African Review of Economics and Finance (2023), **15(2)**, 197–214
ISSN (Print) 2042-1478
ISSN (Online) 2410-4906

ARTICLE

Verifying the Tunisian exchange regime stability in the post-revolution period by state-space models and high-frequency data

Mohamed Bouabidi*

Faculty of Economic Sciences and Management, University of Sousse, Tunisia
* Corresponding Author: abouobaydim@gmail.com

Abstract

The 2010-2019 period was marked by a steady depreciation of the Tunisian Dinar (TND) against the two major international currencies: a depreciation rate of 95% against the United States Dollar (USD) and 63% against the euro (EUR). To examine whether this depreciation is caused by a discrete manipulation of the de facto exchange regime and exchange rate or a natural result of the supply and demand fundamentals under a floating regime, this study applies the State-Space Model technique to daily data because it serves to check whether the weights are time-varying or stagnant. The results show that the steady depreciation of the TND cannot be exclusively attributed to market forces. The de facto regime is crawl-like with implicit time-varying weights that have opposite trends, except in 2017. The TND is implicitly anchored to the two major currencies and the monetary authorities intervene to modulate and moderate its fluctuation. These findings may be important to anticipate the future exchange rate trend; develop an effective hedging strategy; or examine the effect of external shocks and economic fundamentals changes on the exchange rate evolution.

Keywords: Exchange Rate, de Facto Regime, State Space Model, Depreciation, Fear of Floating.

JEL classification: C32, F31, F65.

Article history: Received: 10 November, 2021 || Accepted: 13 July, 2022

1. Introduction

During the post revolution decade, the International Monetary Fund (IMF) annual reports record a chronic divergence between the Tunisian authority statements and the IMF de facto classification of the Tunisian exchange rate regime. While the Tunisian authority claims having adopted a floating exchange regime most of the years, in the last decade, the IMF states, in its annual reports, that the Tunisian exchange regime is always an intermediate regime (stabilized arrangement or crawl-like peg), except for 2017. This inconsistency may have negative impacts on economic research and make it difficult to detect the real causes of the steady and drastic depreciation of the TND. In fact, over the 2010-2019 period, the TND exchange rate exhibited a steady downside movement against the USD as well as against the euro. At the end of 2019, the TND recorded a depreciation rate of 95% against the USD and 63% against the EUR. This drastic depreciation may be caused by a discretionary exchange regime and exchange rate manipulation and /or economic fundamentals deterioration. In fact, it is not surprising that the Tunisian authority discreetly intervenes to manipulate the exchange rate. Theoretically, the discreet manipulation has been explained by two main hypotheses: the 'fear of floating hypothesis' and the 'corner-solution hypothesis'. The fear of floating is the reluctance to allow totally free fluctuations in the nominal or real exchange rate. The corner hypothesis stipulates that intermediate regimes are not viable. The only viable regimes are the two extreme ones: the free floating and the hard peg regimes.

In this vein, the IMF annual reports, as well as the World Bank's (2017) statistical analysis, not only have shown that the TND exchange rate is artificial and its fluctuation is under the control of the monetary authority, but it is also anchored to a currency basket comprising the USD, the EUR, and to a lesser extent the Japanese Yen (JPY). Nevertheless, the IMF 2018 annual report has recorded a sudden change: the TND is no more anchored to the USD. The TND is henceforth exclusively indexed to the EUR, even if more than 22% of Tunisian foreign debts remains denominated in USD. Bouabidi (2020) findings do not support this claim and show that the TND remains anchored to the EUR and USD even in 2018 and beyond.

With these contradictory results and the probable discrepancies between the official claim and the discreet behavior of the monetary authority, it is difficult to detect the nature of the driving forces of the steady depreciation of the TND. Notably, two important issues must be studied: (1) Is the Tunisian exchange regime floating and the relationship between the TND and the two world currencies is simply a fortuitous relation caused by the co-movement of the three currencies? (2) Is the de facto exchange regime stable and are the implicit weights stable or time-varying?

To address these problems, the current study is based on high frequency data (daily data) and a special type of model named the State Space Model (SSM). As compared to linear regression models, the SSM has, inter alia, two main advantages. First, one may extract much more information from the time-varying parameters and their variances. Second, one can easily detect by visual inspection and handle, by intervention variables, structural breaks and outliers. In contrast to the IMF reports, the study shows that since the end of 2016 the implicit weight of the USD has become more important than the implicit weight of the EUR. The implicit weights are time-varying and have opposite trends. The flexibility proxy coefficient is not always very low- it sometimes exceeds 40%. Therefore, the TND critical depreciation marking the last years may be explained partially by economic fundamentals that have an impact on supply and demand as well as by active intervention of the monetary authority on the exchange market to maintain a discretionary flexible peg based on time-varying weights of the USD and EUR.

This paper is structured as follows. Section 2 introduces the theoretical foundations of exchange rate manipulation. Section 3 presents the SSM principle, the signal and state variables as well as the equations. Section 4 summarizes the main results and their discussions. Eventually, section 5 offers some concluding remarks.

2. Theoretical foundations of exchange rate manipulation

Theoretically, the discreet manipulation has been explained by two main hypotheses: the 'fear of floating hypothesis' and the 'corner-solution hypothesis'. The corner hypothesis states that there are only two viable exchange regimes: free floating and hard peg. In a context marked by high capital movements, open capital accounts, technological changes, it is not easy to contain market pressures. Intermediate regimes become crisis-prone, costly, and short-living (Eichengreen (1994), Fisher (2001)). Frankel et al. (2001) have stated that the non-viability of intermediate regimes lies with an intrinsic characteristic, which is non-verifiability. It is not easy to verify intermediate regimes because they are sophisticated, so they cannot survive. For Branson (2001) the basis for the corner solution hypothesis is neither an intrinsic factor nor environmental development. The leading cause of intermediate regimes' non-viability is the impossible trinity: The impossibility to have simultaneously fixed exchange regime, free capital movements, and an independent monetary policy. However, Frankel et al. (2001) have refused to consider the impossible trinity the cornerstone of the corner solutions hypothesis because national authorities can adopt against the wind strategy. They can continue using an intermediate regime and abandon it whenever there is a shock large enough to use up half its reserves. The question is: how the corner hypothesis explains the exchange rate manipulation? The IMF support of the corner exchange regime solutions and the speculative attack risk under the intermediate regimes motivate national authorities to claim a floating regime and discreetly manipulate the exchange rate.

Fear of floating arises from the combination of lack of credibility, high exchange rate pass-through, and inflation targeting, Calvo and Reinhart (2002). Developing economies characterized by their inefficient financial systems, weak law enforcement, and low degree of accountability need to reinforce their credibility by a hard peg exchange regime (Kimakova (2008) and Russell (2011)). A high exchange rate pass-through makes the floating regime costly because of the following two negative effects of the exchange rate depreciation. First, the exchange rate depreciation has a direct negative effect on consumer prices (the imported inflation). Second, the exchange rate depreciation increases the cost of foreign debts (the balance sheet effect). Low political and financial credibility and a high pass-through phenomenon increase the fear of floating and motivate monetary authorities to claim an official regime (the de jure regime) and apply discreetly another one (the de facto regime). Levy-Yeyati and Sturzenegger (2005) have found that there is an increasing number of countries actually adopting a fixed regime and officially claiming another.

