International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 50 No. 1 April 2025, pp. 598-611

Measuring US Core Inflation: A Structural Var Approach

Samuel Albert Andriamiarintsaina RANDRIANTSOAVINA

PhD in Economics at the University of Antananarivo (Madagascar), Faculty of Economics, Management and Sociology, Assistant Professor, Speciality : Money- Banking - Finance, Tel: (+261)32 40 891 66 / (+261) 34 92 710 58; E-mail: albertrandriantsoavina@gmail.com

Abstract: The main objective of this work was to determine the core inflation in the United States over the period from the first quarter of 1979 to the first quarter of 2023 based on the techniques of the methods of Blanchard and Quah (1989), Quah and Vahey (1995) and Marianno Matilla Garcia et al. (2002). We determine the core inflation using a structural VAR from the following five variables: Δy_t is the real GDP growth rate, $\Delta custr_t$ is the customs revenue growth rate, Δr_t is the change in the interest rate, Δp_t is the price growth rate and Δm_t is the change in the money supply.

The results obtained are fully consistent with those predicted by economic theory. Analysis of the graphics showed that core inflation remains above observed inflation in periods when the changes in the M3 money supply and the customs revenue growth rate were high and below it in periods when changes in the M3 money supply were moderate.

Keywords: Core inflation, Structural VAR approach, Customs Revenue, Monetary policies.

1. Introduction

The headline inflation rate can often be unstable due to strong fluctuations in commodity or energy prices.

Because of this instability of a key price index, economic managers may have difficulty in correctly assessing the core inflation and its outlook; it may be useful to rely on the core inflation rate, which excludes or minimizes the most unstable price variations in order to highlight the permanent or more durable component.

As a result, central banks must have a good indicator of the evolution of inflation in the long term or be able to isolate this long-term component from the supposed trend inflation and the short-term price factors that are supposed to be transitory or cyclical. Faced with this situation, several methods remain multiple and varied to this day.

Some, called "zero weight methods", proceed by eliminating components deemed too volatile in the price index. Others, older, ignore the individual information contained in price changes by simply smoothing current and past values of inflation rates, either by moving averages or by using the various other available filters. Most of the drawbacks of these different approaches are generally not based on economic theory. It is to fill this gap that other works, born following Blanchard and Quah (1989)[1], Quah and Vahey

[1] **Blanchard etQuah (1989)** . The Dynamic Effects of Aggregate Demand and Supply Disturbances, pp. 655-73.

(1995)[2], have developed the method of determining the Core inflation based on economic theory. Quah and Vahey (1995), Claus (1997)[3] and Jacquinot (1998)[4] exploit, in fact, the verticality of the Philips curve, generally accepted in economic theory, to determine the core inflation. Macroeconomic theory suggests that demand shocks and monetary shocks can have effects on short-term activity. Indeed, these shocks lead to inflationary pressures temporarily wrongly perceived by agents as variations in relative prices. These movements -perceived- in relative prices induce adjustments in the optimal behavior of agents and from there to a variation in supply and GDP. Due to these errors in the perception of the general price level, there is a temporary gap between the current general price level and the general price level anticipated by economic agents. In the long term, the impact of these shocks disappears when agents perceive the true general price level exactly.

During the period of anticipation errors, we therefore observe a correlation between the variation in the inflation or inflation rate and the variation in real GDP.

Since the core inflation is considered to be the purely trend component of inflation, it cannot have any real effects. It therefore has no long-term effect on the level of production. The other components that do not respect this neutrality are assimilated to short-term inflation or cyclical inflation. We are then faced with a problem of identifying shocks affecting the economy and that can be solved using a structural VAR model. It is therefore by exploiting this type of modelling that we propose to evaluate the core inflation in the United States.

2. Structural VAR Model and the Long-Term Restrictions Method

The presentation of the structural VAR model used in this subsection is considered necessary because the performance of the results obtained on the core inflation will depend on the specification of the VAR chosen. We first present the VAR model before applying the long-term restrictions method

2.1 Structural VAR Model

We assume that the US economy is affected at different times by five types of shocks: the supply shock, the customs shock, the interest rate shock, the demand shock and the monetary shock. These five shocks have impacts on the evolution of macroeconomic quantities in the US and we assume that the customs shock, the interest rate shock, the demand shock and the monetary shock have no long-term effects on real production, only the supply shock has a permanent impact on production while the other four shocks have only transitory effects on production.

