

Empirical and theoretical consistent early warning system models: the case of Angola

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Abstract

The objective of this work is to develop an early warning system (EWS) model to estimate the probability of a devaluation in Angola. We discuss the exchange market pressure (EMP), a measure that is commonly used in the literature to identify a crisis event and used as the dependent variable in EWS models, and find that is not always a valid proxy for devaluation pressures. The intuition is that the EMP would always be a correct measure if all the exogenous shocks to the economy imply the same pattern of correlations between the variables used to construct the EMP measure. We specify a stylized model for the Angola economy to show that this is possibly not the case and opt to define a devaluation event with an actual devaluation. We use the same model to identify the fundamentals that are likely to predict the event of a devaluation in Angola and estimate a EWS model. We find that fluctuations in the oil price and in the degree of dollarization are the main drivers of the probability of a devaluation. The estimated model is statistically and economically significant and can be used as a complementary tool by the policy maker.

Introduction

Early warning system models (EWS), as in Kaminsky et al. (1998) and Berg and Partillo (1999), are tools that allow the policy makers to detect signals that a devaluation, or more generally a crisis, is likely to happen. They complement the information that the policy maker has and have the advantage to be an objective, although

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uncertain, measure of vulnerability. The first issue that the literature has confronted in developing an EWS model is the definition of a crisis. Eichengreen et al. (1994, 1995) argue that currency crisis cannot be identified with actual devaluations and propose to measure the depreciation that would occur to the currency in case policy makers would be passive. The motivation of this definition is that on occasion central banks do resort to contractionary monetary policy and foreign exchange market intervention to repel the possibility of a devaluation. The exchange market pressure (EMP) variable is a measure that captures these manifestations of tension in the currency value. The EMP, or more often a transformation of the EMP, is therefore the dependent variable in a EWS model. Given its importance we review the literature on the EMP and in the spirit of Klassen and Jager (2011) we derive a model consistent EMP measure. We find that the measure of EMP used in the literature is not adequate to identify a devaluation pressure, at least in an economy with the characteristics of Angola. The intuition is that the EMP would always be a correct measure if all shocks hitting the economy implied the same pattern of correlations between the variables used to construct the EMP measure. We show that is not always the case. The second issue that the literature has confronted in developing a EWS model is the identification of the independent variables. A typical list could include the degree of the overvaluation of the exchange rate, the current account (as a percentage of GDP), the short-term debt to reserves ratio, domestic credit growth, real GDP growth and fiscal deficit. While the list is sensible, it originates from the need to uncover general recurrences that anticipate crisis in cross-sections of countries. We follow a more idiosyncratic approach and derive the list of explanatory variables from the characteristics embedded in the model we specify. We find that the two key drivers of the EWS model are the oil prices and a measure of the share of foreign currency liabilities.

The first section of the paper presents a review on EMP measures. The second section presents some particular aspects of the Angolan economy to motivate a stylized model for the Angolan economy and a model consistent EMP measure to discuss some pitfalls of the traditional EMP measure. The third section estimate a EWS model to predict devaluations in Angola.

Models of the exchange rate in the EMP literature

EMP is a broad concept that can encompass every deviation of the actual exchange rate from a latent equilibrium flexible exchange rate. Deviations can originate from macroeconomic forces or from financial forces. Girton and Roper (1977) and Weymark (1997) are two examples of the vast literature on EMP. Both studies derive a measure of the excess demand for a currency by deriving the gap between the observed exchange rate and a notional exchange rate that would prevail in a pure floating regime conditional on current monetary policy. Closely related is the vast literature on currency crisis that started with Krugman (1979), Flood and Garber (1984) and then continued with Obstfeld (1994). Indeed, most models of speculative attacks derive a “shadow” exchange rate, usually defined as the implicit floating exchange rate that would prevail once the exchange rate peg cannot be maintained. Both approaches

are conceptually similar and making them operational requires the estimation of the structural parameters of the specific model used in the analysis. Meese and Rogoff (1983) observe that models linking variables like reserve flows and interest rates to the exchange rate exhibit inadequate empirical performance to be operational. This observation motivates Eichengreen, Rose and Wyplosz (1994,1995) to propose an index of exchange rate market pressure model-free. In practice they construct an index using a linear combination of the same variables used in most models considered in the EMP literature but use a number of different weighting schemes induced by the data instead of estimating structural parameters. Another example is Klassen and Jager (2011) who specify a standard monetary model with an endogenous monetary policy response in the form of Taylor rule and obtain the insight that the policy interest rate should enter in levels and not in differences. They then derive a model-free weighting scheme to construct the exchange market pressure measure that now contains the interest rate in level.

In this section we review and discuss the EMP concept in more details.

The EMP measure

The EMP is typically defined as a weighted average of the change in the logarithm of the exchange rate e_t , the change in the interest rate i_t and the change in the logarithm of the foreign exchange reserves f_t .

$$EMP_t = \omega_e \Delta e_t + \omega_i \Delta i_t - \omega_f \Delta f_t, \quad (1)$$

where Δ denotes the first difference operator and the weights ω_e , ω_i and ω_f are the relative precision of each variable so as to give a larger weight to the variables with less volatility. Precision is defined as the inverse of the variance of each variable over the relevant sample. The EMP variable has been extremely popular in applied international macroeconomics as a measure of crisis: when the EMP variable is above a certain threshold, typically two standard deviations above its average, the currency is considered under pressure and a crisis period is identified. As we wrote above, this ad-hoc approach is justified by the absence of an empirically valid exchange rate model. Its intuition is derived from a classic monetary model used by Girton and Roper (1977) who derive the first EMP measure².

The monetary model

Girton and Roper start with a standard money demand:

$$m_t^d - p_t = \phi y_t - \eta i_t, \quad (2)$$

²Somewhat paradoxically, the classical monetary model used to provide an intuition for the EMP measure, outside maybe hyper-inflationary environment, has performed poorly empirically (see for example Obstfeld and Rogoff 1996). However even state of the art New Keynesian dynamic stochastic general equilibrium models (DSGE) of the type we use below and where structural parameters are estimated with Bayesian methods, perform poorly in forecasting the exchange rate.

where m_t^d is the nominal demand of money, p_t is the price level, y_t is the level of income and i_t is the relevant short term rate. All variables are in natural logarithms except the interest rate. ϕ and η are structural parameters. The money supply is

$$m_t^s = f_t + b_t, \quad (3)$$

where f_t are foreign reserves expressed in domestic currency and b_t is domestic credit. Both are expressed in natural logarithms of their ratio to the monetary base. The simplest version of the monetary model determine the exchange rate through a purchasing power parity (PPP) condition:

$$p_t = p_t^* + e_t, \quad (4)$$

where p_t^* is the foreign price level. In this three equations model the exchange rate is determined by the equilibrium in the domestic assets market together with frictionless competitive international trade. Consider the case of a flexible exchange rate where output y_t and domestic credit b_t are exogenous, the foreign reserve f_t and the interest rate i_t are the policy instruments and the domestic money market equilibrium determines the domestic price level p_t . The foreign price level p_t^* is exogenous so that the domestic price level p_t determines the exchange rate through the PPP. The exchange rate, e_t^p , that would prevail with a passive monetary authority, is the implicit exchange rate that would prevail if $f_t = f_{t-1}$, $i_t = i_{t-1}$ and b_t , y_t and p_t^* are at their current values. The model consistent exchange market pressure, emp_t , is therefore an unweighted version of equation (1):

$$emp_t = e_t^p - e_{t-1} = \Delta e_t - \Delta f_t + \eta \Delta i_t. \quad (5)$$

Klaassen and Jager (2011) refine the EMP concept by noting that a monetary authority can be active because of both domestic and exchange rate objectives. They suggest that EMP should measure the depreciation that would occur if the monetary authority is passive relative to the exchange rate but allowing her to be active for what regards domestic objectives³. To illustrate this point using the previous model we assume that the monetary authority also controls the short term interest rate to achieve a domestic target price level p^T while she uses changes in foreign reserves f_t and/or the interest rate to influence the exchange rate. In this case the last term of equation(5) becomes $\eta (i_t^T - i_t)$ where i_t^T is the unobserved target interest rate consistent with the domestic objective while being passive with the external objective. Klaassen and Jager (2011) remark puts back into the discussion the necessity of a model to obtain a measure of i_t^T . In fact one can go further in qualifying what passivity towards the external objective is. In what follows we make a small détour and provide two examples that extend the notion of passivity towards the external objective.