Therefore, the spread of the dual exchange regime phenomenon in developing countries may be attributed to two adverse effects: the strong bias of the IMF toward the corner hypothesis (Calvo and Mishkin, 2003) presses some developing countries to officially claim the floating regime but their fear of floating leads them to discreetly defend a fixed or a crawling peg. Both the IMF and Bouabidi (2020) show that Tunisia is one of these countries: the Tunisian de facto exchange regime is not always consistent with the de jure regime. However, the IMF states that since 2018, the TND is no longer pegged to the USD but Bouabidi (2020) findings prove that it is still pegged to the EUR and USD. The SSM technique applied in this paper is able to adjudicate this controversy because its time-varying-parameters property allows to estimate the time-varying implicit weights of these two currencies and to detect their trends.

3. Methodology

To address the overmentioned problems, the current study uses daily data and a special verification technique named the State Space Model. Because of the time-varying-parameters property of the SSM, it is possible to extract much more information from its output than from a classic linear regression output: (1) it is possible to detect the implicit weights trends and variances; (2) it is possible to separate the stochastic components from the determinant component of the implicit weight; (3) as it is possible to easily detect by visual inspection structural breaks and outliers. In the next steps, we will respectively present in more detail the Data, model specification, results, and discussion.

3.1 Data

Data are collected essentially from the Central Bank of Tunisia (CBT), and the IMF websites. The daily exchange rate series of the TND against the USD, EUR and JPY (Japanese Yen) are published by the CBT. The daily foreign reserves series is also obtained from the CBT by a special request, under the right of access to information act (the law 22/2016). The daily Special Drawing Rights (SDR) values in terms of the USD, EUR and JPY, and also the nominal effective exchange rates (NEER) of the USD, EUR, and TND are collected from the IMF Website. Therefore, the study basically uses daily data covering the period 01/04/2010–12/30/ 2019.

3.2 Model Specification

State space model principles

SSM allows modeling an observed time series as being explained by one or more unobserved state variables. SSM has two forms of equations: the observation (the signal or the measurement) equation, and the transition (or the state) equation(s). In fact, the observation equation describes the dependent variable in terms of the level component (which is the equivalent of the intercept in the classical regression), the explanatory variables, and the irregular component (or the observation noise). Whereas, the state equation(s) defines the state variables(s) in terms of its lagged value, the explanatory variables, and the irregular component (or the state noise).

The SSM is firstly applied by Hwang (2014) to verify if China's exchange regime is a crawling peg regime. Relying on Frankel and Wei's (2008) model, the current study makes two adjustments to the Hwang model. First, Hwang (2014) verifies China's exchange regime only on the basis of an intercept and the currencies of the partners' countries. However, Frankel and Wei add to the partners' currencies a measure of the flexibility level noted EMP that will be defined very shortly. Second, Hwang (2014) does not impose any constraint on the sum of weights, but the sum must not be higher than one. Frankel and Wei (2008) propose a trick helping to add the weights constraint to the linear regression model. Similarly, the current study includes the constraint but in a different manner, that is without modifying the observation equation.

Dependent Variable Definition

As aforementioned, the observation equation describes the dependent variable. Given that the paper focuses on the exchange rate regime, the straightforward way to verify it consists of studying the exchange rate behavior. Instead of using the value or log value of the exchange rate, Frankel and Wei (2008) and Hwang (2014) … recommend, for theoretical and statistical considerations, the use of the exchange rate log difference. On the one hand, with the first differences, a constant can be included to test the likelihood of a trend appreciation or depreciation Frankel and Wei (2008). On the other hand, log differences make it possible to interpret the estimated coefficients as the weights of the component currencies in the basket Hwang (2014).

Nevertheless, Moosa and Li (2017) have recently mentioned that the first log difference use is problematic for two reasons. First, in practice, the exchange rates appear in the basket peg formula in levels and not in percentage change. Second, if level variables are cointegrated, the first difference model will be miss-specified. But still, the log difference remains more appropriate for this study in consideration of two reasons. To start with, the cointegration test shows that the variables are not cointegrated. Second, the study tries to analyze the evolution of the implicit weight and the log differences make it possible to interpret the estimated coefficients as the weights of the reference currencies.

Wang and Wang (2020) have pointed out another possible problem: currency interactions and co-movement may overvalue the implicit weights in the basket. For example, the coefficient (the weight) of the Malaysian Ringgit (MYR) in the Chinese Yuan Renminbi (CNY) basket may be statistically significant not because the Chinese monetary authority uses it as an anchor, but because the MYR is highly correlated to the USD and co-moves with it. However, their empirical tests, (Wang and Wang (2020) tables 3 and 6), show that the coefficients of both the US dollar in the euro "basket" and that of the euro in the US dollar "basket", differently to some other currencies, are very low and statistically insignificant. The USD and the euro are therefore freely floating without co-movements, and no weight correction is needed for the present study.

One cannot calculate the exchange rate changes, in a vacuum, without defining a reference currency or numeraire. The literature presents different numeraire alternatives that can be classified into to two categories: the one currency numeraire and the composite currency numeraire. The one currency numeraire can be a global currency generally used as a legal peg, i.e. the USD or the EUR, Levy-Yeyati and Sturzenegger (2005). It can also be a remote currency of an economy that relies heavily, like many emerging economies, on primary commodity exports, i.e. the Australian Dollar, AUD Calvo and Reinhart (2002); or another floating and stable remote currency, i.e. the Swiss Franc, CHF, Hwang (2014). As for the composite currency numeraire (Hwang, 2014; Ahmad et al., 2011; Frankel and Xie, 2010; Frankel, 2009) use the SDR. Note that when the exchange rate regime is a true basket peg, Frankel and Wei (2008) reported that the numeraire currency is immaterial: the results remain the same whatever it is. However, when the exchange is not a rigid basket peg, it will be useful to rely on a numeraire that is coherent with the yardstick used by the monetary authority. This is likely the case of the Tunisian exchange rate regime: the TND is softly pegged to a basket currency. Indeed, the IMF reports (2010, 2011) and the World Bank's (2017) statistical analysis stated that the TND exchange rate is implicitly linked to a basket currency including the USD, the EUR, and the JPY. For this reason, the current paper chooses the composite currency numeraire alternative and uses the SDR as the currency numeraire for the TND. Therefore, the observation variable will be the log difference of the Tunisian Dinar, Δtnd_t, where tnd_t is the natural log of the amount of SDR per TND at time t $(1TND_t = \text{x}SDR_t)$.

