

Currency Devaluation A Case Study of Excessive Money Supply and Exchange Rate Pass-Through (Erpt) Inflationary Effect

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Abstract

This is a case study of currency devaluation and inflationary pressure as precursors to economic recession. The purpose of this paper is to explore possible policy tools against currency devaluation and inflationary pressure. We selected Laos as a proxy country to explore the interrelationship between currencies through exchange rates against the US dollar. These currencies include Laotian kip (LAK) Chinese renminbi (CNY), Japanese yen (JYN), Singapore dollars (SGD), Thai baht (THB), Vietnamese dong (VND), and the Euro (EUR) trading against the US dollar. The weekly spot rates of exchange rates from January 1, 2012 to May 22, 2022. The sample size included 543 weeks of Asian currencies and EUR against US dollars. We employed Weibull distribution as a tool for constructing a times series equation for the individual currency exchange patterns against the US dollar. We found that the long-term equilibrium point for the Lao currency is $8,541 \pm 928.46$ compared to its last spot rate of 13,240 or devalued by 55%. Among seven currencies commonly traded in Laos, we found that there are 4 currencies that significantly correlated with LAK, namely CNY, SGD, VND, and EUR with T values of 9.06, 10.61, 17.70, and 10.20 or $p = 0.000$ in all cases and R squared was 0.52. We also found that LAK has a tail index of 5.66 under Extreme Value Theory (EVT) and is Frechet distributed with the shape parameter for LAK is $= -0.18$; scale $= -130.57$; and location $= 11,216.32$.

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With the last spot rate at 13,240, LAK faces 18% exchange rate pass-through (ERPT) inflationary pressure. These findings suggest that further devaluation of LAK is expected. The finding of this study is a reminder for all ASEAN countries that excessive foreign currency reserve and rapid increase of money supply (M1) may lead to uncontrollable local currency devaluation.

Keywords: Currency Devaluation, ERPT, Exchange Rate, Extreme Value Theory (EVT), Frechet Distribution, Inflation, Money Supply, Pass-Through, Weibull Distributuion

ค่าเงินอ่อนค่า กรณีศึกษาปริมาณเงินที่มากเกินไปและผลกระทบของภาวะเงินเฟ้อ จากอัตราการส่งผ่านอัตราแลกเปลี่ยน (ERPT)

อินพงษ์ หลวงรัฐ*

รับวันที่ 27 มิถุนายน 2566 ส่งแก้ไขวันที่ 10 เมษายน 2566 ตอปรับตีพิมพ์วันที่ 1 พฤษภาคม 2566

บทคัดย่อ

บทความนี้เป็นกรณีศึกษาของการลดค่าเงินและแรงกดดันด้านเงินเฟ้อที่เป็นต้นเหตุของภาวะเศรษฐกิจถดถอย บทความนี้มีวัตถุประสงค์เพื่อตรวจสอบเครื่องมือนโยบายที่เป็นไปได้ในการลดค่าเงินและแรงกดดันด้านเงินเฟ้อ เราเลือกประเทศ สปป. ลาวเป็นประเทศตัวแทนเพื่อตรวจสอบความสัมพันธ์ระหว่างสกุลเงินผ่านอัตราแลกเปลี่ยนเทียบกับดอลลาร์สหรัฐ สกุลเงินเหล่านี้รวมถึง กีบลาว (LAK) หยวนจีน (CNY), เยนญี่ปุ่น (JPY), ดอลลาร์สิงคโปร์ (SGD), บาทไทย (THB), ดองเวียดนาม (VND) และยูโร (EUR) ที่ซื้อขายกับดอลลาร์สหรัฐ อัตราแลกเปลี่ยนสัปดาห์ตั้งแต่วันที่ 1 มกราคม 2555 ถึง 22 พฤษภาคม 2565 ขนาดตัวอย่างรวม 543 สัปดาห์ของสกุลเงินเอเชียและ EUR เทียบกับดอลลาร์สหรัฐ เราใช้การแจกแจงแบบ Weibull เป็นเครื่องมือในการสร้างสมการอนุกรมเวลาสำหรับรูปแบบการแลกเปลี่ยนสกุลเงินแต่ละรายการเทียบกับสกุลเงินดอลลาร์สหรัฐ เราพบว่าจุดดุลยภาพระยะยาวของสกุลเงินลาวอยู่ที่ $8,541 \pm 928.46$ เมื่อเทียบกับอัตราจุดสุดท้ายที่ 13,240 หรือลดลง 55% ในบรรดาเจ็ดสกุลเงินที่ซื้อขายกันทั่วไปในลาว เราพบว่า มี 4 สกุลเงินที่มีความสัมพันธ์กับ LAK อย่างมีนัยสำคัญ ได้แก่ CNY, SGD, VND และ EUR โดยมีค่า T เท่ากับ 9.06, 10.61, 17.70 และ 10.20 หรือ $p = 0.000$ ในทุกกรณีและ R^2 กำลังสอง คือ 0.52 นอกจากนี้ เรายังพบว่า LAK มีดัชนีส่วนท้ายที่ 5.66 ภายใต้ Extreme Value Theory (EVT) และ Frechet กระจายด้วยพารามิเตอร์รูปร่างสำหรับ LAK คือ -0.18 ; มาตรฐานส่วน = -130.57 ; และที่ตั้ง $= 11,216.32$ ด้วยอัตราสัปดาห์สุดท้ายที่ 13,240 LAK เปรียบเทียบกับแรงกดดันจากอัตราแลกเปลี่ยนผ่าน (ERPT) 18% การค้นพบนี้ชี้ให้เห็นว่าคาดว่าจะมีการลดค่า LAK เพิ่มเติม ผลการศึกษานี้เป็นเครื่องเตือนใจสำหรับทุกประเทศในอาเซียนว่าการสำรองเงินตราต่างประเทศที่มากเกินไปและปริมาณเงินที่เพิ่มขึ้นอย่างรวดเร็ว (M1) อาจนำไปสู่การลดค่าเงินท้องถิ่นที่ไม่สามารถควบคุมได้

คำสำคัญ : การลดค่าของสกุลเงิน ERPT อัตราแลกเปลี่ยน ทฤษฎีมูลค่าสูงสุด (EVT) การกระจายแบบเฟรเชต อัตราเงินเฟ้อ ปริมาณเงิน การส่งผ่าน การกระจาย Weibull

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INTRODUCTION

This paper is a case study of currency devaluation. We select LAK, a currency of Laos as a proxy to carry our analysis. We used a cohort of other currencies in Asia to track the movement of a set of currencies against the US dollar over the same period of 10 years. We used weekly average of the spot rate; the sample size is comprised of 543 spot price of 543 weeks from January 1, 2012 to May 22, 2022. LAK has been devalued significantly for the past 33 weeks in the sampled period. This devaluation puts pressure on the country's because it depends on imports of fuels and consumer goods. As LAK is devalue, the cost of living rises as the result of the effect of exchange rate pass-through effect (ERPT). Unless effective policy tools are implemented to stem the tide of currency devaluation, we might be witnessing economic depression in Laos.

