Is the Augmented Taylor Rule best describe the conduct of monetary policy in Egypt from 2006 to 2020

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Abstract:

This paper investigates whether monetary policy in Egypt is best represented by either the Taylor rule or the augmented Taylor rule from 2006M07 to 2020M01. Using the GMM method in testing six specifications, the study finds that the augmented Taylor rule, which incorporates the exchange rate and government spending, best represents monetary policies in Egypt. The Monetary Policy Committee of the Central Bank follows backward-looking. The results indicate that the interbank interest rate smoothed to 0.88. This implies that past interest rate values carry considerable weight in formulating current interest rates as an operational monetary policy tool.

It finds that the effect of the lagged inflation rate was positive and statistically significant, with a value less than the unit. The central bank has accommodated inflationary pressures. Also, the effect of the lagged output gap was weak. In contrast, the effect of movements in the exchange rate was positive and significant, and the effect of government spending was negative and significant. This means that the monetary authority in Egypt gives considerable weight to the exchange rate and fiscal policy

and less importance to fluctuations in the output gap in the formulation of monetary policy.
***Keywords*:** Taylor Rule, Monetary policy, **GMM** method, Exchange rate, Interest rate, Egypt.

الملخص:
تبحث هذه الدراسة فيما إذا كانت السياسة النقدية في مصر يمكن تمثيلها بشكل أفضل بقاعدة تايلور المعدلة. خلال الفترة من يوليو ٢٠٠٦ إلى يناير ٢٠٢٠ . وباستخدام طريقة **GMM** في اختبار ٦ توصيفات لدالة تايلور، توصلت الدراسة الى أن قاعدة تايلور ذات النظرة الماضية والمعدلة بسعر الصرف والانفاق الحكومي تمثل افضل توصيف لسلوك السياسة النقدية في مصر خلال فترة الدراسة. وتشير النتائج الى أن لجنة السياسة النقدية بالبنك المركزي تتيع النظرة القبلية (استنادا الى قيم المتغيرات الماضية) وان قيم سعر الفائدة ما بين البنوك الماضية تأخذ الوزن الاكبر عند تحديد معدل الفائدة الجاري كهدف تشغيلي، حيث بلغت معلمة التجانس ٠.٨٧ . كما جاء اثر معدل التضخم المبطأ موجبا ومعنويا وبقيمة تقل عن الوحدة، أى أن السياسة النقدية تستوعب التضخم. أيضا جاء اثر فجوة الناتج ضعيفا وبمعنوية منخفضة، بينما جاء اثر التحركات في سعر الصرف الاسمي موجبا ومعنويا ، وجاء أثر الانفاق الحكومي سالبا ومعنويا. ويعنى ذلك ان السلطة النقدية في مصر تعطي أهمية كبيرة لسعر الصرف والسياسة المالية عند صياغة السياسة النقدية مقابل اهمية محدودة للغاية للتقلبات في فجوة الناتج.
الكلمات المفتاحية : قاعدة تايلور- السياسة النقدية - طريقة **GMM** - سعر الصرف - مصر.

Introduction

Since the beginning of the 1990s, there has been a consensus in macroeconomics that monetary policy, which follows instrument policy rules, has a greater advantage in improving economic performance than monetary policy, which follows discretion (Taylor, 1993). As the two studies (Kydland & Prescott, 1977); (Barro & Gordon, 1983) confirmed, the monetary policy that follows discretions is inconsistent over time, meaning that discretions change from time to time according to the preferences and judgments of monetary policymakers.

Interestingly, despite initially overwhelming support for money growth targeting and later for inflation targeting, it was not clear how a rule in monetary policy formulation could be used in practice until John Taylor (1993) presented the case for a conditional and simple interest rate rule, which can be applied practically, and applied it to the American economy over 1970 to 1997.

According to the

(Taylor, 1999b) study, the Monetary Policy Rule can be defined as a description - expressed algebraically, numerically, and graphically - of how policy tools such as (the monetary rule, discount rate, or short-term interest rate) change in response to fluctuations in aggregate economic variables (e.g., inflation and product). The closest and simplest example of policy rules is the rule of constant growth rate of money supply attributed to Friedman.

The literature on rules versus discretions points to the clear distinction between the first: simple instrument rules proposed by (McCallum, 1988); (Taylor, 1993). Second, the targeting rules presented by (Svensson, 2003). Instrument Rules are functions of the current reaction that link the policy instrument with economic performance indicators (Meltzer, 1987). These rules are easy to follow and require little information. They are also robust and technically feasible, meaning compliance with the rule can be easily verified. As for targeting rules, despite their flexibility, they are complex.

Consequently, according to Taylor's argument, the logic that attracted researchers and monetary policy decision-makers to Taylor's rule during the 1990s was that a simple rule would not only have the potential to improve macroeconomic performance but also avoid inconsistency over time. Taylor also emphasizes that the rule does not suffer from an implementation problem because of its ease of verification by economic units outside the central bank. In this context, adherence to this rule becomes technically and practically possible.

Taylor introduced the idea of an instrument rule for conducting monetary policy operations by setting the target nominal rate for interest rate on federal funds (operational target) in the short term, which is equal to the sum of the real "balanced" or natural interest rate in the long-term, and the current inflation rate, plus the weighted average of the monetary authority’s response to the deviation of the current inflation rate than the weighted targeted and average rate for the percentage deviation of the real GDP from its potential level.

However, the Taylor rule has been criticized as overly simplistic because it considers only two variables, the inflation gap, and the product gap, without considering other important information needed to conduct monetary policy. The first criticism relates to the speed of adaptation of the central bank's policies to reach the target interest rate level. Some previous studies, including (Clarida et al., 2000), highlighted that adapting central bank policies to reach the target level is a gradual approach. This study argued that the current decisions taken by central banks depend on the interest rate level in the previous period, assuming that the central bank has complete control over the interest rate. Thus, the idea of smoothing behavior was incorporated with the interest rate.

The second criticism related to the unrealistic assumption that the economy is closed, but if the economy is open, the behavior of the exchange rate becomes an important issue (Esanov et al., 2005); (Kharie, 2006); (Senay, 2008) in the monetary policy response function. Svensson (2000) identified three ways the exchange rate plays a role in the transmission channels for monetary policy: First, it affects the relative prices between domestic goods and foreign goods, subsequently affecting the aggregate domestic demand channel. Second, The exchange rate has an important role in forward-looking behavior and expectations in monetary policy. Third: External imbalances, such as changes in foreign inflation, changes in foreign interest rates, and foreign exchange risk premiums, are all factors that affect investor's decisions through the exchange rate.

Consequently, it was concluded that the Taylor rule would better describe monetary policy behavior if it included the exchange rate. Experiments have shown that monetary authorities in all countries tend to increase interest rates to deal with real currency depreciation.

The third criticism concerns the interaction between fiscal policy and monetary policy. In cases where fiscal policy suffers from problems such as the problem of tight fiscal space, fiscal policy will not only be ineffective, but it will also restrict the use of monetary policy tools (Tan & Mohamed, 2020).

On the other hand, if the budget deficit is financed through bond issuance, increasing pressure will occur on the domestic cost of credit, forcing the central bank to relieve this pressure through monetary policy tools and ultimately push the inflation rate higher. In short, the lack of fiscal space, the loss of financial instruments to effectiveness, and the lack of coordination between monetary and fiscal policies make the inflation-targeting system more difficult.

Thus, several recent studies have concluded that central banks must take into account financial variables when designing monetary policy (Kitano & Takaku, 2016); (Croushore & Van Norden, 2018) by including financial solvency, fiscal deficit, or government spending in the monetary policy response function.

In Egypt, by 2005, a change in the monetary policy occurred through restructuring the strategy for the intermediate goal, which is targeting inflation directly, and the operational goal of the overnight interbank interest rate, whether for deposits or borrowing or what is known as the Corridor System.

Except for the (Emam, 2021) study, which covered the period from 2005 to 2019, all previous studies that investigated the extent to which the Taylor rule was achieved in Egypt covered periods prior to Egypt's shift to an inflation-targeting policy and the short-term interest rate as an operational target after the year 2005. Among the important studies are (the El-Erian and El-Gamal, 2002) study, which covered the period of the nineties, (Moursi et al., 2007) study, which covered the period 2001-2006; and (Salim, 2012) study, which covered the period 2000 -2008.

