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ECONOMICS
Innovative and Economics Research Journal
Volume 12, No. 1, 2024
www.economicsrs.com

MODELLING THE DEMAND FOR INDONESIA'S FOREIGN RESERVES

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Received 08.01.2024. | Sent to review 18.01.2024. | Accepted 04.04.2024.

Original article

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JEL Classification: E58, F31, G15, O11, C32

Doi: 10.2478/eoik-2024-0005

UDK: 339.74:336.745(594)

ABSTRACT

The foreign reserves sufficiency is important to maintain macroeconomic stability. The main objective of this paper is to model the behaviour of the central bank in accumulating the foreign reserves in the case of Indonesia. Unlike the previous empirical studies, this paper disaggregates the components of foreign reserves into foreign currency, securities, gold, and special drawing rights. This paper relies on the Almost Ideal Demand System combined with the Error Correction Model. The estimation result for monthly data over the period 2010(1)-2020(12) reveals that the own-price coefficients are negative and statistically significant which is consistent with the standard theory of demand. While the foreign currency-securities pairwise is substitutive, the foreign currency-gold and the foreign currency-special drawing rights pairwise are complementary or even independent. However, the wealth effect is inelastic except for securities reserves. These results imply that the central bank of Indonesia can re-balance its reserves. The securities holding which have the highest proportion of foreign reserve scan be switched to foreign currency, gold, and/or special drawing rights. The rebalancing measures would remain having an optimal level of foreign reserves holding in terms of its opportunity cost. Therefore, the monetary authority can conduct a further macroeconomic stabilisation without substantially losing the returns.

Keywords: *Foreign Reserves, Cost of Holding Foreign Reserves, Demand System, Error Correction Model*

1. INTRODUCTION

The sufficiency of foreign reserves especially in developing countries is important to maintain macroeconomic stability. It is not surprising therefore that over the last two decades, there has been an increase in the stock of foreign exchange reserves in most developing countries. . International reserve holdings, which averaged about 5 percent of GDP in the 1980s, has been increased to 25 percent of GDP by 2010 (Ghosh et al., 2016). Under the high reserves, they can relatively survive from any external turbulence. The experience of many emerging markets during the global financial crisis in 2008-2009 and Taper Tantrum episodes in 2013, for example, suggests that having relatively large reserves could result in smaller exchange rate depreciations (Arslan and Cantú, 2019).

The above phenomenon is interesting. From the point of view of researchers, the accumu-

lation of reserves is a critical test for the validity of precautionary motives when confronted with mercantile motives. According to the precautionary motives, on the one hand, countries hold reserves as a shock absorber in order to meet unexpected and temporary fluctuations in international payments (Aizenman and Lee, 2007). On the other hand, the mercantile motives argue that international reserves are used to facilitate export growth by averting exchange rate appreciation in order to support export competitiveness and foreign direct investment inflows (Shijaku, 2012).

Froma policymaker's point of view, the high reserves – irrespective of the motive – can dampen the negative impact on the domestic financial market. The growth and size of reserves also serve as signals dealing with the credibility of monetary policy (Andriyani *et al*., 2020). They also provide clarity and certainty of future monetary policy as a useful forward guidance to financial markets (Lebedeva and Shkuropadska, 2023). Eventually, holding a relatively high level of international reserves reduces the vulnerability to promote growth (Cheung and Qian, 2007). The holding of large foreign reserves involves a high degree of risk (Khan and Wang, 2023). The appreciation of domestic currency increases the risk of loss of value of the international reserves with a cost in aggregate income or welfare foregone (Chan, 2007). The continuous reserves accumulation could lead to disrupt the financial markets (Mohanty and Turner, 2006). The holding of foreign reserves has also an opportunity cost when these financial resources are used in a number of productive projects (Green and Torgeson, 2007).

Considering the benefits and costs, the increase in reserves may raise concerns on how developing countries manage their reserves, by continually preserving undervalued exchange rates, and even jeopardising the stability of the international monetary system (Portes, 2010; Dadush and Stancil, 2011; andGhosh *et al*., 2017). Moreover, in the empirical strand, recent studies have failed to explain the role of opportunity cost on the reserves holding. Some countries are less sensitive to its opportunity cost or even insignificant on the optimal foreign reserves (Molapo and Thamae, 2015; Prabheesh *et al*., 2007; Sooriyan, 2017; Puška *et al*., 2018; Oyeniran and Alamu, 2020; and Islam, 2021). Others found that foreign reserves holding are responsive to its opportunity cost so that the actual foreign reserves were above the optimal level (Sinem and Nebiye, 2014; Sanusi *et al*., 2019; Tran and Le, 2020; and Rashid and Basit, 2021).

Accordingly, there has been no consensus on the effects of opportunity cost (or return) on the foreign reserves holding (Abid and Saqlain, 2023). As a consequence, there has been no uniform level of foreign reserves that is universally regarded as either adequate or optimal. Since the circumstances vary across the economy, the amounts of foreign reserves held by the authorities in various countries are not the same, depending on the set of policy-predetermined and other objective factors. In general, developed countries with their floating and highly liquid currencies and stable financial markets tend to derive insignificant value from holding precautionary reserves policy. In contrast, emerging economies whose less liquid currencies and less stable financial markets tend to hold high levels of foreign reserves to reduce both the impacts of current account shocks and capital account crises (Bhakri and Verma, 2021).

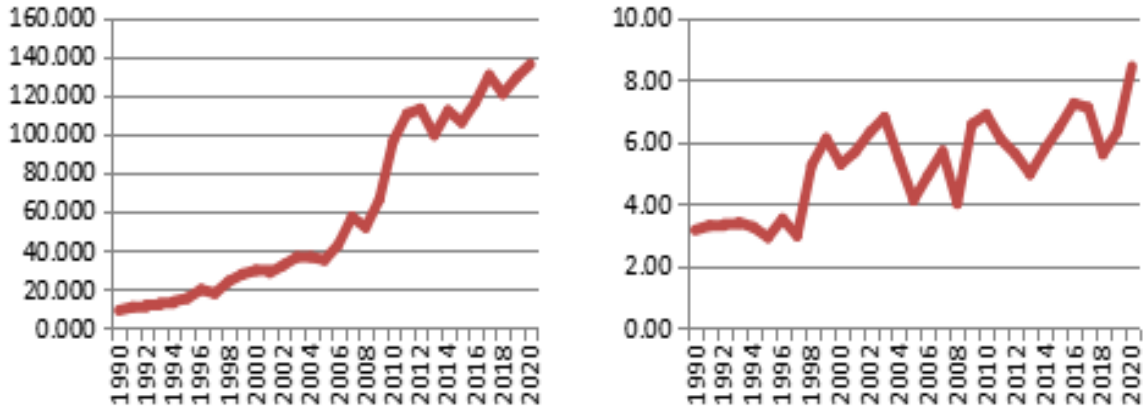
Indonesia is not an exception. The foreign exchange reserves held by the central bank of Indonesia steadily increases since 1990 (see Figure 1). As an open economy with a floating exchange rate system, the accumulation of reserves is quite important to face domestic currency volatilityas happened in the 1997 Asian monetary crisis and the 2008 global financial crisis. The central bank of Indonesia's international reserves skyrocketed to US$138 billion as of January 2021, creating a new record high. The portfolio was equivalent to around 12. 5 percent of GDP andcould cover 10 months of imports – much greater than the conventional wisdom of three-month minimum sufficiency standard. While the foreign exchange reserves descended in the

first quarter of 2020 in accordance with pandemic Covid-19 outbreak, they remained to steadily grow on the annual basis and performed a long term increasing trend (Jeffrey *et al*., 2021).