Laos is an interesting case study for currency exchange management because the country depends on imports of consumer goods and had consistently experience negative term of trade. More over, in the past 10 years, its currency had been stable traded against the US dollar at about 8,540 LAK per US dollar. However, since October 2021 the LAK has been significantly devalued ($p < 0.05$). In the same period, the money supply (M1) in the market also had increased by over 5000%; this increase in M1 coupled with no change in interest rate may have contributed to the devaluation of LAK. In this paper, we examine the devaluation of LAK from the perspective of policy tool search for effective means to stem the tide of LAK devaluation. We selected relevant Asian currency as proxies of possible baskets of currencies.

The money supply (M1) of Laos was 1.607 billion US dollars in Dec 2021. This represents an increase from 1.558 billion US dollars for September 2021. The data reached an all-time high of 1.651 billion USD in Dec 2020 and a record low of 28.814 million USD in Dec 1999 (CEIC Data, 2022). If we tracked M1 expansion between 2019 and 2021, we found that in 2019, M1 of Laos stood at 28.814 million USD; by 2020, this number expanded to 1.651 billion USD, representing a change of $((1,651,000,000 - 28,814,000) / 28,814,000) * 100 = 5,629.85\%$ between 2019 and 2020. The change

between 2019 and 2021 is $((28,814,000 - 1,607,000,000)/28,814,000)*100 = 5,477.15\%$. This paper contends that this M1 expansion is one of the main causes for the extreme devaluation of LAK in the second quarter of 2022. We argue that the devaluation resulted from 2 factors, namely the increase in money supply (M1) without interest rate management, and inflationary pressure from exchange rate pass-through effect.

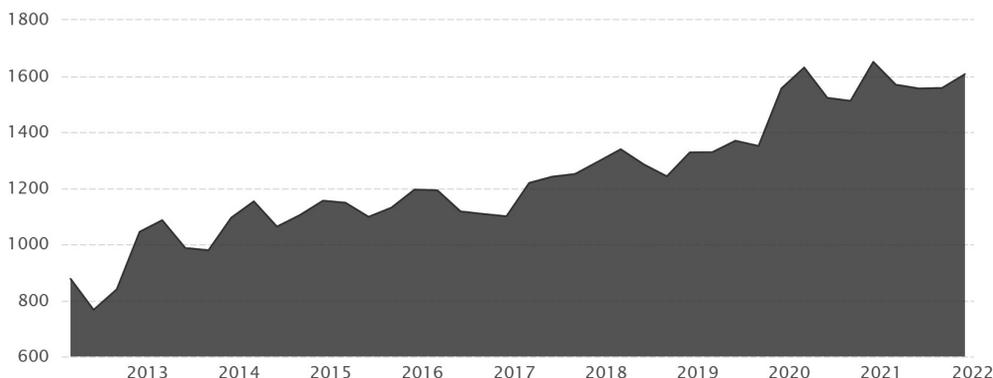


Figure 1: M1 Expansion in Laos 2013-2022

Source: <https://www.ceicdata.com/en/indicator/laos/money-supply-m1>

Accessed: May 29, 2022

The devaluation of LAK was further compounded by Exchange-rate pass-through (ERPT). ERPT is the elasticity of local-currency import prices with respect to the local-currency price of foreign currency. It is often measured as the percentage change, in the local currency, of import prices resulting from a one percent change in the exchange rate between the exporting and importing countries (Goldberg and Knetter, 1997). A change in import prices affects retail and consumer prices. When exchange-rate pass-through is greater, there is more transmission of inflation between countries (Campa and Goldberg, 2005). ERPT may differ from firm to firm in the same country. Studies of firm-level differences explain why exchange-rate pass-through is not equal to one (Berman, Martin and Mayer, 2012). Some studies suggest that increase globalization contributed to a decrease in exchange-rate pass-through (Cook, 2014). However, for countries depending on imports and have poor currency value management policies, ERPT remains a serious and vexing issue.

ERPT is a serious issue for Laos because the country depends on import of fuel, food and consumer goods. For instance, during the first week of 2020 the exchange rates were 8,882 LAK per US dollars and 30.23 Baht per US dollar. By the middle of May 2022, the two currencies were trading at 13,240 LAK per US dollar and 34.39 Baht per US dollars. The increase strength of the US dollars had devalued both LAK and THB. Laos depends on imports from Thailand for its consumer goods which directly impact the cost of living of the people. This devaluation of the LAK could be clearly appreciated when it is read with the change in the per capita GDP. In 2020, the per capita GDP expressed in current US dollar was 2,588.78 for 2020 and 2,757.81 in 2022 (IMF, 2021); the increase in two years was 169.03 or 6.53%. During this same period, the devaluation of LAK was -49.07% compared to Thailand's Baht which devalued only -13.39% for the same period. For every 1,000,000 Baht of imported good from Thailand in 2020, Laos would have to pay 1,490,000 Baht in 2022, assuming that these goods were produced with domestic inputs in Thailand and were not affected by THB/USD exchange rate. The increase in imported goods translates directly to the increase in the cost of living of people in Laos. The 6.53% gain in the per capita GDP growth from 2020 to 2022 has been wiped out by the extreme devaluation of LAK. This ERPT effect presents a serious economic hardship for the local people in Laos.

A good economy exists when the household sector are net savers and the corporate sector are net borrowers, with the government budget nearly balanced and net exports near zero (Koo, 2009, 2011). The devaluation of LAK does not create economic recession. Laos expects to gain at least 4.8% in GDP growth in 2022. However, the continuing LAK devaluation puts economic hardship on people as fuel prices rises. Since fuel is purchased in US dollars, as the local currency devalues, fuel price becomes more expensive from ERPT effect. Similar experience also occurred in food and consumer goods prices.