Moreover, all of these studies for Egypt did not investigate fiscal policy's impact on monetary policy behavior within the augmented Taylor rules framework.

The importance and problem of the study

This study is of great importance, as it provides a transparent description of the behavior of the monetary policy used in Egypt from 2006 to 2020, using monthly data. This is done by shedding more light on the monetary policy reaction functions in Egypt by testing seven different descriptions of the monetary policy reaction function, based on the Taylor rule, which includes information about the exchange rate and government spending, thus strengthening the central bank’s reaction function and improving actual and potential behavior of the Monetary policy in Egypt.

Specifically, a good description of the Taylor function, which applies to the behavior of monetary policy, from the perspective of whether it is forward-looking or backward-looking, and knowing the parameter values of the inflation variables, the product gap, the exchange rate, and the fiscal policy index enables policymakers to determine the extent of the expected success of inflation targeting, and determining whether the central bank seeks to absorb inflation or confront inflation, the extent of its control over macroeconomic stability and the degree of coordination between monetary and financial policies.

In light of the previous importance, the problem under study is to answer the following main question: To what extent do augmented Taylor rules apply the exchange rate and government spending to the monetary policy behavior in Egypt?

Objective, scope, and methodology of the study

The study aims to determine what can be considered the best description of the augmented Taylor rules that apply to Egypt and explain the behavior of its monetary policy by using monthly data during the period since the application of the inflation targeting system, specifically from July 2006 or 2006M7 until January 2020 (or 2020M01), which is the previous month of Egypt's exposure to the Covid-19 virus.

The descriptive approach will be used in presenting and analyzing the theoretical framework of the subject matter of the study and the used model, then using the least squares method and the generalized moment's method (GMM) to test the hypothesis of the study, standardly by the discretion of seven different descriptions of the Taylor rule, which are three descriptions of the simplified contemporaneous Taylor rule, of backward-looking, and forward-looking, two descriptions of the augmented Taylor rules of forward-looking and backward-looking by adding the exchange rate, and two descriptions of the rule that includes government spending as an indicator of fiscal policy with the exchange rate.

To achieve the goal of the study, the study will be divided into 1) Current developments in the monetary policy in Egypt, 2) Review of previous literature, 3) The theoretical framework of monetary policy rules, 4) Description of the augmented Taylor rules, 5) Data, discretion results, and interpretation of the results, 6) Results and recommendations.

1- Current developments in monetary policy in Egypt

First: Monetary policy background for targeting inflation:

The impact of the trends of steering nominal interest rates in the Egyptian money market in the short term has become the operational goal of monetary policy. However, the intermediate goal of monetary policy remained the level of domestic liquidity M2. This was done using the following three monetary tools: the

reserve ratio, open market operations, and the existing facilities.
In 2003, it was announced that the shift away from the monetary aggregate M2, as a tool for achieving the monetary policy to targeting the inflation rate directly by moving towards relying on the interest rate, instead of directly controlling primary instruments, on the basis that the monetary transmission mechanism (to directly influence the level of product, which is reflected on inflation), starts from the interest rate. By 2005, a change occurred in the monetary policy in Egypt through the restructuring of the strategy of its ultimate and operational objective, as follows:

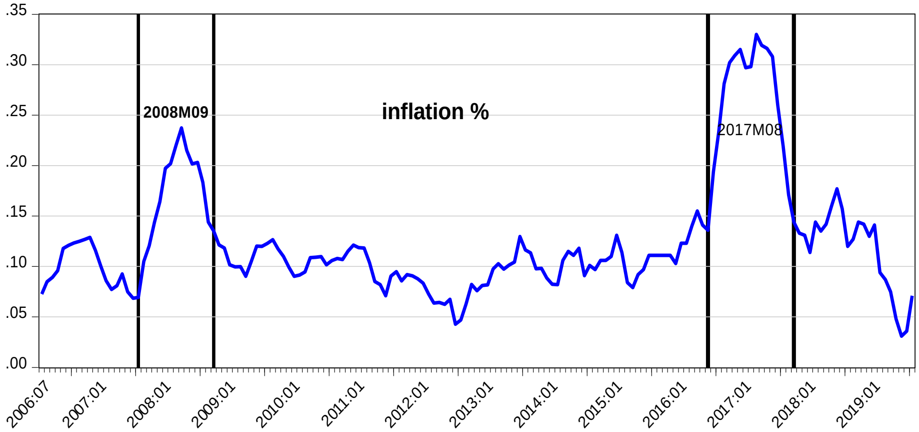
- **Corridor System**: This system is considered the main tool of the monetary policy to achieve the operational goal represented in two overnight interest rates. The first is overnight Interbank rates, in which the overnight deposit interest rate represents the minimum, and the overnight lending interest rate represents its maximum. The interest rate on loans and deposits was also used as a medium-term monetary instrument.
- To meet liquidity requirements, the Cash Reserve Ratio, the rate of total deposits held by commercial banks, was used. To influence liquidity in the market, Open Market Operations were used through buying and selling financial assets, especially treasury bills. As of 2006, the central bank used a tool called central bank notes to absorb excess liquidity from banks.

Second: The performance of monetary policy from 2006-2020.

As Figure (1) shows, inflation rates during the study period increased significantly during two periods: the first period occurred during the years 2008 and 2009; this was concurrent with and after the global financial crisis of 2007/2008. After that, the subsequent period witnessed the effects and repercussions of the January 25, 2011 revolution, as this period was characterized by a severe decline in economic growth rates, achieving a negative growth rate (-3.8). In addition, this period was also characterized by a widening gap between inflation rates and real growth rates of domestic production.

Figure (1)

The development of the monthly inflation rate in Egypt from 2006 to 2020



For this reason, in 2012, the Central Bank made the following:

- Added additional liquidity to banks to address the lack of liquidity in the local currency due to the withdrawal of deposits by investment funds and their use of part of their available liquidity to buy the dollar needed to cover foreigners' requests.

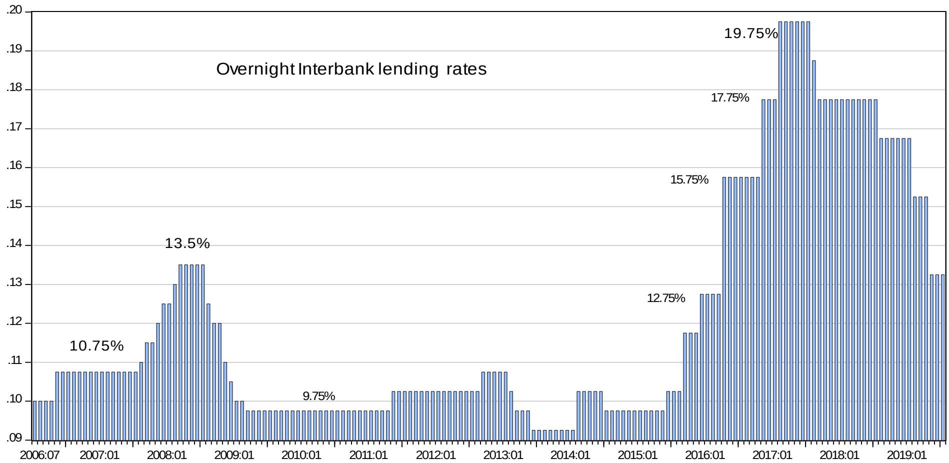
• Reducing the legal reserve ratio from 14% to 10% to provide banks with more liquidity.

• Maintaining the interest rate in the interbank market (corridor) at 9% for deposits and 10% for lending until the end of 2015, as shown in Figure (2).

Then, the year 2016 witnessed an increase in the dollar's exchange rate from 7.63 Egyptian pounds to 8.88 Egyptian pounds, with a gap found between the official exchange rate and the exchange rate on the black market, which led to an increase in the general level of prices.

