Exchange Rate Pass-Through and Inflation Dynamics in Tunisia: A Markov-Switching Approach

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Abstract

This paper studies the effect of exchange rate pass-through on inflation in Tunisia for the period 2001 to 2009. The objective is to track inflation regimes for the Tunisian economy and to forecast its determinants. Using a Markov-switching approach, the authors identified two main regimes for inflation in Tunisia during this period: a low and stable inflation regime associated with a low pass-through level and a high inflation regime associated with a high pass-through level. To highlight the mechanisms underlying shifts in inflation regimes, the authors used a time-varying probabilities approach and identified a set of variables to assess their effects on inflation in Tunisia. The results show that the price level decreases in response to an increase in interest rates. Along with this, the empirical results provide strong evidence that the industrial production index has a negative and significant effect, as it increases the probability to stay in an inflationary regime and remain at a high pass-through level. The results also show robust support for the hypothesis that the imports increase the probability to stay in a high-inflation regime and maintain a high pass-through level. However, exports increase the probability of staying in a low-inflation regime and maintaining a low pass-through level.

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1   Introduction

There is currently a growing consensus about the deleterious impact of high inflation on economic performance and social welfare. After a long period of relative price stability in both developed and developing countries, inflation has re-emerged around the world as a global challenge with serious socio-economic implications. In a recent study, Ben Ali and Ben Mim (2012), present a survey on inflation and its determinants.

The pass-through issue has been widely debated in the economic literature, as one of the main challenges for inflation targeting currently facing emerging economies is to assess the impact of exchange rate shocks on domestic prices and to forecast its determinants (Taylor, 2000; Bailliu and Fujii, 2004; and Gagnon and Ihrig, 2004 for developed economies, Choudhri and Hakura, 2006 and Ca'Zorzi et al., 2007 for emerging markets).

As defined by Goldberg and Knetter (1997), exchange rate pass-through is the percentage change in local currency import prices resulting from a one percent change in the exchange rate between the exporting and importing countries. Changes in import prices are, nevertheless, to some extent passed on to producer and consumer prices. Therefore, in this paper, we use a broader definition of exchange rate pass-through, defining it as the change in domestic prices that can be attributed to a change in the nominal exchange rate.

Tunisia is particularly concerned with this challenge as it pursues economic and financial liberalization. Tunisia has already begun the process of opening its domestic capital market to international capital flows, and it has also adopted more market-based monetary policy tools and is currently planning to progressively opt for capital account liberalization (Ben Ali, 2007). Policy-makers in Tunisia should also consider controlling and targeting inflation, as doing so is a necessary condition for successful capital account liberalization. To react on time, the Tunisian Central Bank needs to base its monetary policy decisions not on past inflation outcomes but, rather, on inflation forecasts (Senhadji, Saadi and Kpodar, 2007). This issue is of particular importance for any monetary authority with an explicit or implicit goal of price stability.

Our purpose in this paper is to present new empirical evidence on the exchange rate pass-through in Tunisia, focusing on its possible role in influencing the inflation environment. Empirical results should reveal those factors that drive

inflation, as monetary authorities should monitor them by if inflation targeting in Tunisia is to be effective. An important issue in controlling for inflation is to assess the pass-through. Exchange rate pass-through may affect the entire monetary policy in Tunisia where the exchange rate is sensitive to capital flows and where shocks in an open economy are often the main reasons for missing inflation targets.

In this study, nonlinearities are important because inflation in Tunisia responds to shocks in different ways depending on the current state of the economy, i.e., a low and stable inflation or a high and volatile inflation. The idea is that inflation in Tunisia may shift alternatively from one regime to the other using a Markov-switching approach.

Following the work of Hamilton (1989), the Markov-switching regime model has been used extensively to study nonlinearities of economic problems and indicators such as inflation. In Hamilton's original model, the transition probabilities were constants. However, constant or fixed transition probabilities are too restrictive to explain inflation behavior. Hence, an extension of Hamilton (1989) allows for time-varying transition probabilities. As explained by Filardo (1994) and Diebold et al. (1999), the Markov-switching model with time-varying transition probabilities (TVTP) has an advantage over the fixed transition probabilities (FTP) with respect to flexibility. For example, it can recognize systematic changes in the transition probabilities before and after turning points, capture more complex temporal persistence and allow expected duration to vary across time. In this context, we use a Markov-switching model in this paper as it allows us to consider possible shifts in the evolution of the inflation process, thus better representing the actual behavior of inflation in Tunisia, which may be subject to a shift from one state to another as it follows a probabilistic approach (Hamilton, 1989 and 1990). Specifically, we suppose that inflation and its potential explicative variables can, alternatively, follow two regimes. Thus, two main objectives direct our study. First, we will assess the impact of pass-through on inflation by distinguishing two different regimes for the nominal effective exchange rate and for inflation. Using the Markov regime-switching framework, we assess the extent to which Pass-through affects inflation when it is subject to regime-switching. Second, we will identify macroeconomic and policy-related determinants that may have contributed to a switch in the inflation process in Tunisia over the last decade and, in particular, during liberalization phases. Our

objective is to determine whether these macroeconomic variables are significant factors underlying the inflation dynamics in Tunisia, and if so, what their effect on the probability of switching between regimes is.

By applying a Markov-switching model in which the transition from one inflation regime to another depends on variables selected as sources of inflation's proxies, this study attempts to shed light on the sources of inflation and the effect of pass-through on inflation and to track factors that could be efficient in controlling for inflation. To our knowledge, this is the first paper to address such issues in assessing the dynamics of inflation in Tunisia and to forecast its determinants. This concern is all the more important insofar as Tunisia will issue in the immediate future the total convertibility of the Tunisian dinar and the liberalization of its capital account.

This paper is organized as follows. In Section 2, we discuss the exchange and monetary policies in Tunisia. Section 3 briefly reviews and highlights specific aspects of the literature on pass-through. A methodology section follows in Section 4, while Section 5 briefly discusses empirical results. Section 6 concludes the paper.