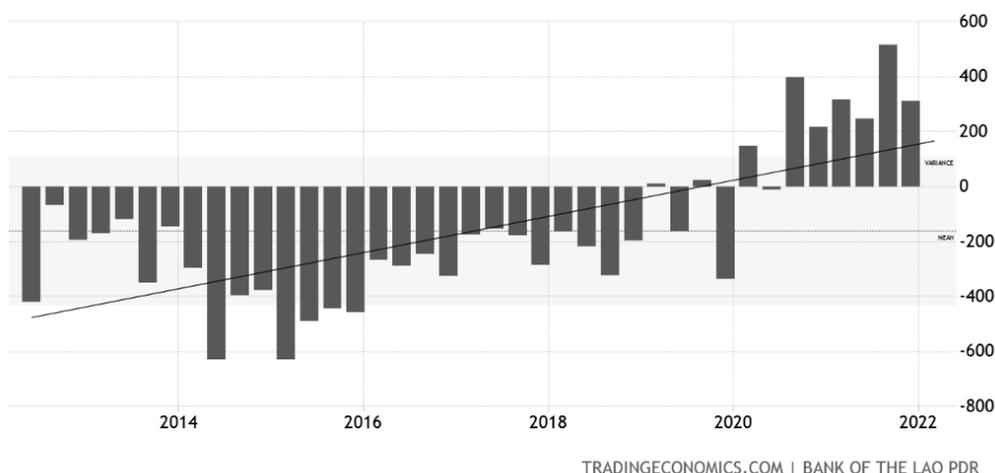


Figure 2: Laos balance of trade 2012-2022

Source: <https://tradingeconomics.com/laos/balance-of-trade>

Prior to 2020, the balance of trade for Laos was consistently negative. There were more imports than exports. Since 2021, Laos began to have positive balance of trade. It exported 1,987.46 and imported 1,472.9 million USD or 35% more exports above imports. Between 2020 and 2021, the country's balance of trade gains decreased by 15%. This slowing down of the balance of trade is reflected by the devaluation of LAK by 56% from 8,600 LAK per USD to the current rate of 13,240 LAK per USD.

This is an interesting case study because LAK is one of the 10 currencies in the ASEAN and is one of the two market-led economies under communist governments, namely Laos and Vietnam. Presently, Laos uses US dollar, Thai baht, and Euro as common currencies in exchange for goods and services. Effective May 2022, the government keeps interest rate at 3.1% compared to 12.50% in 2010. This rate has been stable unchanged since 2020 despite the fact that Laos is dependent on import for fuel and consumer goods. In face recent announcement by the US Federal Reserve to increase interest rate for the second time in the second quarter of 2022 to stem the tide of inflation, the Bank of Laos (BOL) remained inactive and unresponsive to the threat of inflationary pressure and stronger US dollar. As the country continues to import fuel and food products, the price of fuel and food

products became high in the local currency. Without a concomitant increase in wages, fuel and food products became more expensive by the second quarter of 2022. This paper attempts to answer the question of how can the Lao government effectively implement policy tools to reduce the effect of inflation resulted from exchange rate pass-through (ERPT), and what are currencies should BOL use for its basket of currencies to defend the value of LAK. This case study is first of its kind and can serve as a foundational material for further research on this subject. This paper has practical application for stakeholders of in currency market in Laos. Laos is a member of the ASEAN Economic Community (AEC), the impending economic depression brewing in Laos serves as a case study for stakeholders in other ASEAN countries. The effect of money supply policy and effective currency management practice are effective tools to defend a country's currency value.

LITERATURE REVIEW

Monetary discipline is monetary policy that limits the money supply an economy (Melitz, 1987; Neyati and Ozgur, 2007; and Dalmazzo, 2014) by matching the money supply to the level of production in the economy or reserves. One key approach to monetary discipline is constraining money supply and effectively monitor the velocity of money in order to keep inflation under control. Another means to control money supply is by pegging the local currency to a foreign currency (Fielding and Bleaney, 2000). In the time of gold standard, currencies were pegged against gold price (Bordo et al., 2004). For example, the US dollar was defined as 0.048 troy ounce of gold (White, 2008). Central banks of many countries maintain gold reserves to defend the value of their currencies. Pegging is considered a fixed exchange rate. After 1970s, both float and fixed exchange rate systems were used (Kreinin, 2010). Currently, Laos is using fixed exchange rate.

There are three major sources of inflation: Demand-pull inflation, Cost-push inflation, and built-in inflations (Gordon, 1988). Firstly, demand-pull inflation is caused by increases in aggregate demand due to increased private and government spending. This type of inflation contributes to growth because increase demand stimulates economic expansion and growth. Secondly, cost-push inflation, also called “supply

shock inflation,” is caused by a drop in aggregate supply (potential output). This may be due to natural disasters, or increased prices of inputs. The current high oil prices coupled with LAK devaluation are prime condition to create cost-push inflation. Thirdly, built-in inflation is induced by adaptive expectations, and is often linked to the “price/wage spiral”. Workers keep up with inflation by demanding higher wage. Manufacturers pass on the higher cost by increasing price of goods and services. Among these three types of inflation, Laos experiences demand-pull and cost-push inflations.

As LAK is devalued, increase oil prices and shortage of fuel in the local market, there are “too much money chasing too few goods” (Barth and Bennet, 1975) demand-pull inflation is created. Since Laos is import dependent on many goods, LAK devaluation contributed to significant increase in price of imports which are paid in US dollars and Thai Baht. The effect of inflation is more devastating when both demand-pull and cost-push are at work (Samuelson and Solow, 1960).

It has been argued that if economic growth matches the growth of the money supply, inflation should not occur when all else is equal (Sigrauski, 1961). However, this has not been the case in Laos. The economy is expected to grow at 4.8% in 2022; at the same time, the local currency has been devalued by 54% and money supply had grown excessively in the same period. Investment in market production, infrastructure, education, and preventive health care can all grow an economy (Henderson, 1999). This has been the case of Laos. There has been growth in infrastructure investment which had contributed to economic growth. At the same time, the expansion of money supply contributed to inflation at a rate higher than economic growth.

Exchange rate pass-through (ERPT)

Exchange rate pass-through (ERPT) is the degree to which a country’s import, producer or consumer prices change in response to a change in its exchange rate. It is measured as the percentage change, in the local currency, of import prices resulting from a one percent change in the exchange rate between the exporting and importing countries. Countries with lower inflation environment will tend to experience lower ERPT (Taylor, 2000). Low inflation expectations produces credible monetary policy,

the latter can play a role in shaping the ERPT (Gagnon and Ihrig, 2004; McCarthy, 2007; Özyurt, 2016). Low ERPT may contribute to effective monetary policy to stabilize inflation and output (Mishkin 2008).

ERPT studies are confined to mainly in developed countries (Taylor, 2000; Gagnon and Ihrig, 2004; McCarthy, 2007; Özyurt, 2016). Developing economies saw less ERPT research (Choudhri and Hakura, 2006; Akofio-Sowah, 2009; Razafimahefa, 2012; Lariau et al., 2016; Helmy et al., 2018). Some studies saw weak and declining ERPT in both developed countries (Taylor, 2000; Özyurt, 2016) and developing countries (Razafimahefa, 2012; Lariau et al., 2016).