Figure (2)

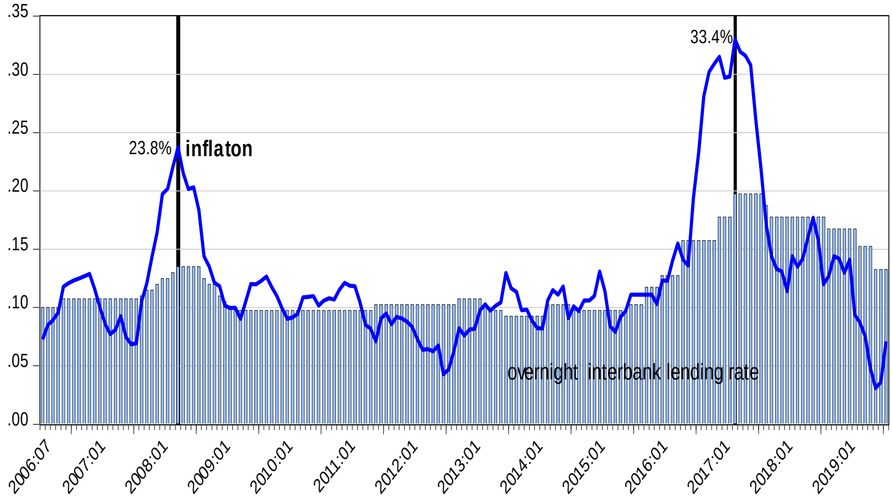
Overnight interbank lending interest rate



Although the Central Bank raised the Corridor interest to 11.75% for deposits and 12.75% for lending, inflation rates reached 14% in 2016, compared to the inflation rate at the end of April 2017, which reached 33.4%.

Figure (3)

The relationship between overnight interbank lending interest rate movements and inflation rate fluctuations



On November 3, 2016, it was announced that the Egyptian pound would be floated and that subsidies on petroleum products would be reduced. This led to a decline in the value of the Egyptian pound by about 50% and an increase in the price of petroleum products to 45%. The price of the U. S. dollar against the Egyptian pound reached 13.5 Egyptian pounds and also rose at the end of November to 17.7 Egyptian pounds; then it rose again on December 20, reaching a peak price of 19.13 Egyptian pounds. After this inflationary wave, the Central Bank took several measures, including raising the Corridor interest to 14.7% for deposits and 15.75% for lending.

In 2017, the inflation rate continued to rise, reaching its highest level of 33.4% in September 2017, the second rise in the inflation rate. This wave came in the wake of floating the exchange rate in Egypt, and the Monetary Policy Committee (MPC) responded by raising the interest rate on deposits and lending between Banks, and the latter reached 19.75% in the same month. At the beginning of February 2018, the inflation rate began to decline, and the MPC Committee responded by reducing the interest rate to 13.25% in January 2020 in light of an inflation rate of 7.1%.

From the previous presentation and Figures (2) and (3), the following can be concluded:

First, In the period from 2010 until late 2015, interest rates and inflation rates remained at relatively low and stable levels.

Second: The Central Bank of Egypt was raising the Overnight Interbank rates in the periods following the periods of increasing the inflation rate or reducing them after the inflation rate decreased, which means that the monetary authority in Egypt during the study period was accommodating and not fighting inflation because it follows the backward-looking of Past values of variables.

2- Review of previous literature

The emergence of the Taylor rule led to more studies focusing on models of central banks' rules and behavior. Using quarterly data, (Judd & Rudebusch 1998) study estimated a simple model of the Federal Reserve's monetary reaction functions based on the Taylor simple rule, 1993. They found that the Taylor rule framework perfectly matches the behavior of US monetary policy from 1970 to 1997.

Then, the study (Seyfried & Bremmer, 2001) expanded the previous study by including different inflation indicators and concluded the same conclusion, which is that Taylor's rules are considered an effective way to design monetary policy. Accordingly, from a theoretical point of view, the simple Taylor rule can give a good description of the behavior of central banks.

In seeking optimal monetary policy, there has been a widespread belief that Augmented Taylor rules would be better suited than simple rules. Consequently, many studies have attempted to determine the optimal monetary policy to achieve the goals of price stability and full employment within the framework of Taylor's rules.

The first modification to Taylor's rule came in a study by (Svensson, 1999), who argued that the simple backward-looking policy for targeting inflation is the optimal response function for monetary policy. On the contrary, a study by (Jondeau Le Bihan, 2002) found that the forward-looking target inflation applied in

Germany is optimal because it led to Inflation stability and increased product.

Accordingly, some researchers studied performance according to the future outlook, such as, for example (Clarida et al., 1998), who generalized the simplified Taylor rule by incorporating future behavior and concluded that it represents the best behavior for determining interest rates in developed countries. At the same time, other studies have found that the Taylor rule, backward-looking, is the most appropriate for developing and emerging countries.

Regarding the role of the exchange rate: The study of (Moura De Carvalho, 2010) showed that Taylor's rules with exchange rates led to results with high predictability in seven emerging economies in Latin America, compared to the simple Taylor rule. The exchange rate effect has also been validated by (Hsing, 2004); (Hsing & Lee, 2004), who studied the monetary reaction function of the Bank of Canada and the Bank of Korea.

On the contrary to these results, the study of (Osawa, 2006) revealed that the central banks of Korea, Thailand, and the Philippines, which target inflation rates, did not respond to changes in the exchange rate. A similar result was also found by (Sek, 2009), who extended the previous study to the period before and after the financial crisis that occurred in 1997.

Regarding the interaction between fiscal policy and monetary policy, some recent studies (Kitano & Takaku, 2016); (Croushore

& Van Norden, 2018) have shown that central banks must take into account financial variables such as government spending, financial solvency, or fiscal deficit when designing monetary policy.

These studies have shown the importance of fiscal policy. However, no consensus has been reached on whether the central bank should target public finance variables with monetary policy variables, as the study (Hasanov & Omay, 2008) discovered that the Turkish monetary authority did not react to the budget deficit, except during periods of economic expansion. Before that, a study conducted (Zoli, 2005) concluded that the financial position of emerging market countries did not affect monetary policy behavior.

Regarding Egypt, in a multi-country study (Egypt, Jordan, Kuwait, Saudi Arabia, and Tunisia), the study (El-Erian & El-Gamal, 2002) estimated the parameters of the Taylor function in the presence of the exchange rate and its absence during the 1990s. For Egypt, the inflation parameter was -0.63. The output gap was 0.34, under the assumption of a closed economy. When the exchange rate was included, the Taylor rule parameters were negative: 0.81 for the current inflation, 0.21 for the output gap, and 9.69 for the exchange rate. The product gap parameter was insignificant in both figures. The study of (Moursi et al., 2007) estimated Taylor's rule for the closed economy from 2001 to

2006, and the inflation gap parameter was slightly less than the unity (0.93).

The study (Salim, 2012), by using the Taylor function, which was modified by Clarida, Galí, and Gertler (CGG) (1998), concluded that monetary policy in Egypt, while using monthly data during the period 2000- AD ton 2008 AD, had accommodated inflation. However, it was not forward-looking and did not provide evidence of the impact of changes in the exchange rate.

By comparing the results of the linear and non-linear Taylor rule discretion, the study of Baaziz and Labidi (2014) concluded that the non-linear form of the Taylor rule best describes the linear form of monetary policy behavior in Egypt from 2008 to 2013. Finally, the study (Emam, 2021) concluded that monetary policy in Egypt from 2005 to 2019 was appropriate for inflation. However, the Central Bank of Egypt responded unevenly to inflation, product, and exchange rate shocks.

3. The theoretical framework of monetary policy rules

According to the study (Taylor, 1999b), a Monetary Policy Rule can be defined as a description - expressed algebraically, numerically, and graphically - of how policy tools, such as (the monetary rule or the discount rate) change, in response to fluctuations in macroeconomic variables (such as inflation and product). The closest and simplest example of the policy rule is the rule of constant growth rate of the money supply. The literature on rules versus discretions points to a clear distinction between:

First, the simple instrument rules, proposed by (McCallum, 1988) (Taylor, 1993), and the rules of the instrument are the contingent reaction functions that link the policy instrument with performance indicators of the economy (Meltzer, 1987). These rules are easy to follow, require little information, and are robust and technically feasible, meaning that adherence to the rule can be easily verified.

Assuming the inflation deviation coefficient is less than zero. Then, the higher inflation would lead to a lower interest rate, leading to increased spending. In turn, this would increase the aggregate demand and, thus, further increase inflation. On the other hand, if it is greater than zero, this instability does not exist because the rule ensures that inflation equals its target value π^*.

