International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Alternative Exchange Market Pressure Index Model for Currency Crisis

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Abstract

Currency crisis is classified as one of the top ranked extreme risks of the third millennium. It becomes a serious financial and economic problem worldwide and researchers have focused their attention on understanding how those crises are studied, modeled and analyzed. These currency crises exist in the form of speculative attacks in the foreign exchange market. These speculative pressures are measured by crisis indexes named exchange market pressure indexes (EMPI), which need to reflect both successful and unsuccessful speculative pressures on local currency. This paper aims to develop an alternative exchange market pressure index model for currency crisis. The methodology that will be adopted to construct the alternative EMP index model is the “EMPI model independent based approach”. A simulation analysis is also performed to validate and verify the theoretical properties of the proposed EMPI model. We end up by studying the different properties related to the EMPI model. This new alternative EMPI model is expected to measures incidence of currency crisis periods in a regional or/and global economies (countries), to measure also incidence for currency crisis for successful and unsuccessful attacks and identify currency crisis happening either in a fixed, floating and/or intermediate exchange regimes. Our investigation suggests that the exchange market pressure index similar to other financial time series tends to be heavy tailed. Overall, the results appear to confirm that the EMPI is stationary and again correlated. A comparison study on Dollar and Euro Kenya's EMPIs is conducted and results reveal a very weak difference between them.

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This study covers only a small area of this growing field of research. It contributes by constructing an alternative EMPI model that may have a position in the toolbox of economists looking for more accurate model in predicting currency crises.

Keywords: Currency crisis; Periods of crisis; Exchange market pressure; Speculative attack; Model-independent.

1. Introduction

The monetary crisis is defined as sudden devaluation or depreciation of the domestic currency that end up causing speculative in the foreign exchange market. It is also considered as one of the top ranked extreme risks of the third millennium, which strikes many countries and which aims to destabilize them economically and financially and to devalue their currencies in the international market of exchange.

In order to measure the severity and the period of this scourge and prepare to fight and deal with such disaster; many models such as GR model [14], DW model [42], ERW model [9], KLR model [24], STV model [38], JL model [31], DS model [39] and ALS model [2] have been brought out to measure and identify crisis periods.

Despite the efforts of researchers over the years and the accurate of the models provided but they remain a flaw and gap on these models, since all the above models behave differently and provide different results. No two or three of them agree and converge in one conclusion. Reference [22] stated that 'Unfortunately, there is no way to judge the accuracy of currency crisis model or dating methods', since there is no consensus about a formal definition of currency crisis model derived from theory and multilateral organizations such as the international monetary fund (IMF) do not systematically categorize country or global currency crisis model.

Therefore, one of the most important aims of this paper is attempting to provide or derive and build an alternative exchange market pressure indexes (EMPI) model for currency crisis.Previous studies on currency crisis built crisis incidence from exchange market pressure (EMP) for instance [9,24,38, 2] and so on. They used many different procedures for the implementation of the EMP indexes include the approach, the selection of the different components of the model, their different ways of defining the components and the calculation of the weights attached to each component.In this work, the researcher will derive an alternative exchange market pressure indexes model which includes the following polices: The exchange rates (E), the interest rate (I) and the international reserve (R) with a weighted schemes which allow the same volatility of the three components of the index, especially the same conditional variance and thus not a single component would affect the model alone.The methodology that will be adopted to construct the alternative EMP index model of currency crisis is the 'EMPI model independent based approach': We employ the exchange market pressure (EMP) methodology pioneered by [14], and further developed by [43, 9, 38, 24, 31, 2] and so on.The author will take an inspiration from five different models: ERW model [9] KLR model [24], STV model [38], JL model [31], DS model [39] and ALS model [2] and their respective characteristic properties and make some formulations, modifications and extension of their EMP formula to derive a single and independent alternative EMP index model of currency crisis. This new model will be able to capture both successful and unsuccessful speculative pressure.

The researcher will consider an economy (countries) with fixed and / or with floating exchange rate regimes. We will also assume that:

a. Authorities used policy tools of reserves and interest rate or one of them to defend the exchange rates.

b. Absence of the policy tools of reserve and interest rate i.e. authorities leave exchange rates to depreciate.

c. keeping all other factors unchanged

The model consistent approach that will be used here is based on a simple model independent approach... incorporate weights to standardize the variance of each component instead of using conversion coefficients. This method is adopted by [9,24, 38,2]. The approach will involve all components as stated in the previous paragraph to derive the new alternative EMP model to measure currency crisis. Our methodology does not employ or specify any particular weighting schemes. The weights attached to each component will be derived from the models underlined above.The rest of this paper is structured as follows. Section 2 deals with the methodology. Section 3 proposes the new alternative EMP model for currency crisis. Section 4 investigates the general mathematical properties related to the new alternative currency crisis model. In section 5, a simulation analysis is performed to check the validity of the proposed alternative EMPI model for currency crisis. Section 6 deals with data collection procedures. Section 7 provides an empirical study about Kenya's EMPIs. Section 8 provides the conclusion.

2. Methods

2.1. EMPI components

In our EMP index for currency crisis three components are of particular interest viz exchange rates (E), interest rates (I) and international reserves (R). These components are considered as the proxy of the currency crisis phenomenon. They are regarded as the most famous indicators of well-being used to describe, detect or construct an EMP index. We remark that in this paper these proxies component will be considered to be substitutable, simple and relative.International reserves and interest rates are both often used tools to fight off any speculative attack that affects the domestic currency by creating instabilities on the exchange rates. We note that through a speculative pressure the exchange rate may depreciate, we speak about successful currency crisis or it may still unchanged but at the cost of loosing international reserve and high interest rate (see figure 1).Diagram (1) explains the relationship between the components (exchange rate, international reserves and interest rate). It shows also the principal role played by each component to defend the exchange rate from depreciation. From the diagram we learn that currency crisis is defined by both successful and unsuccessful attacks. A speculative can pressures on both fixed or /and floating regimes

2.2. Weights schemes

Weighted schemes are some kind of coefficients attached to each component of the EMP model. These coefficients serve as balances between the components in order to avoid the EMP measure being dominated by the most volatile components; and should equalize the conditional volatility of each component. The currently available weighting models technique can be categorize in two groups. These two types of weighting approaches can yield very different results [26].