According to Gopinath and Rigobon (2008), ERPT regression equation is given by:

$$\Delta \ln p_t = \alpha + \sum_{i=0}^N \gamma_i \Delta \ln e_{t-i} + \delta \Delta \ln c_t + \psi \Delta \ln d_t + \varepsilon_t$$

where p is import price, e is the exchange rate, c is marginal costs, d is demand, and Δ denotes a first difference. The exchange-rate pass-through after N periods is $\sum_{i=0}^N \gamma_i$. In this study, we estimated ERPT for Laos and how it affects the valuation of that country's currency (LAK) through inflation.

Money supply, money multiplier and inflation

Money supply is defined as the stock of money in the economy which includes currency in circulation (i.e. physical cash) and demand deposits (depositors' easily accessed assets on the books of financial institutions) (Brunner, 2018). Formally, the stock of money is classified as M0, M1 and M2. M0 consists of central bank's Reserve Notes + paper money + Coins. Between M0 and M1, there is an intermediate class of money stock called MB: The total of all physical currency plus Federal Reserve Deposits (special deposits that only banks can have at the Fed). MB = Coins + US Notes + Federal Reserve Notes + Federal Reserve Deposits. M1 comprises of currency held by the public and demand deposits. M2 includes M1 plus M1, savings deposits and other relatively liquid assets such as small certificates of deposit and money market mutual funds. M3: M2 + all other CDs (large time deposits, institutional money market mutual fund balances), deposits of euro-dollars and repurchase agreements. M4: M3 + Commercial Paper + T-Bills). The stock of money: M0, M1, M2, M3 and M4 collectively are called narrow money.

The money supply is linked to inflation by the equation of exchange: $M \times V = P \times Q$ where M is the total dollars in the nation's money supply, V is the number of times per year each dollar is spent (velocity of money), P is the average price of all the goods and services sold during the year, and Q is the quantity of assets, goods and services sold during the year.

The percentage changes as per unit of time in the monetary exchange equation are given by: $\% \Delta P + \% \Delta Q = \% \Delta M + \% \Delta V$. By rearranging the equation, basic inflation identity is obtained: $\% \Delta P = \% \Delta M + \% \Delta V - \% \Delta Q$. Inflation ($\% \Delta P$) is equal to the rate of money growth ($\% \Delta M$), plus the change in velocity ($\% \Delta V$), minus the rate of output growth ($\% \Delta Q$).

In the present case, the money supply of LAK increases from 28.8414 million USD in 2019 to the high of 1.651 billion USD in 2020. The volume of M1 in Laos continues to expand through 2022. This paper asserts that this expansion of monetary supply contributed to the rapid devaluation of LAK. The rapid devaluation may also be explained by the money multiplier effect.

Money multiplier is the ratio of commercial bank money to central bank money (monetary base) under a fractional-reserve banking system. This multiplier is the reciprocal of the reserve ratio minus one, and it is an economic multiplier. The money multiplier is determined by: $m = 1 / RR$,

“By increasing the volume of their government securities and loans and by lowering Member Bank legal reserve requirements, the Reserve Banks can encourage an increase in the supply of money and bank deposits. They can encourage but, without taking drastic action, they cannot compel. For in the middle of a deep depression just when we want Reserve policy to be most effective, the Member Banks are likely to be timid about buying new investments or making loans. If the Reserve authorities buy government bonds in the open market and thereby swell bank reserves, the banks will not put these funds to work but will simply hold reserves. Result: no 5 for 1, “no nothing,” simply a substitution on the bank's balance sheet of idle cash for old government bonds.” — (Samuelson 1948, pp. 353–354).

Laos allows reserve requirement to be in local and foreign currencies. The current reserve requirement for both foreign and local currencies is 5%. The money multiplier for Laos is $1/0.05 = 20$. This means that at a given level of money supply, the broad money in circulation is as high as 20 times that level.

DATA AND METHODOLOGY

The data used in this research consists of the weekly average of the spot rate for the exchange rate of the following currencies against the US dollar: CNY = Chinese yuan, EUR = euro, JPY = Japanese yen, LAK = Lao kip SGD = Singapore dollar, and VND = Vietnamese dong. The average weekly spot rates from January 1, 2012 to May 22, 2022. The sample size included 543 weeks of Asian currencies against US dollars.

Extreme value analysis

We explored extreme value theory as a possible theoretical framework to explain the devaluation of currency in extreme cases. “Extreme Value Distribution usually refers to the distribution of the minimum of a large number of unbounded random observations” (NIST, 2013). A threshold value is used for removing the minimum or maximum values. In the present case, we set the significance level at 95%; within the bound of 542 weeks of weekly exchange rate, we separate items showing $Z > 1.65$ as extreme devaluation of the currency. We examine this group of data whose probability distribution exceeds the threshold under the tail index. The tail index can provide information about the underlying distribution (Kostov & McErlean, 2002, p. 5).

There are two approaches to extreme value analysis. The first method uses the maxima block of points. This is called annual maxima series (AMS) approach (Hosking et al., 1985, and Madsen et al., 1997). The second method uses a specified points as the threshold beyond which points of values are considered extreme (Leadbetter, 1991). This is known as Peak Over Threshold (POT) approach. Under PDS, the data set is assumed to take a particular distribution (Madsen et al., 1997). The question of “which distribution should PDS assume” remains unsettled.

For instance, Shane and Lynn (1964) assume that PDS is Poisson distributed. Zelenhasic (1970) proposed that the exceedance is gamma distributed. Another group of writers, such as Miquel (1984) and Ekanayake and Cruise (1993), proposed that the exceedance is Weibull distributed. In Rosbjerg et al. (1991), it was suggested that lognormal distribution characterizes the exceedance. Lastly, there are researchers who suggests that the exceedance set is distributed generalized Pareto (Van Monfort and Witter, 1986; Hosking and Wallis, 1987; Fitzgerald, 1989; Davidson and Smith, 1990; Wang, 1991; Rosbjerg et al., 1992; and Madsen et al., 1995). This paper assumes that the data has characterized by Weibull distribution because the currency devaluation is a loss in valued from an expected norm akin to a failure trend analyzed by Weibull. After the extreme value are separated from the rest of the data set, they were analyzed under EVT. Currency devaluation is a cause for concern because extreme devaluation may lead to hardship among people, especially in countries that are dependent. Thus, EVT becomes is relevant in risk management (Embrechts et al., 1999, p. 32).

Rosbjerg and Madsen (1992) recommended that the threshold level (q_0) should be obtained by the sum of the expected mean plus the product of the k count and the sample's standard deviation, thus: $q_0 = E[Q] + kS[Q]$ where $E[Q]$ = observed mean of the sample; $S[Q]$ = sample standard deviation; and k = predefined frequency factor. This method of identifying exceedance level q_0 has been used in flood studies (Rasmussen & Rosbjerg, 1991) and precipitation research (Madsen et al., 1994). There is a limitation in this approach when the data is set is small. In order to make this study be generally applicable in other cases, we opt for the use of standard score equation as the tool for separating extreme points.