Second, for targeting rules presented by (Svensson, 2003), Some central banks adopted a detailed framework to maintain the target inflation rate and the correct product track during the 1990s. This framework begins with a rule that allows some discretionary power to central bank governors. This strategy was then called "constrained discretion" by (Bernanke & Mishkin,1997) and a targeting rule by (Svensson,2002). They are as follows: The central bank announces a numerical inflation target (a point target or a target range), and the monetary policy has a legislative mandate to achieve this target through clear, effective

independence. There is a high degree of transparency in monetary policy and accountability of concerned parties. Inflation expectations are taken as an intermediate target.
Within targeting rules, a distinction is also made between general targeting rules and specific targeting rules. In this context, central banks collect a large amount of data and use a complex policy to formulate and determine the path of the instrument that should satisfy First-order optimal Euler conditions. There is also a clear role for discretion in formulating and implementing monetary policy (Svensson, 2005).
Consequently, the logic that attracted researchers and decision-makers in the field of monetary policy to the Taylor rule during the 1990s is that it offered the tool rule for conducting monetary policy operations by identifying a target nominal rate of interest on federal funds (the operational target) in the short term i_t^* , which is equal to the sum of the “balanced” or natural real interest rate on the long-term, r, the current inflation rate, $\boldsymbol{\pi_t}$, plus the weighted average $\theta_\pi$of the monetary authority’s response to the deviation of the current inflation rate, π_t, from the target rate, $\pi*$, and the weighted weight, β_y, of the percentage deviation of real GDP, y_t, from its probable level y_t^P. The following equation can describe the rule:
$i_t^* = r + \pi_t + \theta_\pi(\pi_t - \pi_t^*) + \beta_y\ (y_t - y_t^P)$**…………………(1)**
The constraints imposed on the parameters to achieve macroeconomic stability are:

$$\theta_\pi \geq 0,,,,\beta_y \geq 0$$

Specifically, Taylor gave a value of 1.5 to the weighed weight of the deviation of the inflation rate from the target rate $\theta_\pi = 1.5$, to reflect the “Taylor principle,” as when the inflation rate rises above the target inflation rate, the real interest rate should increase by more than one for one. He also gave a value of 0.5 for the weighed weight of the outcome gap, β_y.

In order to estimate Taylor's rule, it can be rewritten as follows:

$$i_t^* = \alpha + \beta_\pi \pi_t + \beta_y y_t^g + \varepsilon_t \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .. (2)$$

Where: $\alpha = r - \theta \pi_t^*$, $\beta_\pi = 1 + \theta$, $y_t^g = (y_t - y_t^P)$, represent the product gap.

Ɛ External random error of the interest rate

One of the important amendments to the original Taylor rule is what was presented by the study of Clarida, Galí and Gertler (CGG) (1998), by adding an amendment that embodies the desire of central banks to facilitate changes in interest rates that is, they provide small steps in the policy rate, in order to achieve the desired change in the long-term balanced interest rate, which is a parameter that measures the degree of smoothing of the current interest rate, with the previous interest rate and is referred to by the symbol ρ.

Consequently, the current nominal interest rate i_t is determined by the interest rate of the previous period ρi_{t-1}

$$i_t = (1 - \rho) i_t^* + \rho i_{t-1} + \varepsilon_t \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (3)$$

So that $\mathbf{0 \leq \rho \leq 1}$ is the smoothing parameter. Moreover, the larger values of the parameter ρ indicate a slower adaptation speed. This adjustment leads to, First, increasing the impact of the policy decision on current production and inflation without requiring major changes in the interest rate. Second: Moderate response of interest rates would avoid interest rate volatility and, thus, limit financial market turmoil and reduce capital losses for financial institutions exposed to interest rate risk. Third, It accommodates uncertainty about economic structure parameters (due to incomplete information) and a certain degree of data measurement error.

4- Description of augmented Taylor rules

To determine the best description of the Taylor rule that applies to Egypt and explains the behavior of monetary policy in Egypt during the study period, the study estimated seven different descriptions as follows:

The first description: By replacing equation (2) in equation (3), we obtain the simplest description of the Taylor rule using contemporaneous current values, under the assumption of homogeneity of the interest rate, or the following equation (4), which can be estimated by using OLS:

$$i_t = (1-\rho)\alpha + (1-\rho)\theta_\pi \pi_t + (1-\rho)\beta_y y_t^g + \rho i_{t-1} + \varepsilon_t \ldots\ldots\ldots (4)$$

Where $\boldsymbol{\theta\pi}$: shows the central bank's position on the inflation. If $\theta\pi > 1$, then the priority for the central bank will be to fight inflation, and if 0< θπ <1; then, the central bank will respond by increasing the interest rate in order to reduce inflation. This condition only allows monetary policy to accommodate inflation because the increase in the interest rate will not be sufficient to cause a reduction in the real interest rate.

The parameter βy shows the central bank's position on the product gap. If βy > 0, the central bank can move the interest rate to achieve stability in the product.

The second description presented by the study of (Kozicki, 1999); (Clarida et al., 1998), who refer to the description of the forward-looking Taylor rule:

$$i_t = (1-\rho)\alpha + (1-\rho)\theta_\pi \pi_{t+1} + (1-\rho)\beta_y y^g_{t+1} + \rho i_{t-1} + \varepsilon_t \;\ldots (5)$$

In which the current inflation rate is replaced by the expected inflation rate for the following month, and the current product gap is replaced by the expected gap in the following month, as some studies have shown that the forward-looking rule has the advantage of developed countries.

Third description: The backward-looking Taylor rule

Because the future values of the inflation and product gap are unknown, and slower inflation may affect inflation expectations in emerging economies, the expected values have been replaced by the past values of the inflation and product gap, as policy interacts with the inflation and product gap in the previous month.

$$i_t = (1-\rho)\alpha + (1-\rho)\theta_\pi \pi_{t-1} + (1-\rho)\beta_y y^g_{t-1} + \rho i_{t-1} + \varepsilon_t \dots\dots (6)$$

Fourth description: Taylor's forward-looking rule that includes the exchange rate

According to criticism (Ball, 1999; Moura & De Carvalho, 2010), as well as most previous studies on Egypt, it is necessary to include the Taylor rule in the exchange rate because the stability of the exchange rate represents one of the goals of the Central Bank. Thus, to test how the central bank responds to changes in the exchange rate, the product gap, and inflation, the forward-looking augmented Taylor rules for the exchange rate take the following form:

$$i_t = (1-\rho)\left(\alpha + \theta_\pi \pi_{t+1} + \beta_y y^g_{t+1} + \beta_s s_t\right) + \rho i_{t-1} + \varepsilon_t \dots\dots\dots. (7$$

Fifth Description: Taylor's backward-looking rule that includes the exchange rate

$$i_t = (1-\rho)\left(\alpha + \theta_\pi E\pi_{t-1} + \beta_y E y^g_{t-1} + \beta_s s_t\right) + \rho i_{t-1} + \varepsilon_t \dots (8$$

Where **St** is the exchange rate in period t, βs is the exchange rate parameter, and if βs > 0, the central bank will increase the interest rate if the exchange rate rises to stabilize the foreign exchange market. However, the interest rate will remain relatively low when the exchange rate rises. However, if βs = 0, the central bank will not change the interest rate to stabilize the exchange rate.

Sixth Description: Taylor's forward-looking rule enhanced by the exchange rate and government spending:

It is known theoretically and practically that there is an interaction between monetary policies and fiscal policies. However, the Taylor rule does not take fiscal policy into account. By augmenting the Taylor rule to include financial policy variables, the central bank is the only institution capable of ensuring financial solvency to stabilize the price level. Consequently, it should interact with financial variables when setting its policy. To test the impact of fiscal policy, government spending $\boldsymbol{f_t}$ was added to equations (7) and (8) to form the two equations (9) and (10). Here are the augmented forward-looking and backward-looking Taylor rules with the government spending variable:

$$i_t = (1-\rho)\left(\alpha + \theta_\pi E\pi_{t+1} + \beta_y E y_{t+1}^{g} + \beta_s s_t + \beta_f F f_t\right) + \rho i_{t-1} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots\dots (9$$

Seventh Description: Taylor's backward-looking rule, enhanced by the exchange rate and government spending:

$$i_t = (1-\rho)\left(\alpha + \theta_\pi E\pi_{t-1} + \beta_y E y_{t-1}^{g} + \beta_s s_t + \beta_f f_t\right) + \rho i_{t-1} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots.. (10$$

Whereas $\boldsymbol{\beta_f}$ represents the government spending parameter $\boldsymbol{f_t}$ (assuming constant taxes), and its sign is expected to be negative, as the negative sign $\beta f < 0$ indicates that when fiscal policy is expansionary (increasing government spending or budget deficit), the central bank will expand monetary policy (lowers the interest rate). This goes in line with the study of Sargent and Wallance (1981), who find that fiscal expansions will eventually lead to augmented monetary policy.