The p-order structural VAR model is applied to the vector $X_t = (\Delta y_t, \Delta custr_t, \Delta r_t, \Delta p_t, \Delta m_t)'$ where Δy_t is the real GDP growth rate, $\Delta custr_t$ is the customs revenue growth rate, Δr_t is the change in the interest rate, Δp_t is the price growth rate and Δm_t is the change in the money supply.

$$\Phi(L)X_t = \varepsilon_t \qquad (1)$$

With : V ar(ε_t) =$\sum_\varepsilon$et $\sum_{j=1}^{p} \phi(L) = \phi_j L_j$

[2] **Quah, D., &Vahey, S. P. (1995)**. Measuring core inflation**.** The Economic Journal, 105,pp.1130–1144.

[3] **Clause I. (1997)**. A measure of underlying inflation for the United States, Bank of Canada, Working Paper 97-20.

[4] **Jacquinot P. (1998)** . L'inflation sous-jacente à partir d'une approche structurelle des VAR: une application à la France, l'Allemagne et au Royaume-Uni, Banque de France, Notes d'Etudes et de Recherche, Janvier, 51, pp.3-14.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
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The autoregressive form (1) admits the following Wold representation:

$$X_t = A(0)\,\varepsilon_t + A(1)\varepsilon_{t-1} + \ldots = \sum_{s=1}^{p} A_j \varepsilon_{t-s} \quad (2)$$

That is :

$$X_t = A(L)\varepsilon_t \quad (3)$$

With $A(L) = \sum A_j L_j$

It is then the observations of these five variables that will allow us to distinguish the five types of shocks mentioned above. The logarithm of real gross domestic production (y_t), the logarithm of customs revenue (custr), the level of the interest rate (r_t), the logarithm of inflation (p_t) and the logarithm of the money supply (m_t) are stationary in first difference and not cointegrated (in this study we follow the approach of Quah and Vahey).

This allows us to write the VAR in difference of order p with $X_t = (\Delta y_t, \Delta custr_t, \Delta r_t, \Delta p_t, \Delta m_t)'$, t=1..T. The Five-varied moving average (FMA) form can therefore be written as follows:

$$\begin{bmatrix} \Delta y_t \\ \Delta custr_t \\ \Delta r_t \\ \Delta p_t \\ \Delta m_t \end{bmatrix} = \begin{bmatrix} \sum a11\,(j)L_j & \sum a12\,(j)L_j & \sum a13\,(j)L_j & \sum a14\,(j)L_j & \sum a15\,(j)L_j \\ \sum a21\,(j)L_j & \sum a22\,(j)L_j & \sum a23\,(j)L_j & \sum a24\,(j)L_j & \sum a25\,(j)L_j \\ \sum a31\,(j)L_j & \sum a32\,(j)L_j & \sum a33\,(j)L_j & \sum a34\,(j)L_j & \sum a35\,(j)L_j \\ \sum a41\,(j)L_j & \sum a42\,(j)L_j & \sum a43\,(j)L_j & \sum a44\,(j)L_j & \sum a45\,(j)L_j \\ \sum a51\,(j)L_j & \sum a52\,(j)L_j & \sum a53\,(j)L_j & \sum a54\,(j)L_j & \sum a55\,(j)L_j \end{bmatrix} \begin{bmatrix} \varepsilon_t^{o} \\ \varepsilon_t^{custr} \\ \varepsilon_t^{r} \\ \varepsilon_t^{d} \\ \varepsilon_t^{m} \end{bmatrix}$$

ε_t^{o}, ε_t^{cust}, ε_t^{r}, ε_t^{d}, ε_t^{m} represent respectively the supply shock, the customs shock, the interest rate shock, the demand shock and the monetary shock. After defining our structural VAR model, we need to look for structural errors from the innovations of the reduced form of the VAR, because its errors are not directly observable.

The reduced form of the VAR model can be written as follows:

$$X_t = B(L)\,X_t + v_t \text{ with } Var(v) = \Omega, B(L) = \sum B_j L_j \text{ et } X_t = \begin{bmatrix} \Delta y_t \\ \Delta custr_t \\ \Delta r_t \\ \Delta p_t \\ \Delta m_t \end{bmatrix} \quad (4)$$

The moving average representation will then be:

$$X_t = v_t + C(1)v_{t-1} + \ldots = \sum C(j)v_{t-j} \quad (5)$$

$$X_t = v_t + C(1)v_{t-1} + \ldots = \sum C(j)v_{t-j} \quad (6)$$

Thats is :

$$X_t = C(L)v_t \quad (7)$$

Where :

$Var(v) = \Omega$, $C(L) = \sum C_j L_j$ et $C_0 = I$

If we assume that this representation is obtained by inversion of the stationary autoregressive form of X_t, then this moving average form is unique.

