}$$

$$= Y_n^t \left(1 - \gamma - \frac{1+r}{1+g} \lambda\right) + R_t - X_t,$$

$$X_t = \frac{\pi}{\pi + \vartheta(1-\pi)} R_t, \tag{16}$$

According to first-order conditions:

$$\frac{u^{\cdot}(C_t^n)}{u^{\cdot}(C_t^s)} = \vartheta = \frac{\mu_t^n}{\mu_t^s} \tag{17}$$

This result implies that the domestic consumer can substitute consumption between the normal and sudden stop states at the same rate as foreign investors. Before obtaining the final formula for the optimal level of IR-to-GDP, it is necessary to assume that (4) is always binding. Under this assumption, the ratio of short-term external debt to GDP in the normal state is constant, given by

$$\lambda = \frac{L_t^n}{Y_t^n} = \frac{1+g}{1+r} \alpha, \tag{18}$$

Finally, the optimal level of the IR-to-GDP ratio is constant and given by

$$\rho^* \equiv \frac{R_t}{Y_t^n} = \frac{\lambda + \gamma - \left[1 - \frac{r-g}{1+g}\lambda\right]\left(1 - \vartheta^{1/\sigma}\right)}{1 - \frac{\pi}{\pi + \vartheta(1-\pi)}\left(1 - \vartheta^{1/\sigma}\right)}, \tag{19}$$

where ρ^* is positive, and λ is the ratio of short-term debt to GDP, r is the interest rate, σ is risk aversion, g is the growth rate, π is the probability of a sudden stop, γ is the output loss in the first period of the sudden stop, and ϑ is the price of a non-crisis dollar in terms of crisis dollar for global investors. The optimal level increases, more than one for one, with γ and λ. It is also increasing with the probability of a sudden stop. In addition, this formula implies:

$\rho^* < \lambda + \gamma \qquad \vartheta < 1$

$\rho^* = \lambda + \gamma \qquad \vartheta = 1$

$\vartheta = 1$ means that foreign investors do not value liquidity more in a sudden stop, In this case, the reserves contract provides full insurance in the sense that consumption is the same whether or not there is a sudden stop. The optimal level increases with γ, λ (more than one for one), σ, and π.

The Simulation and Measurement of the Optimal Scale

The optimal ratio of reserves is a function of seven parameters that can be calculated according to the data available in the Iranian economy (1973–2021). The following subsector is a summary of how to calibrate and collect each:

Parameters Setting

The Probability of the Occurrence of the Sudden Stop of Capital (π):

Guidotti et al. (2004), provided a simple definition of the shock of capital inflows. They identified a sudden stop in year t if the ratio of capital inflows to GDP falls by more than 5% relative to the year $t-1$.

$k_t - k_{t-1} < -5\%$

The threshold of 5% is obtained from the ratio of the standard deviation of capital inflows to its mean. Since a significant part of the inflow of foreign reserves into the Iranian economy is related to oil exports, we use this variable to obtain the threshold. According to the standard deviation values (8%) and its mean (16%), the threshold is 0.5%, rounded to 1%. In our sample data, the number of years k_t has decreased by more than 1% is 21. So π is about 0.43.

Ratio of External Debt to GDP (λ):

This ratio is equal to 0.0923 on average in our sample.

Output Loss (γ):

The GDP growth rate falls by 0.082 on average if we restrict the sample to the sudden stops in which output falls.

The price of a non-crisis dollar in terms of crisis dollar (ϑ):

Using the Euler and first-order conditions, expression (20) can be obtained in which δ is a pure risk premium that comes from the fact that foreign investors must provide liquidity when it is more valuable to them. In this study, we use the average difference between short and long-term interest rates, 0.06. Therefore, ϑ is 0.79, which is less than one.

$$\vartheta = 1 - \frac{\delta}{(1-\pi)(\pi+\delta)} \tag{20}$$

Short-term Interest Rate (r):

This variable is 0.078 on average in the sample data.

Economic Growth (g):

According to our sample, the average of the economic growth is 0.0167.