The series $X_i : (x_1, x_2, \dots, x_{543})$ for 543 trading weeks called sample $F(X)$ was subjected to standard score equation under 0.95 confidence interval: $Z(0.95)$ where $f(x) > 1.65$. Weekly exchange rates that exceed 1.65 or less that -1.65 are separated into a group called $G(X)$. The elements of $G(X)$ are used to calculate the tail index. For small sample size as in $X_i : (1, 2, 3, 4, 10)$, once extreme points are identified, the entire set is used for the tail index calculation, i.e. $F(X) = G(X)$.

In this study, we obtained the weekly average spot rates for the following currencies traded against the US dollar: CNY = Chinese yuan, EUR = euro, JPY = Japanese yen, LAK = Lao kip, SGD = Singapore dollar, THB = Thai baht and VND = Vietnamese dong. LAK is the target currency for evaluation of extreme devaluation. We have used the standard equation to test for extreme value by using $Z = 1,65$ as the threshold level beyond which the data is separated as extreme. All currency, except LAK, show exceedance group. The first 510 weeks of LAK were trading within the 95% confidence interval. From week 511 to week 543, LAK shows $Z > 1.65$. This exceedance group ($G(X)$) was used for further analysis under EVT.

Extreme values may be analyzed under the generalized extreme value (GEV) distribution proposed by Fisher-Tippett-Gnedenko:

$$H(x; \mu, \sigma, \xi) = \exp \left\{ - \left[1 - \xi \left(\frac{x - \mu}{\sigma} \right)^{-1/\xi} \right] \right\} \quad (1)$$

where μ = location; σ = scale; and ξ = shape. If $\xi > 0$, H becomes a cumulative distribution function (CDF); if $\xi < 0$, it is valid for $x < \mu + \sigma/(-\xi)$; and if $\xi = 0$, H is undefined (Bensalah, 2000). However, if $\xi \rightarrow 0$, then the Fisher-Tippett-Gnedenko equation is reduced to:

$$H(x; \mu, \sigma, \xi) = \exp \left[- \left(\frac{x - \mu}{\sigma} \right) \right] \quad (2)$$

This is known as Gumbel distribution. Note that the parameter ξ is the tail index of the distribution. The tail index may be used to classify the type of extreme value distribution. If $\xi = 0$, the H distribution is Gumbel distribution, also known as Type I where $x \in \mathfrak{R}$ and $\xi = 0$.

If $\xi > 0$, the H distribution is a Fréchet distribution or Type II. The Fréchet distribution is given by:

$$H(x; \mu, \sigma, \xi) = \exp \left\{ \begin{array}{l} 0 \\ \exp \left\{ \left(\frac{x - \mu}{\sigma} \right) \right\}^{-a} \end{array} \right\} \quad (3)$$

If $x < \mu$ then $H(x; \mu, \sigma, \xi) = 0$; if $x > \mu$ then $H(x; \mu, \sigma, \xi) = \exp((x - \mu)/\sigma)^a$. In Fréchet distribution with sample size n and parameters: α and β (Abbas & Yincai, 2012). The maximum likelihood estimation of β is:

$$\hat{\beta}_{ML} = \left(\frac{n}{t} \right)^{1/a} \quad (4)$$

If $\xi < 0$, the H distribution is Weibull distribution or Type III. The Weibull distribution is given by:

$$H(x; \mu, \sigma, \xi) = \left\{ \begin{array}{l} \exp \left\{ - \left(- \left(\frac{x - \mu}{\sigma} \right) \right) \right\}^a \\ 1 \end{array} \right\} \quad \begin{array}{l} \text{for } x < \mu \\ \text{for } x \geq \mu \end{array} \quad (5)$$

Once the tail index is determined, the next step was to classify the type of extreme value distribution of the series through the use of the tail index. There are two methods for the tail index estimation: the Pickands method (Pickands, 1975), and the Hill method. (Wagner and Marsh, 2000). The Pickands method is given by:

$$\hat{\xi}_{k,m} = \frac{1}{m} \sum_{i=1}^k (\ln X_{n-i+1} - \ln X_{n-m}) \quad (6)$$

where m = number of observations whose tail is to be observed and k = sample size. Secondly, the Hill method is given by:

$$\hat{\xi}_{k,T} = \frac{1}{k} \sum_{i=1}^k (R_{i,T} - \ln R_{k,T}) \quad (7)$$

where $R = \sigma Z$; recall that σ is the estimated population standard deviation and Z is the standard score of the series. Both methods follow the same conditions in providing the decision rule for classifying the type of extreme value distribution: *Fréchet* = $\xi > 0$, *Weibull* = $\xi < 0$ and *Gumbel* = $\xi = 0$. In this paper, we opt for the Hill method for calculating the tail index for the extreme group of data.

Weibull analysis for system failure in foreign exchange rate regime

In this paper, we applied Weibull distribution for currency devaluation analysis. We define extreme and rapid devaluation of a currency as a system failure. Therefore, the application of Weibull distribution is an appropriate tool in this study. The use of Weibull in decline curves analysis is not uncommon (Lee, Se and Mallick, 2021). In Weibull distribution analysis, eta (η) is the shape parameter (Jiang, 2011). The interpretation of the shape parameter follows are provided in 3 scenarios: eta < 1, eta = 1, and eta > 1.

A value of eta < 1 indicates that the failure rate decreases over time which corresponds to Pareto distributions (Elizaar, 2017) rather than Weibull distributions). In currency devaluation, this is characterized by extreme and rapid loss of currency value which may be due to internal policy of the government. The tendency is for the devaluation to moved to a stabilized platform where eta = 1. A value of eta = 1 indicates that the failure rate is constant over time. This might suggest random external events are causing the devaluation of the currency. At this point, the devaluation is stabilized.

A value of eta > 1 indicated the failure rate increases with time. This means that the devaluation of the currency causes the loss in currency value with increase in time. This is spiral devaluation. In some cases, countries would abandon their own currencies and adopt other countries' currency as substitute, i.e. Eswatini (alongside Swazi lilangeni); Lesotho (alongside Lesotho loti); Namibia (alongside Namibian dollar); and Zimbabwe (alongside the United States dollar, euro, Chinese Yuan and Botswana pula).