State Variables Definition

The state variables are the implicit weights of the three main currencies that are probably included in the basket (the USD, EUR and JPY) to which is added a measure of the flexibility level proxied by a variable noted emp_t. USD, EUR, and JPY are successively the amount of SDR per USD, the amount of SDR per EUR, and the amount of SDR per JPY. As for the TND, we use their log differences. empt is the sum of the log difference of the TND_t and the log difference of the standardized foreign currency reserves, $RES_t/\overline{M}2$, (Frankel and Wei, 2008; Frankel, 2009; and Frankel and Xie, 2010). A coefficient close to zero means that the exchange rate changes are close to zero, and the de facto regime is a fixed one. A high coefficient, close to one, means that exchange rate changes are not counterbalanced by foreign reserves changes, and the de facto regime is a floating regime. Note that Bleaney and Tian (2017) have presumed that EMP has some econometric problems. First, since one component of the EMP is the dependent variable itself, it should always have a coefficient of one and a correlation with the error term. Second, because the money supply is denominated in domestic currency, the ratio of reserves to the monetary base will tend to increase even if the reserves remain unchanged. These criticisms should not be taken for granted. In fact, there are no two separate components in the EMP. The EMP is one variable that can have values significantly different from the its components values. The output shows that the EMP coefficient is very low and not close to one. As for the reserves' component of the variable, the exchange depreciation can influence foreign currency reserves volatility. Nevertheless, this effect is insignificant when compared to the effect that of foreign currency flows.

$$emp_t = \Delta tnd_t + \Delta \log\left(RES_t/\overline{M}2\right)$$

Signal and state equations and the appropriate model choice The simplest form of an SSM including the aforementioned signal and state variables corresponds to the case where the level is deterministic, and the error terms of the state equations are zeros. Equation (1) represents the signal equation, and equations from (2) to (6) represent the state equations. w_{1t}, w_{2t}, and w_{3t} are successively the weights of the EUR, the USD, and the JPY. Equation (2) describes the trend, equations (3) to (5) describe the weights of basket currencies (the EUR, USD, and JPY), and equation (6) describes the coefficient of the flexibility proxy. Note that this first version of the model supposes that all these state variables are deterministic (they have no stochastic component) and its output conforms to the output of an OLS regression applied to the signal equation.

$$\Delta tnd_t = \mu_t + w_{1t}\Delta eur_t + w_{2t}\Delta usd_t + w_{3t}\Delta jpy_t + \beta_t emp_t + \varepsilon_t \tag{1}$$

$$\mu_t = \mu_{t-1} \tag{2}$$

$$w_{1t} = w_{1t-1} \tag{3}$$

$$w_{2t} = w_{2t-1} \tag{4}$$

$$w_{3t} = 1 - w_{2t-1} - w_{3t-1} \tag{5}$$

$$\beta_t = \beta_{t-1} \tag{6}$$

Frankel (2009) constrains the weights to add up to 1 by supposing one of the weights to be equal to 1 minus the other weights, $w_j = 1 - \sum_{i=1}^{n-1} w_i$, where n is the number of currencies in the basket. This constraint imposes to modify the dependent variable. For instance, Δtnd_t willbe replaced by $[\Delta tnd_t - \Delta e_t]$, where e_t, may be the Log of the EUR, the USD or the JPY (see Frankel (2009) for more details). Since the data of the current study are daily, the adding up constraint can be introduced without altering the signal equation. The constraint can be imposed directly in one of the three state equations describing the weights state variables, i.e. $w_{3t} = 1 - w_{1t-1} - w_{2t-1}$, the state equation (5). Table 1 exhibits the output of this initial model.

Table 1. SSM With Deterministic State Variables

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	-11.80480	0.016785	-703.2977	0.0000
	Final State	**Root MSE**	**z-Statistic**	**Prob.**
Trend	-0.000244	5.60E-05	-4.353153	0.0000
EUR weight	0.512292	0.010049	50.97768	0.0000
USD weight	0.453890	0.012460	36.42800	0.0000
JPY weight	0.033818	0.009725	3.477545	0.0005
Flexibility	0.047080	0.004301	10.94644	0.0000
Log-likelihood	10638.46	Akaike info criterion		-8.924046
Parameters	1	Schwarz criterion		-8.921622
Diffuse priors	5	Hannan-Quinn criterion		-8.923164

Source: Author's estimates

The variances are expressed as exponential functions of the unknown coefficients C(j). So, C(1), in table 1 , is the log of the variance of the signal noise $\varepsilon_t : C(1) = \log \sigma_\varepsilon^2 \Rightarrow \sigma_\varepsilon^2 = e^{C(1)} = e^{-11.8048} = 0.7468E-5$. The exponential function is used to guarantee non-negative variance estimates, Rummel (2015). The final state is the last value of the one-step-ahead estimation for the different state variables. The root MSE is the root mean square error of the state variable. The diffuse priors are the number of diffuse initial values.

In the state space output, there is neither the R2 nor the F-statistic. To determine how well the model fits the data, we use the Akaike Information Criterion (AIC). The AIC statistic measures the information loss relative to the true model and is used to test how well the model fits the data without unnecessary complexity. In other words, it estimates the parsimony of the model. That is, to what extent the model maximizes the goodness of fit with the minimum number of parameters. Taken on its own, the AIC is not very informative. We should compare the AICs of competing models. The best model is the one that minimizes the AIC's value. So, we will use –8.924046, the initial value of the AIC, as a benchmark.

The weight of the EUR, USD and JPY in the basket are respectively 51.2%, 45.4%, and 3.4%, all are statistically significant. The intercept (the trend) is significantly different from zero. The flexibility proxy has a coefficient significantly different from zero, but with a very low value. These are the features of a crawl-like de facto regime. Note that these results are similar to the ordinary least squares (OLS) regression results. So, with constant state variables, the SSM loses its dynamic aspect and gives constant parameters instead of time-varying parameters.

Remember that one of the main reasons for using the SSM is to verify if since 2017 the weight of the USD in the basket has become higher than the weight of the EUR, or conversely, the EUR has been the only anchor, as stated by the IMF report. In order to check for the overtime variability of the unobserved state variables, we need to activate the dynamic feature of the model by replacing their deterministic forms by the stochastic ones described below.

$$\Delta tnd_t = \mu_t + w_{1t}\Delta eur_t + w_{2t}\Delta usd_t + w_{3t}\Delta jpy_t + \beta_t emp_t + \varepsilon_t \tag{7}$$

$$\mu_t = \mu_{t-1} + \chi_t \tag{8}$$

$$w_{1t} = w_{1t-1} + \eta_{1t} \tag{9}$$

$$w_{2t} = w_{2t-1} + \eta_{2t} \tag{10}$$

$$w_{3t} = 1 - w_{2t-1} - w_{3t-1} + \eta_{3t} \tag{11}$$

$$\beta_t = \beta_{t-1} + \vartheta t \tag{12}$$

The error terms follow normal distributions with zero mean and constant variance: $\varepsilon \sim \mathcal{NJD}\left(0, \sigma_{\varepsilon}^2\right); \chi \sim \mathcal{NJD}\left(0, \sigma_{\chi}^2\right); \eta_i \sim \mathcal{NJD}\left(0, \sigma_{\eta_i}^2\right)$, for I = 1, 2 or 3 ; and $\vartheta \sim \mathcal{NJD}\left(0, \sigma_{\vartheta}^2\right)$. The results of this second model will be presented and discussed in the next section.

3.3 Results

Note, firstly, that the top of Table 2 exhibits 5 parameters instead of six (the number of error terms). The error term η_{3t} is removed because its variance is statistically insignificant. Second, the AIC's value (-9.017751), which is lower than the initial value (-8.924046), indicates that the SSM with stochastic state variables provides a better fit than the SSM with deterministic state variables. However, before discussing the results in detail, it is necessary to conduct the check tests of the basic assumptions.