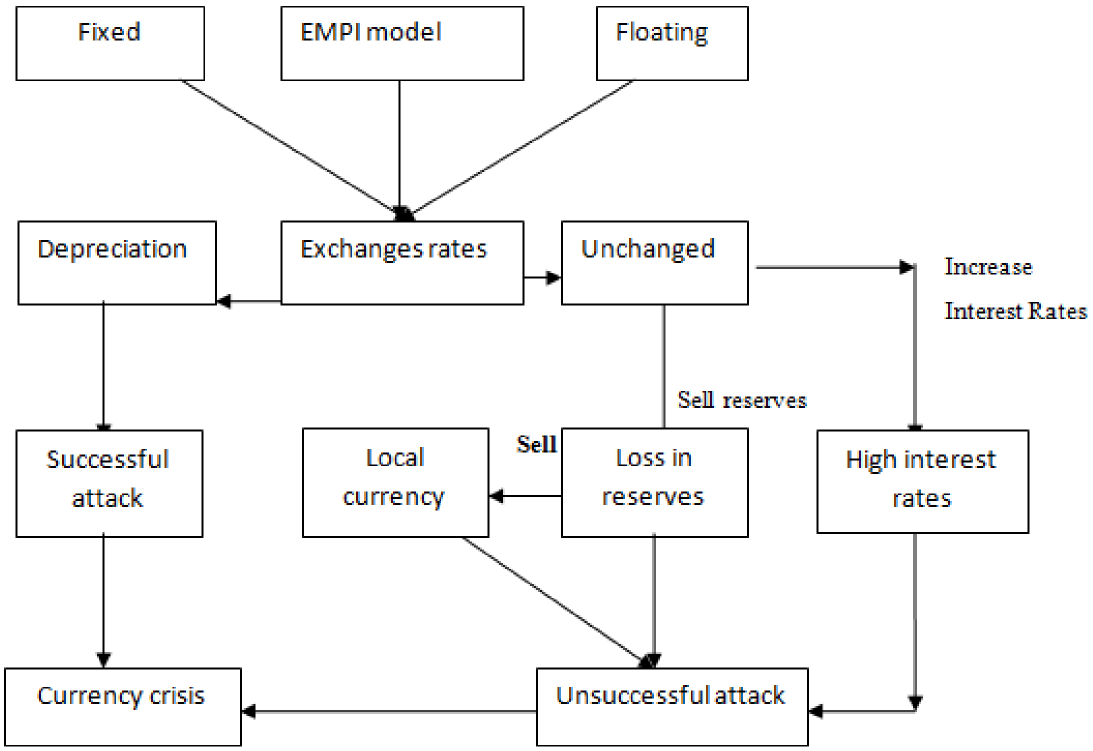

Figure 1: EMPI flow diagram

1. Model-dependent weighting method: This method is dependent on unknown parameters which can be estimated.

2. Model-independent weighting method: This approach starts from the fact that tying exchanges rates to macroeconomic fundamentals is very difficult, and thereby also estimating the true weights using a structural exchange rate model.

In this paper, the researcher will adopt the second type of weighting scheme model independent weighting, since it is more related to the approach employed in this work for computing the EMP index: the model-independent EMP.

2.3. EMPI model approach

To construct a valid, successful and globally alternative EMPI the author adopts the model-independent approaches and follows the diagram path knows as HWI (Human Well-being Index) see in detail [33] used for the first time by the UNDP 2010 to construct a human development index or HDI.

The diagram path consists of first, to chose the type of indicators (substitutable/non substitutable), type of aggregation (simple /complex), type of comparisons to be made (relative/absolute), type of weights of the indicators (subjective /objective). Thus in this papers, we chose the type of indicators (substitutable), the type of aggregation (simple), the type of comparisons to be made (relative) and the type of weights of the indicators (objective).

We notice that our proxies component of the index will take stems from the well being condition or in other word the central element of our model is the dynamic monetary equilibrium condition

$$M_t^s = M_t^d \tag{1}$$

For the practical calculation we take an inspiration from the basic framework of [9, 39, 24, 31, 42] and [2] and make some modification and formulation of the EMP formula.

Following [9,39] we extend the concepts of EMP index from two components as used by [24,2] to three-components. We, however, contrast [9] in the way they first defined the international reserves component and adopt the definition followed by [39,24,2]. We abandoned the relation between foreign reserves and money in home and reference country. We define the international reserves component as the percentage relative change in the ratio of the foreign reserves ($\%\Delta R_{i,t}/R_{i,t}$)

Like [9,42] we define the interest rate component as the nominal interest rate change differential $\Delta(I)$: This definition opposes [39,24,2].

To define the main component which is the exchange rate component we follow [2] and contrast others. We define the exchange rate component as the difference between the percentage nominal exchange rate depreciation and the historical mean of the nominal depreciation. This measure is termed as the standard exchanges rates changes and calculates as follows $\%(\Delta E_{i,t}/E_{i,t} - \mu\Delta E)$.

In order to avoid the EMP measure been driven or dominated by the most volatile component and eliminate biased among the components; we employ two different types of weights together to balance the components. They are historical weights employing by [2] and weighting sum used by [39,42].

2.4. EMPI model formulation

The EMP index possesses three terms: $\%(\Delta E_{i,t}/E_{i,t} - \mu(\Delta E))$, $\Delta(I)$ and ($\%\Delta R_{i,t}/R_{i,t}$). They have different signs, the signs of exchange rates and interest rates are positives, although, that of international reserves is negative, since in absence of any intervention the domestic exchange rate is allowed to depreciate in accordance with the prevailing market condition. However, when the monetary authority, government and central bank intervene, they carry out a strategy to increase interest rate to attract capital inflow and decrease foreign reserves by selling them to meet the demand for foreign currency. In this paper, we use a combination of these three policy option to avoid the exchange rate from depreciation and absorb pressure in the currency market.

First term of Eq(8) presents the movement of the average exchange rate of any local currency against the currency of any considered reference countries and the of relative change of these exchange rates Et over the period of study. We realized that, exchange rate regimes differ from economy to economy (country). Some economies used fixed exchange rate regime, some employ floating exchange rate regime and others prefer an intermediate regime. These regimes have application and/or effect on the exchange rate and also on the EMP index. For instance, when a fixed exchange rate regime is used the exchange rate component is removed from the index since $E_{i,t} = 0$: Therefore, in this paper we seek a form that will work with all the regimes. Under this condition, the author suggests calculating (compute) the exchange rate term as the percentage of the deviation of the average change of exchange rate from its arithmetical mean and weighed by the inverse of its variance.

This approach first allows us to get the standard exchange rate component among all these different exchange rate regimes. Second, it avoids the term to be dominated by some specific episodes of the data. Finally, it adjusts the stress index for differences in volatility.

The second term of the EMP index in Eq (2) reflects the movement in total foreign reserves minus gold ratio. This ratio is a measure of the adequacy of a country as to much the foreign exchange reserves cover the most liquidity money supply. Thus, this term indicates the extent to which the central bank can honor the total local currency in circulation in the event of a capital flight from the domestic currency market. In this sense the reserves ratio measures the potential monetary effects of reserve losses in the wake of a crisis situation. From literature, we know that the market pressure is only over the domestic currency that will let the exchange rate to depreciate Hence, currency crisis appears. However the international reserves still intact. No pressure over the foreign reserve, instead, we look a decrease over its amount since this component is sold to maintain the exchange rate from depreciation and / or to maintain or increase the country domestic reserve, Therefore, the author suggest the reserve component to be computed as the percentage relative change in the ratio of the foreign reserves. The third term of the EMP index in Eq (2) reflects the movement in the interest rate. From literature, we certify that increased difference between domestic and foreign interest rates raises capital inflow and decreases EMP index. Especially, in situation when current exchange rate trend tends to continue and action of central bank is predictable, financial capital largely comes in to profit from interest rate difference. Hence, the author prefers to compute this term as the nominal interest change differential, since the major role of this component is used as a tool to fight off speculative attack.

3. Alternative EMPI model

To construct new alternative EMPI model we are using the following observations and assumptions

3.1. Observations

1. A currency crisis may define as a speculative attack on the foreign exchange value of a currency of a country.

2. A speculative attack may either results in a sharp depreciation or lets the exchange rate unchanged by forcing the authorities to defend their currency.

3. Authorities defend the currency either by selling foreign exchange reserves or /and raising domestic interest rates.

4. Under a fixed exchange rate regime, there is by definition no change in the nominal exchange rate. $\Delta E_{i,t} = 0$.

5. Under a floating exchange rate regime, the monetary authorities abstain from intervention in the exchange market; however, the reserves are left unchanged i.e. $\Delta R_{i,t}$

6. In a successful attack, the currency depreciates, while an unsuccessful attack may leave the exchange rate unchanged but at the cost of spent foreign exchange reserves or higher domestic interest rate.

7. International reserves and interest rate are both often used tools to fight off speculative attacks.

8. International reserves may play a role of controlling exchange rate stability and increase domestic money.

9. Interest rates are the policy instrument, reflecting the tastes and preferences of policy makers.

10. Many developing countries recline more on increasing interest rate to stabilize the exchange rate to make their currency strong

11. Exchange market pressure is absorbed by only the change of nominal exchange rate and / or interest rate in countries with flexible exchange rate regime, by only the change of official reserves and / or interest rate in countries with fixed exchange rate system, and by the changes of exchange rate, reserves in countries and/ or interest rates with managed floating regime.

3.2. Assumptions

1. The components E, R and I are independent random variables; with $E > 0, R > 0$ and $I > 0$. $EMPI_{i,t}$ is a dependent variable; with $EMPI_{i,t} \in IR =]-\infty, \infty[$. If $EMPI > 0$ means successful attack. If $EMPI \leq 0$ means unsuccessful attack.