2 Exchange Rate and Monetary Policies in Tunisia: An Overview

In 1986, with the support of the International Monetary Fund, Tunisia embarked on a structural adjustment program aimed to establish a market-based and private driven economy. As a result, Tunisia initially devaluated its currency by approximately 40% over the next few years, before adopting an effective stable real exchange rate policy relative to a basket of currencies. The effective real exchange rate targeting policy, combined with sound monetary and fiscal policies, helped Tunisia preserve external competitiveness and bring some discipline to its macroeconomic policies. To accompany Tunisia's increased international

integration, Tunisian authorities announced the current convertibility of the Tunisian dinar in January 1993 (Ben Ali, 2007).[1]

Money targeting has been the main objective of the Tunisian monetary policy. In 2003, the Central Bank of Tunisia switched to targeting the M3 money supply growth rather than that of the M2 but without any changes in its monetary policy design and formulation. This helped Tunisia reduce its inflation rates from double-digit rates in the early 1980s to sustainable levels in the 2000s, as presented in Table 1. A slight increase in the inflation rate, however, has been evidenced since 2008 due to an increase in the price level of fuel and due to imported inflation that has occurred as a result of the depreciation of the national currency against the dollar and the euro.

Tunisia has judiciously used discretionary (fiscal and monetary) and indirect (incomes) policies to maintain price stability facilitated by the absence of major terms of trade shocks and capital controls for non-residents. However, this overall policy strategy is likely to become less effective as its economy becomes more vulnerable to external shocks. To curtail the risks of increased international financial integration in an open capital account framework, the Central Bank of Tunisia has adopted more market-based monetary policy tools.

Adopting a flexible exchange rate regime for a small open economy, such as Tunisia, we could expect a close relationship between exchange rate movements and changes in the level of inflation. In the absence of exchange rate targets as nominal anchors for inflation expectations, the Central Bank of Tunisia should consider an inflation targeting framework to control for inflation, providing certain macroeconomic, institutional and operational conditions are fulfilled.

Table 1: The Evolution of Annual Inflation Rates in Tunisia (2001–2009)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Inflation (%)	2.70	2.70	2.72	3.62	2.01	4.50	3.14	5.04	3.5

Source: International Monetary Fund (2009).

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[1] Tunisia issued the current convertibility of the Tunisian dinar in December 1992. Tunisia intends to issue the total convertibility of the Tunisian dinar in the near future. For further details of the exchange rate policy, refer to Ben Ali (2007).

3   Literature Review

Much of the monetary macroeconomics literature stresses the importance of assessing the degree of pass-through as it is a key issue in the conception and the control of the monetary policy (Gagnon and Ihrig, 2004, Edwards, 2006 and Mishkin, 2008). Indeed, a small degree of pass-through would mean that the variations in the foreign exchange rate have less effect on consumer prices and, consequently, on short-term inflation.

In its broad meaning, exchange rate pass-through is used to refer to the effects of exchange rate changes on another variable. Generally, four variables are considered when dealing with pass-through: import and export prices, consumer prices, investments and trade volumes (Campa and Goldberg, 1999).

Studies on the pass-through are diverse. Using a model of firm behavior based on staggered price setting and monopolistic competition, Taylor (2000) examines the relation between exchange rate variation and inflation and finds that a low inflation environment in many industrialized countries, which was brought about by more credible monetary policies, has successfully reduced the degree of the exchange rate pass-through (ERPT) to domestic prices. He further documents that the ERPT is primarily a function of the persistence of the exchange rate and price shocks, which tend to be reduced in an environment where inflation is low and the monetary policy is credible. This result is later claimed by Gagnon and Ihrig (2004), who assert that there has been a secular decline in pass-through from exchange rates to consumer prices in industrial countries over the past 35 years, thus linking this decline to monetary policy credibility.

Choudhri and Hakura (2006) examine the hypothesis of Gagnon and Ihrig (2004) and derive a pass-through relation based on new open economy macroeconomic models using a large database that covers 71 countries for the period 1979 to 2000. Arguing that the estimated ERPT tends to vary systematically with the mean inflation rate, they show strong evidence of a positive and significant relationship between the pass-through and the average inflation rate across countries and periods. Later, Choudhri and Hakura (2006) assess the importance of price inertia and expectations for the exchange rate pass-through, claiming that because prices are set by firms, the pass-through will include the expected effect of change in the exchange rate on future costs and prices and that this depends on the inflationary environment. They also report that

for high inflation regimes, the effect of monetary shocks is more persistent and likely to be reflected in exchange rates, thus concluding that the exchange rate pass-through would be larger in high inflation regimes. For countries with very high inflation rates, Devereux and Yetman (2002) find, as in Choudhri and Hakura (2001), that aggregate pass-through is extremely high. They also report a non-linear relationship between the estimated pass-through coefficient and average inflation rates. Indeed, as inflation rises, pass-through rises, though at a declining rate.

Using data from 20 industrialized countries, Gagnon and Ihrig (2004) test whether the change in pass-through is explained by the change in the inflation regime by relating the estimated pass-through pre- and post-inflation regime change for each country with the corresponding inflation regimes. They find that the decline in pass-through is explained by the decrease in inflation variability. Their findings also support the view that countries with low and stable inflation rates tend to have low estimated rates of pass-through from exchange rates to consumer prices. This result is not consistent with the documented evidence in Barhoumi (2006). Using data from a large set of developing countries, Barhoumi (2006) finds little difference in the long-run exchange rate pass-through in countries with widely divergent inflation regimes. His empirical findings further suggest that homogeneity of pass-through rates across countries can be rejected and that countries with fixed exchange rates and lower tariff barriers exhibit a higher long-run exchange rate pass-through of import prices to domestic prices than countries with higher tariff barriers and floating rates.

Ihrig, Marazzi and Rothenberg (2006) examine the effects of exchange-rate pass-through to both consumer and import prices to determine the extent to which they have fallen in the G–7 countries since the late 1970s and 1980s. Their findings document a numerical decline of all countries in the responsiveness of import prices to exchange-rate movements. They also argue that while 10 percent depreciation in the local currency would have increased import prices by nearly 7 percent, on average, across these countries in the late 1970s and 1980s, it would have only increased import prices by 4 percent in the last 15 years. Their study also indicates evidence of responsiveness of consumer prices to declines in exchange-rate movements for nearly every country. Finally, the study shows that a 10 percent depreciation in the local currency would have increased consumer prices by almost 2 percent, on average, in the late 1970s and 1980s.