Table 2. SSM With Stochastic State Variables

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	-12.05529	0.021976	-548.5703	0.0000
C(2)	-21.11890	0.641645	-32.91366	0.0000
C(3)	-10.83099	0.573467	-18.88686	0.0000
C(4)	-10.99016	0.815861	-13.47063	0.0000
C(5)	-6.880521	0.109018	-63.11344	0.0000
	Final State	**Root MSE**	**z-Statistic**	**Prob.**
TREND	0.000213	0.000255	0.837007	0.4026
EUR weight	0.390121	0.057010	6.843036	0.0000
USD weight	0.599868	0.059497	10.08239	0.0000
JPY weight	0.010011	0.067334	0.148675	0.8818
Flexibility	0.090915	0.112164	0.810549	0.4176
Log-likelihood	10754.16	Akaike info criterion		-9.017751
Parameters	5	Schwarz criterion		-9.005635
Diffuse priors	5	Hannan-Quinn criterion		-9.013342

Source: Author's estimates

The SSM supposes that error terms are NID (Normal and independently distributed) with zero mean and constant variance. Subsequently, the error terms must satisfy three main assumptions: independence, homoscedasticity and normality. To check whether the residuals satisfy these assumptions, we use the standardized prediction errors, noted v_t^*, where:

$$v_t^* = \frac{v_t}{\sqrt{F_t}}$$

v_t are the one-step-ahead prediction errors, and F_t is their variance. The one-step-ahead prediction errors can be briefly defined in the following lines.If we have an observation variable y_t, a column vector of exogenous variables C_t, a row vector of unobserved state variables α_t, a term error ε_t and therefore, an observation equation $y_t = C_t\alpha_t + \varepsilon_t$ and the one-step-ahead prediction error v_t, can be defined as: $v_t = y_t - C_t a_t$. Where a_t is the conditional expectation of α_t given all the previous observations Y_{t-1}, $a_t = \mathrm{E}(\alpha_t/Y_{t-1})$. To apply these formulae to the current study, just replace y_t by Δtnd_t, take $C_t = (1\Delta eur_t\Delta usd_t\Delta jpy_t emp_t)$ and $\alpha_t = (\mu_t w_{1t} w_{2t} w_{3t}\beta_t)'$.

The histogram and the Jarque-Bera statistic are used to diagnose the normality assumption of the residuals. The correlogram and the Ljung-Box Q-statistics check the independence assumption. As for the homoscedasticity assumption, Durbin and Koopman (2012) propose a simple test that is obtained by comparing the sum of squares of two exclusive subsets of the sample. These subsets can be the first third part and the last third part of the series, Commandeur et al. (2011). This test is none other than the F-test of the equality of variances: $F = \frac{S_L^2}{S_S^2}$, where S_L^2 is the larger variance and S_S^2 is the smaller. Table 3 exhibits the output of the three tests.

Table 3. Check tests of the initial output of the SSM with stochastic state variables

Independence test				
	AC	PAC	Q-Stat	Prob.
1	-0.20	-0.206	100.87	0.000
2	0.030	-0.013	103.05	0.000
3	0.018	0.022	103.79	0.000
4	0.015	0.024	104.30	0.000
5	0.035	0.044	107.24	0.000
6	0.045	0.063	112.14	0.000
7	-0.012	0.009	112.49	0.000
8	0.059	0.057	120.87	0.000
9	-0.017	0.003	121.55	0.000
10	0.034	0.027	124.26	0.000
Homoscedasticity test				
	S_i^2	n_i	DF_i	Calculated F
Subgroup L	0.92	792	791	
				1.15
Subgroup S	0.8	792	791	
	Critical values		$F_{(0.975;791;791)}$	$F_{(0.025;791;791)}$
			0.869	1.149
Normality test				
	Skewness	Kurtosis	Jarque-Bera	Probability
	0.0179	5.811	785.29	0.000

Author's estimates

The top part of Table 3 exhibits a sample of autocorrelation (AC) and partial autocorrelation (PAC) coefficients. The P-values, that are less than 0.05, show that the standardized residuals are not independent. The middle of the table shows that the F-calculated value lies outside the interval between 0.869 and 0.149. The standardized residual variances are not equal. Therefore, the standardized residuals are heteroscedastic. As for the normality assumption, the bottom of table 3 shows that even if the distribution is symmetric (the Skewness is 0.0179), the standardized residuals are not normally distributed because the Jarque-Bera value is very high (785). They have an excess Kurtosis (5.811), which reflects the existence of outliers or heavy tails. Consequently, the three basic assumptions are not verified.

A second diagnostic step can be achieved using another type of standardized residuals which are the auxiliary residuals adopted in order to diagnose the model appropriateness. Also, their visual inspection allows for the detection of outliers and structural changes. They are calculated by dividing the smoothed observation disturbance, $\hat{\varepsilon}$ and the smoothed state disturbances $\hat{\chi}, \hat{\eta}_i$ and $\hat{\vartheta}$, with the square root of their corresponding variances. Unlike the prediction error, the smoothed error is calculated based on all the observations of the sample and not only the current and the past observations. For example, $\hat{\varepsilon}_t = y_t - \hat{a}_t$, with $\hat{a}_t = E(\alpha_t / Y_T)$ and so on. Y_T includes all the observations of the sample. The ratios of the smoothed disturbances to their variances give the standardized smoothed observation and state disturbances (or observation and states auxiliary residuals):

$$\hat{e}_t = \frac{\hat{\varepsilon}_t}{\sigma_{\hat{\varepsilon}_t}}; \hat{x}_t = \frac{\hat{\chi}_t}{\sigma_{\hat{\chi}_t}}; \hat{n}_{it} = \frac{\hat{\eta}_{it}}{\sigma_{\hat{\eta}_{it}}}; i = 1, 2 \text{ or } 3; \hat{\nu}_t = \frac{\hat{\vartheta}_t}{\sigma_{\hat{\vartheta}_t}}$$

The visual inspection of the standardized smoothed observation disturbance, $\hat{e}_t$, allows for the detection of possible outlier observations, while the inspection of the standardized smoothed state disturbances, $\hat{x}_t \ldots \hat{\nu}_t$, permits the detection of structural changes. Indications of outliers (or structural change) arise for values greater than two in absolute value, Harvey and Koopman (1992): a value of the standardized smoothed state disturbances greater than two indicates a structural change, and a value of the standardized smoothed observation disturbances greater than two is a sign of an outlier. Note that the auxiliary residuals are autocorrelated even when the model is correctly specified, Harvey and Koopman (1992). So, a high absolute value may be followed by one or more other high absolute values because of the correlation. Moreover, they tend to have a higher variance at the end and the beginning of the series, Harvey and Koopman (1992).

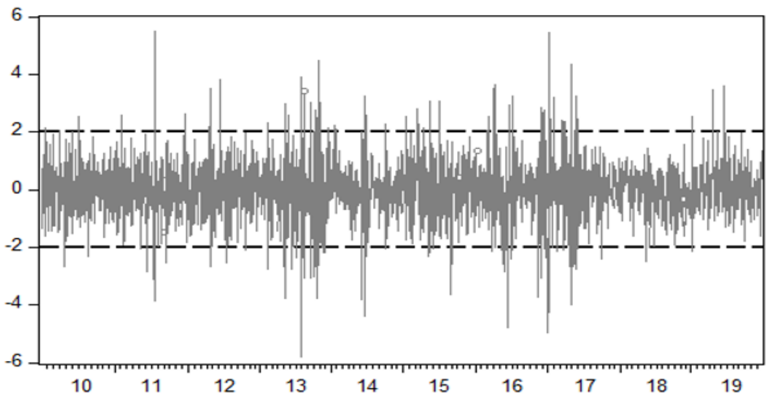

Figure 1. Standardized Smoothed Observation Disturbances

Figure 1 shows that a number of the auxiliary residuals values exceed the upper and lower limits of the confidence interval (± 2) . In fact, this number is 129 and is slightly higher than 120 (the number corresponding to 5% of the total number of observations). Furthermore, some values are very high, more precisely, exceeding the 4 standard-deviations which proves the existence of outliers. That is to say, in state-space methods, if the outliers are not caused by measurement or typing errors they can be handled by adding a pulse intervention variable consisting of 1 at the time point corresponding to the outlier observation, and 0 elsewhere instead of removing them, Commandeur and Koopman (2007). The state-space model adjusted for the outliers and the serial correlation problems paves the way to the final output presented in Table 4. The check tests output appears in Table 5.