2. The currency crisis (depreciation) is due to a speculative attack on the foreign exchange market. This means that $E_{c,t} \geq E_{i,t}$, $R_{c,t} \geq R_{i,t}$ and $I_{c,t} \leq I_{i,t}$. Where $E_{c,t}$, $R_{c,t}$ and $I_{c,t}$ are the exchanges rates, the foreign reserves and the interest rates for the foreign market respectively.

3. The speculative pressure hits both countries with fixed and / or floating exchange rate regimes. When it is fixed regime $\Delta E = 0 \Longrightarrow EMPI_{i,t} = EMPI(R, I)$, when the regime is floating then $\Delta R = 0 \Longrightarrow EMPI_{i,t} = EMPI(E, I)$.

4. The authorities (government and central bank) carry out the following policy to defend the currency

i. Let the exchange rate depreciate$R = 0$, $I = 0$ and $E_{i,t} = EMPI(E)$.

ii. Intervene in the exchange market by selling international reserves $I = 0$ and $E_{i,t} = EMPI(E, R)$.

iii. Increase interest rate to offset the speculative pressure $R = 0$ and $E_{i,t} = EMPI(E, I)$.

iv. Intervene by selling reserves and increase interest rates$R \neq 0$, $I \neq 0$ and $E_{i,t} = EMPI(E, R, I)$.

3.3. Model

Following closely the definitions of currency crisis stated in section 1, the EMP flow diagram given in section 2 figures 1, covers the different observations and assumptions in section 3.1 and 3.2, and the EMPI approach mentioned in section 2.3 and EMPI formulation in section 2.4, the author defines and constructs the new alternative EMPI model as follows:

Definition:

The EMP is the sum of a weighted average of the percentage of the difference between the nominal exchange rate depreciation and the historical mean of the nominal depreciation, the nominal interest rate differential and percentage relative change in the ratio of the foreign reserves.

Consequently, the alternative EMPI formula for a country i at a time t can be written as follows:

$$EMPI_{i,t} = \alpha \times \% \left(\Delta E_{i,t}/E_{i,t} - \mu\Delta E\right) + \beta \times \Delta(I_{i,t}) - \gamma \times (\%\Delta R_{i,t}/R_{i,t}) \qquad (2)$$

And

$$\alpha = \frac{1/\sigma_E\Delta E}{1/\sigma_E\Delta E + 1/\sigma R + 1/\sigma I},\ \beta = \frac{1/\sigma R}{1/\sigma E + 1/\sigma R + 1/\sigma I},\gamma = \frac{1/\sigma I}{1/\sigma E + 1/\sigma R + 1/\sigma I}$$

Where: $E_{i,t}, R_{i,t}$ and $I_{i,t}$ are respectively the exchange rate movement, the total foreign reserves holding minus gold and the interest rate movement for country i at period t. $\mu\Delta E$ Denote the historical means of nominal depreciation of the exchanges rates. $\Delta E_{i,t}$ And $\Delta R_{i,t}$ denote the changes in the exchange rate and total reserves minus gold, respectively. $\sigma_i\Delta E$ Stand for historical standard deviation of the difference between the nominal exchanges rates depreciation and the historical mean of the nominal depreciation $\left(\Delta E_{i,t}/E_{i,t} - \mu_i\Delta E\right)$. σI Denotes the standard deviation of the nominal interest rate differential $\Delta(I_{i,t})$ and σR is the standard deviation of the percentage relative change in the ratio of the foreign reserves$(\Delta R_{i,t}/R_{i,t})$.

To explain the EMPI model in Eq (2) we follow the dynamic monetary equilibrium condition stated in Eq (1).

$$M_t^s = M_t^d$$

The traditional function of money supply $M_s(t)$ is determined by the money multiplier m_t and base money B_t

$$M^s(t) = m(t)B(t) \tag{3}$$

With

$$B(t) = R(t) + D(t) \tag{4}$$

Where R_t - sum of foreign assets of the central bank and D_t - net domestic assets.

$$M^s(t) = m(t)[R(t) + D(t)] \tag{5}$$

On the other hand the function of money demand $M^d(t)$ is described by the classical representation.

$$M^d(t) = kP^dYe^I \tag{6}$$

Where k denotes a constant fraction of income held as money balance (or simply surplus income), Y- domestic real income, I stands for interest rate and P - domestic price. We note that the purchasing power parity condition linking the domestic price P^d level with foreign price P^f level is given by

$$P^d(t) = E(t)P^f(t) \tag{7}$$

Where E_t denotes the bilateral exchange rate. It is defined as price of foreign currency in domestic units. Thus, positive changes in $E_t$represents depreciation of the domestic currency and negative changes its appreciation. Substituting the value of P^d of Eq (7) into Eq (6) we get

$$M^d(t) = kE(t)P^fYe^I \tag{8}$$

From section 3.1 and 3.2, the author defines the exchange rate component or say computes the exchange rate term as the deviation from its mean in order to fulfill the observation, assumptions and methods given above

$$E_t = E(t) - \mu E(t) \Longrightarrow \nabla E_t = \nabla E(t) - \mu\nabla E(t) \tag{9}$$

From monetary equilibrium condition equation we are equating the right hand sides of Eq (5) and Eq (8) we have:

$$kE(t)P^f(t)Y(t)e^{I(t)} = m(t)[R(t) + D(t)] \tag{10}$$

Taking logarithm of both side of Eq (10) we have

$$\ln\left(kE(t)P^f(t)Y(t)e^{I(t)}\right) = \ln(m(t)[R(t) + D(t)])$$

Developing we get

$$\ln k + \ln E(t) + \ln P^f(t) + \ln Y(t) + I(t) = \ln m(t) + \ln(R(t) + D(t)) \tag{11}$$

Differentiating both side of Eq (11) we get

$$0 + \frac{\frac{dE(t)}{dt}}{E(t)} + \frac{\frac{dP(t)}{dt}}{P(t)} + \frac{\frac{dY(t)}{dt}}{Y(t)} + \frac{dI}{dt} = \frac{\frac{dm(t)}{dt}}{m(t)} + \frac{\frac{dR(t)+dD(t)}{dt}}{R(t) + D(t)}$$

Arranging we have

$$\frac{\frac{dE(t)}{dt}}{E(t)} + \frac{dI}{dt} - \frac{\frac{dR(t)}{dt}}{R(t) + D(t)} = \frac{\frac{dD(t)}{dt}}{R(t) + D(t)} + \frac{\frac{dm(t)}{dt}}{m(t)} - \frac{\frac{dP(t)}{dt}}{P(t)} - \frac{\frac{dY(t)}{dt}}{Y(t)}$$

Then

$$\frac{\nabla E(t)}{E(t)} + \nabla I - \frac{\nabla R(t)}{R(t)} = \frac{\nabla D(t)}{D(t)} + \frac{\nabla m(t)}{m(t)} - \frac{\nabla P(t)}{P(t)} - \frac{\nabla Y(t)}{Y(t)}$$

Hence

$$\frac{\nabla E(t)}{E(t)} + \nabla I - \frac{\nabla R(t)}{R(t)} = d_t + m_t - p_t - y_t \tag{12}$$

Where d_t- change in share of domestic credit in money supply, m_t- change in money multiplier, y_t-change in domestic income and p_t- change in foreign price.