Risk Aversion Index (σ):

Amini Rad et al. (2019) calculated this index on average 3.18 for the Iranian Economy using data from 1970 to 2018.

Based on above analysis, calculation results of each parameter can be summarized as follows, including calculated values in the JR model.

Table 1. Calculated Values

Related Parameters	Iranian Economy	JR Model
Probability of a sudden stop (π)	0.43	0.1
Ratio of External Debt to GDP (λ)	0.0923	0.107
Output Loss (γ)	0.082	0.065
Price of a non-crisis dollar in terms of crisis dollar (ϑ)	0.79	0.885
Short-term Interest Rate (r)	0.078	0.05
Economic Growth (g)	0.0167	0.066
Risk Aversion Index (σ)	3.18	2

Source: Research finding, based on data of Central Bank of Iran and the World Bank**.**

Optimal Level of IR

By calculating seven parameters, we can do the numerical simulation to conduct Iran's optimal foreign exchange reserves under the utility maximization framework and compare it with the actual foreign exchange reserves. Using Equation (19), the calculated parameters in Table 1 imply an optimal IR level of GDP (10.5%). To be more intuitive, the optimal IR level and actual level are shown in Figure 1.

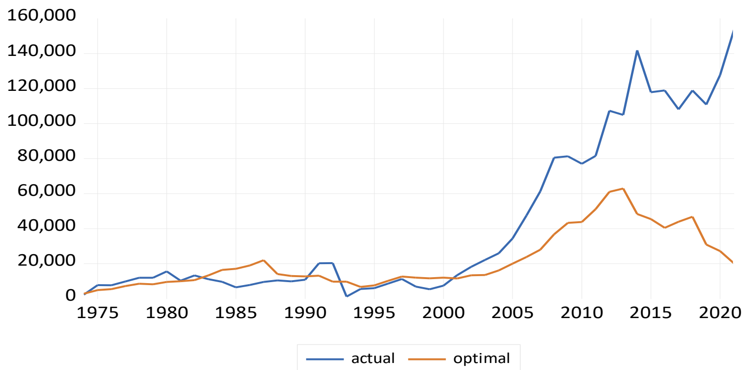

Figure 1. The Actual and Optimal Scales of IR (Million USD)
Source: Research finding.

As can be seen, the optimal level has changed significantly with short-term changes in the actual scale of IR. After 2002, due to a sharp and continuous increase in oil exports, the actual level was higher, and this gap increased until 2021. Although a high level of IR can have some economic advantages, it imposes a high opportunity cost on the economy. In addition, it affects the monetary base and inflation.

Zhu et al. (2018) and Molapo (2016) calculated the optimal ratio for China and Lesotho, respectively, at 13.5% and 44%. Jeanne and Rancière (2011) calculated this ratio for Korea, Malaysia, the Philippines, and Thailand, respectively, at 16%, 20%, 9%, and 19%. As stated, following Equation (15), the optimal ratio of IR to GDP is a function of seven parameters, which increases or decreases linearly or nonlinearly with changes in each of them. For example, Figure 2 shows the changes in the optimal ratio with changes in π, γ, λ, and σ. The vertical axis shows changes in the optimal ratio.