The increase in foreign reserves for Indonesiais needed to implement various macroeconomic measures (Mastilo *et al*., 2024). Strengthening monetary policy, for example, is likely to require an increase in the international reserves. In light of the fact that Indonesia is an open economy, small-country in the international context, the scope for actively manipulating international trade as well as affecting the global financial market to increase foreign exchange inflows remains limited. Moreover, as many developing Asian countries, Indonesia faces large external risks in the medium term so it would be suboptimal to cut back international reserves to make more room for speculative attacks. This brings back the role of opportunity costs in the central bank's behaviour in foreign reserves holding.

This paper contributes the literature on international monetary economics in the context of developing countries with focus on Indonesia. Unlike the previous studies which focus merely on the total foreign reserves and exchange rate, interest rate, and gold price as the main opportunity costs, this paper disaggregates the foreign reservesinto foreign currencies, securities, gold, and special drawing rights. Since they have their own opportunity cost, we model them simultaneously on the demand theory basis. Hence, the behaviour of the monetary authority in holding each reserve component in relation to monetary policy can be analysed further. Hopefully, the lessons from Indonesia will be fruitful to develop a better stabilisation monetary policy design for other developing countries.

Figure 1. Foreign Reserves and Month Import



Source: IMF

2. LITERATURE REVIEW

In the international monetary economics literature, the discussion of foreign exchange reservesis often related to the exchange rate system. On the one hand, under a fixed or pegged exchange rate system, countries or monetary authorities need to have adequate international reserves. In its most extreme form, monetary authorities implement a foreign exchange control system. Accordingly, the foreign exchange supply curve is assumed to be horizontal.It means that the monetary authority will meet whatever foreign currency is demanded. The inability to meet the demand for foreign exchange resulted in the failure of the fixed or pegged exchange rate system.

On the other hand, the monetary approach of balance of payment believes that the foreign currency and domestic currency are substitutable for each other. Therefore, a change in foreign

reserve holdings is associated with the disequilibrium in the domestic money market (Ford and Huang, 1994). International reserves will enlarge when there is an excess demand for money, by assuming that the domestic credit is constant; and conversely international reserves will shrink if there is an oversupply of money (Lee and Yoon, 2020). Thus, according to the monetary approach, the international reserves are residual holding by a country (Edwards, 1985).

Reconciling the two approaches above, the movements of reserves respond to deviations between the desired reserves (to preserve the fixed exchange rate) and the actual reserves (as a disequilibrium in the domestic money market) held by a country (Clark, 1970; Edwards, 1985). In this regard, most empirical studies were motivated by a monetary approach to the balance of payments rather than the fixed exchange rate approach (Elbadawi, 1990; Badinger, 2004). The lack of countries that adhere to a fixed exchange rate system is suspected to be the primary cause, especially since the collapse of the Bretton Woods fixed exchange rate system in early 1970s.

Under a pure flexible exchange rate system, on the other hand, countries theoretically need not have much reserve (Lee and Yoon, 2020). The exchange rate is solely determined in the market mechanism through full interaction between demand and supply forces. Monetary authorities do not necessarily intervene in the market. As a result, the price of foreign currency in terms of domestic currency will increase sharply when there is an excess demand for foreign currency. In contrast, the price of foreign exchange will decrease deeply if there is an excess supply of foreign currency. In short, the exchange rate under the pure flexible exchange rate systemis quite fluctuating.

To reduce the exchange rate fluctuations, many countries adopt the managed float exchange rate system. Under the managed float exchange rate system, monetary authorities intervene in the foreign exchange market. The monetary authorities will buy the foreign exchange when the price is considered ‘too low’ and sell the foreign exchange when the price is claimed ‘too high’ from the desirable rate. Sellingthe foreign exchange needs international reserves. Accordingly, international reserves in themanaged float exchange rate system can be up and down. The exchange rate is somewhat more stable compared to the pure flexible exchange rate system (Melvin and Norrbin, 2017).

Even though adopting a managed float exchange rate system, countries may still hold adequate foreign reserves. The underlying motives are generally classified in two groups, namely the precautionary and mercantile motives (Mendoza, 2004). The former refers to the fact that countries with a high degree of economic openness are likely to come across random shocks to their external balance, which creates temporary deviations between international payments and receipts or produces balance of payments discrepancy (Zatonatskiy and Lavrentiev, 2023). Under such conditions, the international reserves can be employed as a shock absorber, reflecting the economy’s ability to cover the payments deficit without suffering unfavourable adjustments (Aizenman and Lee, 2007; and Chan, 2007).

There are some further arguments to explain why countries hold sufficient international reserves. Steiner (2013) attributes accumulation of foreign reserves mainly to the ‘fear of capital mobility’. Steiner (2013) argues that accumulation of official reserves is used to compensate for the capital market’s liberalisation. This is contrary to the findings by Calvo and Reinhart (2002) which argue that ‘fear of floating’ rather than ‘fear of capital flight’ is the main determinant of reserve holdings especially in emerging Asian economies. Meanwhile, Yeyati *et al*. (2013) brought the issue of asymmetry into the discussion of the ‘fear of floating’ as the sole determinant of reserves accumulation.

Regarding the mercantile motive, Shijaku (2012) argues that international reserves are used to facilitate export growth by hindering exchange rate appreciation in order to support export competitiveness and foreign direct investment inflows. Therefore, most of the regulations related to the demand for foreign exchange reserves of a country refer to the mercantile motives. Jovanovic and Frenkel (1981) state that the mercantile motive stake into account several variables, such as imports, exports, foreign debt, and the level of trade shocks that may occur, as well as consideration of monetary policy. However, mercantile motive has playeda less prominent role relative to precautionary motives in explaining the hoarding of international reserves by developing countries (Aizenman and Lee, 2007). Several studies, including Winjuholds and Kapteyn(2001), Cheung and Qian (2009), Bastourre *et al*.(2010), Obstfeld *et al*.(2010), and others also support the importance of precautionary motives.