In a more recent paper, Júnior and León-Ledesma (2010) perform regression analyses to test the hypothesis, arguing that exchange rate pass-through (ERPT) into domestic inflation has been declining in many countries following a dramatic change in the inflation environment during the 1990s. Using a state-space model that allows ERPT to be time varying and dependent on the inflation environment, the authors estimate the model for 12 developed and emerging economies and test whether inflation contains significant information about the future evolution of the ERPT. Their paper reports evidence of a smooth decline in the impact of exchange rates on domestic inflation, but they do not support the hypothesis that lower inflation precedes a decline in the ERPT.

To assess the effect of exchange regimes on pass-through, Kara and Öğünç (2005) explored two subsamples to distinguish between the pre-float and the float behavior of exchange rate pass-through in Turkey. Their findings indicate that pass-through has weakened and slowed down after the adoption of the floating exchange rate regime. Furthermore, their findings suggest that most of the pass-through is completed within four to five months of the pre-float period, whereas it takes approximately one year under float. They highlighted a diminished magnitude of pass-through, in addition to the slowdown in its pace. In a two-year horizon, the total pass-through was estimated at approximately 60 percent for the pre-float period, while it had fallen to 30 percent under the floating regime.

4   Methodology

In this section, we discuss the Markov-switching approach used in our empirical study. We then present the data and variables.

The Markov-Switching Approach

There has been a large debate on the correct characterization of economic time series in general and on inflation in particular that often seems to be non-stationary. Specifically, this debate emphasizes the integrated nature of inflation behavior dynamics that often seem to go through distinct phases and exhibit various behaviors over time. This study makes use of an alternative time-series characterization for inflation that allows for distinct and varying periods of

inflationary behavior, each period characterized by its own time-series properties depending on a probabilistic process.

This paper builds on an approach introduced by Hamilton (1989) for analyzing such discrete qualities of inflation. This approach is appealing for three reasons. First, it fits with the fact that inflation can perform differently in different sub-periods as it is a switching process where sudden changes can occur. Second, the Markov-switching modelling approach we apply in this study imposes a simpler-than-conventional structure on the inflation process within any given regime, but it gains power to fit the historical data by allowing regimes to change. The distinctive feature of this approach is the use of simple equations for inflation within a framework that allows for discrete regime shifts. Specifically, Markov-switching models allow for two or more processes to exist with a series of shifts between the states occurring in a probabilistic manner such that shifts occur endogenously rather than being imposed. Third, this Markov-switching methodology has been modified by the patterns of inflation for Tunisia that have historically switched in response to the many oil shocks.

Compared to other switching approaches, such as the structural switching method, that can only give us the different switching dates of inflation, the Markov-switching approach allows us, through the smoothed probabilities graph, to have a probabilistic approach of appurtenance of each regime, while explaining inflation by macroeconomic factors conditional with all of the information in the sample. Markov-switching models are an alternative that takes into account market changes that can potentially cause changes in parameter estimates of models and, ultimately, improve forecasting accuracy. Furthermore, it is well established in the literature that the Markov approach presents more sophisticated methods and original results compared to other structural break tests such as the Chow test (Hamilton, 1989 and 1990).

It is worth noting that we compared a single-regime linear model with the two-state Markov- switching model. To do so, we conducted the likelihood ratio test introduced by Garcia (1992) and found that the statistics test largely exceeds the empirical values, thus allowing us to retain a specification of two regimes.[2]

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[2] This result has not been reported in the manuscript, but it is available upon request.

Two main methods for estimating transition probabilities can be distinguished when dealing with the Markov-switching process: fixed transition probability (FTP) and time-varying transition probability (TVTP).

FTP Approach

The fixed transition probability (FTP) approach is the Markov-switching model in its standard form. Its main feature is that it does not allow the transition probabilities to vary. The basic idea of Markov-switching model is to describe the stochastic process that determines the switch from one regime to another using a Markov chain. The Markov chain is used to model the behavior of a non-observed state variable that determines which regime is current. As first introduced by Hamilton (1989, 1990), a Markov chain can be represented as follows. Suppose that the probability of a variable s_t assuming some a particular j value and depending only on the previous value s_{t-1}, is given by the following equation:

$$P\{s_t = j \setminus s_{t-1} = i, s_{t-2} = k...\} = P\{s_t = j \setminus s_{t-1} = i\} = P_{ij}$$

(1)

This process is described as a Markov chain with M states where probability P_{ij} indicates the probability of state i being followed by state j. Thus, we can build the Markov transition matrix of first order where the probability of transition to the next regime relies only on the current regime. As presented in the seminal paper of Hamilton (1989), two transition probabilities are distinguished:

$p = \Pr(s_t = 1 \setminus s_{t-1} = 1)$ is the probability of staying in a low inflation regime.

$q = \Pr(s_t = 2 \setminus s_{t-1} = 2)$ is the probability of staying in a high inflation regime.

We estimate the Markov-switching model by maximum-likelihood using the Kittagawa-Hamilton filter (see Hamilton, 1990 or 1994 for this filter). Hamilton's filter consists of two stages. First, initial values of the vector of parameters Θ are initialized using the ordinary least squares method. Then, the series is sorted and split into M parts on which initial conditional regressions are computed to launch the maximum likelihood descent. Second, the model is recursively estimated

through the EM algorithm,[3] beginning with the unconditional density of the explained variable y_t calculated by summing conditional densities over possible values for S_t, as follows:

$$f(y_t \setminus I_{t-1}, \Theta) = \sum_{j=1}^{M} P(S_t = j, y_t \setminus I_{t-1}, \Theta) \qquad (2)$$

or, $f(y_t \setminus I_{t-1}, \Theta) = \sum_{j=1}^{M} P(S_t = j \setminus I_{t-1}, \Theta). f(y_t \setminus S_t = j, I_{t-1}, \Theta).$ (3)

The maximum likelihood estimate of Θ is obtained by maximizing the log-likelihood as follows:

$$L(\Theta) = \sum_{t=1}^{T} \ln(f(y_t \setminus I_{t-1}, \Theta)) \qquad (4)$$

where Θ is the vectorized matrix of parameters.