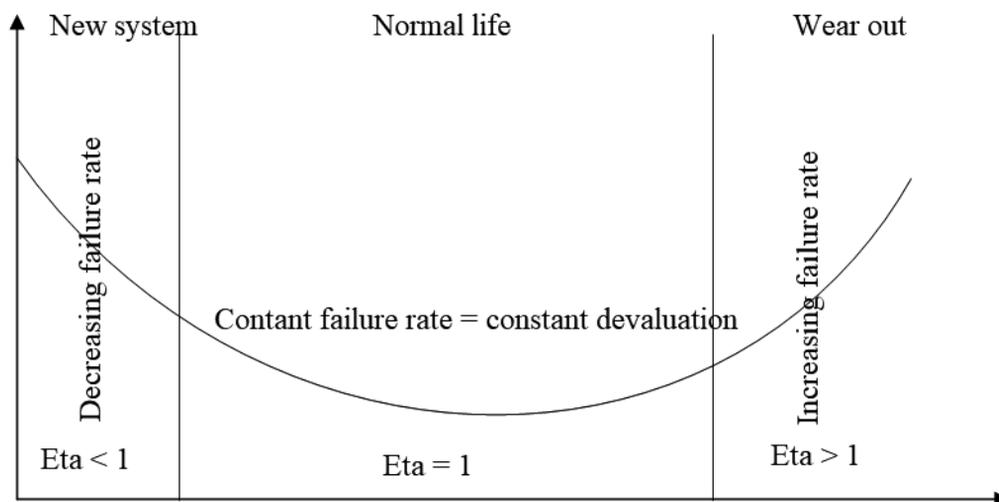


Figure 3: Behavior of Weibull system failure

RESULTS AND ANALYSIS

We presented our findings and discussion in three sections. Firstly, we presented the characteristics of the seven currencies exchanges against USD by looking at the descriptive and inferential statistics. The inferential statistics tells us about the expected exchange rate that should be at the end of the period of our study on May 22, 2022. Both the descriptive and inferential statistics of the exchanges rate provided us with reference points for the movement of the seven currencies against the US dollar. Secondly, we present our findings on the model selection. We examine autoregressive model (AR) and Weibull system analysis of failure rate. We acknowledged that AR is a common tool for time series data analysis. Exchange rate over time is a time series data set; however, when dealing with steady devaluation after a long period of stability, AR may not be appropriate. In this case study, LAK had been stabilized for the past nine years. However, on its tenth year in 2022, we witness extreme devaluation. This extreme divergence from the long-term equilibrium made AR modeling inappropriate. Therefore, we adopted Weibull distribution as a tool to model the devaluation of LAK and the rest of the currencies in the basket for our study. Lastly, we noted that the last 33 weeks ending May 22,

2022 LAK had experience extreme devaluation. Under these circumstances, we employed Extreme Value Theory (EVT) as a tool to study the behavior of LAK. We found that currencies showing positive tail index indicated extremely strong and negative tail index indicated extremely weak currencies.

Characteristics of selected currencies

The series of the data extends 543 weeks (January 1, 2012 to May 22, 2022). We can summarize the trajectory of the exchange rate movement of these seven currencies under autoregressive (AR) model and Weibull time series to show the predictive function for exchange rates movement. The descriptive and inferential statistics of these currencies over a period of 543 weeks are summarized in table 2. We note that the sample mean and expected mean of LAK were 8,556.79 and 8,496.35 respectively. These figures may be compared to the last spot rate on May 22, 2022 at 13,240 LAK per US dollar which represents a devaluation of 54%.

Selected Currencies*	Descriptive Statistics		Inferential Statistics	
	Mean	STD	μ	δ
CNY	6.51	0.30	6.49	0.30
EUR	1.19	0.09	1.18	0.09
JPY	106.70	11.07	105.92	11.07
LAK	8,556.79	853.55	8,496.35	853.55
SGD	1.34	0.06	1.33	0.06
THB	32.48	1.70	32.36	1.70
VND	22,275.43	895.14	22,212.05	895.14

Table 1: Basket of currencies under analysis as weekly rate against USD ($n = 543$)

* CNY = Chinese yuan, EUR = euro, JPY = Japanese yen, LAK = Lao kip, SGD = Singapore dollar, THB = Thai baht and VND = Vietnamese dong

Model selection and predictive functions of currency movement

In this case study we are faced with the issue of model selection. Model selection problem is selecting a few representative models from a large set of computational models for the purpose of decision making or optimization under

uncertainty (Shirangi and Durllofsky, 2016). There are two goals of model selection: model selection for inference and model selection for prediction (Ding, Tarok and Yang, 2018). We are faced with the choice between autoregressive (AR) modeling for time series data. This approach is not an effective tool for making inference or prediction when the data does not return to its long-term equilibrium. AR is more appropriate for a stable system of data. Currency devaluation in extreme cases where the devaluation spirals downward and showing no sign of returning to its long-term equilibrium, AR is not an appropriate model. AR is more appropriate for a stable system and to analyze the effect of external shock. In this case, study we are faced with a system failure that requires a different approach to system analysis. As such, we opted for Weibull distribution as a tool to analyze the devaluation of LAK by defining the devaluation as a system failure. Secondly, Weibull distribution is used for specific period of devaluation that is considered extreme. Thus, this case study also applied extreme value theory (EVT) as a tool to analyze the extreme currency devaluation. We illustrate the efficacy of AR and Weibull in Table 2.

Selected Currencies	Autoregressive (AR(1)) Model	Weibull system analysis Model
CNY	$Y = 6.72 + 0.02X$	$Y = 1.58 + 0.02X$
EUR	$Y = 0.94 - 0.001X$	$Y = -0.20 + 0.03X$
JPY	$Y = 129.70 + 0.47X$	$Y = -3.76 + 4.82X$
LAK	$Y = 13,765.93 + 304.08X$	$Y = 8.92 + 0.11X$
SGD	$Y = 1.38 - 0.0005X$	$Y = 0.27 + 0.02X$
THB	$Y = 34.37 + 0.03X$	$Y = 3.47 + 0.01X$
VND	$Y = 23,207.35 + 43.99X$	$Y = 9.95 + 0.05X$

Table 2: Predictive function of time series for six currencies under autoregressive (AR) and Weibull models

AR model is an effective tool to estimate the long run expected value, i.e. mean. However, if we are looking for indication of significant devaluation, the long run equilibrium point under AR may not be appropriate. Current devaluation process in a steady decreasing process, such that witnessed by LAK in this study, is not meaning unless a block of data defined by time period and sifting by a fixed

threshold ($F(Z) > 1.65$) and analyze separately under EVT. Thus, for extreme value analysis of currency devaluation, we opt for Weibull and EVT. Weibull has long been applied in social science for failure analysis. Extreme currency devaluation represents a fail pattern of exchange rate regime and policy of a country.