³In a model with an open capital account this ability of the monetary authority to have simultaneously a domestic and an exchange rate objective is only possible in the presence of capital controls.

Qualifying active external policy: two examples

First consider to augment the monetary model with international capital flows using an uncovered interest parity (UIP):

$$i_t = i_t^* + E_t[e_{t+1}] - e_t + \psi_t,$$

where ψ_t is a catch-all term to introduce imperfect capital mobility that we assume to be controlled by the monetary authorities and E_t is the mathematical expectation operator⁴. The equilibrium flexible exchange rate is now:

$$e_t = \frac{1}{1 + \eta} \sum_{s=t}^{\infty} \left(\frac{\eta}{1 + \eta} \right)^{s-t} E_t [f_t + b_t - \phi y_s + \eta i_s^* + \eta \psi_s - p_s^*].$$

This expression highlights the role of the exchange rate as an asset price that depends on the expectations on future fundamentals and policy actions and must qualify what we intend by a passive monetary authority in the definition of the exchange rate market pressure. Here forward guidance of the future path of the money supply $\{m_s = b_s + f_s\}_{s=t+1}^T$ by the monetary authorities is an active monetary policy that can also aim at managing the exchange rate.

The second example is more relevant for small exporters of commodities. Consider a producer of commodities with a fixed or a managed exchange rate, the country budget constraint is:

$$\Delta nfa_{t+1} = v_t + nx_t(p_{c,t}),$$

where nfa_t is the natural logarithm of the value of the net foreign asset position v_t is the value loss or gain (including interests) on the net foreign asset position and nx_t is the ratio of the trade balance to net foreign asset position which depends on the commodity price $p_{c,t}$. Foreign reserves are a part of the foreign asset position held by the monetary authorities and their increase or decrease can reflect different causes. In our example the country budget constraint must hold intertemporally so that an increase in the price the export commodity that is expected to revert in the future might warrant an accumulation of foreign reserves. This point raises the issue that the accumulation of reserves might not be associated with an exchange rate pressure when we consider the intertemporal dimension into account. This consideration is likely to be important in the case of Angola or for other countries that rely heavily on exports of commodities.

We presented these two examples to convey the intuition that the characteristics of an economy can determine a structure of correlations between the variables used in the construction of the EMP, here the foreign reserves and the exchange rate, that is conditional on the exogenous causes of the dynamics. We discuss more formally this issue below after developing a model for Angola.

⁴When $\psi_t = 0$ and there are no capital controls, the domestic and external objective are not independent.

A stylized model for Angola

Angola characteristics

The characteristics that deserve special attention in the specification of a model of exchange rate determination for the Republic of Angola are a closed financial account⁵, a current account that is also subject to controls⁶ with oil, whose price is determined in the world markets, as the predominant component of exports and finally a heavily dollarized economy. This sub-section presents graphically some stylized facts that illustrate those characteristics and motivate the modeling assumptions. Figure 1 shows the last fifteen years of exchange rate regimes in Angola together with the discount rate controlled by the National Bank of Angola (BNA). Somewhere between 2005 and early 2006 Angola started a de facto successful exchange rate management while monetary policy normalized after a turbulent period. Figure 2 shows the components of the financial and current account from 2005 to 2013 and highlights the tight management of the financial account through foreign reserve management⁷. Figure 3 shows the Angolan and US consumer price indexes. Except for the global financial crisis that corresponded to a relatively large 17 percent depreciation of the Angolan currency, the inflation differential drives the real exchange rate. Notice that the inflation differential was not affected by the depreciation during the crisis. This observation suggests a degree of control of the domestic inflation by the central bank relatively independent of the exchange rate management. The second panel of Figure 3 shows the level of exports in goods together with the price of a barrel of oil in the World market. Given that virtually the entirety (ninety-eight percent) of goods exports are composed by oil and gas⁸ changes in the level of export in goods are mostly driven by price changes and are exogenous to Angola. Finally Figure 4 shows the ratio of deposits in foreign currency over the money supply (M2), the ratio of foreign reserves over M2 and the ratio of foreign currency deposits over M2. The figure shows that the economy is going through a strong process of de-dollarization but foreign currency deposits and loans (not shown) are still an important share (around 50 percent) of total deposits and loans.

The model

The model is a small open economy (SOE) new Keynesian model that features a closed capital account and a Central Bank (CB) that manages both the exchange rate through foreign exchange reserves operations and inflation by controlling the short term interest rate. Furthermore exports are commodities with an exogenous price denominated in foreign currency. We also present an extension with a portfolio choice between assets and liabilities denominated in domestic and foreign currency to consider the case of a dollarized economy. An appendix presents the complete non-linear microfounded model. Here we present a log-linearized version of the benchmark model given that the

⁵according to some measures Angola has the most controlled financial account in the World

⁶Today, membership to the IMF requires full liberalization of the current account, and national discretion for what regards the degree of regulation of the financial account.

⁷Notice that during the last three years of the sample current account surpluses have increasingly financed direct investment.

⁸domestic energy production has peaked in 2008 and then remained flat after that.

emphasis is to derive a model consistent EMP measure and a list of variables that the model identifies as important in the determination of the notional flexible equilibrium exchange rate.

The benchmark model

Aggregate (expenditure) consumption c_t is a composite index of non-tradable goods $c_{N,t}$, produced domestically, and imported goods $c_{M,t}$ ⁹. The economy can be characterized by three equilibrium conditions and two policy rules. The first equation is a forward looking IS-type equation which describes how expenditure in non-tradables depends on the term structure of real interest rates relevant for consumption decisions:

$$y_{N,t} = E_t y_{N,t+1} - \frac{1}{\sigma} E_t [i_t - (\zeta_N \pi_{N,t+1} + \zeta_M \pi_{M,t+1})], \quad (6)$$

where $y_{N,t}$ is non-tradable output, i_t is the one period nominal interest rate, π_N is the inflation rate on the non-tradable consumption basket and π_M is the inflation rate on the imports consumption basket. σ , ζ_N and ζ_M are parameters¹⁰. The second equation is a New Keynesian Phillips curve that determines inflation in the non tradable given a path for non tradable output and for the relative price of imports:

$$\pi_{N,t} = \beta E_t \{\pi_{N,t+1}\} + \kappa_N y_{N,t} + \kappa_M (p_{M,t} - p_t) - (1 + \phi) a_t. \quad (7)$$

$(p_{M,t} - p_t)$ is the imports price consumption index in domestic currency deflated by the consumption price index and plays here the role of a real exchange rate. a_t is a labor productivity shock in the non-tradable sector and β , κ_N , κ_M and ϕ are parameters. The index price of imports in domestic currency $p_{M,t} = e_t + p_{M,t}^*$ depends on the nominal exchange rate and an exogenous price index in foreign currency determined abroad. The third equation is the log-linearized national budget constraint (expressed in foreign goods):

$$f_t = \varphi_F (f_{t-1} - \pi_{M,t} + i_{F,t-1}) + \phi_X x_t - \phi_N y_{N,t} + \phi_M (p_{M,t} - p_t), \quad (8)$$

where f_t are net foreign currency reserves, $\pi_{M,t}$ is the change in the price of imports, $i_{F,t}$ the interest rate of net foreign reserves, x_t are oil exports and are here assumed to be exogenous and $\phi_N y_{N,t} - \phi (p_{M,t} - p_t)$ are imports that depend on non tradable output (expenditure) and their relative price. $\phi_F, \phi_X, \phi_N, \phi_M$ are parameters. The exchange rate policy can be described by a simple rule such as:

$$\Delta f_t = -\phi_e \Delta e_t, \quad (9)$$

⁹Small letters with a time subscript indicate deviations of the natural logarithm of a variable from the steady state value of the variable. Capital letters without a time subscript indicate the steady state value of the variable. The only exception are interest rates where $i_{A,t}$ is the natural logarithm of the gross yield on asset A .