Figure 2.1. π

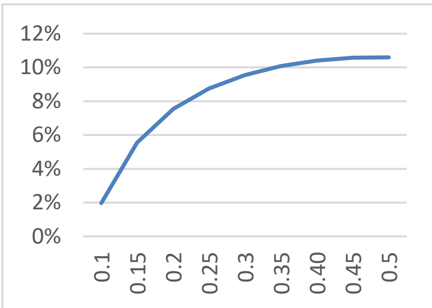

Figure 2.2. γ

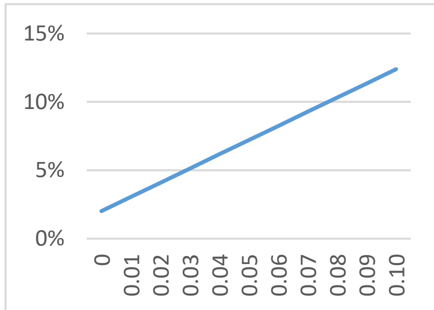

Figure 2.3. $\boldsymbol{\lambda}$

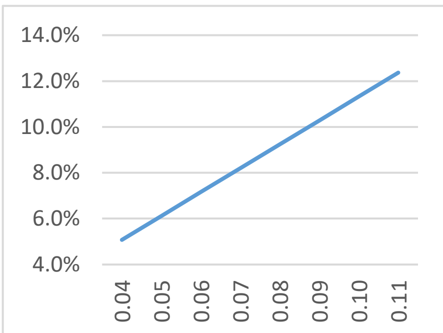

Figure 2.4. $\boldsymbol{\sigma}$

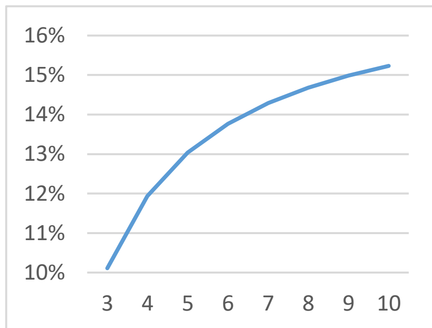

Figure 2. Response of the Optimal Ratio to Parameter Values
Source: Research finding.

Demand for IR: A Monetary Disequilibrium

As we showed in Section 3, the level of international reserves has been above the optimal level over the last two decades. Some macroeconomic factors affect the level of international reserves, causing actual values not necessarily to equal optimal values. In this section, we present the empirical model incorporating various determinants of Iran's reserve demand. In addition to the mercantilist and precautionary approaches, which we explained in Section 2, we consider the monetary approach to the balance of payments to estimate the demand for IR. The monetary approach can be considered one of the most important theoretical approaches in the international economic literature, especially in international finance, and it is central to many economic views in this field. This approach to the balance of payments examines the relationship between the domestic money market and the level of foreign reserves.

The core of the monetary approach was presented by the International Monetary Fund (Pollack and Argy, 1971), and it is based on the quantity theory of money, money creation, the monetarist view, and the concept of the money multiplier. According to this theory, the balance of payments reacts to monetary variables. Johnson's model (1972; 1976) is also based on the monetary approach and considers money a substitute for foreign reserves. Therefore, any factor that increases the demand for domestic money reduces the demand for IR, especially in the private sector, and ultimately leads to an increase in IR held by the central bank. Hence, variables such as economic growth, due to the positive income elasticity of money demand, and inflation, due to transaction motives, increase the demand for money and reduce the demand for foreign reserves, especially foreign exchange reserves, and thus positively affect IR. Thus, the central bank will hold a level of international reserves that can offset imbalances in the domestic money market. This means that if there is excess demand for money, the volume of IR will increase, and vice versa; if there is a shortage in the demand for money, the level of IR will decrease. In some studies, such as Islam (2021), Nayak and Alim Beg (2019), Afarin et al. (2014), and Badinger (2004), the variable of money disequilibrium is used as one of the pillars of the monetary approach to the balance of payments[1].

Following these theories and in the context of Iran, the model (21) presents the demand function of IR. Regressors are divided into two general groups: (a) factors that stimulate the increase of international reserves and (b) factors that prevent the accumulation of these reserves. Following the monetary approach, we use economic growth GR_t, inflation INF_t, and monetary disequilibrium MD_t. Following the mercantilist approach, we use the moving average of the ratio of export to import MX_t, and foreign exchange rate E_t. Finally, according to the precautionary framework, we consider adjustment costs AC_t , and external debt, $DEBT_t$.

[1]. To study more about the demand for IR, see Kashif and Sridharan (2020), Lee and Yoon (2020), Manja (2020), Bošnjak et al. (2020), and Yazdani and Pirpour (2017).

$$lnIR_t = \beta_0 + \beta_1 INF_t + \beta_2 GR_t + \beta_3 MX_t + \beta_4 lnAC_t + \beta_5 lnDEBT_t + \beta_6 lnE_t + \beta_7 MD_t + u_t \quad (21)$$

All data are collected from the Central Bank of Iran and the World Bank for 1973-2021. But we must calculate the monetary disequilibrium and adjustment costs theoretically.