Eq (12) has proportional correlation which is given foreign inflation and growth of domestic income, increase in domestic credit or money multiplier decrease reserves in fixed exchange rate regime, depreciate nominal exchange rate in floating regime and cause decrease reserve and depreciation of exchange rate in manage floating regime (intermediate regime). Furthermore, increase of domestic income or foreign price has correlation to appreciation of national currency or increased inflow of foreign currency.The right hand side of Eq (12) is known as the exchange market pressure.

$$EMPI_t = d_t + m_t - p_t - y_t \tag{13}$$

Substitute the left hand side of Eq (13) into Eq (12) we get the so called EMP index.

$$EMPI_t = \frac{\nabla E(t)}{E(t)} + \nabla I(t) - \frac{\nabla R(t)}{R(t)} \tag{14}$$

Replacing Eq (9) in Eq (14) we get

$$EMPI_t = \left(\frac{\nabla E(t)}{E(t)} - \mu \nabla E(t)\right) + \nabla I(t) - \frac{\nabla R(t)}{R(t)} \tag{15}$$

Taking the percentage in the first term and in the foreign change term as stated in section 2.5, we have

$$EMPI_t = \%\left(\frac{\nabla E(t)}{E(t)} - \mu\nabla E(t)\right) + \nabla I(t) - \left(\frac{\%\nabla R(t)}{R(t)}\right) \tag{16}$$

Multiplying Eq (16) by their attached weights $\alpha, \beta$and γ we get the requested EMPI model in Eq (2).

$$EMPI_t = \alpha \times \%\left(\frac{\nabla E(t)}{E(t)} - \mu\nabla E(t)\right) + \beta \times \nabla I(t) - \gamma \times \left(\frac{\%\nabla R(t)}{R(t)}\right)$$

4. EMPI model properties

Now that the EMPI model in Eq (2) has been formulated we aim to determine its different standard properties. This EMP index model as well as other EMPIs models possesses a variety of characteristics, general ones as well as specific ones. When we talk about EMP index without specifying any economy or country that is belonged to, in this case we have a general EMP index and it is entitled with general characteristics. In other hand, when we specify the EMP index to a particular economy or say a particular country, in this case the EMP is empowered with both general and particular properties according to the economy that is belonged to.

In this paper both of these properties, general ones as well as the particular ones will be enumerated. Because, in order to verify the accuracy of the model formulated in section (3.3) Eq (2), it is needed to study a special case. In practical, it is needed to specify a sample data. Thus the EMP in this case is belonged to a particular country and their properties become specific.

4.1. EMPI performance measures

In this section, some of the different measures related to the constructed exchange market pressure index model in Eq (2) are discussed. Recall that the model in Eq (2) can be rewrite again as follows:

$$EMPI_t == \alpha \times X_{t_1} + \beta \times X_{t_2} - \gamma \times X_{t_3} \tag{17}$$

Where $EMPI_t$ is the response at time t. The constants α, β and γ are defined as in Eq (2). The variables X_{t_1}, X_{t_2} and X_{t_3} are random defined as $X_{t_1} = \%\left(\Delta E_{i,t}/E_{i,t} - \mu_i \Delta E\right)$, $X_{t_2} = \Delta\left(I_{i,t}\right)$ and $X_{t_3} = (\%\Delta R_{i,t}/R_{i,t})$.

We now discuss the expectations arising from our random variables X_{t_1}, X_{t_2} and X_{t_3} of Eq (17). Assume that E_t, I_t and R_t are three different stationary time series with a linear trend. They have all of them constant means, finite variances and co-variance depending only on time difference.

$$E[E_t] = \mu_e,\ E[I_t] = \mu_i \text{ And } E[R_t = \mu_r]$$

$$var(E_t) = \sigma_e,\ var(I_t) = \sigma_i \text{ And } var(R_t) = \sigma_r$$

$cov(E_t, E_s) = \varphi(k_e)$, $cov(I_t, I_s) = \varphi(k_i)$ And $cov(R_t, R_s) = \varphi(k_r)$ with $k = t - s$

Then

$$E[X_{t_1}] = (\mu_{et} - \mu_{et-1})(1 - \mu_{et})/\mu_{et} = \mu_{x_1}$$

$$E[X_{t_2}] = (\mu_{it} - \mu_{it-1}) = \mu_{x_2}$$

$$E[X_{t_3}] = (\mu_{rt} - \mu_{rt-1})/\mu_{rt} = \mu_{x_3}$$

The $EMPI_t$ mean function is defined as

$$\mu_{EMPI_t} = E[EMPI_t] = E[\alpha X_{t_1} + \beta X_{t_2} - \gamma X_{t_3}]$$

Using the property of linearity of expectation we get:

$$\mu_{EMPI_t} = E[EMPI_t] = \alpha E[X_{t_1}] + \beta E[X_{t_2}] - \gamma E[X_{t_3}]$$

Replacing X_{t_1}, X_{t_2} and $X_{t_3}$by their expected values, we get

$$E[EMPI_t] = \alpha\mu_{x_1} + \beta\mu_{x_2} - \gamma\mu_{x_3} = \mu_{EMPI_t} \quad (18)$$

Where μ_{x_1}, μ_{x_2} and μ_{x_3} are given as above.

Similarly

$$\mu_{EMPI_t} = E[{EMPI_t}^2] = E[(\alpha X_{t_1} + \beta X_{t_2} - \gamma X_{t_3})^2]$$

Implies

$$E[{EMPI_t}^2] = \alpha^2 \mu^2{}_{x_1} + \beta^2 \mu^2{}_{x_2} - \gamma^2 \mu^2{}_{x_3} + 2\alpha\beta\mu_{x_1}\mu_{x_2} - 2\alpha\gamma\mu_{x_1}\mu_{x_3} - 2\beta\gamma\mu_{x_2}\mu_{x_3} = \mu^2{}_{EMPI_t} \quad (19)$$

Using the same way we get

$$E[{EMPI_t}^3] = \mu^3{}_{EMPI_t} \; and \; E[{EMPI_t}^4] = \mu^4{}_{EMPI_t} \quad (20)$$

The variance of the $EMPI_t$ is defined as

$$Var\,(EMPI_t) = E[(EMPI_t - \mu_{EMPI_t})^2]$$

Because of the linearity of the expectation we have

$$Var\ (EMPI_t) = E\left[{EMPI_t}^2\right] - (\mu_{EMPI_t})^2$$

Then

$$Var\ (EMPI_t) = {\mu^2}_{EMPI_t} - (\mu_{EMPI_t})^2$$

Substitute the value of ${\mu^2}_{EMPI_t}$and μ_{EMPI_t} we get the variance of$EMPI_t$. If we denote the value of the variance of $EMPI_t$ by σ_{EMPI_t} then

$$Var(EMPI_t) = {\mu^2}_{EMPI_t} - (\mu_{EMPI_t})^2 = \sigma_{EMPI_t} \tag{21}$$

4.2. Properties

The preceding definitions of the $EMPI_t$ measures are completely general. Although, we have not made any special assumptions about the behavior, characteristics and properties of our EMPI time series model. In this section, we introduce and study the different properties related to our constructed EMPI model.

4.2.1. Stationary

When a random /stochastic variables say X is indexed to time, usually denoted by$t$, the observations $\{X_t, t \in T\}$is called a time series, where T is a time set.

Stationary is a critical assumption in time series models. It implies homogeneity in the series that the series behave in a similar way regardless of time, which means that its statistical properties do not change over time.

A stationary time series X_t is called strongly stationary if its statistical distributions remain unchanged after a shift of the time scale. Then the marginal distribution of X_t is independent of t. The two dimensional distributions of (X_{t_1}, X_{t_2}) are independent of the absolute location of t_1 and t_2, only the distance $t_1 - t_2$matters. As a consequence the mean function $E[X_t]$ is a constant, and the co-variance function $cov(X_t, X_{t-k})$ is a function of k only. In another hand a time series is said weakly stationary when the mean, variance, and auto-co-variance are all independent of time.