¹⁰ σ is the inverse of intertemporal elasticity of substitution, while ζ_N and ζ_M are convolutions of structural parameters of the non-linear model.

where ϕ_e is a policy coefficient chosen by the monetary authority that describes the exchange rate policy: when $\phi_e \rightarrow 0$ the exchange rate is perfectly flexible and when $\phi_e \rightarrow \infty$ the exchange rate is fixed ($\Delta e_t = 0$). The interest rate rule is usually described with a Taylor rule:

$$i_t = \phi_\pi \pi_t + \epsilon_t^m, \quad (10)$$

where ϕ_π is a policy coefficient chosen by the monetary authority that describes how strongly the interest rate reacts to CPI inflation¹¹ $\pi_t = \omega \pi_{N,t} + (1 - \omega) \pi_{M,t}$ and ϵ_t^m is an exogenous component. In short the Central Bank controls the short term interest rate through management in the bank reserves market while the money demand is kept in the background¹² and determines residually the money supply¹³. The five equations represent a system of stochastic difference equations that can be solved with standard techniques as in Blanchard and Khan (1989).

Nominal and real shocks

Consider first the case of a shock to x_t due to an unexpected change in the oil price. When the exchange rate is fixed ($\phi_e \rightarrow \infty$) and prices are sticky the endogenous variable that adjusts is the net foreign reserves. In this case domestic demand is not affected and the shock to x_t is completely absorbed by a change in f_t . When the exchange rate is flexible ($\phi_e \rightarrow 0$) and becomes the endogenous variable that adjusts for the equation 8 to hold. In this case the relative price of imports changes and domestic demand is affected. Now consider a shock to $p_{M^*,t}$, the price of imports. When the exchange rate is fixed ($\phi_e \rightarrow \infty$) net foreign reserves do adjust but domestic demand is affected because of the change in the relative price of imports. When the exchange rate is flexible ($\phi_e \rightarrow 0$) the change in the imports price index is completely absorbed by a change in the exchange rate and domestic demand remains unaffected. What we are describing is the well known difference between nominal and real external shocks and their different propagation in the case of fixed and flexible exchange rate¹⁴. To illustrate the discussion Figure 5 shows the responses of the economy to a positive shock in the oil price (that affects x_t) and to a positive shock in the imports price index p_{M^*} in the case of a flexible and a fixed exchange rate. In both cases the (notional) flexible exchange rate should appreciate so that the foreign exchange reserves increase to maintain the parity. However while the policy interest rate would decrease in the case of x_t shock under flexible exchange rate it would stay constant in the case of p_{M^*} shock.

¹¹We choose to specify a Taylor rule that contains only CPI for expository simplicity. There is a vast literature that analyzes the differences between different specifications of Taylor rules in open economy models. See for example Gali and Monacelli (2005).

¹²The "micro-founded" money demand depends on consumption rather than output: $m_t^d - p_t = \phi c_t - \eta i_t$.

¹³A common modeling approach of the New Keynesian literature has been to not incorporate money explicitly in the analysis and to have a monetary authority that follows an interest rate rule. Woodford (2003) provides a detailed discussion of that approach.

¹⁴See for example Friedman (1953)

A simple dollarized economy

We introduce dollarization with a simple portfolio decision in deposits. Depositors choose to hold a fraction δ_t of their total deposits in nominal currency deposits and a fraction $(1 - \delta_t)$ in foreign currency deposits. As in Kouri (1976) and in Branson and Hendersen (1984), the portfolios decisions are not explicitly micro-founded and we assume that the portfolio shares $\delta_t(\rho_t, z_t)$ depend on a premium $\rho_t = i_{D,t} - i_{D^*,t} - E_t[\Delta e_{t+1}]$, where $i_{D,t}$ and $i_{D^*,t}$ are one period nominal interest rate on deposits in domestic and foreign currency and an exogenous preference variable z_t . The interest rate relevant for consumption decisions is now the portfolio interest rate:

$$i_t = \delta_D (\delta_t + i_{D,t}) + \delta_{D^*} (i_{D^*,t} - \delta_t),$$

in the log-linear model where δ_D and δ_{D^*} are parameters. It has been pointed out, for example in Edwards (1989) than in highly dollarized economies the size of the liabilities denominated in domestic currency that a central bank must purchase to defend a peg can be quite large. Here the quantity of foreign money supply is limited by the amount of foreign reserves, $f_t + \mu_t^* > m_t^*$ where m_t^* is the supply of foreign currency in the domestic market and μ_t^* is the foreign currency money multiplier. We assume that this inequality is always satisfied. The equilibrium in the foreign currency money market ($m_t^{d^*}$ is equal to a fraction $(1 - \delta_t)$ of total money demand) determines the interest rate on foreign currency held by domestic residents while the interest rate on domestic currency is determined by the same Taylor rule than before. Figure 6 shows the response to a negative shock in z_t (a move towards foreign denominated deposits) and a negative shock to ϵ_t^m (a discretionary expansionary domestic monetary policy). The point to notice is that both shocks create a pressure for a devaluation but opposite effects on the equilibrium interest rates (and the spread $i_{D,t} - i_{D^*,t}$).

Model consistent and empirical EMP measures

Formally the exchange rate equilibrium dynamics can be expressed as a linear function of the state variables¹⁵:

$$e_t = \Psi_e(\phi_e; \theta) S_t,$$

where in our model $S_t = \{\Delta f_{t-1}, m_{t-1}^*, p_{M^*,t}, x_t, a_t, \epsilon_t^m, z_t\}$ and $\Psi_e(\phi_e; \theta)$ is a vector containing the elasticities of the exchange rate to the state variables. These elasticities are convolutions of ϕ_e , the parameter that measures the exchange rate management stance, and of θ a vector containing other parameters of the model¹⁶. The exchange market rate pressure consistent with this model is therefore:

$$emp_t = \Delta e_t + [\Psi_e(0; \theta) - \Psi_e(\phi_e; \theta)] S_t, \quad (11)$$

¹⁵We need to assume parameters that deliver a unique solution to the system.