A high level of international reserves is also costly, however (Protsenko, 2023). The reserve accumulation could result in high economic and social costs, including a high opportunity cost originating from low returns on reserve assets, losses in consequence of reserve currency depreciation, and forgone earnings from investment and public expenditures that could be borned by these reserves (Elhiraika and Ndikumana, 2007). Rodrik (2006) found that differences between the yield on reserve assets and the cost of foreign borrowing in developing countries induced an income loss of approximately one percent of GDP due to the increase in foreign exchange reserves.

The excessive reserves accumulation also contributes to higher price levels and overheating bank loan and asset markets (Mohanty and Turner, 2006). Moreover, efforts to stabilise its effect on the domestic money supply might harm domestic banking systems, while its efficacy in avoiding real exchange rate appreciation in the long run is not robust yet (Dadush and Stancil, 2011). The high level of foreign reserves could create the loss of resources which could be better off if the reserves have been employed in alternative ways such as investment in the infrastructural facilities (Green and Torgeson, 2007). In developing countries, for example, the opportunity cost could be high due to the demand for funds to cover developmental projects is always greater than the available supply (Mishra and Sharma, 2011).

Regardless of the precautionary-mercantile motives and the exchange rate regimes, the demand for foreign reserves always exists (Oskoee and Brown, 2002). The international reserves are considered asnecessary financial resources of an economy (Molapo and Thamae, 2015). Therefore, the international reserves tend to be stockpiled to a high level or even greater than the optimal one (Fazlollahtabar, 2022). The optimal level of foreign reserves is defined as that which maximises the difference between benefit and cost derived from holding reserves. More specifically, the optimal amount of reserves depends on the balance between the total adjustment costs emerging from reserves depletion and the opportunity cost of holding reserves (Heller, 1966).

Pioneered by Heller (1966), empirical studies on demand for foreign reserves have been conducted extensively (Clark, 1970; Jovanovic and Frenkel, 1981; Edwards, 1985; Ford and Huang, 1994; Mendoza, 2004; Rodrik; 2006) for multicountry. Nevertheless, recent empirical investigations in developing countries have dealt with the cost of holding reserves. Prabheesh*et al*.(2007) and Sooriyan (2017) show that foreign reserve accumulation in India is less responsive to its opportunity cost. The same result is found in the case of Lesotho (Molapo and Thamae, 2015), Pakistan (Azeem and Khurshid, 2019), and Bangladesh (Islam, 2021). Oyeniran and Alamu (2020) show that the opportunity cost of holding reserves has an insignificant impact on Nigeria's optimal foreign reserves. Conversely, Sinem and Nebiye (2014) indicates that the opportunity cost strongly affected the reserve demand in the Turkish case.

The diverging results above measure the opportunity cost mostly using interest rate differential

(Shevchenko, 2023). Other researchers expand the scope of opportunity cost. In a panel study for Southern African countries, Sanusi*et al*.(2019) conclude that exchange rate and inflation rate are significant determinants of foreign reserve holdings. Rashid and Basit (2021) found that gold price volatility positively contributes to exchange rate volatility in Bangladesh, Indonesia, and Malaysia, resulting in their actual foreign reserves were above the optimal level. In contrast, Tran and Le (2020) show lending rate of home currency (as a proxy of opportunity cost) induced the optimum reserves in Vietnam close to the actual ones.

Purely in the case of Indonesia, the related studies are still limited. Diwantari (2010) obtained that the long term determinant of the international reserves holding has not only a precautionary motive, but also a mercantile motive. Her research unfortunately shows that interest rate differential insignificantly influences the central bank on deciding its international reserves level in the long term. Andriyani *et al*. (2020) found that the exchange rates negatively and significantly affect the foreign exchange reserves, meanwhile the inflation rate has an insignificant negative effecton the foreign exchange reserves.

In general, the above empirical studies rely on the foreign exchange reserves in the whole term, implying the opportunity cost of holding reserves is measured by a single variable. None study breaks down the foreign exchange reserves into their individual components along with their respective opportunity cost. This research examines foreign exchange reserves which are divided into four main components, i. e. foreign currency, securities, gold, and special drawing rights whose own-opportunity cost. Those are analysed simultaneously in the demand system framework. Taking the case of Indonesia, this approach allows us to identify substitutability, complementarity and/or independence possibility of each pairwise of the foreign exchange reservescomponent to arrange the optimal reserves composition.

3. ANALYTICAL FRAMEWORK

Modelling an economic agent's behaviour to consume goods/services begins with the estimation of demand functions extracted from neoclassical consumer theory. Four flexible demand systems have received considerable attention in the literature since their relative empirical worthiness. They are the Linear Expenditure System (LES) developed by Stone (1954), the transcendental utility logarithmic function (translog) proposed by Christensen*et al*.(1975), the Almost Ideal Demand System (AIDS) developed by Deaton and Muellbauer (1980), and the Quadratic Almost Ideal Demand System (QUAIDS) of Banks*et al*. (1997).

In our empirical analysis, we employ the QUAIDS model which is based upon the AIDS model. The QUAIDS allows us to have a more flexible Engel curve shape. The nonlinear terms are restricted to be a quadratic in log income to offer a significantly better fit of budget shares to changing income levels while remaining a parsimonious model specification (Yoon and Heo, 2017). This model is designed to estimate a complete demand system which is in line with both microeconomic theory and available expenditure and price data. Adding up the quadratic log income term in the AIDS model allows goods to be luxuries at some income levels but necessities at others (Oliver, 2014).

The QUAIDS has rank three as the usual linear AIDS and translog models. It can also better estimate non-linear Engel curves in the empirical works. Since a QUAIDS model generates a considerably larger regular region than the locally flexible forms, it can be categorised as effectively globally regular. The corresponding utility and indirect functions, and cost functions meet their theoretical requirements for all non-negative demand, price, and all utility levels as appropriate. The QUAIDS model refers to the following indirect utility function (U):

$$ln\,U(P,Y) = \left[\left\{\frac{lnY - ln\,a(P)}{b(P)}\right\}^{-1} + \lambda(P)\right]^{-1} \quad (1)$$

where the term in the brace is the indirect utility function of a Price-Independent Generalised Logarithmic (PIGLOG) demand system, Y indicates total wealth of economic agents, and Pre-presents a vector of prices. $a(P)$ is a differentiable and homogeneous function of degree one in prices. The form of $\lambda(P)$ and $b(P)$ are homogeneous functions of degree zero in prices.