Comparing equations (2) and (6) we have:

$$v_t = A(0)\varepsilon_t \quad (8)$$

And :

$$\Omega = A(0)\sum_{\varepsilon} A'(0) \quad (9)$$

It is therefore the knowledge of A(0) that will allow us to find ε(t), since v(t) can be obtained from the standard VAR.

Considering the relations (3), (7) and (8), we determine A(L) and we therefore have:

$$A(L) = C(L)\,A(0) \quad (10)$$

Knowing C(L) from the standard VAR and A(0) will allow us to identify A(L).

2.2 The identification problem:

In general, the equations of the Structural VAR cannot be directly estimated because the errors are correlated with the variables while the estimation techniques require an absence of correlations between the regressors and the error terms. This type of problem does not exist for the standard form of the VAR, and ordinary least squares can be used to estimate the variance-covariance matrix. The question that arises is whether it is possible to identify all the elements of the structural VAR. The number of parameters of the Structural VAR model is equal to $n^2 + n(np+1) + \frac{n(n+1)}{2}$ parameters, while the Standard VAR only contains $(np+1) + \frac{n(n+1)}{2}$.

The Structural VAR model is therefore under-identified because the n^2 parameters cannot be directly identified from the estimated VAR. It is therefore necessary to look for n^2 identifying constraints. By normalization, the elements of the matrix A(0) are equal to 1. Therefore, only $(n^2 - n)$ parameters remain to be identified.

The technique of identifying a Structural VAR requires the application of orthogonalization constraints of the variance-covariance matrix of shocks, and also constraints based on economic theory on the coefficients of the matrix A(0) and on the long-term multipliers. For the case of the variance-covariance matrix(Ω), we assume that it is diagonal. The only unknowns are then the parameters of its diagonal. Therefore, only $\frac{n(n-1)}{2}$ unidentified parameters remain. We must therefore find $\frac{n(n-1)}{2}$ additional constraints. These additional constraints will be obtained from economic theory. In our case, with a five -varied VAR, we have: $\frac{n(n-1)}{2}$ =10. We therefore only need to impose ten restrictions on its parameters, so that the model is identified. Firstly, we assume that the four shocks (the customs shock, the interest rate shock, the demand shock and the monetary shock) have no long-term effects on real GDP. Secondly, we suppose that the interest shock, the demand shock and the monetary shock have no long run effects on the customs revenue. Thirdly, the demand shock and the monetary shock have no long run effects on the interest rate. Finally, prices and money suffer the same effects of the monetary shock according to the quantity theory of money.

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2.3 The long-term restrictions technique

According to the previous restrictions, the long-term impact matrix can be written as follows:

$$A(1) = \begin{bmatrix} A_{11} & 0 & 0 & 0 & 0 \\ A_{21} & A_{22} & 0 & 0 & 0 \\ A_{31} & A_{32} & A_{33} & 0 & 0 \\ A_{41} & A_{42} & A_{43} & A_{44} & A_{45} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_{55} \end{bmatrix} \quad (11)$$

With $A_{45} = A_{55}$.

To solve this identification problem, we will use the approach technique of Mariano Matilla Garcia et al. (2002). This technique consists in identifying the matrix A(0) as a lower triangular matrix by the following method:

Let T be a lower triangular matrix such that: T = FA(1) (12)

$$\text{With } F = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

According to relations (9) and (10), we have:

$$C(1)\,\Omega C(1)' = A(1)\,A(1)' \quad (13)$$

Using relation (12), which gives us:

$$FC(1)\,\Omega C(1)'F' = TT' \quad (14)$$

T is an upper triangular matrix, in order to solve the elements of the matrix T, we apply the cholesky decomposition of equation (14) containing known elements. So, the long-term impact matrix is finally obtained by: $A(1) = F^{-1}\,T$ while A(0) is solved by:

$$A(0) = C(1)^{-1}\,A(1)$$

3. The study data:

From a methodological point of view, we have adopted the Structural VAR method and we can therefore retain the following variables:

Real Gross Domestic Production or Real GDP.

The Customs Revenue or CUSTR.

The Nominal Interest Rate or R.

The Consumer Price Index or CPI.

The Money Supply M3.

For this reason, we use quarterly data covering the period from the first quarter of 1979 to the first quarter of 2023.

The five series were obtained from the Federal Reserve Economic Data.

4. The calculation method

Our calculation method consists of eliminating the component correlated with real production to obtain the core inflation.