The exchange market pressure index $(EMPI_t)$ is stationary if its mean, variance and auto-covariance are independent of time. Thus for all $t \in T$

$$i. E[EMPI_t] = \mu$$

$$ii. Var(EMPI_t) = E\left[\left(EMPI_t - \mu_{EMPI_t}\right)^2\right] = \varphi(0)$$

$$iii. Cov(EMPI_t\,, EMPI_{t-k}) = E\left[\left(EMPI_t - \mu_{EMPI_t}\right)\left(EMPI_{t-k} - \mu_{EMPI_t}\right)\right] = \varphi(k)$$

$$i. E[EMPI_t] = \mu$$

$$E[EMPI_t] = \alpha\mu_{x_1} + \beta\mu_{x_2} - \gamma\mu_{x_3} = \mu_{EMPI_t}$$

Where α, β and γ are constants and

$\mu_{x_1} = (\mu_{et} - \mu_{et-1})(1 - \mu_{et})/\mu_{et}$, $\mu_{x_2} = (\mu_{it} - \mu_{it-1})$ *and* $\mu_{x_3} = (\mu_{rt} - \mu_{rt-1})/\mu_{rt}$

Then

$$E[EMPI_t] = \alpha\mu_{x_1} + \beta\mu_{x_2} - \gamma\mu_{x_3} = \mu_{EMPI_t} = \mu$$

$ii. Var(EMPI_t) < \infty$

$$Var(EMPI_t) = E\left[\left(EMPI_t - \mu_{EMPI_t}\right)^2\right] = E\left[{EMPI_t}^2\right] - (\mu_{EMPI_t})^2$$

From (i.) $E[EMPI_t] < \infty$ And μ_{EMPI_t} is constant

$$\Longrightarrow \mu^2{}_{EMPI_t} - (\mu_{EMPI_t})^2 < \infty$$

Hence

$$Var(EMPI_t) = \mu^2{}_{EMPI_t} - (\mu_{EMPI_t})^2 = \sigma_{EMPI_t} < \infty$$

$iii. Cov(EMPI_t, EMPI_{t-k}) = \varphi(k)$

$$Cov(EMPI_t, EMPI_{t-k}) = \varphi(t, t-k)$$

$$\varphi(t, t-k) = E[(EMPI_t - \mu)(EMPI_{t-k} - \mu)]$$

$$\varphi(t, t-k) = E[EMPI_t . EMPI_{t-k}] - \mu^2$$

$$\varphi(t, t-k) = \mu_{EMPI_{(t,t-k)}} - \mu^2$$

In other hand

$$\varphi(t-k, t) = E[(EMPI_{t-k} - \mu)(EMPI_t - \mu)]$$

$$\varphi(t-k, t) = E[EMPI_{t-k} . EMPI_t] - \mu^2$$

$$\varphi(t-k, t) = \mu_{EMPI_{(t-k,t)}} - \mu^2$$

This implies that

$$\varphi(t, t-k) = \varphi(t-k, t) = \varphi(k)$$

Hence

$$Cov(EMPI_t\,, EMPI_{t-k}) = \varphi(k)$$

From (i), (ii) and (iii) the exchange market pressure index ($EMPI_t$) time series model is stationary.

4.2.2. Dependence

One of the interests in studying time series is the extent to which successive terms in the series are correlated. In order to answer questions of this sort, we need to define serial Correlation and the auto-correlation function of the $EMPI_t$ model.

Correlation: The $EMPI_t$ time series model is said to be auto-correlated if for all different times t and s,

$$Cov(EMPI_t\,, EMPI_s) = \varphi(t, s) \neq 0$$

The auto-co-variance of the $EMPI_t$ is defined as the second moment product between two times t and $t-k$.

$$Cov(EMPI_t\,, EMPI_{t-k}) = E\left[\left(EMPI_t - \mu_{EMPI_t}\right)\left(EMPI_{t-k} - \mu_{EMPI_t}\right)\right]$$

By the linearity of the expectation we get

$$Cov(EMPI_t\,, EMPI_{t-k}) = E(EMPI_t\,, EMPI_{t-k}) - \mu_{EMPI_t}.\mu_{EMPI_t}$$

Where

$$E(EMPI_t\,, EMPI_s) = E\left[\left(\alpha\, X_{t_1} + \beta X_{t_2} - \gamma X_{t_3}\right)\left(\alpha\, X_{(t-k)_1} + \beta X_{(t-k)_2} - \gamma X_{(t-k)_3}\right)\right] = \mu_{EMPI_{(t,t-k)}}$$

Substitute each expectation by its value we get:

$$Cov(EMPI_t\,, EMPI_{t-k}) = \mu_{EMPI_{(t,t-k)}} - (\mu_{EMPI_t})^2$$

By the stationary propriety of $EMPI_t$ we found that

$$\varphi(t, t-k) = \varphi(t-k, t) = \varphi(k), with\; k = t - s$$

Again from definition of correlation of $EMPI_t$ we have

$$\varphi(k) = Cov(EMPI_t\,, EMPI_{t-k}) = \mu_{EMPI_{(t,t-k)}} - \left(\mu_{EMPI_t}\right)^2 \neq 0$$

$$\Longrightarrow\; \forall\; (t, s) \in T:\; \varphi(t, s) = Cov(EMPI_t\,, EMPI_{t-k}) \neq 0$$

Then the exchange market pressure $EMPI_t$ is auto-correlated index time series.

Serial correlation: The $EMPI_t$ model is said to be serial correlated if for all different times t and s,

$$\rho(t,s) = Cov(EMPI_t\,, EMPI_{t-k})/\sigma_{EMPI_t}.\sigma_{EMPI_s} \neq 0 \; where -1 \leq \rho(t,s) \leq 1$$

The Auto-correlation function of the $EMPI_t$ by definition can be computed from the auto-co-variance function of$EMPI_t$ by dividing by the standard deviation of $EMPI_t$ t and $EMPI_{t-k}$ which correspond to

$$\rho(t,t-k) = \varphi(t,t-k)/\sqrt{\varphi(t,t)\varphi(t-k,t-k)}$$

$$\rho(t,t-k) = Cov(EMPI_t\,, EMPI_{t-k})/\sigma_{EMPI_t}.\sigma_{EMPI_{t-k}}$$

$$\rho(t,t-k) = E\left[\left(EMPI_t - \mu_{EMPI_t}\right)\left(EMPI_{t-k} - \mu_{EMPI_t-k}\right)\right]/\sigma_{EMPI_t}.\sigma_{EMPI_{t-k}}$$

$$\rho(t,t-k) = \mu_{EMPI_{(t,t-k)}} - \mu_{EMPI_t}\mu_{EMPI_{t-k}}/\sigma_{EMPI_t}.\sigma_{EMPI_{t-k}} = \mu_{EMPI_{(t,t-k)}} - (\mu_{EMPI_t})^2/(\sigma_{EMPI_t})^2$$

Where $\mu_{EMPI_{(t,t-k)}}$, $(\mu_{EMPI_t})^2$ and σ_{EMPI_t} are defined as above.

Again by definition of auto-correlation of $EMPI_t$we have

$$\rho(t,t-k) = \mu_{EMPI_{(t,s)}} - \mu_{EMPI_t}\mu_{EMPI_s}/\sigma_{EMPI_t}.\sigma_{EMPI_s} \neq 0$$

$$\Longrightarrow \; \forall\,(t,s) \in T : \; \rho(t,s) = Cov(EMPI_t\,, EMPI_{t-k})/\sigma_{EMPI_t}.\sigma_{EMPI_s} \neq 0$$

Then the exchange market pressure index $EMPI_t$ is a serial correlated index time series. Hence one can indeed conclude that $EMPI_t$ is correlated index time series.

4.2.3. Normality

We now cover the descriptive statistics properties related to our model and give a brief analysis about the quality and the shape of the EMP index distribution. We first discuss some of the basics theoretical and empirical assumptions concerning the analysis of our EMPI distribution. We enumerate some different quantitative mathematical test that are get used to check either the EMPI distribution is normal or non normal i.e. to test either the distribution is heavy tailed, thin tailed or short tailed. There are many methods for doing this. There are analytic and graphical methods. The most popular are the skewness and kurtosis.

Skewness: The skewness of the $EMPI_t$ distribution denoted by Sk_{EMPI_t}tells us the amount and direction of the EMPI skew (departure from the horizontal symmetry). It is given as

$$Sk_{EMPI_t} = E[\left(EMPI_t - \mu_{EMPI_t}\right)^3]/\left(\sigma_{EMPI_t}\right)^3$$

$$Sk_{EMPI_t} = \frac{\mu^3{}_{EMPI_t} - 3\mu_{EMPI_t}\mu^2{}_{EMPI_t} + 2(\mu_{EMPI_t})^3}{\left(\sigma_{EMPI_t}\right)^3}$$

It tells us again whether the distribution of $EMPI_t$is symmetric or skewed in one side. A reference standard is the normal distribution which has a skewness of zero (i.e.$Sk = 0$).