These functions are defined as:

$$ln\,a(P) = a_0 + \sum_{i=1}^{k} a_i\, ln p_i + \frac{1}{2}\sum_{i=1}^{k}\sum_{j=1}^{k} \gamma_{ij}\, ln p_i\, ln p_j \quad (2a)$$

$$b(P) = \prod_{i=1}^{k} p_i^{b_i} \quad (2b)$$

$$\lambda(P) = \sum_{i=1}^{k} \lambda_i \ln p_i, \text{ where } \sum_{i=1}^{k} \lambda_i = 0 \quad (2c)$$

Implementing the Roy's identity into the indirect utility function as Equation (1), we get the budget share equation for commodity i:

$$s_i = \frac{\vartheta \ln a(P)}{\vartheta \ln p_i} + \frac{\vartheta \ln b(P)}{\vartheta \ln p_i}(\ln Y) + \frac{\vartheta \lambda}{\vartheta \ln p_i}\frac{1}{b(P)}(\ln Y)^2 \quad (3)$$

where s_i is defined as $s_i = p_i q_i / Y$ representing the budget share for commodity i. In line with the relevant economic theory, the parameters should impose the restrictive conditions that (i) aggregation: $\sum_{i=1}^{k} a_i = 1$, $\sum_{i=1}^{k} b_i = 0$, $\sum_{j=1}^{k} \gamma_{ij} = 0$, (ii) homogeneity: $\sum_{j=1}^{k} \gamma_{ij} = 0$, and (iii) symmetry: $\gamma_{ij} = \gamma_{ji}$.

Substituting Equation (2) to Equation (3), we obtain the QUAIDS expenditure share equation:

$$s_i = a_i + \sum_{j=1}^{k} \gamma_{ij} \ln p_j + b_i \ln\left\{\frac{Y}{a(p)}\right\} + \frac{\lambda_i}{b(p)}\left[\ln\left\{\frac{Y}{a(p)}\right\}\right]^2 \quad (4)$$

When the quadratic term is zero, Equation (4) will become the AIDS model which is the most widely used for modelling consumption patterns for grouped commodities.

The coefficient of b_i represents 100 times the effect on the share of commodity i (s_i), of a 1 percent increase in wealth, with all commodity prices remaining constant. The coefficient of γ_{ij} measures the effect on s_i of a one percentage point increase in the commodity price p_i, all other things being equal.

To apply the QUAIDS model in the international reserves, we assume that the central bank has four main foreign reserves, i. e. foreign currency (C), securities/bonds (B), gold (G), and special drawing rights (S). The central bank's utility is an increasing function of the four foreign reserves:

$$U = f(C, B, G, S) \quad (5)$$

Each foreign reserve has a different return or price. The return can be symmetrically considered as the opportunity cost. Therefore, we can rewrite:

$$Z = C + B + G + S \quad (6)$$

The nominal reserve value is the multiplication of price and quantity. This notion is applied on the whole individual reserves:

$$Y = PZ = \sum_{i=1}^{k} p_i z_i \quad (7)$$

Under those conditions, the central bank is assumed to maximise utility as Equation (5) subject to the budget line as Equation (7), yielding the ordinary theory of demand. By inserting Equations (5) and (7) into the QUAIDS, we have:

$$s_i \equiv \frac{p_i z_i}{Z} = a_i + \sum_{j=1}^{k} b_{ij} \ln p_j + c_i \ln\left\{\frac{Z}{P}\right\} + d_i \left[\ln\left\{\frac{Z}{P}\right\}\right]^2 \quad (8)$$

The linear-approximate QUAIDS should be run as a system of equations by imposing some restrictions on the parameter estimates. The own-price elasticity can be calculated from the structural parameter estimates as:

$$\epsilon_{ii} = -1 + \left(\frac{b_i}{s_i}\right) - c_i + \left[2\, d_i \ln\frac{Z}{P}\right] \quad (9)$$

The uncompensated (Marshallian) price elasticity of commodity *i* with respect to change in the price of reserve *j* is

$$\epsilon_{ij} = \left(\frac{b_{ij}}{s_i}\right) - \left(\frac{c_i}{s_i}\right) s_j + \left[\left(2\, d_i \ln\frac{Z}{P}\right)/s_j\right] \quad (10)$$

The income (wealth) elasticity for reserve *i* is

$$\epsilon_{iZ} = 1 + \left(\frac{c_i}{s_i}\right) + \left[\left(2\, d_i \ln\frac{Z}{P}\right)/s_i\right] \quad (11)$$

Equation (9) implies that if the coefficient of b_i is positive, then commodity *i* will have a wealth elasticity greater than unity. Meanwhile, if the coefficient of b_i is negative, then commodity *i* will have a wealth elasticity less than unity.

Equation (8) represents the long run demand function as expected by theory. In the short-run, we propose the error correction demand system for reserve *i* as suggested by Engle and Granger (1987):

$$\Delta s_i \equiv \Delta\frac{p_i z_i}{Z} = \sum_{j=1}^{k} b_{ij}\Delta \ln p_j + c_i \Delta \ln\left\{\frac{Z}{P}\right\} + d_i \Delta\left[\ln\left\{\frac{Z}{P}\right\}\right]^2 + \varphi_i EC_{it-1} \quad (12)$$

where Δ is the first difference operator and EC_{it-1} is the error correction component created from the long-run demand system, i. e. the static almost demand system as specified by Equation (8). The application of error correction model has been extensively employed not only in the analysis of international reserves (Badinger, 2004; Gosellin and Parent, 2004; Prabeesh *et al*., 2007; Diwantari, 2010, and Oyeniran and Alamu, 2020) but also in the macroeconomic policy (Kuncoro, 2018; 2019) and services industry (Yoon and Heo, 2017).

It seems more straightforward to directly analyse those variables. However, estimation of a single demand function produces the problem that the quantity demanded projections may not fulfil the requirements of demand theory, primarily the budget constraint. The estimation method proposed by Zellner (1962) for Iterative Seemingly Unrelated Regressions Estimation (ITSURE) serves the more efficient estimates. In the first stage, the ordinary least squares is used to estimate the variance-covariance matrix among residuals. In the second stage, the estimated matrix is employed in the generalised least squares estimation.

Since the covariance matrix among residuals is singular (because the residuals satisfy the budget constraint), the typical procedure consists in removing one of the equations of the demand system. The coefficients from the removed equation can be computed from the parameters of the other equations through the restrictions on them. In general, the result of ITSURE will be similar to the maximum likelihood estimators (Greene, 2012). To acquire a symmetric and homogeneous equation system, estimation on the shares of foreign currency, securities, and

goldwill be done directly, while the estimation on the share of special drawing rights will be done indirectly. The ITSURE procedure yields the parameters of the system of equations which are invariant to the reserve-share equation dropped.

As outlined in the conventional theory of demand, the relationship between two goods vis-á-vis can be regarded as substitutive, complementary, and independent (see for example: Varian, 1992). The substitutability and/or independence among the four foreign reserves implies that the re-balancing international reserves policy is feasible to pursue. Conversely, the complementarity among thefour foreign reserves presents that the re-balancing international reserves policy is not advisable. In such a case, the change in portfolio composition will reduce the central bank revenue or the central bank will bear a higher opportunity cost.