Table 4. Final Output Of The Ssm With Stochastic State Variables

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	-12.56226	0.031914	-393.6226	0.000
C(2)	-19.6858	0.358955	-54.84197	0.000
C(3)	-10.5669	0.496172	-21.29685	0.000
C(4)	-10.58874	0.610787	-17.33623	0.000
C(5)	-8.061217	0.162724	-49.53907	0.000
C(6)	-10.02974	0.119435	-83.97672	0.000
	Final State	**Root MSE**	**z-Statistic**	**Prob.**
TREND	0.000367	0.000322	1.137197	0.2555
EUR weight	0.364862	0.054552	6.688369	0.000
USD weight	0.607836	0.05979	10.1661	0.000
JPY weight	0.027302	0.065292	0.418146	0.6758
Flexibility	0.068135	0.074482	0.914785	0.3603
Log likelihood	11065.53	Akaike info criterion		-9.28202
Parameters	6	Schwarz criterion		-9.267477
Diffuse priors	6	Hannan-Quinn criterion		-9.276728

Source: Author's estimates

The AIC's value, -9.28202, is the lowest. The handle of the outliers by the intervention variable improves the quality of the model. The diagnostic tests, according to Table 5, prove that the three basic assumptions are verified. The null hypothesis is rejected for all the six coefficients. Bearing in mind that these coefficients are the log of the variances of the error terms of the signal and state equations, rejecting the null hypothesis means that the state variables are time-varying (stochastic).

The TND changes series has a trend, but its stochastic component outweighs its deterministic component. Figure 3(a) shows that the trend fluctuates between -0.12% and 0.04%. It was negative most of the covered period. It reached its lowest value at the mid of 2018 and it crossed again the zero line at the end of the first quarter of 2019. Figure 2(c) shows that the trend records structural shifts in the mid of 2018 and the first quarter of 2019.

Table 4 shows that the EUR and the USD are the main currencies of the basket having time-varying weights. 0.364862 and 0.607836 are their final value. In other words, the values at the end of the period and not over the period. The JPY is far less important than the EUR and USD. The significant stochastic components suggest that the implicit weights are not constant. Unlike the Chinese Yuan (CNY), the TND basket is essentially a two currencies basket of USD and EUR. By applying the same technique, the SSM, Hwang (2014) has found that, during the period of 2005-2012, the CNY basket is essentially considered a one currency basket of the US dollar. Consequently, China's exchange rate regime can be well characterized being a discretionary crawling peg to the US dollar.

Table 5. Check tests of the initial output of the SSM with stochastic state variables

Independence test				
	AC	PAC	Q-Stat	Prob.
1	-0.036	-0.036	3.1394	0.076
2	-0.015	-0.016	3.6751	0.159
3	0.014	0.013	4.1439	0.246
4	-0.008	-0.007	4.2883	0.368
5	-0.008	-0.008	4.44	0.488
6	0.033	0.032	7.0399	0.317
7	0.018	0.02	7.791	0.351
8	0.008	0.011	7.9457	0.439
9	0.009	0.009	8.1329	0.521
10	0.007	0.008	8.2481	0.605
Homoscedasticity test				
	S_i^2	n_i	DF_i	Calculated F
Subgroup L	1.006	792	791	
				1.13
Subgroup S	0.888	792	791	
	Critical values		$F_{(0.975;791;791)}$	$F_{(0.025;791;791)}$
			0.869	1.149
Normality test				
	Skewness	Kurtosis	Jarque-Bera	Probability
	-0.03708	3.126735	2.140887	0.342856