According to the skewness of the EMPI distribution given above

If $Sk_{EMPI_t} > 0$ then the EMPI distribution is skewed right or positive skewed.

If $Sk_{EMPI_t} < 0$ then the EMPI distribution is left skewed or negative skewed.

Kurtosis: The kurtosis of the distribution $EMPI_t$ tells us how tall and sharp the central peak is relative to a standard bell. It is given as:

$$Sk_{EMPI_t} = E[\left(EMPI_t - \mu_{EMPI_t}\right)^4]/\left(\sigma_{EMPI_t}\right)^4$$

$$Sk_{EMPI_t} = \frac{\mu^4{}_{EMPI_t} - 4\left(\mu_{EMPI_t}\right)\mu^3{}_{EMPI_t} + 6(\mu_{EMPI_t})^2\mu^2{}_{EMPI_t} - 3(\mu_{EMPI_t})^4}{\left(\sigma_{EMPI_t}\right)^4}$$

The reference standard is the normal distribution which has a kurtosis of 3(i.e. k = 3).

According to the kurtosis of the EMPI distribution given above

If $K_{EMPI_t} < 3$, then the EMPI distribution is called platykurtic. Compared to a normal distribution, its central peak is lower and broader, and its tail is shorter and thinner.

If $K_{EMPI_t} > 3$, then the EMPI distribution is called leptokurtic. Compared to a normal distribution, its central peak is higher and sharper, and its tail is longer and fat.

Jarque-Bera value: Another useful measure for testing the quality of the distribution is the Jarque Bera value. It is an analytic method based on the skewness and kurtosis. It comes to support the result obtained by the skewness and the kurtosis. The EMPI Jarque-Bera test statistics denoted by JB_{EMPI_t} is defined as

$$JB_{EMPI_t} = \frac{N}{6}\left(Sk_{EMPI_t} + \frac{\left(K_{EMPI_t} - 3\right)^2}{4}\right)$$

Like each hypothesis test, it is necessary to pose a null hypothesis to validate.

H_0 : The EMPI data follows a normal distribution

H_1 : The EMPI data does not come from a normal distribution.

Since this test is related to the skewness and the kurtosis, the hypothesis test can be also given as:

$$H_0: \quad Sk_{EMPI_t} = 0, \;\; K_{EMPI_t} = 3$$

$$H_1: \quad Sk_{EMPI_t} \neq 0, \;\; K_{EMPI_t} \neq 3$$

If H_0 is accepted and H_1 is rejected then the JB_{EMPI_t} will give a good evidence that the null hypothesis of normality is accepted and the EMPI distribution is normal.

If H_0 is rejected and H_1 is accepted then the JB_{EMPI_t} will give a good evidence that the null hypothesis of normality is rejected and the EMPI distribution is not normal and has fat distribution. We notice that the critical value of the Jarque-Bera statistics will be taken at 5% with two degree of freedom which is equals to 5.99.

4.2.4. Trend / no trend

In order to study a time series in greater detail, it is helpful to check whether the time series present some trends components and seasonal components or not and then remove them. There are a variety of ways this can be done. However, we present one method.

Difference: Differentiating is a way of removing trend in time series. The first difference operator r is defined as

$$\nabla X_t = X_t - X_{t-1}$$

If the differentiating operator $\nabla$is applied to a time series with linear trends; it yields a time series with constant mean and the linear trend is eliminated.

Let us return to our $EMPI_t$ time series example and use this difference approach to remove the trend if there were any of them. From Eq (17) we have

$$EMPI = \alpha \; \times X_{t_1} + \beta \times X_{t_2} - \gamma \times X_{t_3}$$

Recall that the variables $X_{t_1}, \; X_{t_2}$ and X_{t_3} are random defined as

$$X_{t_1} = \% \left(\Delta E_{i,t}/E_{i,t} - \mu_i \Delta E\right), \;\; X_{t_2} = \Delta\big(I_{i,t}\big) \text{ and } X_{t_3} = (\%\Delta R_{i,t}/R_{i,t}).$$

WhereE_t, I_t and R_t are stationary time series with linear trend. This means that $X_{t_1}, X_{t_2}\; and\; X_{t_3}$become time series without trends. Then the $EMPI_t$ time series

$$EMPI = \alpha \; \times X_{t_1} + \beta \times X_{t_2} - \gamma \times X_{t_3}$$

Is indeed a time series without trends, hence $EMPI_t$ has no trends components.

5. EMPI simulation model analysis

The simulation study is performed to evaluate the validity of the proposed EMPI model in Eq (8) to the available sample data. In this paper, we are using a model validation called 'Face Validity' since we are proposing an alternative system. We are comparing to see if the results are consistent with how we persuade our model to operate. Following the model validation method underlined above, we compare the simulated results (output) to the results (output) for the data collected (real data) from the proposed real system. Two analyses are addressed in this work in order to validate the model. The analysis of measure of performances: the mean, the standard deviation and the confidence interval comparison. The procedure of the simulation is as follow:

1. Collect data on exchange rates foreign reserves and interest rates as the EMPI requires
2. Fit the three components with a distribution fitting tool and select the distribution that best fit each component.
3. Take n the sample size of the data.
4. Generate n random variables for each of the three components form the distributions obtained in step 2.
5. Use the generated random variables in step 4 to build the EMPI model in Eq (8) and its transformations.
6. Use the EMPI in step 5 to estimate the mean, the standard deviation and the 95% confidence interval.
7. Repeat steps 4 to 6 m times. We used m = 5000

To validate the model, our studies are based on the analysis of the measurements of performance, especially the mean, the standard deviation, the confidence interval. Since no distribution is known to fit well the simulation model of EMPI, we conduct a more helpful method known as "Bootstrap interval" for computing confidence interval.

1. From our sample of size n, we draw a new sample, with replacement, of size n.
2. Calculate the sample average, called the bootstrap estimate.
3. Store it.
4. Repeat steps 1-3 many (m) times
5. For our 95% CI, we will use the 2.5% sample quantile as the lower bound, and the 0.975% sample quantile as the upper bound. (Alpha = 5%, so alpha/2 = 2.5%. So chop o_ that top and bottom 2.5% of the observations).

Suppose the real model and the simulated model possesses both the mean μ_0 and μ_1 respectively, with difference $\kappa = \mu_0 - \mu_1$. Let Lcl and Ucl assign to the lower and upper limits of the simulated model.Then:

1. If $|Lcl - \mu_0| > \kappa$ and $|Ucl - \mu_0| > \kappa$, then the model needs to be adjusted (calibrated).

1. If $|Lcl - \mu_0| < \kappa$ and $|Ucl - \mu_0| < \kappa$, then the model is accepted since both cases the error is close enough

1. If $|Lcl - \mu_0| > \kappa$ and $|Ucl - \mu_0| < \kappa$, or vice-versa then the model is valid however, an additional runs of the model are needed to shrink the interval.

Table 1: Performance measures of the real data EMPI

n	Mean (μ_0)	St Deviation	Lcl	Ucl	Width	Conf Interval
220	0.00319	0.41	-0.0511	0.0575	0.1086	95%

Table 2: Performance measures of the simulated EMPI

n	Mean (μ_i)	St Deviation	Lcl	Ucl	Width
200	0.000098	0.230	-0.00133	0.00153	0.00286
450	0.0000064	0.231	-0.00094	0.00096	0.0019
1000	-0.0000133	0.2313	-0.00068	0.00062	0.0013
1500	0.0000031	0.2313	-0.00052	0.000527	0.001047
2000	0.0000029	0.2314	-0.000450	0.000456	0.000906
3000	0.0000022	0.2315	0.00036	0.00037	0.00073
5000	0.0000007	0.2315	-0.00025	0.000255	0.000505
40000	0.0000005	0.2315	-0.0001	0.00011	0.00021
50000	0.00000029	0.2315	-0.00009	0.000091	0.000181

Results in table1 and table 2 reveal that all the independent means and confidence intervals of table 2 contain in the range (interval) of the confidence interval in table 1.