We note that AR model is not an efficient model for this study because by using the previous exchange rate as the explanatory factor for the current exchange rate, the system tends to show high stability. Even when there is a shock to the system, the self-corrective return to the long-term equilibrium may integrate the effect of shock into the system. In currency devaluation, we note that the trajectory of the falling of currency value is not linear. This falling of currency is akin to survivorship model which could be more appropriately studied under Weibull system analysis. Under the Weibull model, we can predict the shape and scale of the exchange rates distribution and, thus, can learn more of how the currencies behavior. Table 3 below summarizes the Weibull statistics for the seven currencies.

Selected Currencies	Beta (β)	Eta (η)	CDF* (Φ)	PDF (ϕ)	R (<i>Reliability</i>)	Instant Fail ($H(t)$)
CNY	0.52	0.42	1.00	0.18	-	0.84
EUR	4.55	2.21	0.19	0.13	0.81	0.13
JPY	0.21	0.03	1.00	0.05	-	0.46
LAK	0.11	-	1.00	0.02	-	0.26
SGD	3.65	2.01	0.20	0.24	0.80	0.26
THB	0.28	0.08	1.00	0.08	-	0.57
VND	0.10	-	1.00	0.02	-	0.24

Table 3: Weibull distribution analysis of currency exchange rates, $n = 543$

*Predictive value used in calculating Weibull statistics is the observed mean.

The interpretation of Weibull statistics tells us that if beta is less than 1, the system tends to fail at the start. If beta is equal to 1, the failure rate is constant, and if beta is greater than 1, the failure rate increases with respect with time. In the present case, we expect to see continue devaluation of CNY, JPY, LAK, THB and VND. For China, weak CNY does not present a problem because China is export oriented economy.

With eta (η) at 0.11, we are witnessing LAK to go through its decreasing failure rate. If LAK devaluation behaves as predicted by Weibull's probability distribution pattern, we expect LAK to continue to devalue passing through a period of eta = 1 and then finally, if no intervention is made, reaching a complete failure when eta > 1. The prime time for intervention is a period where eta \leq 1, which is now.

Currency devaluation analysis under extreme value theory (EVT)

In the 543 weeks of the data, we found that the exchange rate of LAK against USD was stable from January 1, 2012 to September 25, 2021. The currency starts to experience significant devaluation from October 3, 2021 onward. Significant devaluation was verified by the significance level of the rate dispersion among the entire sample of 543 weeks. From the first week (January 1, 2012) to the 510th week, the pValue of the exchange rate per week was greater than 0.05. The descriptive and inferential statistics for the normal period (week 1 to week 510) is given in Table 4.

Group 1: n = 509	Descriptive statistics	Inferential statistics
Mean	8,376.19	8,342.20
Standard deviation	467.56	0.3204
Skewness	1.03	-
Kurtosis	0.10	-
Group 2: k = 33	Descriptive statistics	Inferential statistics
Mean	11,295.77	11,196.86
Standard deviation	346.46	0.8098
Skewness	0.50	-
Kurtosis	0.64	-

Table 4: Descriptive and inferential statistics of non-extreme group weeks 1-510

The devaluation of LAK becomes statistically significant since October 2021. Although there is a sign of spiraling effect of the devaluation, it is still in an early stage for government intervention. In the second quarter of 2022, the US, UK, and Canada

announced that their central banks will increase interest rate in response to inflation. This interest rate increase will make US dollar stronger. As the result LAK will further devalue because the Bank of Laos does not keep up with the US interest hike. So long as BOL remains in active in its interest rate policy, we expect to see further decline of LAK value as it is traded against the US dollar. This problem is more prominent because US dollar is openly used and traded in the country.

After week 510th the rate of LAK against USD shows pValue of less than 0.05. As the result, week 1 to week 510 were separated and treated as normal exchange rate data set. A period from week 511 to week 543 was treated as extreme value set. Table 6 below shows the Weibull statistics of the extreme value set.

$n = 33$	Value	Interpretation
Weibull linear equation	$Y = 9.36 + 0.05X$	Devaluation is systemic
Beta (β)	19.35	Continuing devaluation
Eta (η)	11,622.62	Expected LAK per USD
Weibull CDF	1.00	Cumulative probability
Weibull PDF	0.02	Probability distribution
R system reliability	0.00	System reliability
H(t) instantaneous failure	0.26 or 0.26%	Devaluation survivorship

Table 5: Weibull statistics for weeks 510-543 of LAK exchange rate against USD

The Weibull linear equation for LAN is $Y = 9.36 + 0.05X$. Since the intercept is in log form, when converted to its original value, the long-term average value for LAK is $\exp(9.36) = 11,622.62$ per one USD. However, the average spot rate for May 22, 2022 (week 543rd) was 13,240.00 with a difference of 1,617.38 or 14% under the expected value. This 14% below expected value of LAK is an inflationary pressure against LAK through exchange rate.

We examined all currency in the basket for this study and found that CNY, THB and VND had no extreme values for either over-valued or under-valued. These countries (China, Thailand, and Vietnam) have effective currency management practice. Their currencies have been stable for the past 10 years or 543 weeks from

2010 to May 2022. We found that two currencies (EUR and SGD) had been overvalued in part of 2014 for EUR and 2013 for SGD.

From the data between weeks 511 to week 543, LAK had show statistically significant devaluation with EVT's tail index of 5.60 and with a beta of 0.11 (less than 1) the devaluation is likely to continue. Since this extreme devaluation had been going on for 33 weeks, it is a prime time for the central bank to defend further valuation of LAK. The devaluation of LAK in an extreme condition is indicated by a large tail index in under EVT analysis ($\xi = 5.60$). As referenced, when the tail index is greater than zero, the distribution is classified as Fréchet distribution. ($\xi > 0$). The result of the tail index calculation and classification of distribution according to the tail index is given in Table 6.

Selected Currencies	K Extreme	Period	ξ Tail Index*	Distribution Type
CNY	34	Aug'19-May-20	2.69	Fréchet
EUR	48	Sep'13 – Aug'14	4.48	Fréchet
JPY	53	Jan – Dec 2012	0.16	Fréchet
LAK	33	Jan – May 2022	(1,628.30)	Weibull
SGD	26	Sep'12 – Feb'13	4.28	Fréchet
THB	N/A	No extreme	No extreme	No extreme
VND	N/A	No extreme	No extreme	No extreme

Table 6: Exchange rates analyzed under Extreme Value Theory (EVT)

*: Fréchet = $\xi > 0$, Weibull = $\xi < 0$ and Gumbel = $\xi = 0$

Under *Fréchet distribution*, three parameters are examined: (i) Shape parameter which is defined as $\alpha = -1/\xi$; (ii) Scale parameter which is determined by $\beta = \sigma/\xi$; and (iii) Location parameter which is given by $\tau = \mu + (\sigma/\xi)$. Under these definition, the shape parameter for LAK is $\alpha = -0.0006$; scale $\beta = -0.54$; and location $\tau = 11,216.32$. Under this prediction, the expected exchange rate for LAK should be 11,226.27 LAK per US dollar. However, the last spot rate traded on week 543 (May 15, 2022) was 13,240----- under shoot by 2,013.73 or 15%. In comparison to our original Weibull estimate at 14%, the estimate of LAK under EVT is 1% down in value.