Monetary Disequilibrium

In calculating monetary disequilibrium, we first need to estimate a simple but standard money demand function. A common empirical specification typically posits that the demand for money is positively related to income or wealth and negatively related to its opportunity cost. However, in oil-dependent economies such as Iran, the foreign exchange rate is also one of the important variables that can affect the demand for money positively or negatively. The coefficient of the exchange rate can be either negative or positive, depending on whether an increase in the exchange rate increases the value of foreign assets in domestic currency (positive) or increases expectations of further depreciation (negative). The outcome of these two channels determines the sign of the coefficient. Within this framework, different estimable functions can be selected depending on the monetary aggregate used, the choice of wealth or income as explanatory variable(s), the particular measures of income (GDP, consumption), and the opportunity cost of holding money. Of the various models, we select a simple one that is relatively standard in the literature and set up the long-run money demand function as:

$$lnM2_t = \alpha_0 + \alpha_1 lnGDP_t + \alpha_2 RR_t + \alpha_3 lnE_t + \epsilon_t, \quad (22)$$

where $M2_t$ is the real liquidity, RR_t is the real interest rate on long-term deposits, E_t is the foreign exchange rate (per USD), and ϵ_t is the error term. Because a significant part of liquidity in the Iranian economy is related to quasi-money, this study uses M2 as a monetary aggregate. All variables except the interest rate are in log form. After estimating the long-run equation, following Nayak and Allim Baig (2019), Afrin et al. (2014), Badinger (2004), and Edwards (1984), we use Equation (23) to calculate the monetary disequilibrium:

$$MD_t = lnM2_{t-1} - lnM2_t^*, \quad (23)$$

where $M2_t^*$ is the fitted or equilibrium values. Negative (positive) values of MD_t are associated with an excess demand for (excess supply of) money. As the money demand function (22) is specified in log form, the monetary disequilibrium is expressed in relative terms.

Adjustment Costs

Following Ramachandran (2004), we use Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models to estimate the conditional variance of IR_t as a measure of its fluctuations and adjustment costs. In particular, this study uses Exponential GARCH (E-GARCH), an asymmetric conditional heteroskedasticity model introduced by Nelson (1991). One advantage of this model is that the conditional variance is in log form, so the coefficients can be positive or negative.

First, using Autoregressive Integrated Moving Average (*ARIMA*) models, we estimate the conditional average of international reserves, Equation (24). Then after applying the ARCH Heteroskedasticity Test of variance, the E-GARCH model will be estimated according to Equation (25).

$$IR_t = \alpha_0 + \alpha_1 IR_{t-1} + \cdots + \alpha_p IR_{t-p} + \rho_1 u_{t-1} + \cdots + \rho_q u_{t-q} + u_t \quad (24)$$

Equation (24) describes the $ARMA\ (p, q)$ model. In an *ARIMA* (*p,d,q*) model, the equation is applied to the *d*-th differences of *IR* instead.

$$\ln\sigma_t^2 = \omega + \beta\ln\sigma_{t-1}^2 + \gamma\frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha\left[\frac{|u_{t-1}|}{\sqrt{\sigma_{t-1}^2}} + \sqrt{\frac{2}{\pi}}\right] \quad (25)$$

where σ_t^2 is the variance of error term u_t in Equation (24), and finally, for the adjustment cost AC:

$$AC_t = \sqrt{\sigma_t^2} \quad (26)$$

Empirical Results

Before estimating Equations (21), (22), (24), and (25), we need to specify the order of integration of the variables. Using the Augmented Dickey-Fuller (ADF) unit root test, we found that economic growth, inflation, and the real interest rate are integrated of order zero, I(0), whereas the other variables are integrated of order one, I(1) (see Appendix, Table I).

Estimating the E-GARCH Model

Since IR_t is integrated of order one, we use ΔIR_t. According to the criteria for selecting the optimal number of lags, Schwarz and AIC, ΔIR_t follows an AR(2) process. An ARCH test with two lags indicates that the variance of the error term in (24) is time-varying, so we can estimate the E-GARCH model. The results are presented in Table 2 and Figure 3.