4. RESULTS AND DISCUSSION

Since this study is concerned with the degree of substitutability and/or complementarity, thus this study needs reliable and long span time series data on foreign exchange reserves covering foreign currency, securities. monetary golds, and special drawing rights. The bilateral exchange rate of US Dollar against Rupiah is used as the price of foreign currency (as used by Andriyani *et al*.(2020)) to measure its opportunity cost. The price of a securities is represented by the 5-year treasury rate (as used by Diwantari (2010)). The price of gold in the world market (in troy ounce) serves as opportunity cost of holding monetary gold (as used by Rashid and Basit (2021)). The value of *special drawing rights* in terms of the *US Dollar* is used as the price of special drawing rights. In general, the data are collected primarily from the central bank of Indonesia, Bloomberg, World Bank, and IMF. The sample periods chosen for this study extend from 2010(1) to 2020(12). The 2010(1) is chosen as the starting point observation related to the diminishing adverse impacts of the 2008 global financial crisis on the Indonesian economy. The total observation is 132 sample points.

Table 1 performs the descriptive statistics comprising mean, median, and extreme (maximum and minimum) values. The share of securities reserves is the highest (84 percent) followed by foreign exchangereserves (11 percent). The high dollar-denominated securitie sand foreign exchange reserves holding is the common figure in developing countries (Gosselin and Parent, 2005). While, the distance between maximum and minimum values for the four foreign reserves are relatively small, all of the median foreign reserve share values are also close enough to the respective mean. The closeness of the median to the mean value preliminary indicates that all of the variables of interest are normally distributed.

However, the Jarque-Bera test rejects the normality distribution. The null hypothesis that most of the series data has the bell-shaped distribution can be rejected in 5 percent significance level. The asymmetric distribution of each foreign reserve share is supported by a non-zero value of skewness. The upper tail of the share of securities distribution, for example, is thicker than the lower tail. Also, the kurtosis coefficients are less than 3. It implies that the tail of the distribution is thinner (moderate) than the normal distribution. This raises a plausible question of whether (in relation to the highest share) the change in securities reserve holding will change the overall central bank's reserves.

The higher securities reserves compared to foreign exchange reserves suggests that the central bank pays more attention to maintaining international reserve holding optimality in terms of benefit and cost. Table 1 also reports the price of each foreign reserve accompanied by its standard deviation. The standard deviation shows how far the dataset spread from its mean. Statistically, a set data is said to be relatively volatile if its CV (coefficient of variation, ratio of standard deviation to its mean) is more than 50 percent. Based on the empirical regularity, the

returns of securities and wealth have the highest CV implying that the associated variables are the most volatile. Accordingly, the central bank holds a high proportion of securities reserves to absorb its price volatility.

Table 1. Descriptive Statistics

	SC	SB	SG	SS	PC	PB	PG	PS	LOG(Z/P)
Mean	0. 1098	0. 8388	0. 0311	0. 0204	12, 077. 43	13. 86	1, 422. 23	0. 69	14. 0376
Median	0. 0970	0. 8593	0. 0307	0. 0230	13, 093. 00	15. 28	1, 357. 50	0. 70	13. 3372
Maximum	0. 2059	0. 9045	0. 0383	0. 0397	16, 310. 00	29. 78	2, 017. 00	0. 74	17. 8387
Minimum	0. 0219	0. 7370	0. 0251	0. 0117	8, 504. 00	0. 21	1, 083. 00	0. 62	12. 5388
Std. Dev.	0. 0455	0. 0487	0. 0040	0. 0074	2, 177. 50	8. 52	204. 32	0. 04	1. 4851
CV (%)	41. 39	5. 80	12. 72	36. 16	18. 03	61. 42	14. 37	5. 18	59. 44
Skewness	0. 5772	-0. 7514	0. 2556	0. 3617	-0. 3762	-0. 3465	0. 8474	-0. 2372	1. 2946
Kurtosis	2. 2907	2. 1641	1. 6779	2. 1313	1. 6111	2. 1937	3. 0754	1. 5771	3. 0319
Jarque-Bera	10. 0975	16. 2659	11. 0499	7. 0280	13. 7244	6. 2172	15. 8301	12. 3738	36. 8766
Probability	0. 0064	0. 0003	0. 0040	0. 0298	0. 0010	0. 0447	0. 0004	0. 0021	0. 0000
Observations	132	132	132	132	132	132	132	132	132

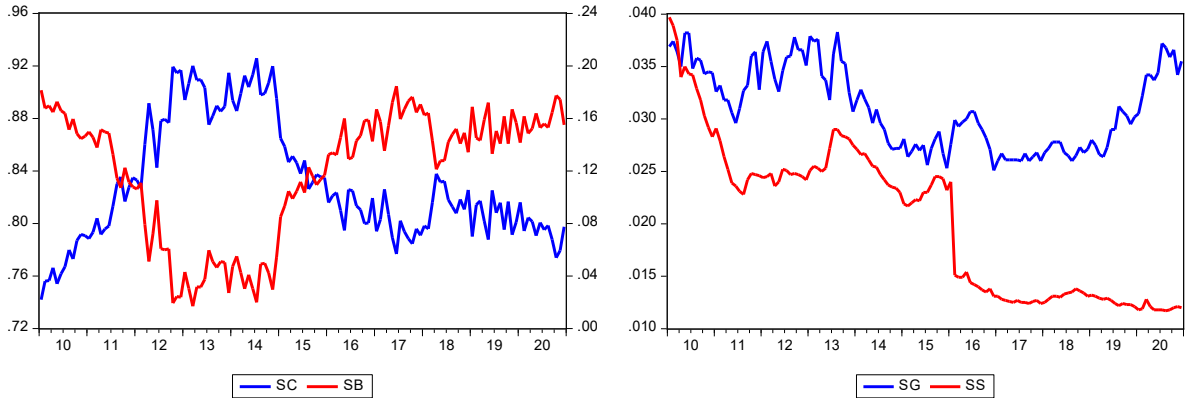
Note: SC = share of currency; SB = share of bond; SG = share of gold; SS = share of SDR
PC = price of currency; PB = price of bond; PG = price of gold; PS = price of SDR
Z = income = C + B + G + S

Source: Authors' work

Figure 2 delivers in more detail the movement of each foreign reserves holding for the whole period of observation. The curve of foreign currency shares has been declining consistently since January 2010. The turning point took place in the mid-2014. Since then, the share of foreign currency reserves has been increasing. In contrast, the share of securities reserves holding has been increasing and then has decreased sharply since the mid-2014 in accordance with the end of commodity boom. It means that the commodity boom episodes provided a lot of foreign currency inflows so that the central bank's foreign currency reserves also increased.