¹⁶When the exchange rate is fixed, $\phi_e \rightarrow \infty$ then all elements of $\Psi_e(\phi_e; \theta)$ are zero.

and the empirical EMP using the unweighted version of equation (1) is:

$$EMP_t = \Delta e_t + \Psi_i(\phi_e; \theta) \Delta S_t - \Psi_f(\phi_e; \theta) S_t. \quad (12)$$

The first remark is that the Klassen and Jager observation solves the issue that in equation (12) the lagged value of S_t enters while it does not in equation (11). The second remark is that the model consistent measure does not contain other control variables such as the interest rate, i_t or the actual change in foreign reserves Δf_t . In fact the equilibrium interest rate and the change in foreign reserves are also a linear function of the states, namely $i_t = \Psi_i(\phi_e; \theta) S_t$ and $\Delta f_t = \Psi_f(\phi_e; \theta) S_t$ as they are control variables jointly determined with the exchange rate. The cost of using the interest rate and the change in foreign reserves to measure the EMP is that the weights on the state variables are wrong. Of course the weights are model dependent and the fact that we still do not have a valid empirical model for the exchange rate is what motivated the applied approach that by-passes the issue of the wrong elasticities by adopting the ad-hoc weighting scheme explained above. In other words the advantage of using the interest rate and the change in foreign reserves to measure the EMP in equation 12 is that you do not need to identify the states S_t which possibly contains unobserved exogenous shocks¹⁷. However there is potentially an issue if the elasticities of the exchange rate, the interest rates and the change in foreign reserves do not always maintain the same pattern of correlation. We showed that this was the case in the examples above: in a purely flexible exchange rate regime a $z_t < 0$ shock pushes towards a depreciation and an increase in the interest rate, while an expansionary monetary policy shock $\epsilon_t^m < 0$ pushes for a depreciation and a decrease in interest rate. The point is that the relevant correlation of the exchange rate, the interest rate and the foreign reserves change is the correlation conditional to the shocks. If the structure of the conditional correlation differ across shocks the EMP measure might not be an appropriate measure of true exchange market pressure.

An EWS model for Angola

We anticipate that the commonly used EMP measure did not perform well in our EWS model. We therefore measure the devaluation event with the actual devaluation, more precisely with a change in exchange rate greater than two percent which corresponds to the band announced by the National Bank of Angola. We follow the recent literature on early warning signals and estimate a discrete choice model to predict the occurrence of a devaluation event in a given window. The dependent variable is a forward looking indicator that takes the value 1 in the event of the devaluation greater than two percent (yearly rate) and 0 in the event of no depreciation (or smaller than two percent). Formally, let y_t^k takes the value 1 if a devaluation occurs between one and three months. The specification assumes a logit model in which the probability of devaluation depends on a vector s_t of observed macroeconomic

¹⁷The policy parameter ϕ_e might not be constant but vary in function of some states, maybe crisis states. In this case the variation in elasticities would contain important information to measure the EMP. This is potentially another advantage of having the EMP explained by other control variable as their elasticities with respect to the state variables will likely to change as well.

variables:

$$P(y_j^k = 1|s) = \frac{e^{s'\gamma_j^k}}{1 + e^{s'\gamma_j^k}}.$$

The choice of the independent variables contained in s_t is usually suggested by a background model and empirical testing. We let data availability and the model developed above (or better the discussion that motivated it) dictate the list of independent variables and try to choose s_t so as to contain S_t . All variables are transformed to be stationary. The first explanatory variable is $\frac{F_t}{M_t}$, the ratio of foreign reserves over a measure of Money supply to proxy the more relevant ratio of foreign currency reserves over foreign currency deposits ($\frac{F}{M^*}$) that is not available for the full sample¹⁸ (this corresponds to m_t^* and maybe z_t in S_t). The second explanatory is $\frac{\Delta F_t}{X_t}$, or the change in foreign reserves over exports and the third explanatory variable is the percentage change in the dollar oil barrel price (respectively Δf_t and x_t in S_t). The fourth variable is the difference of the three months interest rate on domestic currency deposits and the three months interest rate on foreign currency deposits to try to have the monetary policy shock in the specification (ϵ_t^m and maybe z_t in S_t). The fifth variable is the percentage change in the euro-dollar exchange rate to try to measure external shocks to the import price index ($p_{M^*,t}$ in S_t). To confront the possibility of a post-devaluation bias discussed in Bussière and Fratzscher (2006) that is caused by making no distinction between tranquil periods and devaluation/post-devaluation periods, when fundamentals (or state variables) go through an adjustment process, we follow Gourinchas and Obstfeld (2012) and construct a sub-sample that we label tranquil times. The tranquil times sample drops the months when a devaluation occurs as well as the post-devaluation observations for two months afterward. We estimate the model over the sample 2006m1-2015m5.

Results

Table 1 reports the estimates for the one month, two months and three months horizons. The last row reports the overall probability p of a devaluation evaluated at tranquil times. For each explanatory variable s_i the table reports the standard deviation $SD(s_i)$ calculated over the tranquil times sample, the marginal effect $\frac{dp}{ds_i}$ and the change in probability Δp resulting from a one standard deviation increase in s . At one month horizon the probability of a devaluation evaluated at normal times is 4.7 percent and significantly different from zero at the 10 percent level. The probability becomes more significant and increases to 13 percent for a two months ahead window and to 20 percent for a three months ahead window. The first row shows that the ratio of net foreign reserves over the money supply plays a significant role: a decrease of one standard deviation (16.8%) increases the probability of a devaluation from 13 percent to 21.8 percent in the next two months and from 21 percent to 35.4 percent in the next three months. The second row shows that the ratio of the change in net foreign reserves over the trade balance is significant only at the three months horizon and has an important marginal effect at two and at three months horizon: an increase of one standard deviation (25.3%) decreases the probability of a devaluation by 9.2 percent at three months. The third row shows that a monthly increase of 8.9 percent in the oil price decreases the probability

¹⁸4 shows that the two measures are highly correlated.

Table 1: Logit Estimation for the occurrence of a 2 percent devaluation at horizon $t + 1 : t + k$

	$SD(x)$	1 month		2 months		3 months	
		dp/dx	Δp	dp/dx	Δp	dp/dx	Δp
$\frac{F}{M}$	.168	-.293** (.155)	-0.031** (0.0158)	-.83** (.28)	-.088*** (.028)	-1.33*** (.369)	-.144*** (.035)
$\frac{\Delta F}{EX}$	.253	-.034 (.088)	-0.005 (0.014)	-.26 (0.21)	-.042** (.028)	-.63** (.39)	-.093** (.046)
$\Delta \log(Oil)$	.089	-.78** (.39)	-0.036* (0.019)	-1.19** (.63)	-.075** (.03)	-1.51** (.80)	-.104** (.042)
$i_D - i_F$	.018	.45 (2.8)	0.004 (0.028)	1.71 (4)	.016 (.041)	2.33 (4.49)	.022 (.044)
$\Delta \ln(eurdol)$	.018	1.32 (1.13)	0.039 (0.039)	0.58 (2.38)	.013 (.057)	-.74 (2.91)	-.016 (.06)
N	67	67	67	67	67	67	67
p		0.047* (.028)		0.13*** (.045)		0.20 *** (.058)	

Notes: The table reports estimates of a logit model for the occurrence of a devaluation greater than 2 percent 1,2 and 3 months ahead. p is the estimated probability of a devaluation, evaluated at the pre-devaluation sample mean. $SD(x)$ is the standard deviation of a variable in tranquil periods. dp/dx is the marginal effect for variable x evaluated at tranquil sample mean. Δp is the change in probability resulting from one standard deviation increase in x . N is the number of observations. Robust standard errors in parentheses. Significance: *** < 0.01, ** < 0.05, * < 0.1.

of a crisis from by 7.5 percent (from 13 percent to 5.5 percent) at two months horizon and by 10.4 percent (from 20 percent to 9.6 percent) at the three months horizon. The logit estimates yield statistically and economically significant probability effects of the ratio of foreign reserves over the money supply, the oil prices and the ratio of the change in foreign reserves over exports. Both the interest rate differential and the euro-dollar exchange rate are found to yield statistically non significant probability effects.