The means and confidence interval change values an limits as n grow bigger but they still remain inside the sample mean confidence interval of the real model in table 1. These results show that at 95% the performance measures: Mean, SD, and CI of the simulated model imitate those of the real model.

Results in table 3 explain that as n grows, we see a slight decrease for the left limit and a slight increase for the right limit of the CI.

This implies that as n tend to infinity the error decreases and becomes closer in both models

For $n \in]\,0, 40000]$, $|Lcl - \mu_0| > \kappa$ and $|Ucl - \mu_0| < \kappa$. Implies that an additional runs need to shrink the interval. At a point $n \in]\,40000, [$, $|Lcl - \mu_0| < \kappa$ and $|Ucl - \mu_0| < \kappa$. This implies that the two models have the equal confidence intervals, since both cases the errors are close enough.

Table 3: Confidence interval comparison test of the simulated and real data EMPI

N	$\kappa = \mu_0 - \mu_1$	$\lvert Lcl - \mu_0 \rvert$	$\lvert Ucl - \mu_0 \rvert$
200	0.0030	0.00452	0.00166
450	0.0031	0.0041	0.0022
1000	0.0032	0.0038	0.00257
1500	0.00319	0.0037	0.00267
2000	0.00318	0.0036	0.00274
3000	0.00319	0.0031	0.00294
5000	0.0032	0.00301	0.00297
40000	0.0032	0.0030	0.00298
50000	0.0032	0.00298	0.0030

The simulation analysis results suggested that as $n \to \infty$ the model error decreases and tends to zero. The simulated model properties imitate those of real data model. This proves the validity of the proposed alternative EMPI model.

6. Data collection

To illustrate how to implement our new approach and to evaluate its performance in practice as well, we explore an empirical study on Kenya as special case of study. The main source of all data is the Kenya National Bureau of Statistics (KNBS) and the Central Bank of Kenya (CBK). The author collects monthly data for the period covered span eighteen years and half from the fall of January 1999 to April 2017. We will end up with a balance panel data set of 12 months for eighteen years plus four months for the year 2017, which make a total of 216 observations. The data collected include: Exchange rate (E), International reserves (R) and the domestic interest rates (I) see figures (2 and 3). The exchange rate used in the index model is measured relative to the central Bank of Kenya (CBK). The author collects Dollar and Euro versus Shillings. Data from published papers and research workers especially the KNBS and CBK published papers are also used in the necessary to provide baseline parameter values that cannot be obtained. For the entire analysis, the statistical software R is used.

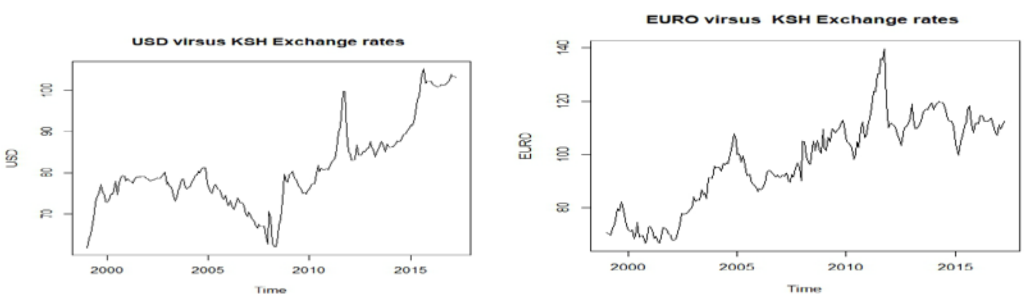

Figure 2: Dollar and Euro exchange rates

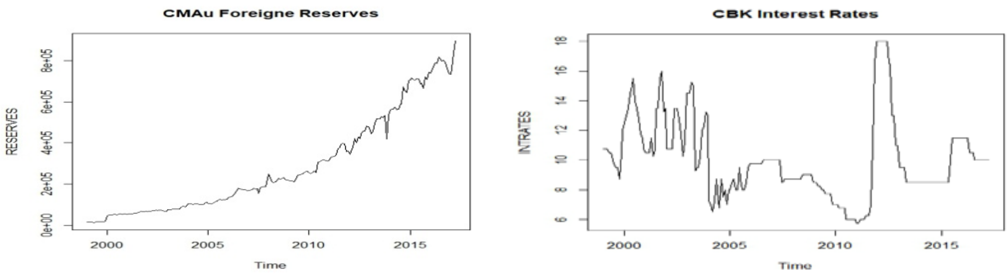

Figure 3: Foreign reserves and Interest rates

7. Empirical study (Kenya EMPI case)

As stated above in the beginning of section 5, we mean by specific properties those EMPI properties relative to a specific economy (country). In this paper we use Kenya' EMPI as a case study. All applications are a specific case of the Kenya exchange market pressure (EMPI) model see figure 4.

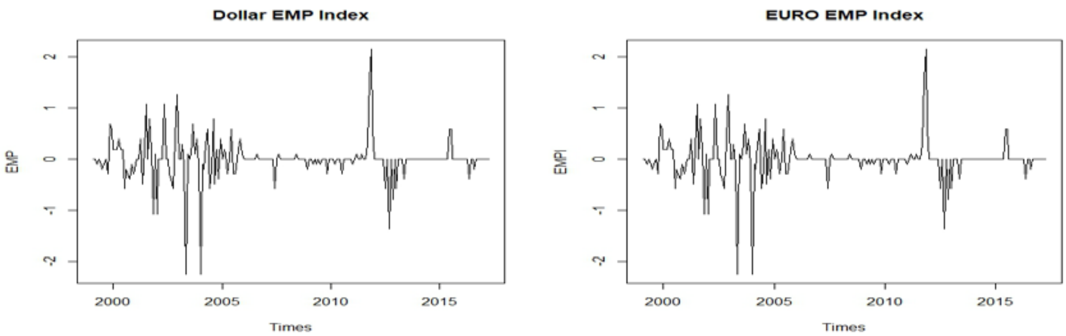

Figure 4: Dollar and Euro EMPIs

In the following tables we provide results for both USD and EURO Kenya EMPI models.

Table 4 lists some descriptive statistics of the EMPI series for both USD and EURO samples data. The skewness result in Table 4 implies that he EMPI distribution of both EURO and USD are slightly skewed to the left.

It is skewed to the left because the computed values are negatives, and are slightly, because the values are close to zero

Table 4: Descriptive statistics of EMPIs, 1999-2017

EMPI	Mean	Standard Deviation	Median	Skewness	Kurtosis	Jarque-Bera
USD	0.00319	0.41	0.0028	-0.571	15.51	1442.2
EURO	0.00024	0.42	0.0016	-0.572	15.52	1442.7

For the kurtosis, we have in both index USD and EURO 15.51 and 15.52 respectively. This implies that the distributions of the data are leptokurtic, since the computed values are positives and greater than 3 found for the normal distribution. The EMPIs distributions for both USD and EURO indicate fat tails; according to the skewness and kurtosis results in Table 4. Simple statistical tests clearly suggest that the monthly EMP index series of Kenya (case study) are not normally distributed. Again the q-q-plot in figure (5) showed big evidence that the data are not normal rather, they have fat tail.