Author's estimates

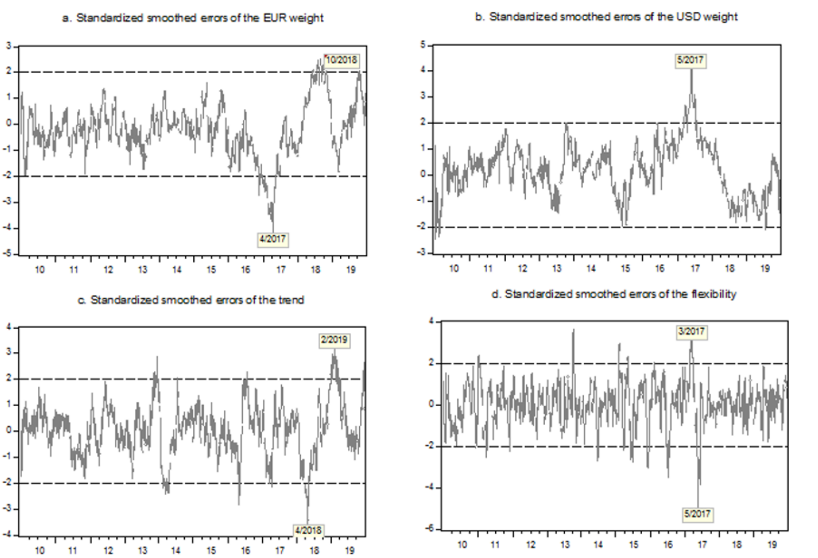

Figure 2. Standardized Smoothed Errors Of The State Variables

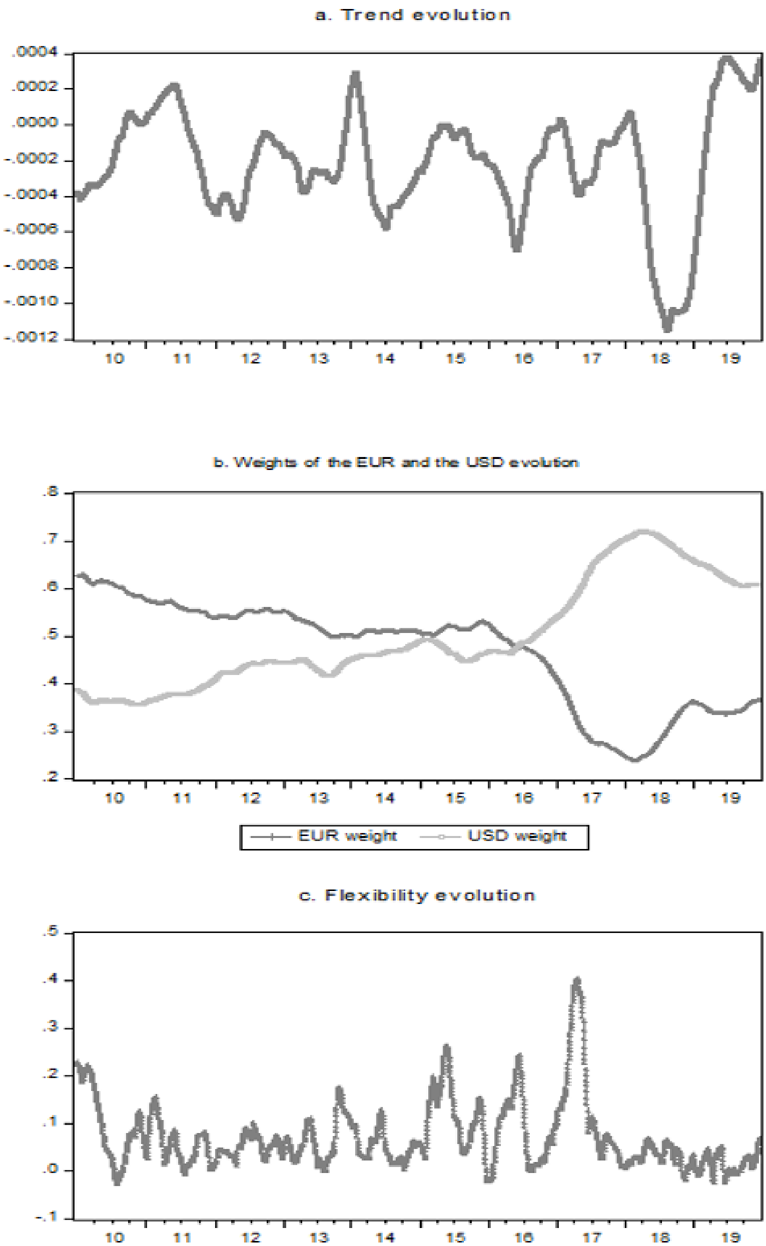

Figure 3. Stochatic State Variables Evolution (The Trend, Weights, And Flexibility)

Figure 3(b) shows that initially, the weight of the EUR was significantly higher than the weight of the USD. However, while the weight of the EUR records a negative trend, the weight of the USD records a quasi-steady increase. The two curves intersect towards the mid of 2016. From the period of mid-2016 to the beginning of 2018, the weight of the EUR experienced a noticeable decrease whereas the weight of the USD registered an acute increase. This inflection point corresponds to an important event that is to mention the act 2016-35(04/25/2016) amending the status of the CBT and establishing its independence. Figure 2(a) shows that the weight of the EUR has experienced two structural changes, in April 2017 and October 2018.In fact, the figure 2(b) shows that the USD weight has experienced a break in May 2017. The 2017 structural changes may be attributed to the lagged effect of the 2016-35 law enforcing the independence of the CBT and boosting the inflation stability objective. Logically, the CBT changes smoothly its policy and the new law outcomes cannot be significant before a transition period. The 2017 IMF annual report 'on exchange arrangements and exchange restrictions' has stated for the first time that the Tunisian de facto exchange regime is a floating one, which confirms the smooth transition hypothesis. As to the 2018 euro weight break, the accelerated depreciation of the Tunisian Dinar (TND) against the euro and its negative impact on the external equilibrium, given the special economic relation between Tunisia and the European Union, prompts the CBT to discretionary intervene in the exchange market to slow down the depreciation speed of the TND against the euro. Undoubtedly, the floating regime did not last and the 2018 IMF annual report has announced that the Tunisian de facto exchange regime is again a crawl-like peg to the euro.

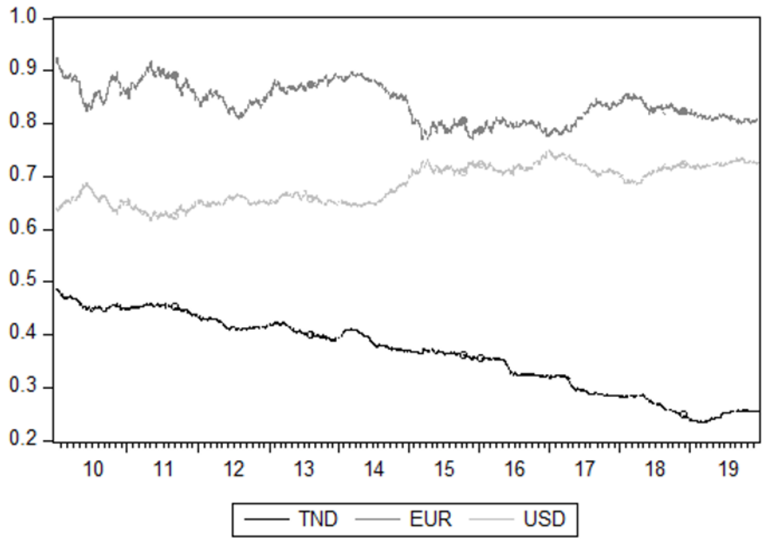

Figure 4. Evolution Of The TND, EUR And USD Rates Against The SDR

These findings are the answer to the question of whether the EUR has become the only anchor for the TND since 2018, as presumed by the IMF. Indeed, they prove that the increase in the USD weight cannot be spurious for several reasons. First, neither the increase in the weight of the USD nor the decrease in the weight of the EUR is sudden. For several years, the weight of the USD has recorded a quasi-steady increase and vice versa the EUR. The intersect point in 2016 is an inflection point that has just reflected the acceleration and not the beginning of the two weights changes. Second, the evolution of the TND/SDR in figure 4 as well as the nominal effective exchange rate

(NEER) of the TND in figure 5, have shown that the TND changes have no close similarity with the USD changes during the last decade. This means that the increase in the USD weight is not a simple coincidence caused by a significant deterioration of the two currencies rates. Rather, the USD records an appreciation. Still, the co-movement of the SDR/TND and SDR/USD may at best explain the accelerated increase experienced in 2017. So, the TND is always implicitly anchored to the EUR and USD with adjustable weights, except during 2017.

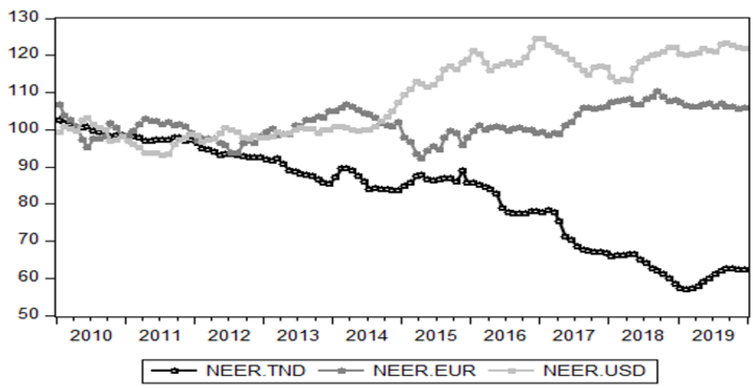

Figure 5. Nominal Effective Exchange Rates of the TND, EUR, And USD

Note that the use of the monthly (this is probably the frequency used by the IMF, given that it publishes only monthly TND/SDR rates) data as shown in figure 6, confirms the positive trend of the USD weight although with a very slight increase. Additionally, the USD weight has never reached the EUR weight. However, it still confirms the aforementioned conclusion: the TND is always anchored to the two world currencies, the EUR and USD. Further, the divergence between the IMF statement and the study findings cannot be attributed to the data periodicity. The stochastic