As a robustness check we estimate the model both for the full sample (Full Sample) and for a larger post devaluation bias choosing to drop the devaluation observation and the subsequent 5 months (Post-Bias 6 months). Table 2 reports the estimates of the three months ahead horizon for these two alternative samples. The full sample results show stronger and more precisely estimated effects for the three significant variables while the longer correction for the post devaluation bias results show that the ratio of the change in foreign reserves over exports ceases to be significant. These results indicate that the post-devaluation bias does not alter the overall message: the key drivers of the probability of a devaluation in Angola are the changes in oil price and the domestic pressures of credit in foreign currency. Finally we compute the EMP as in equation (1) and use different thresholds of standard deviation over the average to identify a crisis/devaluation period. However for the case of Angola the plain-vanilla EMP failed to be an empirically useful proxy for a crisis/devaluation. We omit the results but shows in Figure (7) the EMP measure together with the changes in exchange rate¹⁹.

¹⁹The correlation between the two variables is 0.12.

Table 2: Logit Estimation for the occurrence of a 2 percent devaluation at horizon $t + 3$

	<i>FullSample</i>			<i>Post – Bias 6m</i>		
	<i>SD(x)</i>	<i>dp/dx</i>	Δp	<i>SD(x)</i>	<i>dp/dx</i>	Δp
$\frac{F}{M}$	.178	- 1.44*** (.26)	-.239*** (.037)	.143	-1.52*** (.508)	-.133*** (.038)
$\frac{\Delta F}{EX}$	.233	-.735*** (.24)	-.179*** (.048)	.206	-.402 (.37)	-.069 (.052)
$\Delta \log(Oil)$	.091	-1.61*** (.57)	-.159*** (.048)	.097	-1.56** (.79)	-.108** (.043)
$i_D - i_F$	.01	. 2.59 (3.67)	.035 (.05)	.01	4.81 (4.96)	0.054 (.061)
$\Delta \ln(eurdol)$	.024	-1.90 (1.99)	.056 (.056)	.09	.236 (.749)	.022 (.074)
N	111	111	111	50	50	50
p		.25*** (.055)		.18*** (.059)		

Notes: The table reports estimates of a logit model for the occurrence of a devaluation greater than 2 percent 3 months ahead. The Full Sample reports the results without dropping observations to correct for post devaluation bias. The Post Bias 6m drops from the sample the devaluation month and the subsequent 5 months of observations. p is the estimated probability of a devaluation, evaluated at the pre-devaluation sample mean. $SD(x)$ is the standard deviation of a variable in tranquil periods. dp/dx is the marginal effect for variable x evaluated at the relevant sample mean. Δp is the change in probability resulting from one standard deviation increase in x . N is the number of observations. Robust standard errors in parentheses. Significance: *** < 0.01, ** < 0.05, * < 0.1.

Conclusion

This paper develops an early warning system model for predicting a devaluation in Angola. Its main differences with existing models are first that the event of a devaluation is defined as a change in the exchange rate above the band set by the monetary authority and second that the selection of the explanatory variables is based on the characteristics of the economy. We have specified a simple open economy model whose main ingredients reflect the salient characteristics of the economy to derive and discuss the theoretical consistent exchange market pressure measure. Our aim was to understand why the commonly used EMP measure appeared to be not appropriate for Angola. We have shown that the pattern of correlation between the variables used to construct the EMP change in function of the shock that hits the economy, at least in the model. This observation implies that the standard EMP is not always an appropriate variable to identify a crisis. Some of the idiosyncracies of Angola, such as its dependency on oil exports to accumulate reserves are likely to be important for other commodity exporters that are price-taker. From a policy perspective our model is a useful complementary tool to anticipate devaluation pressures that can guide the Angolan monetary authority to obtain signals about when and how to take actions in order to mitigate or prevent a devaluation. At a broader level we believe that a balance must be found between general and idiosyncratic features of economies when specifying a model that aims to have predictive power.

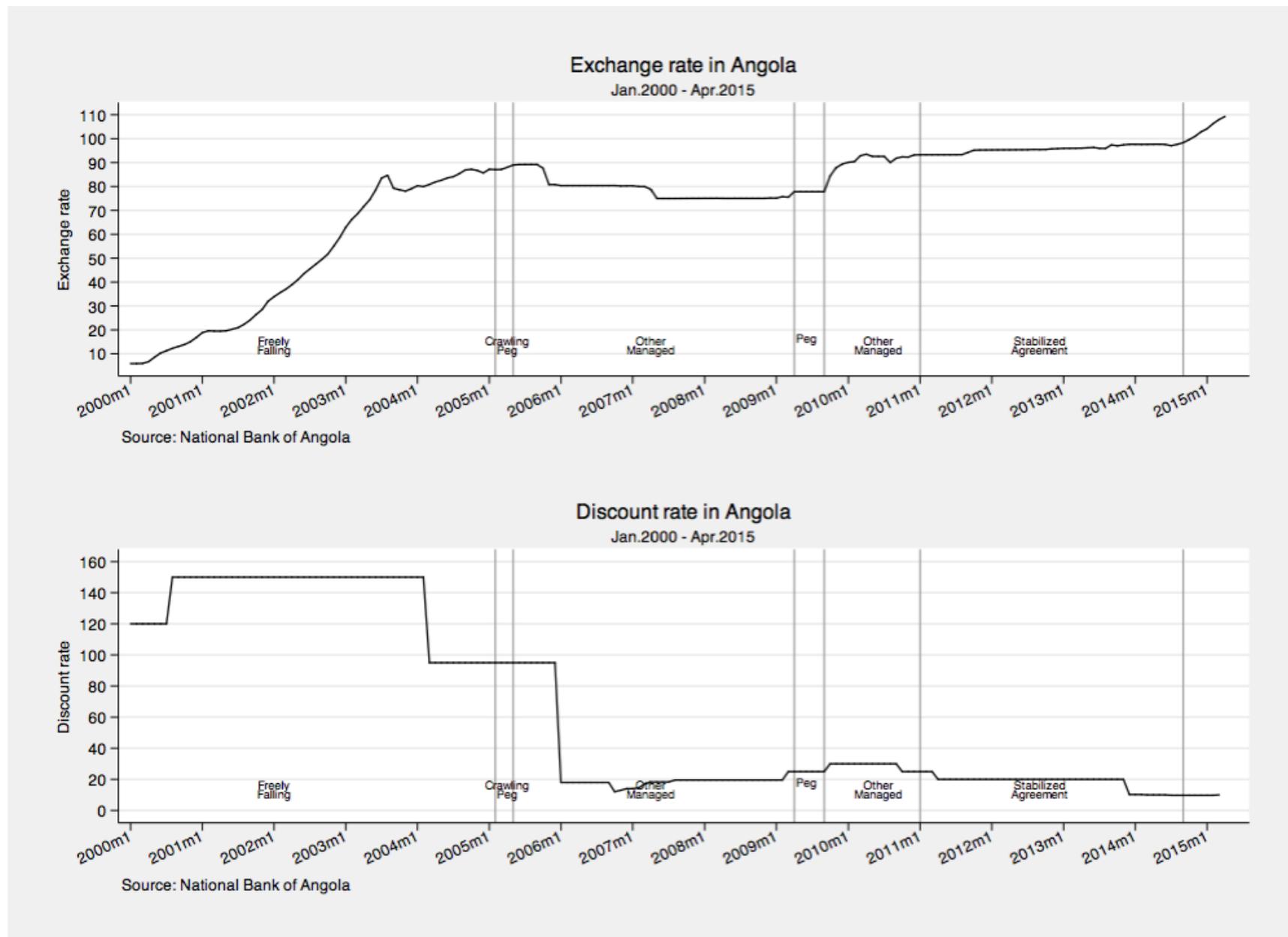


Figure 1: The Exchange rate and the Discount rate in Angola 2000-2015. The upper panel shows the exchange rate between the kwanza and the US dollar. The lower panel shows the discount rate set by the BNA.