We define $S_t = \{1,..., M\}$ as an M state unobserved variable following a first order Markov chain and representing the number of regimes. *St = 1 (resp. St = M)* means that the time series are said to be in the lowest (resp. the highest) regime.

$I_{t-1} = (y_{t-1},..., y_1)$ is the information set available in *t*-1, which is the lagged values of the endogenous variable that will provide information relevant for the estimation of the Markov-switching model.

P_t is the conditional probability related to the state *j*.

In this paper, the Markov-switching approach describes the inflation process as being governed by two different regimes where switches between them are based on a probabilistic process. Estimates of parameters for the two most likely regimes are generated using maximum likelihood techniques. With the parameters previously identified, namely, the interest rate (TMM), the industrial production index (IPI), the exports (X) and the imports (M) unit values, it is then possible to estimate the probability that our variable of interest (inflation) is following one of the alternative regimes. This involves identifying where in the probability distribution of each regime the observation falls at each point in time. That is, the likelihood is calculated for each possible state.

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[3] For a detailed description of the EM algorithm, see Hamilton (1990, 1994).

TVTP Approach

The time-varying transition probability (TVTP) is a Filardo (1994) extended version of the fixed transition probability approach (FTP) that allows the transition probabilities to be time-varying. Following Filardo (1994), we allow the transition probabilities to be time varying and dependent on macroeconomic and monetary policy-related variables. The logistic function for the transition probabilities specification was first introduced by Filardo (1994) and then generalized by Filardo (1998), Gray (1996), Beine, Laurent and Lecourt (2003), Isogai, Kanoh and Tokunaga (2004):

$$p_{i,j,t} = \Pr\left[S_t = j \setminus S_{t-1} = i, Z_{t-1} \right] = \frac{\exp(\lambda_{i,j,0} + Z'_{t-1}\,\lambda_{i,j,1})}{1 + \exp(\lambda_{i,j,0} + Z'_{t-1}\,\lambda_{i,j,1})} \tag{5}$$

where,
$$i = 1, 2, \ldots, M\,;\ j = 1, 2, \ldots, M - 1 \text{ and}$$

$$p_{i,M,t} = \Pr\left[S_t = M \setminus S_{t-1} = i, Z_{t-1} \right] = 1 - \sum_{j=1}^{M-1} p_{i,j,t}, i = 1, 2, \ldots, M \tag{6}$$

M is the number of regimes, and s_t is a first-order Markov variable. Z_t is a vector of the economic variables explaining the transition from one regime to the other. Following Filardo (1994), the time-varying probabilities for two regimes is described as below:

$$\Pr(s_t = 1 \setminus s_{t-1} = 1) = \frac{\exp(\lambda_{10} + \sum_{j=1}^{n} Z'_{t-1}\,\lambda_{1j})}{1 + \exp(\lambda_{10} + \sum_{j=1}^{n} Z'_{t-1}\,\lambda_{1j})} \tag{7}$$

$$\Pr(s_t = 2 \setminus s_{t-1} = 2) = \frac{\exp(\lambda_{20} + \sum_{j=1}^{n} Z'_{t-1}\,\lambda_{2j})}{1 + \exp(\lambda_{20} + \sum_{j=1}^{n} Z'_{t-1}\,\lambda_{2j})}. \tag{8}$$

where, $\Pr(s_t = 1 \setminus s_{t-1} = 1)$ is the probability of remaining in a low inflation regime, given that the previous regime is characterized by a low and stable inflation, and $\Pr(s_t = 2 \setminus s_{t-1} = 2)$ represents the probability of a high inflation regime preceded by a high and volatile inflation.

Z_t is a vector of j macroeconomic and policy-related variables considered to predict the future course of inflation, as described in the following subsection. By allowing transition probabilities to vary over time, we can analyze the mechanisms underlying shifts from a low inflation regime ($St=1$) to a high inflation regime ($St=2$), and vice versa. In particular, we will use this econometric framework to determine the effect of macroeconomic and policy-related variables on the shift of inflation from one regime to another.

The key parameters affecting the probabilities of transition from one regime to the other are the coefficients λ. In particular, it is important to examine the sign of these coefficients. For example, if the coefficient λ_{11} is positive, the corresponding economic fundamental Z is a significant factor in increasing the probability to remain in a disinflationary regime (regime 1). However, if the coefficient is negative, the corresponding macroeconomic variable Z decreases the probability of remaining in a low inflation regime and increases the probability to overbalance towards a high and volatile inflation (regime 2). Similarly, the coefficient λ_{21} measures how the exogenous variable Z affects the probability of staying in a high inflation regime (regime 2) and eventually the probability of switching to a low inflation regime (regime 1) depending on whether this coefficient is, respectively, positive or negative.

Data and Variables Description

The main interest of the study is to examine the inflation dynamics and track its determinants. Inflation is tracked as a function of a set of macroeconomic and policy-related determinants. The study is conducted using a Markov-switching analysis of monthly observations from January 2001 to December 2009. The frequency of the data (from 2001 to 2009) yields 108 observations, which is satisfactory from an econometric perspective. To our knowledge, our data

correspond to the largest sample used in the literature to track the inflation determinants in Tunisia. Moreover, the robustness of our empirical findings are evidenced by two significant inflation regimes in mean and variance for both FTP and TVTP approaches, as discussed in detail in the results section.

Given the importance of the European Union as Tunisia's main trading partner (with more than 85% of Tunisia's trade) and given that Tunisia's major international trade and financial transactions are carried in euros, we consider the euro/dinar nominal daily average exchange rate (T), as published in the financial statistics of the Central Bank of Tunisia.

The consumer price index (CPI) measures changes through time in the price level of consumer goods and services purchased by households. The monthly growth rate of the CPI is used to compute the inflation rate.