The Structural VAR (1) in its reduced form can be written as follows:

$$\begin{bmatrix} \Delta y_t \\ \Delta custr_t \\ \Delta r_t \\ \Delta p_t \\ \Delta m_t \end{bmatrix} = \begin{bmatrix} \sum a11\,(j)L_j & \sum a12\,(j)L_j & \sum a13\,(j)L_j & \sum a14\,(j)L_j & \sum a15\,(j)L_j \\ \sum a21\,(j)L_j & \sum a22\,(j)L_j & \sum a23\,(j)L_j & \sum a24\,(j)L_j & \sum a25\,(j)L_j \\ \sum a31\,(j)L_j & \sum a32\,(j)L_j & \sum a33\,(j)L_j & \sum a34\,(j)L_j & \sum a35\,(j)L_j \\ \sum a41\,(j)L_j & \sum a42\,(j)L_j & \sum a43\,(j)L_j & \sum a44\,(j)L_j & \sum a45\,(j)L_j \\ \sum a51\,(j)L_j & \sum a52\,(j)L_j & \sum a53\,(j)L_j & \sum a54\,(j)L_j & \sum a55\,(j)L_j \end{bmatrix} \begin{bmatrix} \varepsilon_t^o \\ \varepsilon_t^{custr} \\ \varepsilon_t^r \\ \varepsilon_t^d \\ \varepsilon_t^m \end{bmatrix}$$

Where

Δy_t is the first logarithmic difference of Real Output.

$\Delta custr_t$ is the first logarithmic difference of Customs revenue.

Δr_t is the change in the interest rate.

Δp_t is the first logarithmic difference of Inflation.

Δm_t is the first logarithmic difference of the money supply.

ε_t^o expresses the supply shock.

ε_t^{cust} expresses the customs shock.

ε_t^r expresses the interest rate shock.

ε_t^d expresses the demand shock.

ε_t^m expresses the monetary shock.

The inflation rate is then transformed as follows:

$$\Delta P_t = A_{41}(L)\varepsilon_t^o + A_{42}(L)\varepsilon_t^{custr} + A_{43}(L)\varepsilon_t^r + A_{44}(L)\varepsilon_t^d + A_{45}(L)\varepsilon_t^m \quad (15$$

After eliminating the component $A_{51}(L)\varepsilon_t^o$, the core inflation is then composed as follows:

$$\Delta P_t^{CORE} = A_{42}(L)\varepsilon_t^{custr} + A_{43}(L)\varepsilon_t^r + A_{44}(L)\varepsilon_t^d + A_{45}(L)\varepsilon_t^m$$

From which:

$$\Delta P_t^{CORE} = \sum_{s=0}^{\infty} A_{42,s}\,\varepsilon_{t-s}\,\varepsilon_t^{custr} + \sum_{s=0}^{\infty} A_{43,s}\,\varepsilon_{t-s}\,\varepsilon_t^r + \sum_{s=0}^{\infty} A_{44,s}\,\varepsilon_{t-s}\,\varepsilon_t^d + \sum_{s=0}^{\infty} A_{45,s}\,\varepsilon_{t-s}\,\varepsilon_t^m \quad (16)$$

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This last equation shows that the core inflation is obtained by the four components of inflation which have no long-term effects on the level of production (it is assimilated here as expected inflation).

6. Results

We assume that five kinds of innovations can influence the real output, the customs revenue, the nominal interest rate, the observed inflation and the money supply while the economy is disrupted by a larger number of shocks. This assumption justifies, on the one hand, that only one type of shock would each determine the customs revenue, the nominal interest rate, inflation and the money supply, which may seem acceptable, and on the other hand, that there would only be one real shock, which is certainly less so. Since our analytical objective is focused on the dynamics of inflation, we can hope that this last restriction will not disrupt the results too much even if it makes the interpretation of the real shock more uncertain.

We chose one lag in the long-term specification of the model as suggested by the information from AIC (Akaike Information Criterion).

The graphics 1 and 2 below indicate the responses of output and then inflation to a shock of one standard deviation on ε_t^o, ε_t^{cust}, ε_t^r, ε_t^d and ε_t^m. The standard deviations are obtained by the Monte Carlo method with 10,000 draws.

With regard to output, the four shocks (the customs shock, the interest shock, the demand shock and the monetary shock) ε_t^{cust}, ε_t^r, ε_t^d and ε_t^m (Graphic 1 and Graphic 2) have, in accordance with the identification constraints imposed, without effects on output. The impact of these four shocks stabilize after about seven quarters. The relatively short adjustment period towards the long-term situation may suggest a Philips curve close to the vertical with a rapid return to the equilibrium situation. We can also say that in the United States, monetary policy is relatively neutral in the short term.