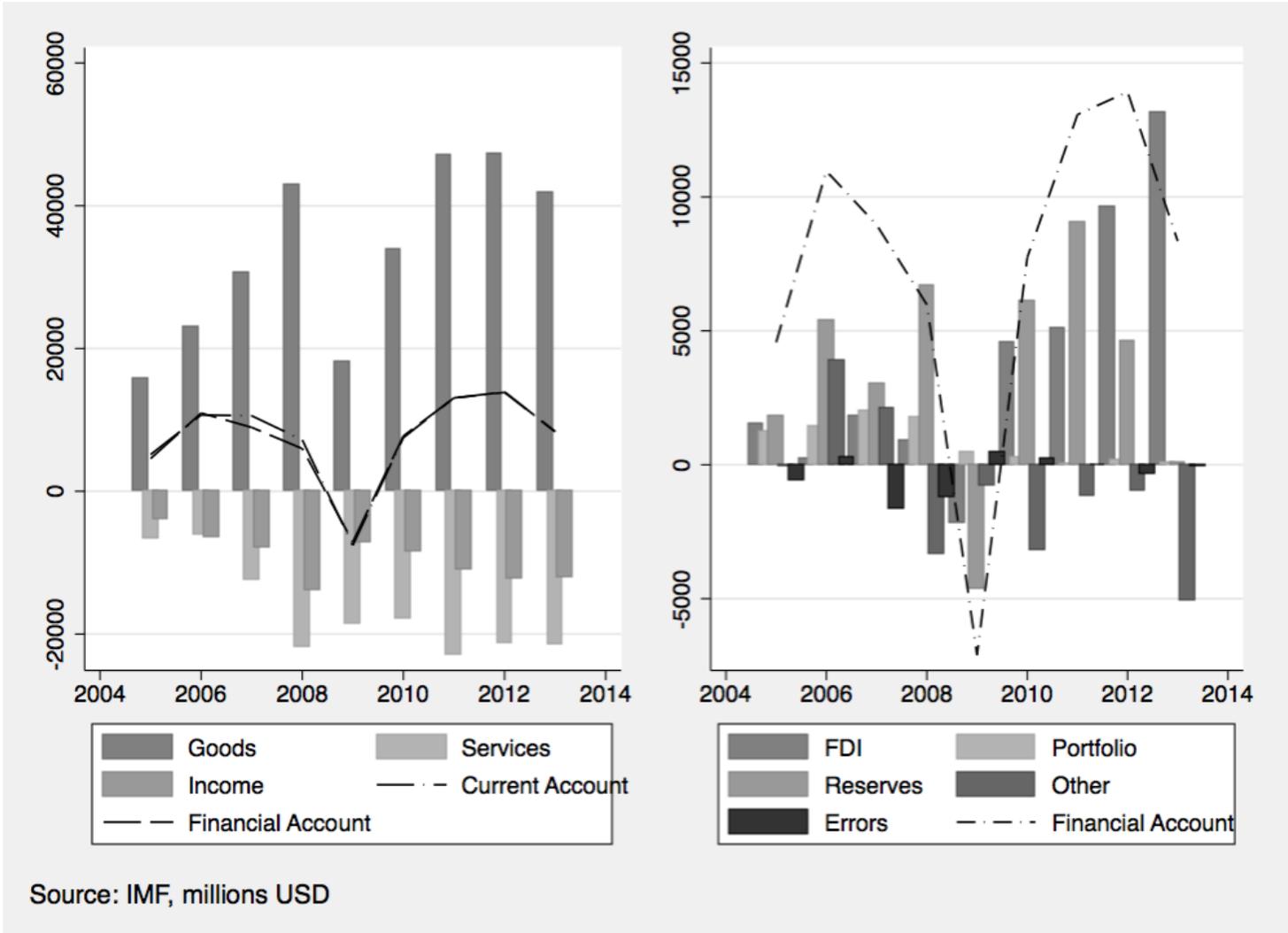
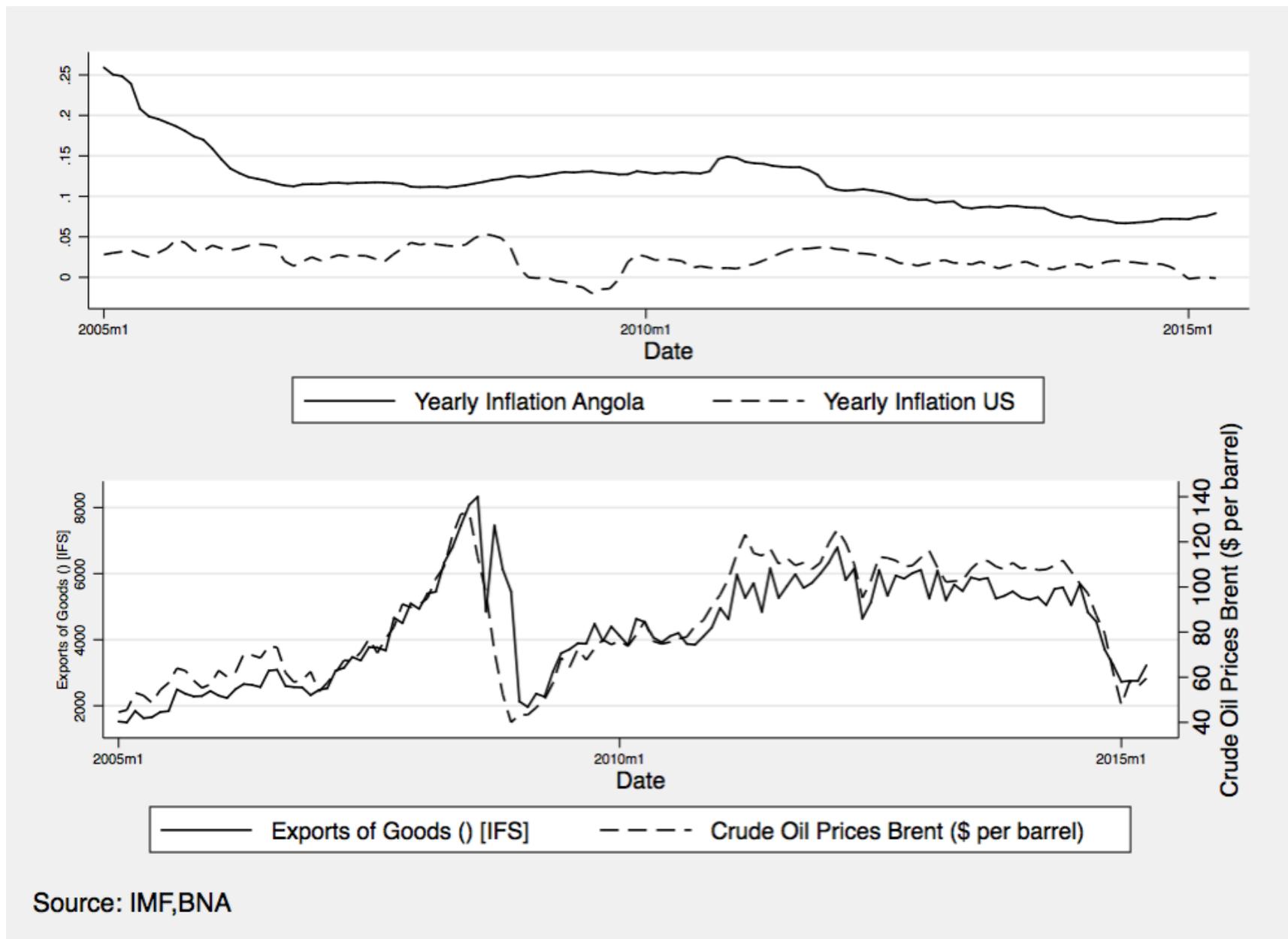
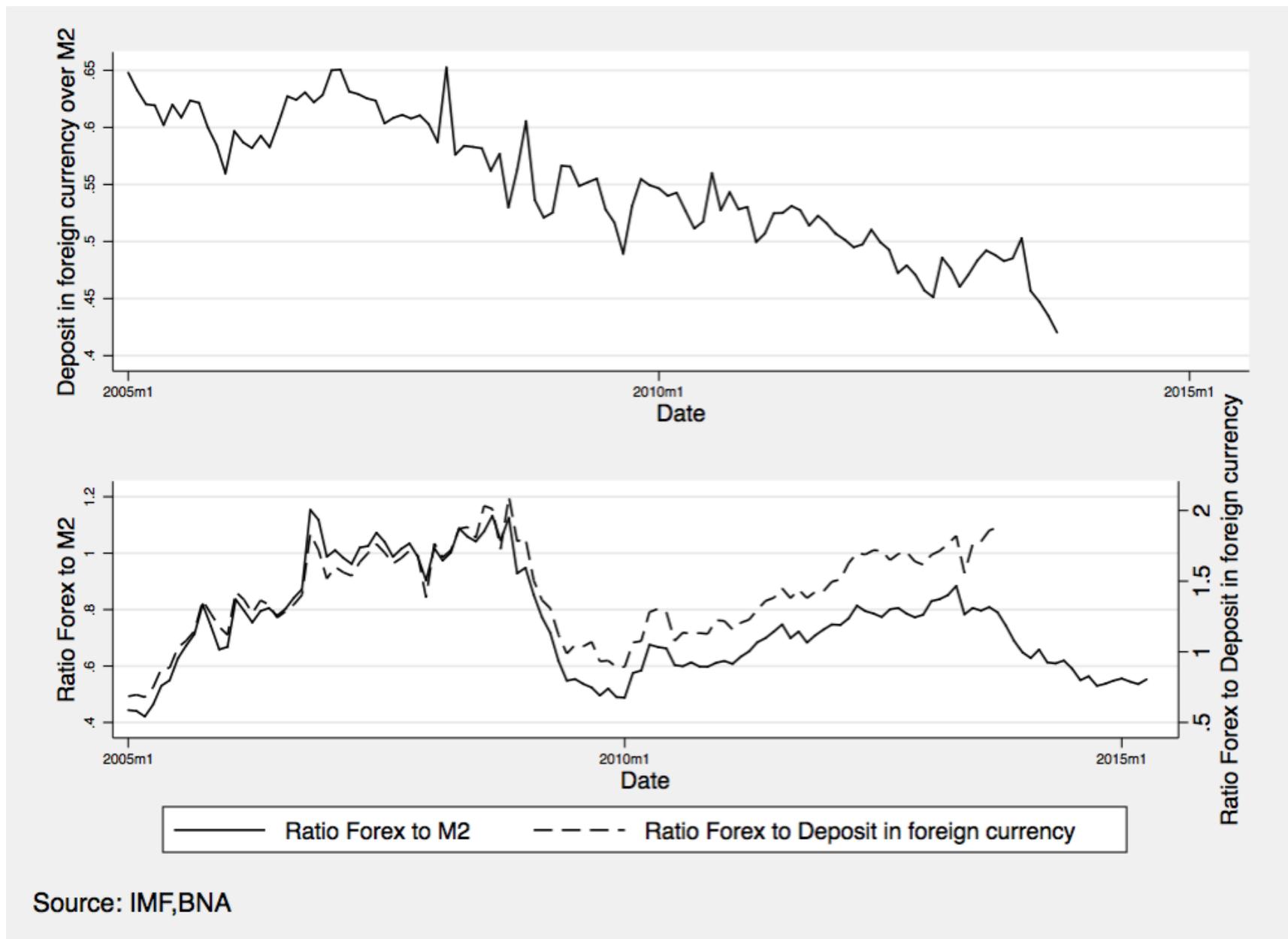