Comparing the shares of gold and special drawing rights reserves holding offers an interesting picture. The movement of gold reserves holding seems to be synchronous with the special drawing rights reserves holding. Accordingly, the two foreign reserves are likely complementary to each other. However, the share of gold and special drawing rights reserves holding is out of synchrony with the foreign currency and securities reserves holding. This raises a preliminary hypothesis that the foreign currency and securities reserves are substitutesto each other. We may also expect thatgold and special drawing rights are independent with the foreign currency and securities reserves holding. This will be examined later using more sophisticated devices.

Figure 2. Shares of Reserve



Source: Authors' work

Before estimating the short-run QUAIDS error correction model as Equation (12), we observe the stationarity of the variables. Table 2 performs the Augmented Dickey-Fuller (1979) unit roots test resultsfor the underlying series data both in levels and first differences. The null hypothesis of nonexistence of unit roots can be accepted for each of the variables in the level and thus we conclude that the series data are non-stationary. The nonrejection of the null hypothesis of unit roots may be the result of shifting deterministic trend.

However, the null hypothesis is rejected even at the 1 percent of significance level for all of series data in their first-differences. This indicates that after first-differencing, stationary is achieved, i. e. all the series data are *I(1)*. In such a case, all the variables in the first difference formsare stationary. It means that the behaviour of the variables moves around the mean value and time-invariant (Enders, 2004). The absence of unit roots in the series provides an early symptom of shocks having permanent or long lasting effect, thus making it very hard for conventional stabilisation policies to defend.

Table 2. Unit Roots Test

	Level			First-difference			Conclusion
	t-stat	SE	Prob.	t-stat	SE	Prob.	
SC	-1. 6670	0. 0291	0. 4456	-11. 3512	0. 1358	0. 0000	I(1)
SB	-1. 2002	0. 0265	0. 6732	-11. 0428	0. 1364	0. 0000	*I(1)*
SG	-2. 1737	0. 0308	0. 2169	-12. 0804	0. 0884	0. 0000	*I(1)*
SS	-2. 6581	0. 0117	0. 0842	-10. 7785	0. 0882	0. 0000	*I(1)*
PC	-1. 0962	0. 0136	0. 7161	-12. 5287	0. 0880	0. 0000	*I(1)*
PB	-1. 7030	0. 0285	0. 4274	-10. 9717	0. 0883	0. 0000	I(1)
PG	-1. 5666	0. 0297	0. 4968	-12. 4179	0. 0888	0. 0000	*I(1)*
PS	-1. 6771	0. 0204	0. 4405	-12. 8129	0. 0878	0. 0000	*I(1)*
Log(Z/P)	-1. 5681	0. 0314	0. 4960	-11. 8915	0. 0883	0. 0000	*I(1)*
$(\text{Log Z/P})^2$	-1. 5193	0. 0313	0. 5209	-11. 8685	0. 0883	0. 0000	*I(1)*

Note: See Table 1

Source: Authors' work

The time series data stationary properties are compulsory to establish cointegration. Cointegration is a fundamental concept to investigate the long-run behaviour of the data. Cointegration is concerned with the analysis of long run relations between variables integrated of the same order and the speed of return to equilibrium after a deviation is measured by the Error Correction

Model (ECM). To prove our hypothesis, we again estimate the Augmented Dickey-Fuller unit roots test individually on the residual generated from Equation (8).

Table 3 shows the Engle–Granger (1987) cointegration test results. All the variables are *I(0)*, implying a cointegrating relationship (in levels) between all variables in Equation (8) exists. This means the existence of a long-run and stable relationship between the level of foreign exchange reserves and its determinants. Thus, any short-term difference in their respective values will disappear in the longer term. These preliminaries perform the presence of cointegration and thus approve the estimation of Equation (12).

Table 3. Cointegration Test

	t-stat	SE	Prob	Conclusion	
QUAIDS					
EC	-3. 9134	0. 0409	0. 0026	*I(0)*	Co-integrated
EB	-3. 9456	0. 0416	0. 0023	*I(0)*	Co-integrated
EG	-3. 9590	0. 0464	0. 0022	*I(0)*	Co-integrated
ES	-3. 3673	0. 0456	0. 0139	*I(0)*	Co-integrated
AIDS					
EC	-4. 8767	0. 0584	0. 0001	*I(0)*	Co-integrated
EB	-4. 8417	0. 0581	0. 0001	*I(0)*	Co-integrated
EG	-5. 5289	0. 0668	0. 0000	*I(0)*	Co-integrated
ES	-3. 6070	0. 0505	0. 0068	*I(0)*	Co-integrated

Source: Authors' work

The ITSURE estimation results of the Zellner's method (1962) for four equations are reported respectively in Table 4. The coefficient estimated structural equation model of the short run QUAIDS is statistically significant for most foreign reserve specifications verified by t-statistics value is greater than the related t-table at 95 percent or even 99 percent confidence levels. The parameter of error correction term is negative implying that our model is well-specified. The corresponding coefficient can capture the adjustment mechanism of all variables to the long run equilibrium.

However, the coefficient of quadratic termsin all equations is insignificant. The insignificance of the squared-log wealth does not permit foreign reserves to be luxuries at some wealth levels but necessities at others. Hence, we re-run the AIDS model (Deaton and Muellbauer, 1980), by removing the squared-log wealth. The results show that most coefficients of estimates are statistically much better. The coefficient of error correction term is also found to be negative implying the lagged residuals (generated from the linear regression) represent the deviation from the long-run relationship in the previous period. The inclusion of an error correction term ensures an appropriate test of the existence of a causal relationship between international reserves and their respective prices.

Those above results are also supported by the previous analysis from descriptive statistics, that all types of the foreign reserves are relatively unstable over the whole period of observation. However, our interest and further analysis are not devoted to the estimation results of the structural model (Table 4). The parameters whose economic meaning are the derived coefficients that demonstrate the price and wealth elasticity indices for the corresponding foreign reserve, instead (Table 5).