Concerning inflation, the four shocks (the customs shock, the interest shock, the demand shock and the monetary shock) ε_t^{cust}, ε_t^r, ε_t^d and ε_t^m (Graphic 1 and Graphic 2) have permanent and significant effects; which is consistent with the idea that these four components determine the long-term evolution of inflation. The effect stabilizes fairly quickly, after about tine quarters. Regarding the effect of the supply shock ε_t^o (Graphic 2), it does not always have an effect on inflation and stabilizes after ten quarters. This makes it possible to clearly distinguish the independence of the five shocks, i.e ε_t^o on production, ε_t^{cust} on the customs revenue ε_t^r on the interest rate, ε_t^d on inflation and ε_t^m on the money supply.

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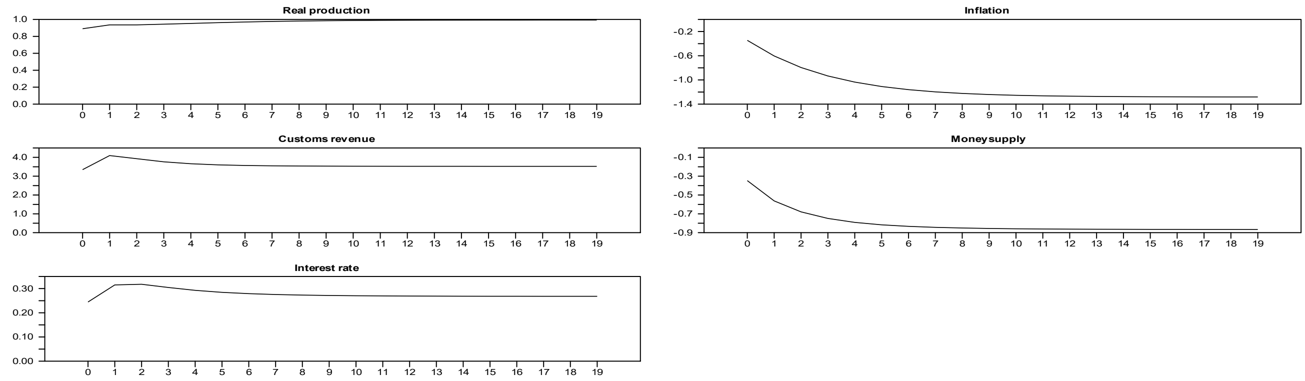
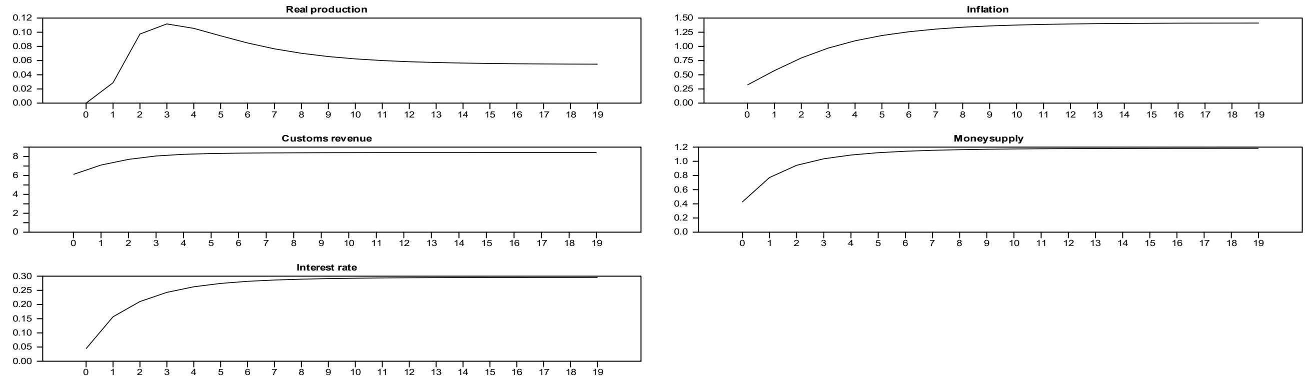
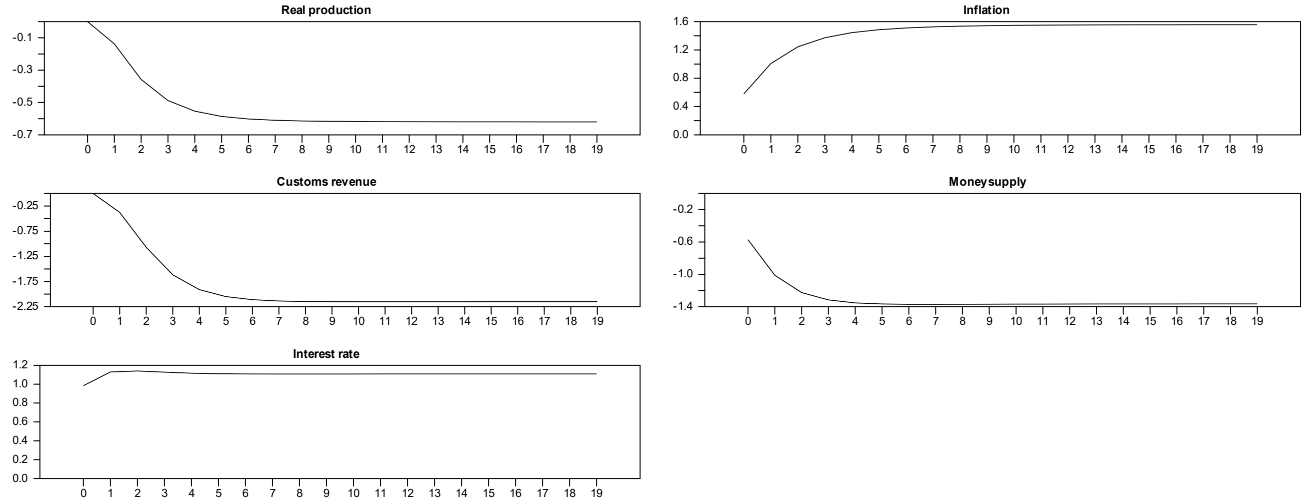
GRAPHIC 1: IMPULSE RESPONSES OF THE SUPPLY SHOCK, THE CUSTOMS SHOCK AND THE INTEREST SHOCK