If $\boldsymbol{\beta_f < 0}$, then the borrowing from the central bank will weaken the monetary policy position. On the other hand, if $\boldsymbol{\beta_f > 0}$, then the government spending and interest rates will change in a different direction, indicating that monetary and fiscal policies are moving in conflicting directions. This also means that the effect of borrowing from commercial banks exceeds that of borrowing from the central bank. If $\boldsymbol{\beta_f = 0}$, the government spending does not directly affect the central bank's behavior.

5/ Data, discretion results, and interpretation of the results

5/1 Data and its graphical analysis:

The monthly data used in calculating the variables used in the discretion are from July 2006 (2006M07) to January 2020 (2020M01). This period was chosen for two reasons. First, It is the period for which data on the Monthly Total Production Index (TPI) was published, which immediately preceded Egypt's exposure to the COVID-19 epidemic, which will be used to calculate the monthly product gap. The indicator data was collected from the Ministry of Planning and Economic Development website.

As for the overnight lending rate between banks as a monthly indicator, the monthly inflation rate, the monthly nominal exchange rate, and the quarterly government spending (which was converted to monthly) from the website of the Central Bank of Egypt (CBE), and the data was completed from the Central Bank's economic magazine, several versions.

Except for the aggregate production index, all data are monthly and seasonally adjusted using the Census X-13 method.

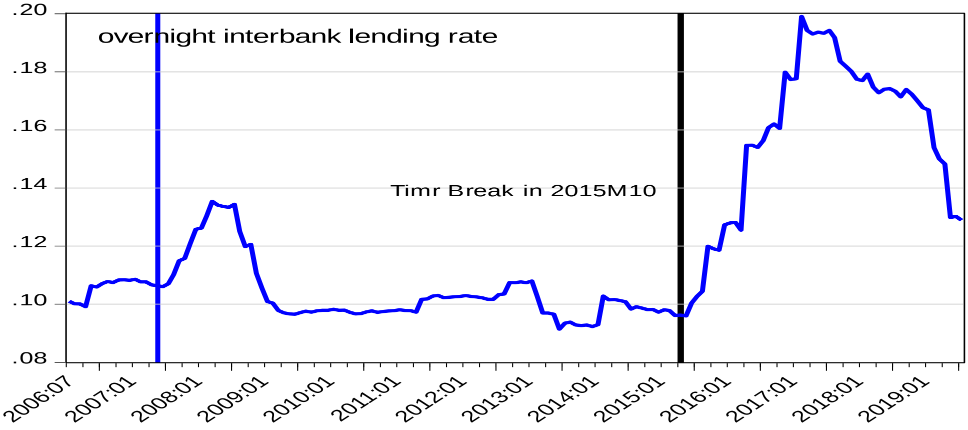
First: The dependent variable: the interest rate on overnight lending between banks i_t. As a monthly average.

Figure (4) shows that the interest rate on Egyptian interbank lending underwent two structural changes, the largest of which began in October 2015.

Consequently, the breaking point in the interest rate series begins in October 2015 or 2015 M10. This observation is important when testing the static time series.

Figure (4)

Overnight interbank lending rate



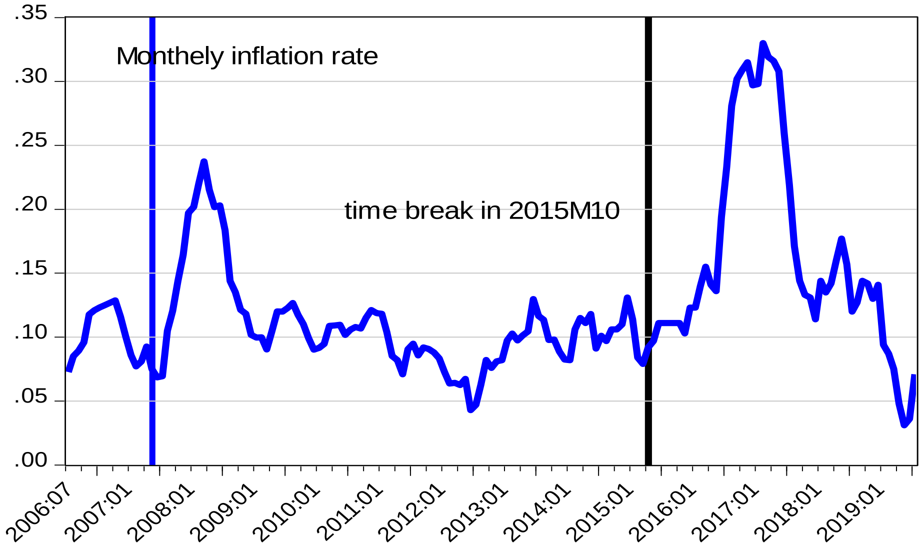
Second: The explanatory variables are:

▪ Current inflation rate as monthly average π_t:

Figure (5) shows that the inflation rate recorded two increases or underwent two structural changes, the largest of which also began in October 2015.

Figure (5)

Monthly inflation rate in Egypt (July 2006 until January 2020)



Consequently, the breakpoint in the inflation rate series begins in October 2015 or 2015 M10, and this observation is important when testing the static time series.

▪ Lagged inflation rate, π_{t-1} : It represents the one-period lagged value of the current inflation rate π_t.

▪ Future inflation rate, π_{t+1}, which represents the one-period-ahead value of the current inflation rate π_t.

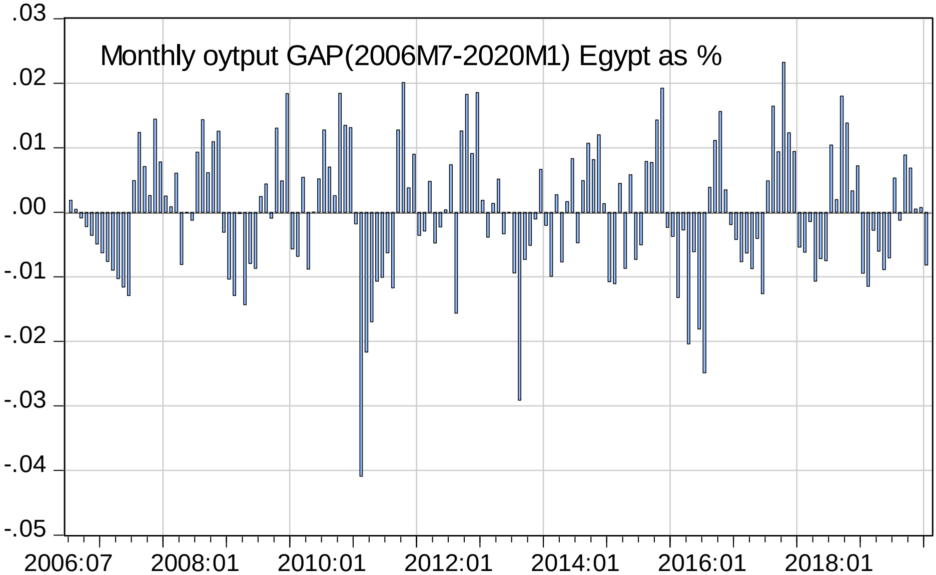
- Real GDP gap, y^G, the monthly GDP index was used to calculate the output gap, and the output gap will be determined by the determination of the potential output y^P, through using the Hodrick-Prescott filter from the data of the monthly GDP index y (see Appendix).

The percentage output gap y^G *(%)* was calculated by using the equation: $y^G = \left(\frac{y-y^P}{y^P}\right)$

Figure (6) shows that the number of positive and negative output gaps is approximately equal during the study period. From the figure, it is clear that the Egyptian economy entered a recession period during the period from September 2006 to July 2007; then, the largest negative gap that the Egyptian economy was exposed to came in February 2011, at a rate of negative 4.1% and continued until August of the same year. Consequently, it can be said that the Egyptian economy entered a recession during this time, and the second largest negative gap came in August 2013, at a ratio -2.4%.