Figure 2: The current and financial account in Angola.



Source: IMF,BNA

Figure 3: The real exchange rate and exports in Angola. The Figure shows the annual price differential between the Angolan CPI and the US. The lower panel of the Figure shows the level of exports in goods together with the price of a barrel of oil in the World market.



Source: IMF,BNA

Figure 4: Dollarization in Angola. The upper panel shows the ratio of deposits in foreign currency over the money supply (M2). The lower panel shows the ratio of foreign reserves over M2 and the ratio of foreign currency deposits over M2.

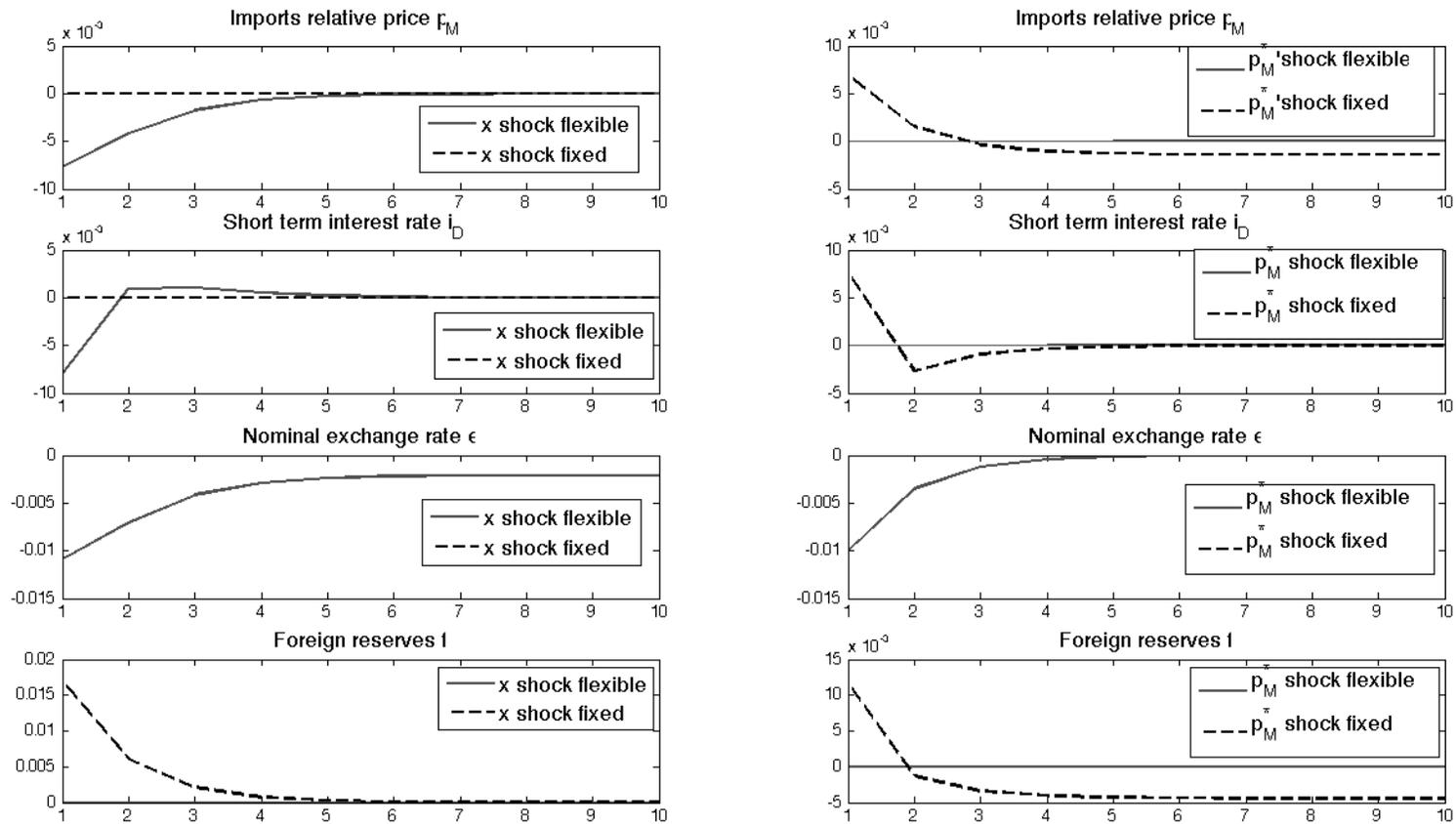


Figure 5: The figure shows the response to a positive shock in the oil price in the case of both a flexible and a managed exchange rate. The details of the response depend on the particular values of the parameters of the model. The exchange market rate pressure is the difference between the managed and the flexible exchange rates.