The industrial production index (IPI) is an economic indicator that measures real production output. Following the literature, the industrial production index (IPI) is taken as a proxy of economic activity (Senhadji, Saadi and Kpodar, 2007; Hassan, 2005).

TMM is the monthly money market average interest rate. This reference rate remained, for long time, at a fixed level to enhance the attractiveness of the Tunisian economy. The financial liberalization program was launched in the mid-1980s, and in the1990s the TMM was relatively liberalized. The TMM now serves as the reference rate for the Tunisian economy by which banks, financial institutions and companies officially acquire liquidities on the Tunisian monetary market. While studies on inflation determinants that include monetary market rates as determinants of inflation are abundant, they are primarily confined to country settings, such as Blix (1999)'s study of Swedish inflation and Bleaney and Fielding (1999)'s study of inflation determinants for developing countries. We introduce the TMM as it accounts for the effects of Tunisia's monetary policy on both inflation and the exchange rate (Dropsy and Grand, 2008; Khan, 2003, Deme and Fayissa, 1995). The monthly TMM series and values are provided by the Central Bank of Tunisia.

Because the imported inflation is necessary to describe the pass-through, we consider the relationship between the exchange rate and inflation. Two channels are evidenced through the link with imports and exports. The role of exports (X) in explaining inflation was previously evidenced by Hassan (2005), who argued that since the mid-1980s, Tunisia's exports have been successfully diversified, moving

from an oil-dominated and volatile economy to a more stable and diversified economy with lower inflation. Moreover, exchange rate depreciation lowers export prices and increases import prices, thus leading to an increase in domestic demand and, consequently, in domestic prices. It is noted that in less developed countries (Tunisia in particular) where import goods are different from those for the home market, this impact depends on the relative substitutability between home and export goods. Following Deme and Fayissa (1995), we consider the import unit values (M) in our variables set. Data regarding exports and imports are extracted from the International Financial Statistics-IMF and the annual reports of the Central Bank of Tunisia.

5 Results and Discussion

A natural starting point for any time series analysis before estimating a model is to test for the stationarity of the time series data to be used. This is particularly essential as the stationarity of macroeconomic series are limited, in general (Pedroni, 1996; Froot and Rogoff, 1994; Chinn and Johnston, 1996), and particularly in the developing countries. Accordingly, we use the (Kwiatkowski-Phillips-Schmidt-Shin (1992)-KPSS stationarity test. Having a null hypothesis of stationarity, this test may be conducted under the null of either trend stationarity (TAU Test) or level stationarity (NAU test). Applying this test requires the choice of the number of lags considered in the long-term variance for the residuals autocorrelation. We present herein the data for three lag values: 0, 4 and 8. All the tests and the subsequent estimations are conducted using GAUSS software, version 3.2.32.

The summary results of the KPSS test, reported in Tables 2-a and 2-b, show that the only stationary variable is inflation. In fact, the first column of Table 2-a shows that the KPSS statistic for the inflation variable with a minimum residual lag of 0 and a maximum lag of 8 is, respectively, equal to 0.359 and 0.239 for level stationarity (NAU Test), which is lower than the 5% critical value (0.463). With respect to trend stationarity, this statistic is, respectively, equal to 0.046 and 0.035, which also is lower than the 5% critical value (0.146). Therefore, we can accept the null hypothesis for both level and trend stationarity for inflation. In contrast, we can observe from Table 2-a that all remaining variables are neither

trend nor level stationary. Indeed, the values of the KPSS statistic far exceed the empirical values. For example, the KPSS test statistic for the TMM corresponding to a residual lag of 8 and trend stationarity (TAU test) is equal to 0.151, which exceeds the 5% critical value (0.146), thus suggesting the rejection of the stationarity null hypothesis. This analysis is then generalized to the rest of the macroeconomic variables.

Non-stationary variables must be differentiated. Table 2-b indicates that the KPSS statistics do not reject the stationarity hypothesis for the first differences of the series at the 5% significance level. For example, the KPSS statistic for the IPI variable corresponding to a lag of 4 and for level stationarity (NAU test) is equal to 0.055, which is lower than the critical value (0.146), thus suggesting the null of stationarity for the differentiated series is accepted. To conclude, the KPSS test

Table 2-a: Outcomes of the KPSS Stationarity Test (before Differentiation)

	Inflation		T		TMM		IPI		X		M	
Lag	NU Test	TAU Test	NU Test	TAU Test	NU Test	TAU Test	NU Test	TAU Test	NU Test	TAU Test	NU Test	TAU Test
0	0.359	0.046	10.369	0.912	6.008	1.108	7.012	0.36	8.998	0.572	8.775	0.675
4	0.23	0.031	2.182	0.255	1.314	0.243	1.821	0.164	1.965	0.166	1.988	0.225
8	0.239	0.035	1.27	1.179	0.803	0.151	1.095	0.13	1.141	0.116	1.155	0.154
Critical value	0.463	0.146	0.463	0.146	0.463	0.146	0.463	0.146	0.463	0.146	0.463	0.146

Table 2-b: Outcomes of the KPSS Stationarity Test (after Differentiation)

	Inflation		ΔT		ΔTMM		ΔIPI		ΔX		ΔM	
Lag	NU Test	TAU Test	NU Test	TAU Test	NU Test	TAU Test	NU Test	TAU Test	NU Test	TAU Test	NU Test	TAU Test
0	0.359	0.046	0.155	0.022	0.183	0.159	0.007	0.007	0.013	0.011	0.02	0.009
4	0.23	0.031	0.205	0.030	0.126	0.110	0.024	0.024	0.039	0.034	0.073	0.034
8	0.239	0.035	0.287	0.045	0.120	0.106	0.055	0.055	0.062	0.054	0.085	0.040
Critical value	0.463	0.146	0.463	0.146	0.463	0.146	0.463	0.146	0.463	0.146	0.463	0.146

fails to reject the stationary null for inflation. This result provides strong evidence in favor of a level and trend stationary specification for the inflation data. In contrast, the KPSS test provides strong evidence of a difference in stationarity for the rest of the macroeconomic fundamentals.