Table 2. E-GARCH Model for the International Reserves

Variable	Coefficient	Std. Error	P-Value
AR (1)	-0.122	0.056	0.030
AR (2)	0.495	0.023	0.000
Variance Equation			
ω	7.775	2.221	0.000
β	0.543	0.269	0.000
γ	1.792	0.1201	0.000

Source: Research finding.

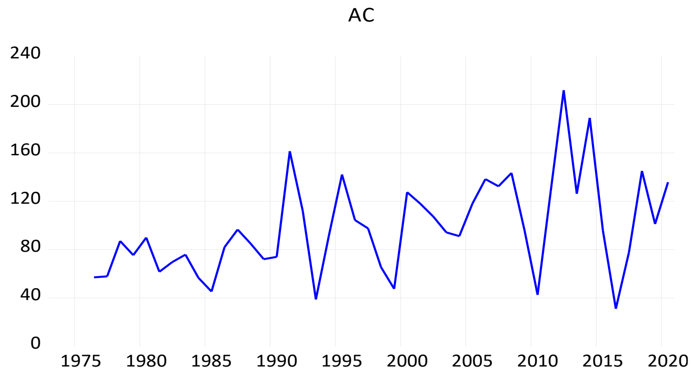

Figure 3. Adjustment cost obtained by Equation (26).
Source: Research finding.

Estimating the Demand for Money

Using EViews 12, we apply the ARDL technique (Pesaran and Shin, 1999) to estimate the cointegrating and error correction model. For the ARDL cointegration test, some variables in an otherwise first-order integrated system can be stationary, I(0). In other words, the ARDL test for cointegration is robust to different integration orders, I(0) and I(1). The model selection criteria, such as Schwarz and AIC, imply an ARDL(1, 0, 0, 0) model (see Appendix, Table II). Table 3 shows the results of the ARDL bounds test. The F-statistic exceeds the upper critical bound, which confirms a cointegrating relationship at the 1% significance level. Table 4 includes the estimate of this long-run relationship.

Table 3. F Bounds Test.

Test statistic	Value	K	$H0$
F-statistic	7.46	3	*No Long-Run Relationship*
Critical Value Bounds			
Significance	I(0) Bound	I(1) Bound	Result
10%	2.72	3.77	*Relationship Exists*
5%	3.23	4.35	*Relationship Exists*
1%	4.29	5.61	*Relationship Exists*

Source: Research finding.

Table 4. Long-run Demand for Money

Variables	Coefficient	Std. Error	P-Value
LnGDP	1.138	0.322	0.0010
RR	0.078	0.025	0.0036
LnER	-0.626	0.343	0.0753
D19-20	1.485	0.592	0.0163
C	3.975	7.757	0.6111

Source: Research finding.

As noted above, a considerable share of liquidity is related to quasi-money and long-term deposits (about 85%). Therefore, the interest rate has a positive effect on total liquidity. This result has been confirmed in many studies of the Iranian economy. Furthermore, foreign exchange and the national currency are substitutes in the Iranian economy. For this reason, the foreign exchange rate has a negative effect on the demand for domestic money. $D19–20$ is a dummy variable that equals 1 for 2019–2020. After estimating the long-run relationship, the monetary disequilibrium can be calculated following Equation (23). Figure 3 shows this variable, in which negative values indicate excess demand.

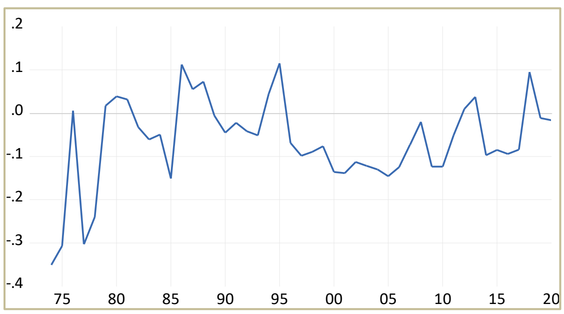

Figure 3. Monetary Disequilibrium

Source: Research finding.