Table 4. Estimation Results of EC-(Quadratic) Almost Ideal Demand System

Dependent Variable	Independent Variable	QUAIDS			AIDS		
		Coeff.	SE	Prob.	Coeff.	SE	Prob.
Δ SC	Δ PC	0. 0577	0. 0288	0. 0461	0. 0683	0. 0287	0. 0179
	Δ PB	-0. 0562	0. 0271	0. 0386	-0. 0681	0. 0269	0. 0117
	Δ PG	-0. 0005	0. 0029	0. 8511	-0. 0007	0. 0028	0. 8063
	Δ PS	-0. 0010[a)]	0. 0056	0. 4902[e)]	0. 0005[a)]	0. 0048	0. 4822[e)]
	Δ Log Z/P	-0. 0206	0. 0687	0. 7641	-0. 0694	0. 0273	0. 0116
	Δ (Log Z/P)^2	-0. 0012	0. 0024	0. 6058	-		-
	EC(-1)	-0. 1942	0. 0366	0. 0000	-0. 1566	0. 0316	0. 0000
Δ SB	Δ PC	-0. 0562	0. 0271	0. 0386	-0. 0681	0. 0269	0. 0117
	Δ PB	0. 1012	0. 0265	0. 0002	0. 1110	0. 0265	0. 0000
	Δ PG	-0. 0269	0. 0028	0. 0000	-0. 0262	0. 0028	0. 0000
	Δ PS	-0. 0181[a)]	0. 0050	0. 0005[e)]	-0. 0167[a)]	0. 0343	0. 0001[e)]
	Δ Log Z/P	0. 0817	0. 0660	0. 2165	0. 1131	0. 0269	0. 0000
	Δ (Log Z/P)^2	0. 0007	0. 0023	0. 7540	-		-
	EB(-1)	-0. 1825	0. 0381	0. 0000	-0. 1491	0. 0331	0. 0000
Δ SG	Δ PC	-0. 0005	0. 0029	0. 8511	-0. 0007	0. 0028	0. 8063
	Δ PB	-0. 0269	0. 0028	0. 0000	-0. 0262	0. 0028	0. 0000
	Δ PG	0. 0280	0. 0016	0. 0000	0. 0276	0. 0015	0. 0000
	Δ PS	-0. 0006[a)]	0. 0024	0. 0378[e)]	-0. 0007[a)]	0. 0023	0. 0251[e)]
	Δ Log Z/P	-0. 0349	0. 0058	0. 0000	-0. 0266	0. 0028	0. 0000
	Δ (Log Z/P)^2	0. 0003	0. 0002	0. 1387	-		-
	EG(-1)	-0. 2591	0. 0603	0. 0000	-0. 2002	0. 0490	0. 0001
Δ SS	Δ PC	-0. 0010[a)]	0. 0056	0. 4902[e)]	0. 0005[a)]	0. 0048	0. 4822[e)]
	Δ PB	-0. 0181[a)]	0. 0050	0. 0005[e)]	-0. 0167[a)]	0. 0343	0. 0001[e)]
	Δ PG	-0. 0006[a)]	0. 0024	0. 0378[e)]	-0. 0007[a)]	0. 0023	0. 0251[e)]
	Δ PS	0. 0197[b)]	0. 0105	0. 0193[f)]	0. 0170[b)]	0. 0087	0. 0105[f)]
	Δ Log Z/P	-0. 0261[c)]	0. 0090	0. 0114[f)]	-0. 0171[c)]	0. 0041	0. 0000[f)]
	Δ (Log Z/P)^2	0. 0003[d)]	0. 0003	0. 5391[f)]	-	-	-
	ES(-1)	-0. 1177[f)]	0. 0706	0. 0963[f)]	-0. 1198[f)]	0. 0532	0. 0248[f)]

Note: See Table 1

SE is standard error

a) estimate is calculated from the restriction: $\sum b_i = 0$

b) estimate is calculated from the restriction: $\sum b_{ij} = 0$

c) estimate is calculated from the restriction: $\sum c_i = 0$

d) estimate is calculated from the restriction: $\sum d_i = 0$

e) standard error is taken from the direct estimation of share of C, B, and S

f) standard error is taken from the direct estimation of share of B, G, and S

Source: Authors' work

The own-price elasticity is found to be negative for all foreign reserves. The minus sign of own-price elasticity meets the requirement of conventional theory of demand behaviour. This means that a rise of 1 percent in 'price' in foreign currency, securities, gold, and special drawing rights, for instance, will reduce the quantity of corresponding foreign reserves demanded, ranging from 0. 08 to 0. 89 percent, ceteris paribus. The highest own-price elasticity of securities is

reasonable. The yield of securities is the most volatile compared to the price of other foreign reserves. Moreover, the securities reserve holding is dominant, resulting in the central bank being more sensitive to the change in securities yields.

Overall, the results of this research are not in line with most previous studies as outlined in the literature review section, such as Prabheesh *et al.*(2007), Molapo and Thamae (2015), Sooriyan (2017), Azeem and Khurshid (2019), and Islam (2021), However, our results support the studies of Sinem and Nebiye (2014), Sanusi *et al.*(2019), Rashid and Basit (2021), and Tran and Le (2020). It seems that differences in measuring foreign reserve prices offer different conclusions. The advantage of this study is that it uses many foreignreserve pricess imultaneously, so the results of this research can reconcile the differences in the results of previous studies.

Furthermore, the wealth elasticity with respect to gold, on the one hand, is the lowest, 0. 14. This result is somehow surprising. An increase of 1 percent in wealth is associated with an increase in the allocation of gold reserves by an average of 0. 14 percent only. The similar result is found in the case of special drawing rights. In fact, the gold and special drawing rights prices are the most stable relative to the prices of other foreign reserves and the proportion of monetary gold and special drawing rights reserve holdings are quite small. Given this result, the central bank seems to consider that the monetary gold reserve is rather a necessary need, which is less sensitive to the change in wealth.

On the other hand, the effect of wealth on the securities reserve holding is highest, 1. 13. An increase of 1 percent in wealth induces the change in the central bank's securities reserve holding for about 1. 13 percent. This result is consistent with the own-price elasticity. The highest own-price elasticity is followed by the highest of wealth elasticity. It means that the central bank is very responsive to the global economic performance in terms of return and risk (Božanić *et al.*, 2023). Therefore, the securities reserves seem to have the potential to be reset in the near future. In the medium-long runs, the increase in uncertainty demands a more optimal mix of foreign exchange reserves and securities.

Overall, the wealth elasticity is positive for all four cases. The positive wealth elasticity index exhibits that the central bank's allocations on foreign currency, securities, gold, and special drawing rights move along the line of the income consumption curve (ICC). The ICC represents in the case that all foreign reserve prices are held constant, any increase in wealth will encourage the demand for all of the four foreign reserves. The effects that lead to the changes in the amount of foreign reserves held since the central banks move along the line of the new ICC to a higher level, which means the same expenditure, is well-known as the expenditure effect (Varian, 1992). In other words, the Engle curve is observable, depicting the demand for foreign reserves as a function of income so that mercantile motives hold.

Table 5. AIDS: Own-Price, Cross-Price, and Wealth Elasticity

	C	B	G	S	Z/P
C	-0. 3085	-0. 0903	0. 0134	0. 0174	0. 3679
B		-0. 9807	-0. 0354	-0. 0227	1. 1348
G			-0. 0850	-0. 0066	0. 1435
S				-0. 1488	0. 1624

Note: See Table 1

Source: Authors' work

So far, we have examined the price and income elasticity individually. Table 5 also highlights the cross-price elasticity for all four types of foreign reserves. The cross price elasticity of

foreign currency with respect to securities appears to be negative (-0. 09). This result suggests that a depreciation of domestic currency relative to securities' yield will induce substantial expansion in the securities reserve, thereby offsetting or even outweighing the adverse impact of the depreciation of domestic currency on the foreign currency reserves demand. Hence, the negative impact holds, i. e. the foreign currency reserves demand is substitutable for securities reserves holding.