After checking for our stationarity variables, we estimate our model in two steps. In a first step, we use the FTP approach, using the Kittagawa-Hamilton filter to investigate the relationship between the exchange rate pass-through and the inflation rate during the different inflation states. In a second step, we use the TVTP approach to assess the impact of a set of macroeconomic variables on explaining the transition from one inflation regime to the other.

FTP

As presented in the Methodology section, we conduct an estimation based on equations 2, 3 and 4. In this case, the endogenous variable y_t corresponds to the inflation rate Π_t. The information set (I_{t-1}) corresponds to the lagged value of the inflation rate Π_{t-1}. We use the exchange rate pass-through ΔT as the vectorized matrix of parameters Θ. S_t is a two state Markov variable.

We can now estimate a Markov-switching autoregressive model with exogenous variables as an MS-ARX model (Hamilton, 1990), as specified in the following equations:

First, inflation is assumed to follow the following process (Hamilton, 1990):

$$\Pi_t = \beta_0(s_t) + \beta_1(s_t)\Pi_{t-1} + \beta_2(s_t)\Delta T + u_t, \tag{9}$$

where Π the inflation rate and ΔT is the exchange rate pass-through.

This model allows β_0 and all of the coefficients β_i, *(i=1,2)* to vary between the two states, *s=1,2*.

The error term u_t, featured by $u_t \sim NID(0, \sigma^2\left[s_t\right])$, is the i.i.d. sequence of the normally distributed variable with zero mean and the following variance

$$\sigma^2 \left[s_t \right] = \begin{vmatrix} \sigma_1^2, if\ s_t = 1 \\ \sigma_2^2, if\ s_t = 2 \end{vmatrix}.$$

Table 3-a reports the results for the FTP model (Equation 9), which is a benchmark model for our study. This table presents significant evidence to support the assumption that two distinct phases characterize inflation in Tunisia. This argument finds support in the inflationary dynamic that occurred in Tunisia with the impact of the first oil shock that caused a peak in inflation in 1974 before quickly decreasing until the second oil shock, which caused a second transitory peak in inflation. Since the mid-1980s, and following the structural adjustment program, Tunisia has successfully managed to gradually reduce its inflation rates to less than 4 percent in 2004.

Our results also show that the point estimate of the state dependent means β_0 is significantly different. Moreover, there is an economic and significant difference between their magnitudes. Thus, the first state is characterized by a low inflation, with a monthly inflation rate intercept of 0.174 percent and a high inflation regime

Table 3-a: FTP-Markov-Switching Approach Estimation Outcomes

Regime 1				
Coefficient	0.174	0.457	-0.132	0.033
Std. error	0.048	0.147	0.037	0.012
t-Statistic	3.642	3.115	-3.623	2.791
Regime 2				
Coefficient	0.275	0.214	-0.005	0.111
Std. error	0.064	0.125	0.039	0.020
t-Statistic	4.288	1.704	-0.136	5.603
Jarque Bera	8.490 (0.014)			
Ljung-Box(11)	24.48 (0.000)			
ARCH (2)	1.209 (0.546)			
log-likelihood	-19.548			

Note: Figure in the parenthesis indicates p-values.

with a monthly inflation rate intercept of 0.275 percent, and with T-statistics, respectively, equal to 3.642 and 4.288, which far exceeds the 5% critical value (1.96). Furthermore, we test for price stability, thus allowing the inflation variance to be state-dependent as major changes in the monetary policy could cause shifts in the mean and/or the inflation variance. Hence, an important finding of this study is that it supports the existence of two regimes for volatility. That is, low inflation volatility with an average inflation variance of 0.033 is associated with the low inflation regime, and high inflation volatility with an average inflation variance of 0.111 is associated with the high inflation regime. These results are consistent with the documented evidence in Loungani and Swagel (2001) and in Dropsy and Grand (2008) providing further support to the assertion of the existence of two regimes for inflation levels (low and high inflation rates) and between the two regimes of inflationary trends (accelerating and decelerating inflation).

The pass-through coefficient β_2 is highly significant and equal to –0.132 in the first regime and insignificant and equal to –0.005 in the second regime. From an economic perspective, it could be interpreted that an appreciation of the dinar relative to the euro leads to a decrease in domestic prices. Furthermore, a low pass-through level leads to a low inflation level, and a high pass-through level leads to a high inflation level. Taylor (2000) was the first to document this link, showing that the more the environment is traditionally marked by inflation, the more the price changes are influenced by exchange rate variations. Studies supporting this evidence are also provided by Campa and Goldberg (2006) and Gagnon and Ihrig (2004) for developed economies and by Choudhri and Hakura (2006) and Ca'Zorzi, Hahn and Sanchez (2006) for emerging market economies.

Note that β_2 in regime 1 is equal to –0.132, which is lower than its level in regime 2 (–0.005). Hence, it is related to low inflation (an intercept of 0.174 percent). Although the pass-through level in regime 2 is not significant, the regime still corresponds to a high significant inflation level and a high volatility.

Furthermore, Table 3-b indicates that the probability of remaining in a low and stable inflation regime at time (t), given that the economy was in the same state at time (t −1), is p=0.942. The probability of being in a high and volatile inflation regime in time (t), given that the economy was in the same regime at time (t −1) is large at 0.966, which is greater than p. These high probabilities indicate that if the

Table 3-b : The Transition Matrix

	Regime 1	Regime 2
Regime 1	0.942	0.034
Regime 2	0.058	0.966

economy is in either a low or a high inflation regime, it is likely to remain in that regime.