Responses to Supply



Responses to Customs



Responses to Interest

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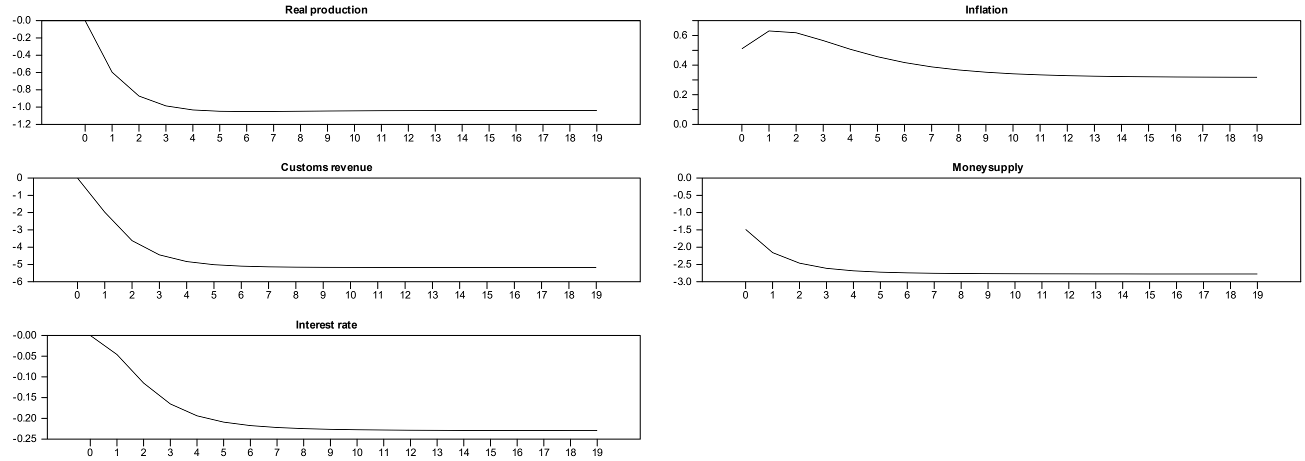
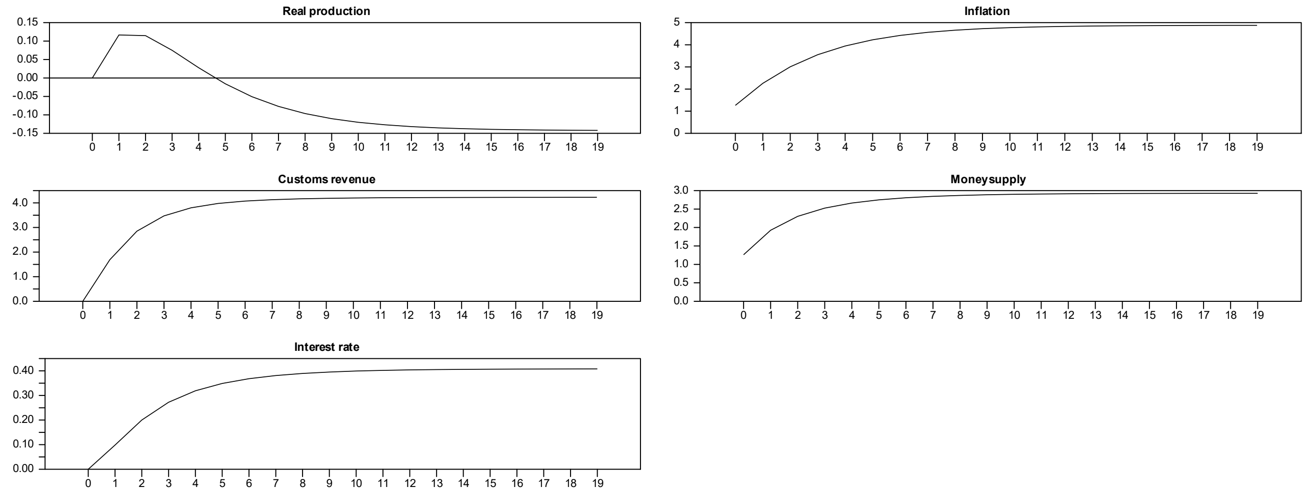
GRAPHIC 2: IMPULSE RESPONSES OF THE DEMAND SHOCK AND THE MONETARY SHOCK