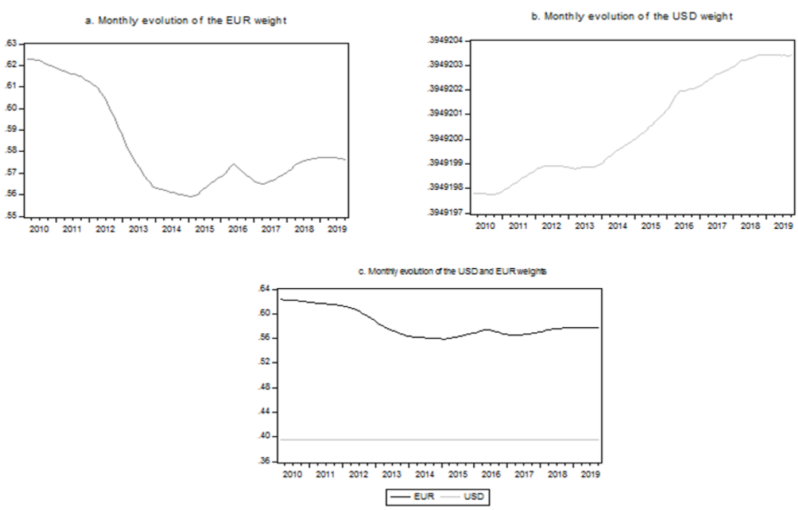

Figure 6. Monthly Evolution Of The Weights Of The EUR And USD

component of the flexibility measure is significantly different from zero. It means that this variable coefficient is not always very low as the linear regression findings show. Figure 3(c) shows that it exceeds 0.4 (it reaches 0.5 for the unconstrained model) in 2017, the year for which both the IMF and the Tunisian authority agreed that the Tunisian exchange regime is floating. Figure 2(d) shows that it has experienced a structural break in this year. Thus, this variable has an acceptable quality. Figure 3(c) shows that the de facto exchange regime, recorded in 2017, did not last long. In 2018, it ceases to be floating and turns back to the crawl-like situation, in accordance with the IMF 2018 report.

3.4 Discussion and Implications

The old exchange regime verification techniques can be classified into two groups: the weight-inference technique (Haldane and Hall (1991), Frankel and Wei (1994), BénassyQuéré (1999), ...) and the flexibility-inference technique (Hausmann et al. (2001), Levy-Yeyati and Sturzenegger (2005), ...), see Frankel (2009) and Hwang (2014) for more extensive literature. The weight-inference technique regresses changes in the value of the national currency against changes in the values of the reference currencies. The flexibility-inference technique uses a flexibility criterion (i.e. the relative volatility used by Hausmann et al. (2001)). In order to combine the two, Frankel and Wei (2008) propose a technique able to estimate simultaneously the implicit currency weights and the degree of flexibility around that anchor. They add to changes in the values of the reference currencies a flexibility proxy variable named the exchange market pressure (EMP) and impose the condition that the basket weights sum to one. Nevertheless, Bleany and Tian (2017) criticize the condition and the flexibility measure used by Frankel and Wei (2008). They use an unconstrained model and propose an alternative measure of the flexibility degree, the root mean square error (RMSE) of the regression. On the other hand, in order to track the time evolution and structural changes of the implicit weights, Frankel and Wei (2008) apply the ordinary least squares (OLS) regression on a split-sample arbitrarily chosen. To avoid the subjective choice of sub-samples, Frankel (2009) uses the rolling regression, and Fankel and Xie (2010) apply the Bai-Perron technique to the overall sample in order to detect possible structural breaks and regime shifts at irregular intervals (endogenous structural breaks). In the same vein, Hwang (2014) uses a more efficient and methodical weight-inference technique, the State-Space Model. The SSM allows tracking of the evolution of the implicit weight and detecting regime shifts by visual inspection without loss of information. Based on Frankel and Wei's (2008) model, this paper adjusts the Hwang model in order to estimate both the implicit weights and the flexibility: It adds the flexibility proxy variable developed by Frankel and Wei (2008) to the signal equation and it imposes the sum-to-one condition without modifying the numeraire or the signal equation.

On the practical side, this paper confirms Bouabidi (2020) findings and shows that the TND is still anchored to the EUR and USD. Their implicit weights are time-varying and they have reversal trends. The stochastic component of the flexibility measure is significantly different from zero, which means that this variable coefficient is not always very low as the linear regression findings of Bouabidi (2020) show.

These discussed results have some important implications. First, there is a discrepancy between the official and the de facto Tunisian exchange regime. Tunisia is urged to abandon the dual regime and claim a regime that it really applies. What is the use of claiming a regime that is not actually applied when the IMF in its public reports and the empirical verification techniques of exchange rate regimes show that this regime is not the one that it is actually applied? Second, the Tunisian de facto regime is roughly stable, the implicit weights are time-varying, and the stochastic component of the flexibility measure is significantly different from zero. These sources of uncertainty increase the exchange rate risk and hinder foreign investments. Third, until the Tunisian monetary authority abandons the duality, researchers interested in exchange rate changes and Tunisian exchange regime choice should be aware of the fact of duality and instability of the Tunisian exchange regime. Fourth, the TND remains anchored to the EUR and USD with time-varying weights, and its evolution cannot be exclusively explained by the supply and demand fundamentals. Finally, on the practical side, the TND indexation to more than one numeraire, the probably low-frequency peg, the implicit time-varying weights, and the active intervention in the foreign exchange market complicate the exchange risk anticipation and hedging. An effective risk hedging strategy must take all these factors into account.

4. Concluding Remarks

The study presents an empirical examination of the critical depreciation of the TND over the last decade. It uses daily data and a dynamic model with time-varying parameters, the SSM. The results show that the Tunisian de facto regime is roughly stable. It is a crawl-like regime and not a floating regime, except in 2017 when signs of floating regime appeared, such as the relatively high flexibility, the quasi-free-falling of the principal anchor weight (the EUR), and the structural changes recorded for the flexibility and the two implicit weights. However, the implicit weights are not stable. the results show that the TND has two main anchors which are the EUR and USD, with time-varying weights. In fact, from the beginning of the covered period until mid-2018, the weight of the EUR has experienced a negative trend while the USD experiences a positive trend. Nonetheless, the end of the covered period marks a trend reversal. These findings do not fit with the 2018 IMF report stating that the EUR turns to be the only anchor for the TND. The TND remains anchored to the two world currencies.

The results support also the existence of a discrepancy between the official and the de facto Tunisian exchange regime. This discrepancy may be explained by the fear of floating and the corner solution hypotheses. In fact, the Tunisian authority is under the pressure of two strong powers. On the one hand, the IMF pressure toward a more flexible exchange (a corner solution) so that the TND reaches its equilibrium level. This pressure is justified by the TND overvaluation caused by the successive slippages in the economic situation in Tunisia (Derbali, 2021) and the strong bias of the IMF toward the floating regime (Calvo and Mishkin, 2003). On the other hand, it faces social strikes, energy deficits, and huge foreign currency debts, all of which can be worsened by a weak TND. Consequently, it officially claims a floating regime to please the IMF and support discretionary the TND to reduce the social and economic negative effects of a weak TND (fear of floating).