Figure 1 plots the probability of being in a low inflation regime at each date in the sample, and it depicts the evolution of the smoothed probabilities of state 1. The inference is based on the full sample and the estimated maximum likelihood parameters (Table 3-a). Switches between regimes are sudden, deep and sporadic.
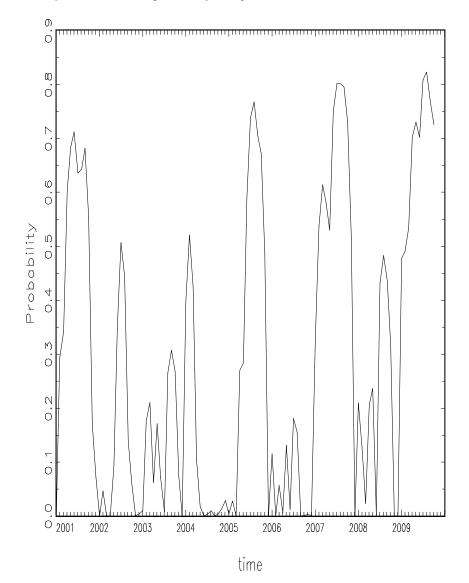
The economy stays in a low inflation regime most of the time, thus confirming the shorter duration of high inflation episodes in Tunisia. One of the explanations for the shorter duration is the strong commitment to sound monetary and fiscal policies that helped Tunisia implement discipline in the macroeconomic policies and reduce exposure to exogenous shocks.

An important finding of this study is the existence of four major changes from a high inflation rate to a low inflation rate in the sample, as revealed in Figure 1. The first change occurred between 2001 and 2002, a period marked by external economic shocks following the 9/11 attacks in the US. The second occurred between 2004 and 2005. After that, the economy experienced two low inflation phases, one between 2007 and 2008 and the second at the end of 2009. The latter two periods correspond to the international financial crisis.

Figure 2 depicts the smoothed probability in regime 2. We can notice that there is a first peak of the variation of the exchange rate in Tunisia in 2004, which simultaneously leads to an increase in the probability of staying in a high and volatile inflation regime. In addition, at the beginning of 2009, the variation of the exchange rate increases significantly and reaches a second peak, which is consistent with a high inflation rate (the probability of staying in a high inflation rate is close to 1 in Figure 2), which can be explained by the international financial crisis, as previously mentioned herein.

Figure 3 plots the variation of the nominal average exchange rate euro/dinar. We notice that any variation in the exchange rate leads to a rapid reaction of inflation in Tunisia.

Figure 1: Smoothed probability in regime 1 (low and stable inflation)
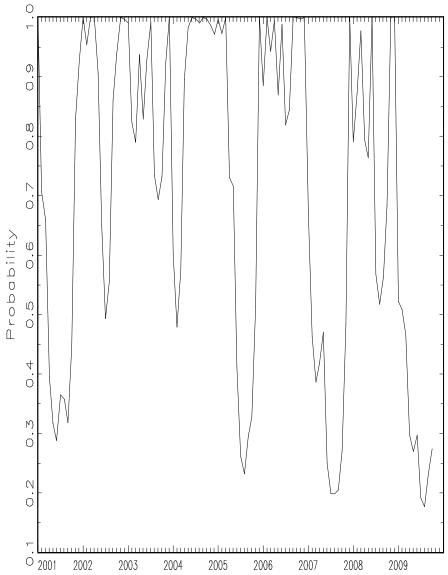
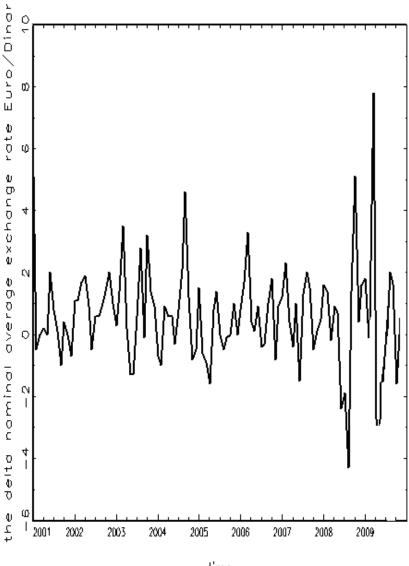*Figure 2:* Smoothed probability in regime 2 (high and volatile inflation)

Figure 3. The variation of the nominal average exchange rate Euro/Dinar

TVTP

Our actual research focuses also on identifying macroeconomic and policy-related variables to highlight the mechanisms underlying inflation dynamics in Tunisia throughout the period of study. For this purpose, we consider a set of four explanatory variables to explain shifts in inflation regimes. Studies on inflation dynamics use several sets of economic fundamentals, such as money supply, gross domestic product, effective exchange rate, past inflation, money growth, oil prices, exchange rates, monetary market interest rates, nominal effective exchange rates, consumer price index, industrial production index, ratio of the government budget balance to growth domestic product and the growth of money supply (M2).

In our study, we use the interest rate (TMM), the industrial production index (IPI), the export unit values (X) and the import unit values (M) as economic fundamentals. The regression results of the TVTP-Markov-switching approach based on different variables, providing the empirical effects of these variables on inflation dynamics, are reported in Table 4. The specification of the transition probabilities presented in previous subsections are as follows.

$$\Pr(s_t = 1 \setminus s_{t-1} = 1) = \frac{\exp(\lambda_{10} + \lambda_{11}TMM_{t-1} + \lambda_{12}IPI_{t-1} + \lambda_{13}X_{t-1} + \lambda_{14}M_{t-1})}{1 + \exp(\lambda_{10} + \lambda_{11}TMM_{t-1} + \lambda_{12}IPI_{t-1} + \lambda_{13}X_{t-1} + \lambda_{14}M_{t-1})} \quad (10)$$

$$\Pr(s_t = 2 \setminus s_{t-1} = 2) = \frac{\exp(\lambda_{20} + \lambda_{21}TMM_{t-1} + \lambda_{22}IPI_{t-1} + \lambda_{23}X_{t-1} + \lambda_{24}M_{t-1})}{1 + \exp(\lambda_{20} + \lambda_{21}TMM_{t-1} + \lambda_{22}IPI_{t-1} + \lambda_{23}X_{t-1} + \lambda_{24}M_{t-1})}. \quad (11)$$

First, we observe from this table that the data for all specifications can be split into two main regimes. The first is a low inflation state with a low volatility and a low pass-through level, and the second is a high inflation state with a high pass-through level and a high volatility. For example, Table 4 shows that the monthly inflation rate estimated with a TVTP based inference switches between two different regimes, that is, $\beta_0 = 0.156$ percent for the first regime and 0.226% for the second regime. The corresponding T-student statistics are, respectively, 6.274 and 5.087, which far exceed the 5% critical value. Moreover, the pass-through