Responses to Demand



Responses to Monetary

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ISSN: 2509-0119.

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7. Variance decomposition

Table 1 and Table 2 below present a summary of forecast errors variance decomposition. This decomposition shows what share of the variance of the errors of the endogenous variables is due to each of the structural shocks for different horizons. The table1 shows that the four shocks (the customs shock, the interest rate shock, the demand shock and the monetary shock) have no impact on activity since over a horizon of 1 to 24, they only explain less than 6 % of the forecast error of production. This result is consistent with the identification scheme chosen which imposes the long-term neutrality of these four shocks on activity. Nevertheless, the majority (more than 97%) of the variance of inflation is explained by the four shocks (the customs shock, the interest rate shock, the demand shock and the monetary shock). Given the weakness of the significant effect of the supply shock on inflation, this is not surprising.

Table1: Forecast errors variance decomposition of Inflation

			Inflation		
Horizons	Supply shock	Customs shock	Interest shock	Demand shock	Monetary shock
1	1.963	9.238	13.928	13.801	61.070
2	1.990	9.441	13.905	10.366	64.297
4	1.046	10.130	12.324	9.787	66.713
8	1.076	10.391	11.614	9.546	67.374
12	1.078	10.407	11.569	9.539	67.407
20	1.078	10.408	11.566	9.539	67.409
24	1.078	10.408	11.566	9.539	67.409

Table2 : Forecast errors variance decomposition of Production

			Production		
Horizons	Supply shock	Customs shock	Interest shock	Demand shock	Monetary shock
1	100.000	0.000	0.000	0.000	0.000
2	86.157	0.070	1.598	1.027	1.149
4	96.105	0.428	1.271	1.067	1.129
8	94.484	0.447	1.621	1.887	1.561
12	94.450	0.452	1.618	1.867	1.613
20	94.448	0.452	1.618	1.866	1.616
24	94.448	0.452	1.618	1.866	1.616

8. Observed inflation(ACTINFL) and Core inflation(COREINFL)

Graphic 3 (year -on -year) presents the result of the core inflation obtained from a five variables structural VAR. The core inflation was nothing other than the heavy trend of observed inflation, and we see that the two series present similar evolutions. On this graph, we see that the core inflation remains below the observed inflation from the second quarter of 2008 to the first quarter of 2009, which is the period during the United States experienced the subprime crisis due to excessive personal debt. Faced with this situation, the monetary authorities in the United States decided to increase the interest rate and moderate the money supply growth rate.

On the other hand, from the second quarter of 2021, we observe that the core inflation is above the observed inflation. Since this period, as part of the programs to support economies in the face of the Covid-19 pandemic, the central banks of the main advanced countries have continued their accommodative monetary policies in the second quarter of 2021. In the United States, the Federal Reserve renewed the target range of rates between 0 and 0.25%. This led to an increase in the money supply of around 26% and a decrease in additional demand of 6%.