Recall that the main issue was to detect the causes of the steady depreciation of TND over the post-revolution decade. What is clear is that the Tunisian de facto regime is not a free-floating regime. Even in 2017, there were reasonable signs of floating (not free-floating), but they rapidly vanished. Hence, the critical depreciation of the TND cannot be exclusively attributed to market forces. The Tunisian monetary authority discretionary anchors the TND to the EUR and USD. It intervenes actively in the exchange market to modulate the TND exchange rate movement. The implicit weights are not only disguised but are time-varying, which makes a currency attack more difficult. The economic fundaments deterioration caused by social instability and terrorist attacks may explain a part of the downside trend to the TND. In 2017, the year when the exchange regime acquired the floating regime characteristics, the TND recorded its highest annual depreciation against the EUR (21.25%), which may indicate that it is decelerated by active interventions in the other years.

The study shows that the findings are sensitive to the data periodicity. The monthly data output shows that the implicit weight of the USD is practically stagnant (the horizontal line at 39% in Figure 6). In fact, it is not strictly constant, but it fluctuates in a very narrow band. The implicit weight of the EUR fluctuates in relatively higher bandwidth but is significantly shorter than the bandwidth based on the daily data. This may be interpreted as a sign of a low-frequency adjustable peg. Additionally, the paper does not test the possible reverse causality between the EUR weight and the USD weight, as it does not examine the economic determinants of the basket currency weights.

Such points should be further explored in future studies

Biographical Notes

Mohamed Bouabidi is an assistant Prof. of finance at the FSEG of Sousse, Tunisia. He has obtained his bachelor's degree in Management Sciences and Economics from the FSEG of Sousse, a Master (DEA) of Finance and a Master (DEA) of International Economics and Finance, and PhD degree from the FSEG of Tunis. His research effort focuses mainly on Small and Medium Enterprises (SME) financing and International Economics and Finance.

Acknowledgements

I'm thankful to the handling Editor, Associate Professor Hebatallah Ghoneim and two anonymous reviewers whose insightful comments made this article better.

Conflicts of interest

The author declares no conflict of interest.

References

Bénassy-Quéré, A. (1999). Exchange rate regimes and policies: an empirical analysis, in Collignon, S., Pisani-Ferry, J. and Park, Y.C. (Eds.): Exchange Rate Policies in Emerging Asian Countries, Routledge, London, pp.40–64.

Bouabidi, M. (2020), The Tunisian exchange rate regime: Is it really floating? International journal of finance and economics. DOI: 10.1002/ijfe.2394

Bleany, M. and Tian, M. (2017). Measuring exchange rate flexibility by regression methods. Oxford Economic Papers, 69(1), pp. 301–319.

Branson, W. H. (2001). Intermediate exchange rate regimes for groups of developing countries, published in the book don't fix don't float: The exchange rate in emerging markets transition economies and developing countries (1st Ed). Paris, Development Centre Studies, OECD Ed.

Calvo, G.A. and Mishkin, P.S. (2003). The Mirage of Exchange Rate Regimes for Emerging Market Countries. Journal of Economic Perspectives,17(44), pp. 99-118.

Calvo, G.A. and Reinhart, C.M. (2002). Fear of floating. The Quarterly Journal of Economics, 117(2), pp. 379-408. DOI:10.1162/003355302753650274

Commandeur, J.J.F., Koopman, S.J., and Ooms, M. (2011). Statistical Software for State Space Methods. Journal of Statistical Software, 41(1), pp.1-18. DOI: 10.18637/jss.v041.i01

Commandeur, J.J.F., and Koopman, S.J. (2007). An Introduction to State Space Time Series Analysis, 1st ed. Oxford University Press Inc., New York, USA.

Derbali, A. (2021). The misalignment of real effective exchange rate: Evidence from Tunisia. IHEID Working Papers, No 04-2021.

Durbin, J., and Koopman, S.J. (2012). Time Series Analysis by State Space Methods, 2nd ed. Oxford University Press, United Kingdom.

Eichengreen, B. (1994). International Monetary Arrangements for the 21st Century (1st Ed). Washington, DC, Brookings Institution Ed.

Fischer, S. (2001). Exchange rate regimes: Is the bipolar view correct? Distinguished lecture on economics in government. Journal of Economic Perspectives, 15(2), pp.3–24.

Frankel, J. (2009). New estimation of China's exchange rate regime. Pacific Economic Review, 14(3), pp. 346–60. DOI: 10.1111/j.1468-0106.2009.00454.x

Frankel, J., and Wei, S. J. (1994). Yen bloc or dollar bloc? Exchange rate policies of the East Asian economies, in Ito, T. and Krueger, A. (Eds.): Macroeconomic Linkage: Savings, Exchange Rates and Capital Flows, University of Chicago Press, Chicago, pp.295–329.

Frankel, J., and Wei, S.J. (2008). Estimation of de facto exchange rate regimes: Synthesis of the techniques for inferring flexibility and basket weights. IMF Staff Papers 55, pp. 384-416.

Frankel, J.A., and Xie, D. (2010). Estimation of de facto flexibility parameter and basket weights in evolving exchange rate regimes. American Economic Review: Papers Proceedings, 100(2), pp. 568–72. DOI: 10.1257/aer.100.2.568

Frankel, J.A., Fajnzylber, E., Schmukler, S. L., Servén L. (2001). Verifying exchange rate regimes. Journal of development economics, 66(2), pp. 351-86.

Haldane, A., and Hall, S. (1991). Sterling's relationship with the dollar and the deutschemark: 1976–1989. The Economic Journal, 101(406), pp.436–443.

Harvey, A.C., and Koopman, S.J. (1992). Diagnostic Checking of Unobserved- Components Time Series Models. Journal of Business Economic Statistics vol. 10(4), pp. 377-389.

Hausmann, R., Panizza U., and Stein, E. (2001). Why do countries float the way they float? Journal of Development Economics, 66(2), pp. 387-414.

Hwang, J.D. (2014). Verifying China's exchange rate regime: it is a discretionary crawling peg to the US dollar! Int. J. Trade and Global Markets, 7(3), pp. 250–270. DOI: 10.1504/IJTGM.2014.064912

International Monetary Fund (1979-2018). Annual report on exchange arrangements and exchange restrictions. The IMF website.

Kimakova, A. (2008). The political economy of exchange rate regime determination: Theory and evidence. Economic Systems, 32(4), pp.354-71.

Levy-Yeyati, E., and Sturzenegger, F. (2005). Classifying exchange rate regimes: Deeds vs. words. European Economic Review, 49(6), pp. 1603-35. DOI: 10.1016/j.euroecorev.2004.01.001

Moosa, I., and Li, L. (2017). The mystery of the Chinese exchange rate regime: basket or no basket? Applied Economics, 49(4), pp. 349-360. DOI:10.1080/00036846.2016.1197370

Rummel, O. (2015). Estimating the output gap for Kenya: a practical guide to some state-space and Kalman filter trend-cycle decompositions, Centre for Central Banking Studies, Bank of England.

Russell, J. (2011). Hidden patterns in exchange rate regime choice. Empirical Economics, 40(2), pp. 425-49. DOI:10.1007/s00181-010-0359-6

Wang, P. and Wang, P. (2020). Assessment on estimations of currency basket weights-With coefficient correction for common factor dominance, International Journal of Finance & Economics, 27(1), pp. 1401-18. DOI: 10.1002/ijfe.2222

World Bank. (2017). A hard swap – supporting Tunisia in better understanding the foreign currency exposure for government debt operations, July 2017. WB website.