Table 4: TVTP-Markov-Switching Model Estimation Outcomes

	Regime 1				Regime 2		
	Coefficient	Std.error	T-Student		Coefficient	Std.error	T-Student
	0.156	0.0249	6.274		0.226	0.044	5.087
	-0.446	0.0753	-5.921		0.344	0.096	3.570
	-0.092	0.016	-5.879		-0.0373	0.0314	-1.190
	0.004	0.002	2.158		0.091	0.013	6.916
	-6.586	313.036	-0.021		7.450	2.949	2.525
	0.679	0.116	5.853		0.251	0.399	0.628
	10.583	177.122	0.059		-0.706	0.359	-1.965
	1.607	0.763	2.106		0.035	0.076	0.457
	3.917	155.157	0.025		0.313	0.135	2.314

level coefficient (β_2) is low, negative and highly significant for the first regime ($\beta_2 = -0.092$) and high but not significant for the second regime. The results can be generalized for the other specifications as they are mostly highly significant and close to the FTP benchmark estimates. This provides further support to the robustness of the methodology used in this paper.

The TVTP can provide valuable additional information about whether a particular phase has occurred and whether a turning point is imminent by incorporating an economic inflation time series that can help identify the phase that the economy is in as well as forecast when the economy may switch phases.

Recall, for example, that from equations (10) and (11) we developed in the section corresponding to the Markov-switching approach (TVTP), the coefficient λ_{11}, which measures the impact of the economic variable on explaining the probability of remaining in the first, low inflation regime $\Pr(s_t = 1 \setminus s_{t-1} = 1)$. Similarly, the coefficient λ_{21} represents the economic impact of the macroeconomic fundamentals on the probability of remaining in the second, high inflation regime $\Pr(s_t = 2 \setminus s_{t-1} = 2)$. The sign of the λ coefficient is important as it allows us to

show the effect of the variables on remaining in the first or second regime (positive sign) or on overbalancing into the other regime (negative sign).

Our results show that the price level decreases in response to an increase in TMMs. In fact, we observe from Table 4, that the respective coefficient indexed by state 1, λ_{11} is positive and equal to 0.679. This coefficient is significant as the corresponding T-statistic (5.853) far exceeds the 5 percent critical value. This indicates that the higher the TMM, the higher the probability of remaining in a low inflation regime, thus the lower the inflation and the pass-through levels. We can then conclude that the TMM variable is a significant factor in increasing the probability of remaining in a disinflationary regime (regime 1) and a low significant pass-through level. This emphasizes the notion that the interest rate is one of the main instruments used by the Central Bank of Tunisia to control for inflation. Any increase in interest rates causes a decline in credit demand and, therefore, an increase in the domestic demand leading to downward movements in the domestic prices. We further note that in Tunisia, all lending rates are indexed on the TMM and this reference rate has remained for long time at a fixed level to stimulate investments and to promote a policy of economic growth driven by exports.

With respect to the IPI variable, we find that it has a negative and significant effect on increasing the probability of remaining in an inflationary regime (regime 2). Its coefficient λ_{22} indexed by state 2 is negative and equal to –0.706. Furthermore, it is significant at the 5% level, thus supporting the premise that the IPI has a negative impact on the probability of remaining in the second regime and then a positive impact on switching to the first regime. Accordingly, we conclude that when the IPI increases, inflation decreases. This result provides further support of the documented evidence of Omay, Karadagli and Aluftekin (2010) that states that Turkish inflation is affected by the industrial production index via the nominal uncertainty channel. In this regard, a declining industrial production index leads to a slowdown in economic growth and, as a result, to high levels of inflation.

With respect to the estimation outcomes of the TVTP model based on export unit values, we find a positive sign for the coefficient λ_{13} (1.607). This coefficient is statistically significant at conventional levels (T-statistic = 2.106), thus suggesting that the export unit values have a positive impact on the probability of staying in the first disinflationary regime. This also gives support to the fact that

exports increase the probability of remaining in a low inflation regime and a low pass-through level. A depreciation of the Tunisian dinar relative to the euro causes imported inputs to be more expensive relative to the dinar, thereby leading to a decrease in imports. With respect to imports, we find a positive sign for the λ_{24} coefficient in Table 4, suggesting that the imports increase the probability of remaining in a high inflation regime and a high pass-through level.

6 Concluding Comments

This paper theoretically and empirically examined the impact of exchange rate changes on inflation and described the nature, degree and direction of the relationship between the nominal exchange rate and inflation for the Tunisian economy, focusing mainly on the dynamic governing the transmission mechanism of exchange rate changes on consumer prices. Using fixed transition probability and time-varying transmission probability-Markov-switching approaches, we investigated the existence of a relationship between pass-through and inflation. Our results revealed a robust significant relationship between inflation and pass-through levels.

Our empirical results support the argument that the transition probabilities present, in almost all cases, the sign suggested by economic intuition. Indeed, the probability of remaining in a low and stable inflation regime increases with an increase in the monetary market interest rate (TMM), the industrial production index (IPI) and the export unit value (X), and it decreases with the import unit value (M). Indeed, for most specifications, the low inflation regime is associated with a low pass-through level, either for the FTP or the TVTP approach. Our results suggest that generally and for significant values of inflation rates and pass-throughs, these variables move in the same direction. First, the lower the inflation is, the lower the pass-through level and price volatility will be. Finally, we found that the TVTP model yields more information than the FTP model because the probabilities have changed significantly during the period under analysis and the explanatory variables are very informative in dating the evolution of the state of the economy.

Drawing on our empirical research, Tunisia should control for exchange rate movements to implement a credible exchange rate policy, especially with the

transition of Tunisia to a more flexible exchange rate regime as greater flexibility of inward and outward capital flows could lead to increased sensitivity of prices to upward or downward movements of the exchange rate.

This recommendation also relies heavily on the credibility of the Central Bank of Tunisia (CBT) to design a stable monetary policy. The credibility of the Central Bank is a key issue for the monetary policy as it keeps inflation levels low.

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