International Journal of Progressive Sciences and Technologies (IJPSAT)
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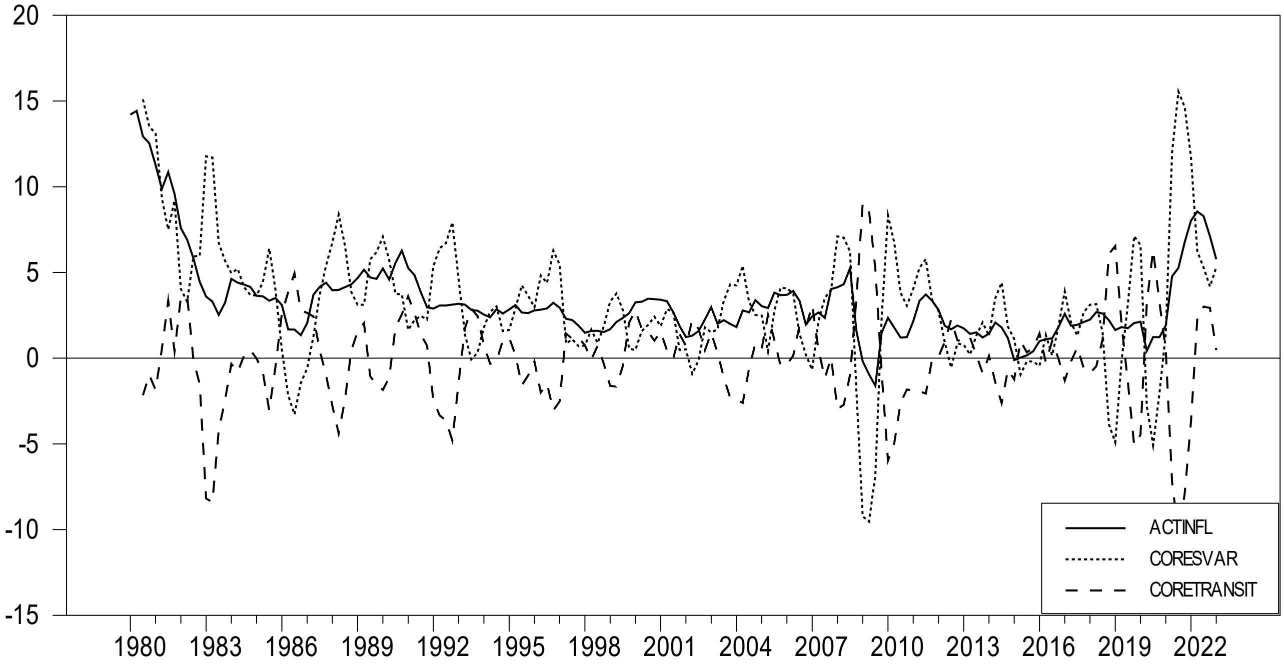
GRAPHIC 3 : OBSERVED INFLATION (ACTINFL), CORE INFLATION (COREINFL) AND CORETRANSIT (transitory inflation interpreted as additional demand) (year –on-year)



9. Conclusion

The objective of this work was to identify the core inflation in the United States using the structural VAR approach. This technique was based on the analysis of the following authors: Blanchard and Quah (1989), Quah and Vahey (1995) and finally Marianno Matilla Garcia et al. (2002). Reading the graphs of impulse responses and the analysis of the variance decomposition of shocks confirm that our identification hypothesis is well validated, and consistent with that expected theoretically (the verticality of the Philips curve). The results showed that the core inflation remains above the observed inflation during the period of accommodative monetary policy and the opposite in the period of rising interest rate and decreasing customs revenue. However, the measurement of the core inflation must allow central banks to recognize in time a variation in inflationary trend. To this end, various central banks have set their inflation target based on core inflation. Furthermore, even if central banks set their main target based on observed inflation, they have an interest in knowing the degree of predictability of core inflation, which is supposed to reflect the inflationary trend.

International Journal of Progressive Sciences and Technologies (IJPSAT)
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APPENDIX : UNIT ROOT TEST IN LEVEL AND IN FIRST DIFFERENCE

Variables	Trend significance	Augmented Dickey-Fuller statistics	Critical values			Existence of unit root
			1%	5%	10%	
Log(GDP) = y_t	With trend	-1.32	-3.46	-2.87	-2.57	Yes
Log(CUSTR) = custr	With trend	-0.40	-3.46	-2.87	-2.57	Yes
R = r_t	No trend	-2.01	-3.46	-2.87	-2.57	Yes
Log(CPI)= p_t	With trend	-2.82	-3.46	-2.87	-2.57	Yes
Log(M3)= m_t	With trend	-0.19	-3.46	-2.87	-2.57	Yes
Dlog(GDP)= Δy_t	No trend	-9.05	-3.46	-2.87	-2.57	No
Dlog(CUSTR)= $\Delta custr_t$	No trend	-9.07	-3.46	-2.87	-2.57	No
DR= Δr_t	No trend	-10.27	-3.46	-2.87	-2.57	No
Dlog(CPI) = Δp_t	No trend	-5.37	-3.46	-2.87	-2.57	No
Dlog(M3)= Δm_t	No trend	-5.70	-3.46	-2.87	-2.57	No

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