Demand for IR

After computing the adjustment costs and monetary disequilibrium, we can estimate the demand function for IR by applying the ARDL method. By selecting different numbers of lags for the dependent and explanatory variables, the Schwarz, AIC, and HQ criteria are minimized for the ARDL(1, 1, 1, 0, 0, 0, 0, 0) model (see Table 5). The results of the bounds test in Table 6 indicate that there is a cointegrating relationship, as shown in Table 7.

Table 5. ARDL (1, 1, 1, 0, 0, 0, 0, 0) Model for Demand for IR

Variables	Coefficient	Std. Error	P-Value
ln*IR*(-1)	0.699	0.045	0.000
INF	0.020	0.004	0.000
INF (-1)	-0.007	0.003	0.045
GR	0.019	0.004	0.000
GR(-1)	-0.008	0.004	0.032
MX	0.003	0.002	0.082
ln*AC*	0.082	0.042	0.059
ln*DEBT*	0.181	0.036	0.000
ln*E*	-0.007	0.000	0.000
MD	-0.335	0.179	0.069
D7578	-0.573	0.117	0.000
D6163	-0.354	0.129	0.010
Constant	3.107	0.611	0.000
R-squared = 0.980		*p-Value = 0.000*	

Source: Research finding.

Table 6. F Bounds Test

Test statistic	Value	*K*	*H*0
F-statistic	4.39	7	*No Long-Run Relationship*
Critical Value Bounds			
Significance	I(0) Bound	I(1) Bound	Result
10%	2.03	3.13	*Relationship Exists*
5%	2.32	3.5	*Relationship Exists*
1%	2.96	4.26	*Relationship Exists*

Source: Research finding.

Table 7. Long-run Equation for the demand for IR.

Variables	Coefficient	Std. Error	P-Value
INF	0.043	0.017	0.021
GR	0.034	0.018	0.069
MX	0.012	0.007	0.085
ln*AC*	0.274	0.152	0.081
ln*DEBT*	0.603	0.087	0.000
LnE	-0.024	0.004	0.000
MD	-1.115	0.697	0.106
D7578	-1.90	0.424	0.000
D6163	-1/177	0.464	0.016
Constant	10.34	1.001	0.000

Source: Research finding.

Table 8. EC Equation for the demand for IR

Variables	Coefficient	Std. Error	p-Value
D(INF)	0.020	0.004	0.000
D(GR)	0.019	0.004	0.000
D(MX)	0.003	0.002	0.082
D(ln*AC*,2)	0.082	0.042	0.059
D(ln*DEBT*)	0.181	0.036	0.000
D(*LnE*)	-0.007	0.000	0.000
D(*MD*)	-0.335	0.179	0.069
D(*D7578*)	-0.573	0.117	0.000
D(*D6163*)	-0.354	0.129	0.010
ECM (-1)	-0.300	0.045	0.000

Source: Research finding.

Coefficients of inflation, economic growth, and monetary disequilibrium are consistent with the monetary approach, because any factor that increases the demand for domestic money reduces the demand for IR, especially by the private sector, and ultimately leads to an increase in IR held by the central bank. Monetary disequilibrium has a negative effect on the level of IR, so excess supply of money leads to a decrease in the level of IR; in contrast, excess demand leads to an increase in IR. According to the monetary approach, monetary disequilibrium has a short-term effect on the level of IR. As shown in Tables 7 and 8, it is significant in the short-run equation, but its significance decreases in the long run. The coefficients of the export-to-import ratio and the exchange rate are in line with the mercantilist approach. According to empirical evidence, when the Iranian foreign exchange market faces excess demand, the Central Bank injects IR into the market to prevent an increase in the foreign exchange rate, which leads to a reduction in the volume of IR.