Figure (6)

Evolution of the output gap in Egypt (July 2006 to January 2020)

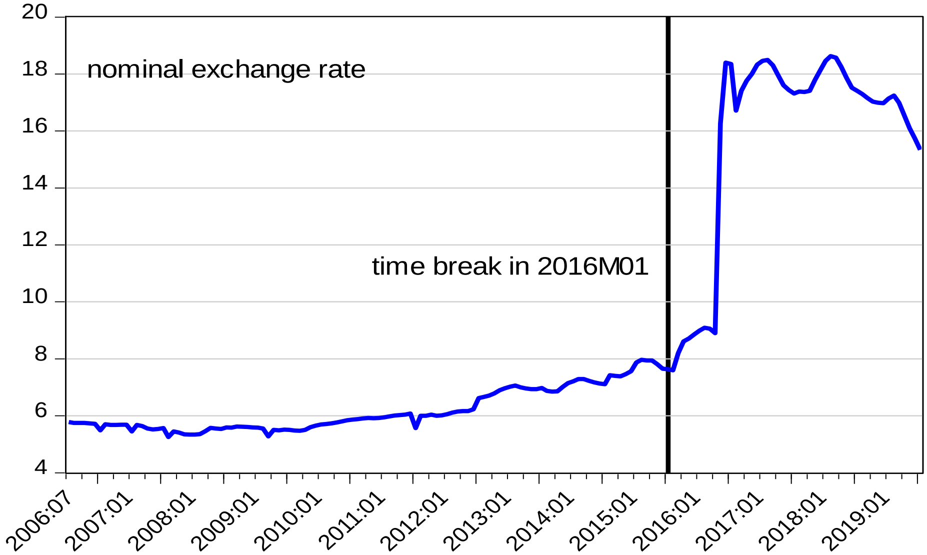


If we focus on the positive gap directly related to inflation, the Egyptian economy witnessed the highest inflationary wave when it recorded the largest positive output gap in September 2017.

It is clear that the output gap appears static graphically, and the breaking point will be automatically chosen by using the package used in the measurement (EViews.10).

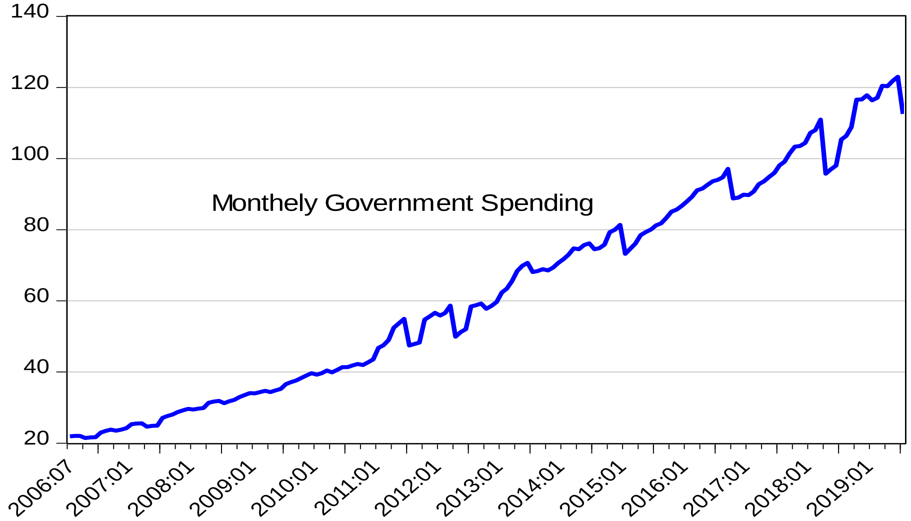
Figure (7)

The development of the nominal exchange rate in Egypt (July 2006 until January 2020)



▪ The nominal exchange rate: Figure (7) shows that the exchange rate fluctuated normally until the end of 2015. However, it witnessed a major structural change that began in January 2016 in preparation for floating the exchange rate in October of the same year. Consequently, the exchange rate series breakpoint begins in January 2016, or 2016M01. This observation is also important when testing the static time series.

Figure (8)
Evolution of government spending in Egypt (July 2006 to January 2020)



Government expenditure: Figure (8) shows that the government expenditure variable series includes an increasing time trend and that they also have breaks during the year. This should be considered when testing the unit root in the government expenditure series.

5/2 Unit root test results

The basic condition for using the original variables in the estimation is stationary time series used in the estimation, meaning that they do not include a unit root. The traditional unit root tests may lead to unreal results by accepting that the series is not stationary; while it is stationary, it includes a structural change. This fear exists because the graphical analysis of the data has proven that the variables include structural breaks in some years.

Therefore, the presence of a unit root will be tested, under the assumption of the presence of a Time Break (TB) point in the series data, with the following two tests: The first test, Innovational Outlier (IO), which assumes that there is a gradual change in the mean of the time series. The second test is additive outliers (AO), which assumes a sudden shift in the mean of the time series; that is, the presence of sudden structural changes in the data.

Based on the graphical examination of the data, a unit root test will be conducted under the following assumptions:

• The beginning or time of break (TB) for the interbank interest rate and the inflation rate variables is in October 2015 or 2015M10.

The exchange rate variable's Time Break(TB) is January 2016 or 2016M01.

• The Time Break (TB) for the exchange rate variable is January 2016, or 2016M01.

• The slowdown period is 4 periods for all variables.

• All tests for the unit root will be in the presence of the constant only, except for the government spending series, which will be in the presence of the constant and the time of the series and break.

Table (1) shows that all-time series, namely the interbank interest rate, the inflation rate, the output gap, the nominal exchange rate, and government spending, do not include a unit root, meaning that the series is stationary, and they are integrated of order zero, I(0).

Therefore, the study will use the original values of all variables after logarithmic transformation, except for the interest rate and inflation rate series, which were used as decimal values.

Table (1)

Results of the unit root test in the presence of structural changes

Symbol	Variable	Innovational Outlier (IO) t-Statistic	Innovational Outlier (IO) TB	additive outliers (AO) t-statistic	additive outliers (AO) TB
Interbank interest rate	i_t	-3.7** (4)	2015M10	-3.76** (4)	2015M10
Inflation rate	π_t	-3.7** (4)	2015M10	-3.68** (4)	2015M10
Output gap	*yG*	-7.7*** (0)	2007M05	-8.15*** (0)	2011M02
Nominal exchange rate	*ex*	-3.86** (4)	2016M01	-4.27*** (4)	2016M01
Government spending	*G*	-5.07*** (4)	2010M03	-5.91*** (4)	2012M03
	CV^{+++}	*-3.542*		*-3.507*	

This estimation and all the following estimations and tests were performed using the E Views 10 package.

****, *** are Significant at the 5% and 1% levels, respectively.**

TB=Time Break.

The test was carried out under the assumption of Lags = 4 and the constant only for all variables except government spending, under the constant, and time in the series, and Break, the critical value CV +++ , at 5%.

t-Satistic represents the Augmented Dickey-Fuller test statistic, and the numbers in parentheses are the slowdown period --

5/3 Justifications for using the GMM method to estimate Taylor’s rule and deriving its amount.

When using the augmented Taylor equation to test and describe the behavior of monetary policy in Egypt, we face several problems related to the characteristics of the estimated parameters in terms of consistency and lack of bias, which are:

First: the problem of measurement errors. The output gap variable is used as an approximate indicator of the true marginal cost, which is also calculated through the estimation of the production function, and one of the production function variables (the capital) is an unobserved variable. Also, the output gap can be calculated by many statistical methods, each with drawbacks.

Second, Including the backward-looking interest rate as an explanatory variable means that there is a problem with the existence of a correlation between the explanatory variables and the error limit. These variables can be described as endogenous variables, which violate the condition of using the ordinary or weighted least squares method.

We can use the two-stage least squares (2 SLS) method to estimate the model parameters. However, the following conditions should be met: First, We should have good variables or auxiliary tools (i.e., variables that are not related to the remainder of the equation but are related to the independent variables of regression). Second, If we used the actual values as an alternative indicator for any expected future values, we should add a moving average errors variable. Third, we should ensure that the residuals have the properties of non-autocorrelation or heteroskedasticity by adding sufficient lagging variables. For this last reason, the generalized moments method (GMM) will outperform TSLS, as GMM can correct the problems of non-stationarity of variance and autocorrelation.