A lower value for the home currency will raise the price for imports while making exports cheaper (Owen, 2005). However, for import dependent economy, weak currency or currency devaluation could be devastating for the local market because the price of imports becomes more expensive (Cooper, 1971). According to Krishna, a strong currency was commonly seen as a mark of prestige, while devaluation was associated with weak governments (Krishna, 2002). With the on-going long lines at gas station and increased cost of living, the devaluation of LAK inflict hardship on local people.

A reason for preferring devaluation common among emerging economies is that maintaining a relatively low exchange rate helps them build up foreign exchange reserves, which can protect against future financial crises (Sloman 2004; Wolf 2009; and Owen 2005). However, the devaluation of LAK did help BOL to shore up its foreign reserve. Immediately after COVID-19, BOL's foreign exchange reserved stood at about 800 million USD; this figure increased to almost 1.4 billion USD in 2021---at the height of LAK devaluation (CEIDATA, 2022). A rule usually followed by central banks is to hold in reserve at least three months of imports. However, currently, BOL's foreign exchange reserves could afford the country for only two months.

BOL is caught in a bind. In order to meet the bar set by Basel III of 3 months worth of foreign exchange currency reserves, it must increase its reserves. Foreign exchange reserves expansion causes the local currency to devalue. As BOL expands its foreign currency reserves, LAK continues to devalue. This problem is further compounded by the fact that the current conflict between Russia and Ukraine and the simultaneous increase of oil price in the world market makes the price of food and fuel even more expensive throughout the world. As an import dependent economy, Laos stands to see more devaluation of LAK throughout this fiscal year.

The prospect of continue devaluation of LAK is predicated upon the value of η in the Weibull statistics. According to the rule of interpretation of Weibull, $\eta < 1$ indicates that the failure rate decreases over time and will stabilize where $\eta = 1$. Presently, LAK's devaluation has $\eta = 0.11$. It will most likely approach 1 and then greater than 1 according to the Weibull η 's trajectory. If that is the case,

the devaluation is still at its early stage where intervention is possible. As we have shown in the data plotting of extreme values, the last 33 weeks ending May 15, 2022, the devaluation of LAK became significantly high and is treated as extreme. With the tail index of 5.60 between January and May 2022, LAK had been extremely weakened. The current weakening of LAK translated into economic hardship of people as the local economy depends on fuel imports. In order to import fuel, LAK must be exchange for US dollar. This means that BOL must shore up its foreign currency reserve. As the central bank increases its foreign currency reserve to meet foreign currency exchange needs, LAK is further devalued.

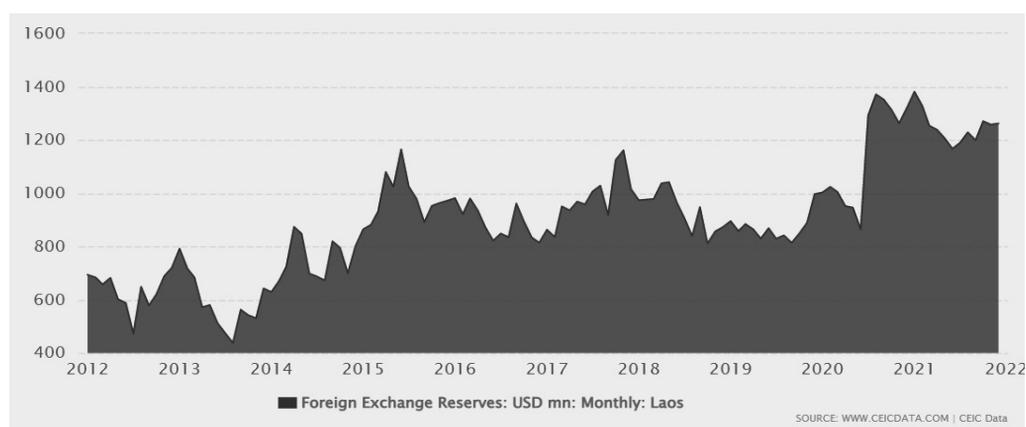


Figure 4: Foreign exchange reserve of Laos

Source: <https://www.ceicdata.com/en/indicator/laos/foreign-exchange-reserves>

Accessed: June 2, 2022.

CONCLUSION

In this case study, we learned that increasing foreign exchange reserved couple with devaluation of the country's currency will result in currency devaluation. The devaluation of LAK in the second quarter of 2022 has caused traumatic consequences in the local market creating long lines at gas station and increasing cost of living. The devaluation created inflationary pressure on the local market through the ERPT effect. The effect of ERPT detracts the impetus of growth from the economy. The GDP of Laos was expected to grow by 4.8% in 2022; the country's currency

devalued by 49% in the same year. The Lao economy is at the verge of slipping into recession. In order to solve the continuing devaluation of LAK, the Central Bank of Laos must intervene by pegging its interest rate with the US. By stabilizing interest rate at 3% in Laos while the US had increased its interest rate in the first two quarters of 2022, LAK is losing its value against the US dollar. Part of the devaluation comes from expansive money supply policy. With an increase in interest rate, M1 should contract and the devaluation of LAK could be hemmed.

RECOMMENDATIONS

The government should maintain an effect policy mix. The policy mix is the combination of a monetary policy and fiscal policy. These policies are used to stimulate growth and employment (Reynolds, 2002). In face if extreme devaluation of LAK, the government should engage in contractionary monetary policy in order to fight inflation, ensure price stability, and increase the strength of LAK (Levy and Sturzenegger, 2010). Contractionary money policy tools may include:

1. Increase reserve requirement (RR)

Presently, the RR rate is 5% making the money multiplier effect of $1/0.05 = 20$ times. It is recommended that RR be increase to 10 or 15% to slow down the money multiplier effect and stem the tide of LAK devaluation.

2. Foreign exchange reserve control

Decrease foreign exchange reserve to shore up LAK devaluation. The increase of foreign exchange reserve has the effect of devaluing the local currency because the local currency is exchanged for US dollar.

3. Basket of currencies

LAK must be peg against the US dollar. This pegging practice would imply that BOL must peg its interest rate with the US Federal reserve. In addition, other currencies that correlate with LAK under USD exchange regime include: SGD, CNY, VND and EURO, together these currencies produced R-squared of 0.52 of the exchange rate against USD and each has significant relationship with LAK against USD at $p = 0.000$.

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