The estimated results suggest that the more Iran moves to a free-floating regime, the less foreign exchange reserve it will demand in the long run, assuming that the effects of all other determinants remain constant. The findings of this study are similar to those of Aizenman and Marion (2004) for panel data from 100 developing countries and Mishra and Sharma (2011) for the Indian economy. Finally, the coefficients of adjustment costs and foreign debt are consistent with the precautionary theory. The central bank holds IR to reduce the cost of adjustment policies because high fluctuations in the balance of payments increase adjustment costs. The coefficient of ECM_{t-1} is -0.33, which means that each year, 33% of the error or disequilibrium disappears.

Conclusion

In the past three decades, the level of international reserves held by central banks has increased, especially in developing countries. Much research in international economics has focused on this issue. In this study, we addressed two main questions regarding international reserves in the Iranian economy. In the first part, using the JR model as an optimization model, we estimated the optimal IR-to-GDP ratio, which helps protect the economy against sudden stops in capital inflows. Using annual data from 1974 to 2021, we obtained seven parameter values, including a sudden-stop probability of 43%. The result of the final formula shows that the optimal IR-to-GDP ratio is 10.5%. According to the calculations, after 2002 the actual level was higher, due to a sharp and continuous increase in oil exports, and this gap widened until 2021. Although a high level of IR can have some economic advantages, it imposes a high opportunity cost on the economy. In addition, it affects the monetary base and inflation.

In the second part, we examined the determinants of IR held by the central bank by applying the cointegration technique. First, we calculated adjustment costs using an E-GARCH model and then measured monetary disequilibrium by estimating the money demand function. According to the monetary approach to the balance of payments, domestic inflation positively affects IR, and excess money demand (supply) causes an inflow (outflow) of IR. The foreign exchange rate affects IR negatively. When the Iranian foreign exchange market faces excess demand, the Central Bank injects IR into the market to prevent an increase in the foreign exchange rate, which leads to a reduction in the volume of IR. This result is consistent with mercantilist theory. In other words, the more flexible the regime, the more automatic market adjustments and mechanisms eliminate disequilibrium in the balance of payments. Finally, the central bank holds IR to reduce the cost of adjustment policies because high fluctuations in the balance of payments increase adjustment costs; therefore, according to the precautionary approach, adjustment costs increase the level of IR. According to the results, especially those discussed in the first part, BOP stability is strongly affected by oil exports. Given that the Iranian economy and government budget are highly dependent on oil revenues, fluctuations in this variable affect the level of international reserves. Therefore, implementing macroeconomic policies that reduce dependence on oil exports and fluctuations in the foreign exchange market can ultimately help stabilize the BOP.

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Appendix

Table I. Results of the Unit Root Test

Variables	Function	Test Statistic	Result
ln*M2*	*(C, T, 0)*	-2.349	*I*(1)
ln*M2D*	*(C, -, 0)*	-5.94	
ln*GDP*	*(C, T, 1)*	-2.79	*I*(1)
*D*ln*GDP*	*(-, -, 0)*	-4.87	
RR	*(C, -, 0)*	-5.28	*I*(0)
ln*E*	*(C, -, 0)*	-1.82	*I*(1)
DLnE	*(-, -, 0)*	-5.4	
LnIR	*(C, -, 0)*	-2	*I*(1)
DLnIR	*(-, -, 0)*	-9.27	
INF	*(C, -, 0)*	-5.04	*I*(0)
GR	*(-, -, 0)*	-4.87	*I*(0)
MX	*(C, -, 0)*	-2.01	*I*(1)
DMX	*(-, -, 2)*	-5.81	
LnAC	*(C, T, 1)*	-2.66	*I*(1)
DLnAC	*(-, -, 0)*	-12.05	
LnDEBT	*(C, T, 0)*	-2.16	*I*(1)
DLnDEBT	*(-, -, 0)*	-7.75	

Source: Research finding.

Table II. Result of ARDL Model for Money Demand

Variables	Coefficient	Std. Error	P-Value
ln*M2*(-1)	0.901	0.025	0.0000
ln*GDP*	0.111	0.055	0.0516
RR	0.007	0.0008	0.0000
ln*ER*	-0.061	0.021	0.0065
D19-20	0.145	0.042	0.0015
C	0.389	0.678	0.5687
R-squared = 0.995		*Prob (F-statistic)* = 0.000	

Source: Research finding.