For this reason, most previous studies used the Generalized Method of Moments (GMM), which partially avoids the previous three problems, which are from the family of what is known as limited information methods. (For the derivation of the GMM amount, see the appendix).

However, the basic condition is that the forecast error in the interest rate is not related to the set of information included in the matrix of variables or auxiliary instruments Zt, or what is known as the Instrument **Orthogonality** condition. For example, if the third description is used in the estimation:

$$i_t = (1-\rho)\alpha + (1-\rho)\theta_\pi \pi_{t-1} + (1-\rho)\beta_y y_{t-1}^{g} + \rho i_{t-1} + \varepsilon_t \ldots\ldots (6)$$

The following statistical **Orthogonality** condition should be met:

$$E\{(i_t - (1-\rho)\alpha - (1-\rho)\theta_\pi \pi_{t-1} - (1-\rho)\beta_y y_{t-1}^{g} - \rho i_{t-1}) Z_t\} = 0$$

Whereas Z_t represents the set of variables or Instrumental variables.

5/4 Estimation results

First: Diagnostic test results

The OLS method was used to estimate the simple Taylor equation; then, the GMM method was used to estimate the parameters of the rest of the Taylor rule specifications. In the light of existing Instrumental variables, which are the backward-looking values of four periods for all variables, it is clear from the diagnostic tests for the six descriptions in Tables (2), (3), and (4) that.

▪ All probability values for the J-statistic are greater than 5%, meaning that it is possible not to accept (reject) the null hypothesis, meaning there is a problem of over-identification in describing the six relationships.

▪ The probability of the statistical C-test or Eichenbaum, Hansen, and Singleton (EHS) Test, which tests the orthogonality or statistical independence (Instrument Orthogonality Test) between the auxiliary variables and the estimated parameters, leads to accepting the null hypothesis, which says that the variables or tools that were chosen are suitable to be valid instruments because the probability values exceed 5% for all descriptions.

Table (2)
Results of estimating Taylor's basic rule

	Estimated parameters					**Quality of Description**		**Diagnostic tests**	
Description	ρ	$\theta\pi$	β_y	β_s	β_f	**R^2**	**D-W**	J-statis (Prob)	**C-test (Prob)**
1-Simple Taylor rule	0.94*** (67.1)	0.64*** (5.364)	0.753 (1.314)	--	--	0.98	2.112	--	--
2-Forward-looking	0.964*** (104.1)	0.71*** (5.38)	0.54 (0.26)	--	--	0.98	2.227	11.26 [0.258]	2.014 [0.569]
3-Backward-looking	0.958*** (79.8)	0.65** (3.93)	0.72 (0.87)	--	--	0.98	2.064	12.86 [0.169]	3.792 [0.285]

The numbers in parentheses ( ) represent the t-statistic, and those in parentheses [ ] represent the probability.

****,*** Significant at 5% and 1% levels, respectively.**

▪ Based on the results of the diagnostic tests, the R2 coefficient, the value of the D-W statistic, and the number of significant parameters, it is clear that the descriptions that rely on backward-looking are the best descriptions, meaning that the Monetary Policy Committee of the Central Bank of Egypt does not have a forward-looking view when identifying the interest rate as an operational target.

Table (3)
Results of the augmented Taylor rules for the exchange rate

	ρ	$\theta\pi$	β_y	β_s	β_f	R^2	D-W	J-statis (Prob)	**C-test (Prob)**
4-Forward-looking	0.949*** (52.62)	0.604** (3.27)	0.55 (0.355)	0.012 0.608	--	0.98	2.234	12.689 [0.392]	2.891 [0.576]
5-Backward-looking	0.91*** 34.35	0.326** 3.995	0.370 1.215	0.004*** 5.371	--	0.98	2.062	14.83 [0.251]	2.170 [0.705]

The numbers in parentheses ( ) represent the t-statistic, and those in parentheses [ ] represent the probability.

****,*** Significant at the 5% and 1% levels, respectively**

Since one of the study's objectives is to identify the role of the exchange rate and government spending on the behavior of the monetary policy function response, the seventh description in the second row of Table (4) is the best model according to all tests. Therefore, it can be considered as the standard model.

Second: Results of estimating Parameter and interpretation of results

- **Smoothing parameter for the backward-looking interest rate p**

It is clear from Tables (2), (3), and (4) that the values of the smoothing parameter for the backward-looking interest rate variable ρ range between 0.88 and 0.96 and that all of them are remarkably significant. This means that previous interest rate values take the greatest weight in formulating current interest rate decisions. This indicates that the Monetary Policy Committee of the Central Bank tends not to change interest rates strongly from one month to another but rather prefers to make slight, gradual changes to the interbank interest rate based on their values in the previous months so as not to disrupt the economy or cause unnecessary instability in financial markets.

Table (4)

Results of estimating the augmented Taylor rule for the exchange rate and government spending

	ρ	$\theta\pi$	β_y	β_s	β_f	R^2	D-W	J-statis (Prob)	C-test (Prob)
6-Forward-looking	0.939*** (41.40)	0.516** (2.46)	1.004 (1.014)	0.024 (0.609	-0.007 -0.241	0.98	2.241	13.226 [0.585]	3.420 [0.636]
7-Backward-looking	0.878*** 33.80	0.246*** 4.240	0.308* 1.680	0.064*** 5.141	-0.023** -2.215	0.98	2.045	14.980 [0.452]	3.556 [0.615]

The numbers in parentheses ( ) represent the t-statistic, and those in parentheses [ ] represent the probability.

***, **, *** are significant at the 10%, 5%, and 1% levels, respectively.**

▪ The impact of the inflation rate on the behavior of monetary policy:

a) It is clear from Tables (2), (3), and (4) that the parameter of the current, backward-looking, or advanced inflation rate θπ, was positive and significant in all descriptions and amounts to 0.246 in the seventh description in the second row of Table (4). This means that the inflation rate is important when making decisions regarding monetary policy in Egypt.

b) Specifically, a % increase in the inflation rate by 1% results in the Monetary Policy Committee increasing the interest rate by a quarter of a percentage point or 0.25%. This means that Egypt's monetary policy is based on accommodating inflation because the increase in the interest rate will not be sufficient to cause a reduction in the real interest rate.

c) But the value of the parameter $\theta\pi$ did not reach a value greater than one, as indicated by the Taylor rule; therefore, the central bank has not yet reached the point of confronting inflation, which is one of the conditions for applying the inflation targeting system.

- **The impact of the output gap on the behavior of monetary policy:**

a) The current, backward-looking, or advanced output gap parameter β_y was insignificant in all descriptions, except for the seventh description when the exchange rate and government spending were added. However, the level of significance was marginal, as the probability of rejecting the null hypothesis is more than 5% and less than 10%. This result (non-significant output gap) is consistent with the results of all previous studies on Egypt and perhaps with the results of most previous studies in developing countries.

b) The explanation may be that the Monetary Policy Committee at the Central Bank of Egypt does not give importance to the output gap when making monetary policy decisions. This may also be because the potential output used in measuring the output gap is considered an unobserved variable and can be estimated differently. Every method of estimating it has many drawbacks.

▪ **The impact of the nominal exchange rate on the behavior of monetary policy:**

a) The estimation results in Tables (3) and (4) show that exchange rate movements represent an important factor when making a decision regarding changes in interbank interest rates. The results of the backward-looking estimation descriptions in Table (4) indicate that the exchange rate parameter β_s is equal to 0.06, meaning that a decrease in the value of the Egyptian pound against the US dollar (an increase in the exchange rate) by 1%, is associated with an increase in the overnight interbank interest rate by 0.06%, and the shift to Restrictive monetary policy, to achieve stability in the exchange rate.

b) This can be explained as follows: The exchange rate system in Egypt during the period up to 2017 AD tends to be a managed float. In such a small and open economy system, currency depreciation is countered by selling foreign currency reserves to maintain the managed float. Intervention in the foreign exchange market leads to an increase in the supply of Foreign exchange and domestic money supply decrease, hence, upward pressure on domestic interest rates. This result is consistent with previous literature that supports the important role of the nominal exchange rate in influencing domestic monetary policy in Egypt (Moursi & El Mossallamy, 2007), (Hosny, 2014).