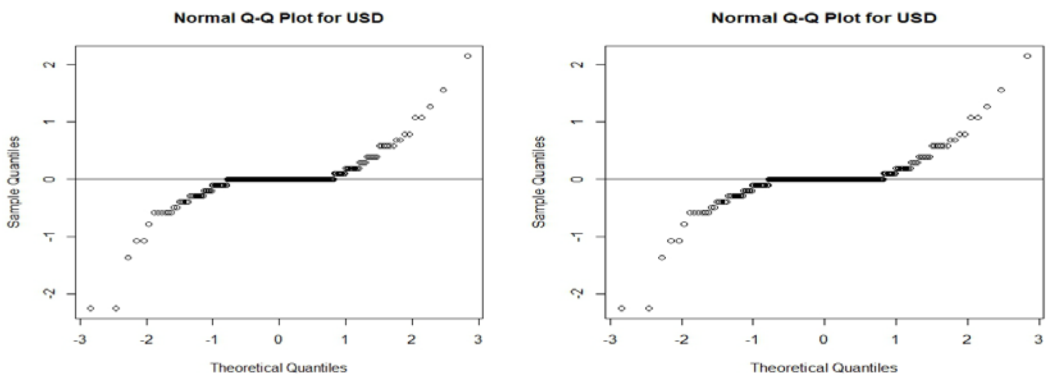

Figure 5: Dollar and Euro q-q-plot

Jarque-Bera statistic gives good evidence that the null hypothesis of normality is rejected with very high level of confidence (above 99.5%) in all cases.

The jarque-Bera test comes to support the results obtained by the kurtosis and the skewness. We note that the critical value of Jarque-bera statistic at 5% with two degree of freedom is 5.99.

Thus we conclude that at 5% level our data are not normal and has both fat distributions.

Table 5 shows the results of the two types of unit root tests, the ADF which tests the null hypothesis that the EMPI has a unit root against the stationary alternative, and the KPSS test which tests the stationary against the unit root alternative.

Table 5: Augmented Dickey-Fuller and KPSS tests of EMPIs, 1999-2017

	ADF statistics			KPSS statistics		
EMPI	No trend	Lags(s)	Trend	No trend	Lag(s)	Trend
USD	6.49	(1)	-3.43	0.02208	(3)	0.023156
EURO	6.49	(1)	-3.43	0.02216	(3)	0.23193

We notice that the number of lags for the unit root tests here is based on the Schwartz information criterion. At the 5% level, the ADF test critical values with trend and without trend for each EMPI are found to be -8.9072 and 39.6694, respectively. The critical values of the KPSS test at 5% level are 0:46 and 0:15 for no trend and trend specification, respectively.

According to the results given in Table 5 for the ADF test, we observe that at lag one (lag=1) the trend value for both EMPIs is -3.443 which is greater than the chosen critical statistical value. The non trend value for both EMPIs is found to be 6.49 which is less than the given critical statistic value. These observations indicate that the null hypothesis of unit root is rejected and also the presence of the trend is rejected. Furthermore it is found that the calculated p-value is very small compared to the given critical level 0.05.

Table 5 for KPSS test read that at lag three (lag =3) the value of trend and no trend for both EMPIs are smaller comparing to the critical statistic values of KPSS at 5%. In addition, we realized that the calculated p-value is very big than the critical value 0.05. This observation forces the author to accept the null hypothesis of stationary against the unit root.

Therefore, the general conclusion from Table 5 is that all EMPIs series can be treated as stationary. The unit root null hypothesis for the ADF test is rejected at 5% level for both EMPIs series. In addition the outcomes of the KPSS tests support also the null hypothesis that he series are stationary.

Note that Ljung-Box Q-statistics and Box-Pierce Q-statistic test the null hypothesis of no correlation. ARCH Lagrange multiplier tests the null hypothesis of conditional homoscedasticity. All three tests statistics follow a chi-square –distribution with degree of freedom equal to number of lags. At 5% level, exactly, the level we are using here, the critical values of all tests for lags 1, 12 and 24 are 3.84, 21.03 and 36.42 respectively.

Table 6 and 7 report tests results of serial correlation, and ARCH effects for the EMPI series at lag 1, 12 and 24.

Table 6: Serial correlation tests of EMPIs, 1999-2017

	Ljung-Box Lag(s)			Box-Pierce Lag(s)		
EMPI	1	12	24	1	12	24
USD	6.7421	50.668	76.027	6.6506	48.434	71.489
EURO	6.7443	50.65	75.999	6.6528	48.423	71.463

Table 7: ARCH effect tests of EMPIs, 1999-2017

	ARCH Lagrange Multiplier Lag(s)		
EMPI	1	12	24
USD	7.653	62.57	81.07
EURO	7.762	61.87	80.82

According to the results observed in all lags the statistics values are considerably greater than the given critical value at 5%. It also found that in all three tests the calculated p-values are very small comparing to the selected critical value 0.05.

Therefore, for EMPIs, the Ljung-box Q-statistic and Box-Pierce q-statistic tests reject the null hypothesis of no correlation at 5% level. The outcomes of the ARCH LM test shows that ARCH effects are found for both EMPIs.

8. Conclusion

Currency crisis is a sudden devaluation or depreciation of the domestic currency that end up causing speculative pressure in the foreign exchange market. This crisis is classified among other extreme risks. It became a serious problem worldwide. Therefore, monetary authorities need some kind of indexes that observe change in certain macroeconomic variables. Modeling and measuring the severity and the incidence of this crisis lie in the heart of much research. One of the most important indexes is the exchange market pressure (EMP) index among international and macro-economists.

This paper has developed an alternative exchange market pressure index for currency crisis. This index is able to date currency crisis periods in a regional or/and global economies, to measure incidence for currency crisis for successful and unsuccessful attacks and identify currency crisis happening either in a fixed, floating and/or intermediate exchange regimes.

It is clear that one of the more important contributions of this paper lied in the use of an improved methodology for the construction of the EMP index. This improvement contribution lied on the new suggestion and calculation technique of the terms and weights of the EMP index.

Our investigation suggested that, as established by the previous literature for other economies (e.g. Asian, Latin American, central and Eastern Europe countries (economies)), our Exchange Market Pressure indexes of Kenya economy (case of study) similar to other financial times series tend to be heavy-tailed. This implies that relative large mass information is concentrated in the tail of the distribution. While tail events are still relatively rare event, they tend to happen much more frequently than would be the case if these variables were normally distributed. Consequently, we proved the pitfalls of assuming normality and showed that for many studies assuming that the series is normally distributed can lead to a strong underestimation of the risk of crises. Overall, the results also appeared to confirm that our EMPI (Kenya EMPI) is stationary and presents a dependence structures and some financial effects (ARCH and GARCH).

A comparison study between Dollar and Euro Kenya's exchange market pressure indexes is conducted and the results revealed that there is a very weak difference between them. However, they still sharing most of the properties and behave the same way.

There is clearly substantial additional work needed in the field of modeling currency crisis systems. This paper covered only a small area of this growing field of research. Hopefully our investigations contribute to these efforts by constructing an alternative EMPI model that may have a position in the toolbox of economists looking for more accurate models in predicting currency crises.

9. Limitations of the study

The study focuses on developing a Mathematical model for currency crisis known as Exchange Market Pressure Index (EMPI) which can be expected to measures incidence of currency crisis periods in a regional and /or global economies (countries) and its properties.

This index can be built using many different components but an EMPI model depends more on the type of regime installed by country's economy. It can be either, fixed exchange rate, floating exchange rate or intermediate exchange rate. Our study considers an EMPI that capture incidence in both fixed and /or floating exchange rate. Therefore, for the sake of generality, due to the most proxy components employed by literature and the consideration of both interventions of the monetary authorities and the possibility of the change of the exchange rate, our EMPI model includes three components: Exchange rate (E), Interest rate (I) and Foreign reserves (R).

As it is known an intermediate speculative attack on the currency does not induce a direct currency crisis. However, for the sake of generality we consider currency crisis induced by both successful and unsuccessful speculative attacks.

Literature from all generations built exchange market pressure index (EMPI) employing various techniques among them two techniques are more popular: The model dependent approach and the model independent approach. In this paper the researcher undertakes the model independent approach.

For numerical simulation purpose and the application of the different standard properties of the exchange market pressure (EMPI) model, the data will be taken from Kenya as a case study, therefore our scope will be limited as Kenya EMPs level due to time and space constrains.

Acknowledgements

This study is supported by the Pan African University (PAUSTI) in collaboration with Jomo Kenyata University of Agriculture and Technology (JKUAT). The authors are very grateful and extend their appreciation to everyone who contributes for the execution of this work.

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