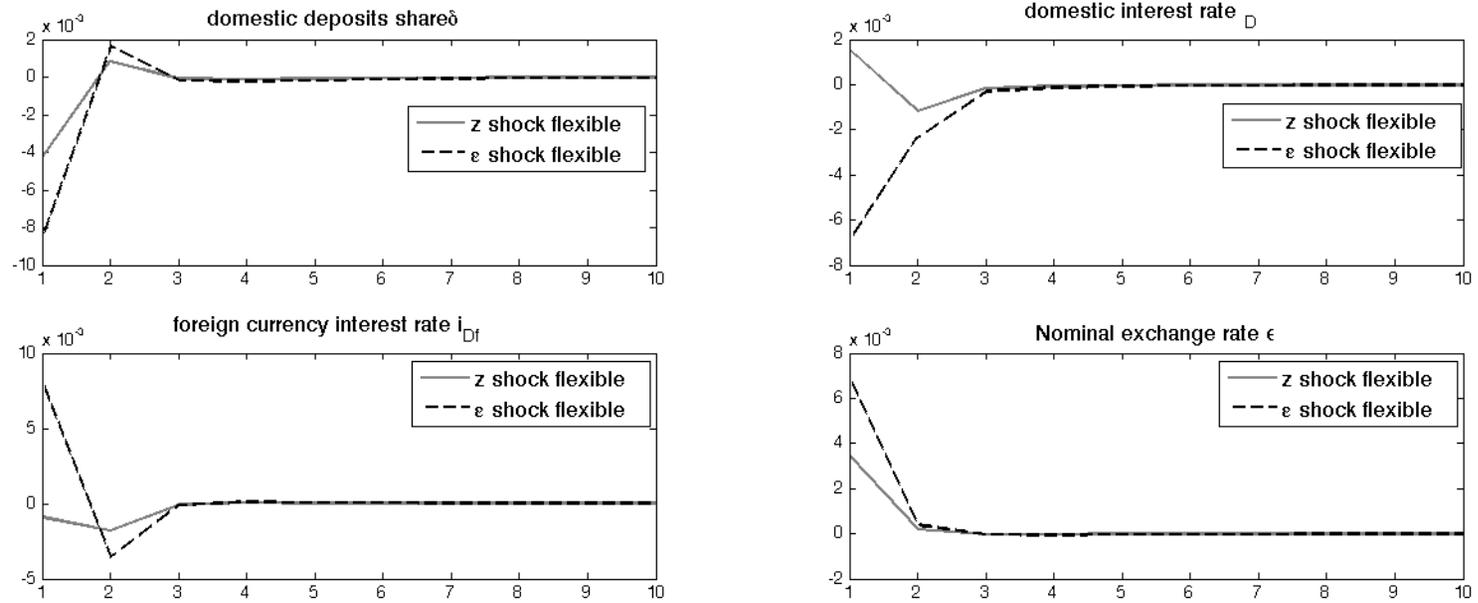


Figure 6: The figure shows the response to a portfolio shift towards foreign denominated deposits (z -shock) and an expansionary monetary policy (ϵ^m -shock) for a dollarized flexible exchange rate economy.

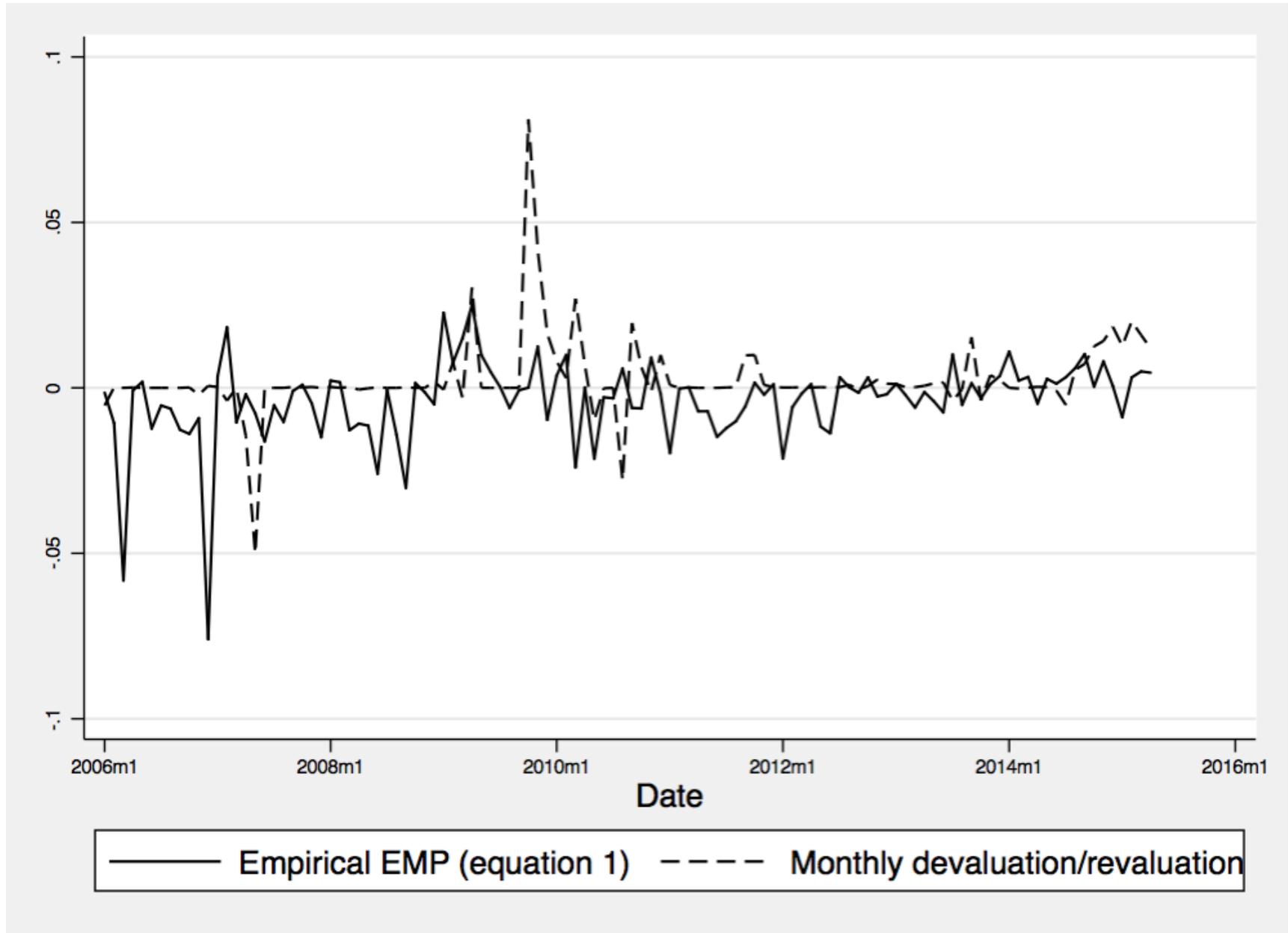


Figure 7: Empirical EMP as in equation 1 and the Exchange rate monthly percentage change in Angola. The correlation between the two variables is 0.12.

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