- **The impact of government spending on monetary policy behavior:**

a) The results of estimating the augmented Taylor rule with the exchange rate and government spending in the seventh description indicate that the government spending parameter β_f was negative and significant with a value of -0.023. This means that government spending influenced the decisions of the Monetary Policy Committee, as the Central Bank of Egypt facilitates monetary policy by reducing the interest rate when the government increases its spending.

b) This finding is consistent with the findings of studies, such as the study of (Saghir & Malik, 2017) on Pakistan and the study of (Tan & Mohamed, 2020) on Malaysia, Thailand, and Singapore, which found that higher budget deficits led to lower interest rates.

c) But it should be emphasized that the government's borrowing from the central bank will weaken the monetary policy position in this case.

Results and recommendations

This study aims to determine the characterization of the augmented Taylor functions of the role of the exchange rate and government spending, which apply to the behavior of monetary policy in Egypt from 2006M07 to 2020M01. Using the Generalized Moments Method (GMM) to test 6 descriptions of the simple and augmented Taylor function, and after verifying that the diagnostic tests were passed in terms of quality and distinction of the different descriptions, the study concluded the following results:

First, The Taylor rule, which looks at the variables' past values and is enhanced by the exchange rate and government spending, represents the best description of the behavior of monetary policy in Egypt during the study period.

Second, The Monetary Policy Committee of the Central Bank follows a backward-looking view and considers the slight gradual change in the interbank interest rate as an operational target based on the values of the past variables, where the smoothing parameter reached 0.88.

Third: The effect of the backward-looking inflation rate was positive and significant, with a value less than unity amounting to 0.264, which means that the central bank is accommodating inflation and not confronting it because the value of the parameter does not meet Taylor’s principle that the inflation rate factor should be greater than one.

Fourth: The effect of the output gap was insignificant in all descriptions, except for the modified formula of backward-looking on the exchange rate and government spending, in which the effect was weak and marginally significant, and the value of the parameter does not meet Taylor’s principle, which is that the output gap factor should be equal to 0.5.

Fifth: The effect of movements in the exchange rate was positive and significant, with a value of 0.06, and the effect of government spending was negative, significant, and with a value of 0.02. This means that the monetary authority in Egypt gives great importance to the exchange rate and fiscal policy when formulating monetary policy, compared to limited importance to fluctuations in the output gap.

This means that if the monetary authorities in Egypt wanted to control prices or stabilize output, they would not succeed unless the exchange rate stability was maintained and financial discipline was achieved. There is a need to coordinate policies to influence the targeted variables in the desired direction.

The central bank should consider fiscal policy variables when designing monetary policy because it is the only institution that can guarantee financial solvency.

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Study appendices

Appendix (1): Derivation of the GMM estimator

The easiest way to understand how to derive the GMM estimator, is to start with the IV Instrumental variables estimator for the two-stage least squares method, because the last estimator represents a special case of the GMM estimator:

Using matrices, and if we have a dependent variable y and explanatory variables x, the regression equation is:

$$y = X\beta + u \ldots\ldots\ldots\ldots\ldots E(uu') = \Omega$$

The matrix of explained variables X of order n×K, where n represent the number of observations and k represents the number of explanatory variables or parameters. Where some explanatory variables are internal variables related to the error limit, the violation $\boldsymbol{E(X_i\, u_i) \neq 0}$ occurs. Therefore, the matrix of explained variables X is divided into: X_1 as $\boldsymbol{K_1}$ Endogenous variables to be excluded, and the remaining variables X_2 as Exogenous variables, and with $\boldsymbol{(K\text{-}K_1)}$ parameters, which are the included variables unrelated to error.

The set of instrumental variables is Z, and its rank is n×L. They are all exogenous variables, meaning that E(Zi ui) = 0. The matrix of variables Z is divided into: Z1 with L1 parameters, which are the auxiliary variables that are excluded, Z2 with L2 parameters (L-L1) that are kept in the discretion Included, so that only the exogenous X2 variables and the remaining auxiliary variables Z2 remain in the discretion, that is, Z2≡X2. The above is explained as follows:

Regressors X = [X1 X2] = [X1 Z2] = [Endogenous Exogenous]
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The rank condition for identifying the equation is L ≥ K, meaning the number of excluded auxiliary variables must be at least equal to the number of internal variables. The equation is said to be exactly identified if L = K, and excessively discriminated if L > K.

The two-stage least squares (2SLS) estimator is:

$$\hat{\beta}_{IV} = (X'Z(Z'Z)^{-1}Z'X)^{-1}X'Z(Z'Z)^{-1}Z'y = (X'P_ZX)^{-1}X'P_Zy$$

Where Z' represents the rotated matrix,

The 2SLS estimator represents a special case of the GMM estimator. However, according to the GMM method, the auxiliary variables L give us a set L of moments, each moment as shown in the following equation:

$$g_i(\beta) = Z_i' u_i = Z_i'(y_i - X_i\beta$$

The externality of the auxiliary variables means the presence of a number L of moment conditions or statistical orthogonality (independence) conditions that verify that the parameter's actual value is equal to the estimated value. Therefore, the starting point for estimating GMM is to assume the existence of a set of moment conditions whose number is L, which the estimated parameters β and their number K must satisfy. The conditions can be very general, and each model for which estimation is required often has more specific moment conditions than parameters to be estimated. This instantaneous condition L≥K is written in the form: $E\big(m(y_t.\beta)\big) = 0$

Therefore, the focus when estimating GMM is on restricting the conditions of the moment, which can be written as the statistical orthogonality condition, between the remainders of the equation estimation and the set of auxiliary variables Zt, whose number is K, as follows: $E(Z_t, u_t(\beta)) = 0$

Where the remainders are in the equation $\boldsymbol{u_t(\beta)=u(y_t.X_t.\beta)}$. The traditional estimator of the GMM system is obtained by replacing the moment terms in Equation 7 as the corresponding sample estimator and estimating the parameters β as follows:

$$m_t(\beta) = \frac{1}{T}\sum_t Z_t u_t(\beta) = \frac{1}{T} Z^* u(\beta) = 0$$

However, if Equation 8 is overidentified, that is, when L>K, there is no definite solution, and therefore we can reformulate the problem as one of choosing the β parameters so that the sample moment $m_T(\beta)$ is "closed" to zero as much as possible, where "closure" is defined by using the quadratic formula:

$$J(\beta, \hat{W}_T) = T\, m_T(\beta)'\, \hat{W}_T^{-1}\, m_T(\beta)$$
$$= \frac{1}{T} u(\beta)' Z\, \hat{W}_T^{-1}\, Z' u(\beta)$$

Then, the required will be the estimation of β, which is the minimum of the objective function J No. 9, where W represents the weighting matrix, or by matrix method, the GMM estimator is: $\hat{\beta}_{GMM} = (X'ZWZ'X)^{-1}X'ZWZ'y$

Appendix (2): Steps to estimate the output gap using the Hodrick-Prescott filter

The resulting gap was estimated using a Hodrick-Prescott filter. This filter is based on the idea of separating the values of the actual output series Y_t (for which we will use the monthly production index as an indicator), into two components; the first:

the trend component (potential output Y_t^P) after its smoothing, and the second is the periodic component (residuals Y_t^C), under the assumption that the average values of the periodic component series are equal to Zero. The directional component whose sum of squared deviations of the values of the original series from their trend values is least is estimated under the assumption that the sum of the square of the second differences of the directional component series (growth rate or rate of change) is equal to zero. If we use the logarithmic transformation $\boldsymbol{y_t}$ and assumed that:

$$y_t = y_t^P + y_t^C$$

Where: y_t^P is the directional component y_t^C is the periodic component or the business cycle component; then, the directional component y_t^P can be obtained by minimizing the amount:

$$\left[\sum_{t=1}^{T} (y_t - y_t^P)^2 + \lambda \sum_{t=3}^{T} [(y_t^P - y_{t-1}^P) - (y_{t-1}^P - y_{t-2}^P)]^2 \right]$$

Where the symbol λ represents the smoothing or filtering coefficient

The output gap y^G ***(%)*** can be calculated by using the equation:

$$y^G = \left(\frac{y - y^P}{y^P}\right)$$