Conversely, the cross-price elasticity of foreign currency reserves with respect to gold and special drawing rights reserves shows a positive sign, 0. 01and 0. 02 respectively. Merely referring to the positive sign of the corresponding variable, it can be said that the foreign currency and gold and the foreign currency and special drawing rights are pairwise complementary. Nevertheless, they are even independent of each other when we consider the statistical results from the structural model. It implies that an increase in exchange rates that makes foreign currency holding cost reduction will not generate a large positive effect on the gold and special drawing rights reserves holding, that falls behind the substitution effect. They lead to a simultaneous contraction in securities holding that further reduces international reserves. These prognostications about the two kinds of reserves holding' reaction to foreign currency appear to be in line with what we have detected in the post commodity boom.

To confirm our findings, we perform a robustness test. As a validity test, we re-estimate the EC-AIDS model as equation (12) by incorporating a dummy variable to capture the pandemic Covid-19 (2020 = 1, others= 0). Unfortunately, the corresponding coefficient of the additional dummy variableis insignificant (see: Appendix). The result does not alter the main conclusion that opportunity cost plays an important role in foreign reserves. Those results are consistent with the unit roots tests. Despite structural breaks present, the foreign reserves growth is stable in accordance with a disequilibrium process. Accordingly, our conclusions are robust, independently of the explanatory variables to be used in the econometric model.

The substitution, complementary, and independent relationships among pairwise foreign reserve components indicate that the precautionary motives hold. They implicitly suggest further there is achance for foreign reserves restructuring policy. Hence, foreign exchange reserves restructuring policy is feasible for Indonesia to run foreign exchange rate market stabilisation more along with avoiding substantially the high opportunity cost of holding other reserves. The increase in foreign exchange rates does not immediately induce the central bank to intervene in the market, which could impact the international reserves level. The increase in foreign exchange rates cannot be accompanied by the increase in the securities yields. In contrast, the increase in foreign exchange rates may be compensated by the increase in gold and special drawing rights holdings. In the case of Indonesia, where the international reserves are dominated by securities holding, the foreign exchange reserves restructuring policy should remove them so the central bank is flexible-to-recompose.

5. CONCLUSION

This paper models the behaviour of foreign reserves holding in the case of Indonesia. The foreign reserves holding extends foreign currency, securities, gold, and special drawing rights. Different from the previous studies, the four reserves are assessed using a system-wide approach to consumption economics. The Almost Ideal Demand Systemproposed by Deaton and Muellbauer (1980) combined by Engle and Granger's (1987) two-steps Error Correction Model is employed to test whether the conventional theory of demand holds. Applying on the monthly data during 2010-2020 in the case of Indonesia, we find that the basic theory of demand behaviour is generally acceptable.

The results indicate that the wealth elasticity for securities holding is larger than unity whereas that for other foreign reserves is less than unity. As expected, the own-opportunity cost coefficients are negative and statistically significant. The own-opportunity cost elasticities for foreign currency, securities, gold, and special drawing rights in the short run are -0. 31, -0. 98, -0. 08, and -0. 15 respectively. The cross-opportunity cost elasticities mostly are negative, representing that the pairwise reserve component is substitutive. The cross-opportunity cost elasticities of foreign currency-gold pairwise and foreign currency-special drawing rights pair are positive, suggesting that the two pairwise reserves are complementary or even independent.

The own- and cross-elasticity estimates of this study will be useful for monetary policy formulation. The central bank of Indonesia might rebalance its portfolio. Since the proportion of securities holding is the highest, the central bank of Indonesia can switch it to foreign currency, gold, or special drawing rights. Accordingly, the central bank of Indonesia can conduct exchange rate stabilisation (as the main task) more without substantially losing the returns. In other words, by substituting parts of securities into foreign currency, for example, the central bank of Indonesia remains having an optimal level of reserves holding in terms of its opportunity cost.

Further research is advisable to pay more attention to the foreign currency and securities reserves. The reserves holding reveal an overweight in securities whose different maturity. Apart from the US Dollar, the foreign currency reserves consist of many other foreign currencies. Data on the foreign currency and maturity of the securities breakdown of central banks' balance sheets is confidential, precluding any formal analysis of the behavioural model of foreign exchange reserves holding.

ACKNOWLEDGMENT

This work was financially supported by the Faculty of Economics and Research and Community Service Institution (LPPM) State University of Jakarta, Indonesia.

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APPENDIX

Extended EC-AIDS Model with Dummy Covid-19

Dependent Variable	Independent Variable	AIDS		
		Coeff.	SE	Prob.
Δ SC	Δ PC	0. 0697	0. 0285	0. 0150
	Δ PB	-0. 0690	0. 0268	0. 0103
	Δ PG	-0. 0007	0. 0028	0. 8126
	Δ PS	0. 0000[a)]	0. 0049	0. 4732[e)]
	Δ Log Z/P	-0. 0697	0. 0272	0. 0108
	EC(-1)	-0. 1669	0. 0327	0. 0000
	DCOV	-0. 0059	0. 0043	0. 1663
Δ SB	Δ PC	-0. 0690	0. 0268	0. 0103
	Δ PB	0. 1117	0. 0263	0. 0000
	Δ PG	-0. 0260	0. 0028	0. 0000
	Δ PS	-0. 0167[a)]	0. 0356	0. 0000[e)]
	Δ Log Z/P	0. 1133	0. 0268	0. 0000
	EB(-1)	-0. 1577	0. 0341	0. 0000
	DCOV	0. 0048	0. 0041	0. 2420
Δ SG	Δ PC	-0. 0007	0. 0028	0. 8126
	Δ PB	-0. 0260	0. 0028	0. 0000
	Δ PG	0. 0276	0. 0015	0. 0000
	Δ PS	-0. 0009[a)]	0. 0023	0. 0968[e)]
	Δ Log Z/P	-0. 0265	0. 0028	0. 0000
	EG(-1)	-0. 2303	0. 0517	0. 0000
	DCOV	0. 0006	0. 0003	0. 0626
Δ SS	Δ PC	0. 0000[a)]	0. 0049	0. 4732[e)]
	Δ PB	0. 0167[a)]	0. 0356	0. 0000[e)]
	Δ PG	-0. 0009[a)]	0. 0023	0. 0968[e)]
	Δ PS	-0. 0158[b)]	0. 0088	0. 0148[g)]
	Δ Log Z/P	-0. 0171[c)]	0. 0046	0. 0001[f)]
	ES(-1)	-0. 1211[f)]	0. 0595	0. 0424[f)]
	DCOV	0. 0003	0. 0004	0. 4951

Note: See Table 4