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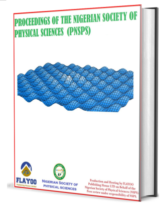

Numerical assessment of economic crisis on consumers purchasing power in Nigeria

Chigozie Chibuisi[a,*], Prisca Udodiri Duruojinkeya[b], Christie Yemisi Ishola[c], Bright Okore Osu[d]

[a]*Department of Mathematics, Federal University of Technology Owerri, Owerri, Nigeria*
[b]*Department of Mathematics and Statistics, Federal Polytechnic Nekede, Owerri, Nigeria*
[c]*Department of Mathematics, National Open University, Abuja, Nigeria*
[d]*Department of Mathematics, Abia State University, Uturu, Nigeria*

ABSTRACT

The uncertainties influencing consumers' purchasing power in Nigeria and other developing economies have become recurring issues which pose serious threat to the survival of its citizens and business collaborations. Waves of instabilities in vital economic indicators significantly affect consumer purchasing power and spending decisions in the market. This study focuses on modeling the resulting impact of Nigerian economic crisis on the purchasing power of consumers using second derivative block Adams Moulton methods (SDBAMM). Following the instability display of the absolute wave errors (AWEs) of the modeled equation, the discrete schemes of partition p=4 of SDBAMM gave better and faster computational solutions than other lower partitions p=2 and 2 when compared with other applied numerical methods in literature. This study recommends that adopting stronger monetary policy tools by the Nigerian government to manage tariff uncertainty, inflation and exchange rate waves will improve consumers' purchasing power and reduce economic fluctuations in the Nigerian markets.

Keywords: Consumer purchasing power, Nigerian economic crisis, Second Derivative Block Adams Moulton Methods (SDBAMM), Monetary policy tools.

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1. INTRODUCTION

One of the major crises in the financial market is the purchasing power of the consumers. The sustainability and growth of businesses rely on the rate of consumers' demand of the product. Economic instabilities in the markets influence the purchasing power of consumers which in turn affect the overall stability of an economy [1]. Economic crisis is often associated with tariff uncertainty, inflation and exchange rate depreciation. The consumer confidence and consumption patterns are often affected by these economic factors [2]. Understanding the stability of the market influences the purchasing power of customers [3]. Economic crisis in Nigeria has significantly eroded consumers' purchasing power through persistent inflation and macroeconomic instability. Inflation-driven increases in the cost of living have reduced real income and household welfare [4]. Empirical evidence further shows that food inflation—exceeding 40% in recent years—has intensified economic hardship and weakened purchasing capacity [5]. Refs. [6, 7] studied that high tariff rates disrupt economic stability, leading to economic crisis and closing down of businesses which affect the consumers purchas-

*Corresponding Author Tel. No.: +234-703-7194-869.
e-mail: chigozie.chibuisi@futo.edu.ng (Chigozie Chibuisi)

ing power and standard of living. Additionally, exchange rate volatility and rising interest rates have altered consumer purchasing power, forcing households to adopt survival strategies such as reduced consumption [8, 9]. Economic crisis indirectly introduces scale of preference and opportunity cost as economic tools in the daily spending of customers making them to change what they choose to spend on [10].

Ref. [11] modeled the equation of volatility time-delay differential equation (VTDDE) which contains the current state and the volatility state as presented below:

$$\begin{aligned} ds(t) &= A\left(s(t), s(t-\tau), t\right)dt + B\left(s(t), s(t-\tau), t\right)d\Phi(t) \\ &\quad \text{for } t>0, \tau>0, \\ y(t) &= \Phi(t)d\Phi(t), \quad \text{for } t>0. \end{aligned} \tag{1}$$

Following the statistic model formed by Ref. [12], a multiple regression equation containing the factors of economic instability was obtained and presented as:

$$CBB = \alpha + \delta_1 TU + \delta_2 I + \delta_3 ERD + \varepsilon_i. \tag{2}$$

Incorporating equation (3) into equation (1), the modeled equation for this study becomes:

$$\begin{aligned} dCBB(t) &= A\left(CBB(t), CBB(t-\tau), t\right)dt \\ &\quad + B\left(CBB(t), CBB(t-\tau), t\right)d\left|\varepsilon_i\right|(t) \ \ for\ t>0, \tau>0, \\ CBB(t) &= \mu(t)d\left|\varepsilon_i\right|(t), \quad \text{for } t>0, \end{aligned} \tag{3}$$

where $\alpha(t)$ is the initial function, A, B are the mean and variability parameters.

Many scholars have applied numerical methods to solve the modeled equation but encountered setbacks in preserving the accuracy of their solutions [13–15]. To overcome these setbacks and the challenges faced by consumers in Nigeria, second derivative block Adams Moulton methods (SDBAMM) shall be applied in solving the modeled equation together with help of new formulas constructed by Ref. [16] for delay term and volatility term evaluations.

2. MATERIALS AND METHODS

The discrete schemes of second derivative block Adams Moulton methods (SDBAMM) were derived by matrix inversion method on the p-step multistep collocation approach [17] and presented as:

p = 2 SDBAMM

$$\begin{aligned} y_{n+1} &= y_n + \frac{h}{2}(f_n + f_{n+1}) + \frac{h^2}{12}(g_n - g_{n+1}), \\ g_{n+1} &= f'(y_{n+1}). \end{aligned} \tag{4}$$

p = 3 SDBAMM

$$\begin{aligned} y_{n+1} &= y_n + \frac{h}{24}(9f_n + 19f_{n+1} - 5f_{n+2} + f_{n+3}) \\ &\quad + \frac{h^2}{720}(-19g_n + 99g_{n+1} + 45g_{n+2} - 5g_{n+3}), \\ y_{n+2} &= y_{n+1} + \frac{h}{24}(-5f_n + 9f_{n+1} + 19f_{n+2} - f_{n+3}) \\ &\quad + \frac{h^2}{720}(5g_n - 19g_{n+1} + 99g_{n+2} + 45g_{n+3}), \\ y_{n+3} &= y_{n+2} + \frac{h}{24}(f_n - 5f_{n+1} + 9f_{n+2} + 19f_{n+3}) \\ &\quad + \frac{h^2}{720}(45g_n + 5g_{n+1} - 19g_{n+2} + 99g_{n+3}). \end{aligned} \tag{5}$$

p = 4 SDBAMM

$$\begin{aligned} y_{n+1} &= y_n + \frac{h}{720}(251f_n + 646f_{n+1} - 264f_{n+2} + 106f_{n+3} - 19f_{n+4}) \\ &\quad + \frac{h^2}{60480}\Big(-954g_n + 1926g_{n+1} + 2124g_{n+2} - 594g_{n+3} \\ &\quad + 54g_{n+4}\Big), \\ y_{n+2} &= y_{n+1} + \frac{h}{720}\Big(-19f_n + 251f_{n+1} + 646f_{n+2} - 264f_{n+3} \\ &\quad + 106f_{n+4}\Big) + \frac{h^2}{60480}(54g_n - 954g_{n+1} + 1926g_{n+2} \\ &\quad + 2124g_{n+3} - 594g_{n+4}), \\ y_{n+3} &= y_{n+2} + \frac{h}{720}(106f_n - 19f_{n+1} + 251f_{n+2} + 646f_{n+3} \\ &\quad - 264f_{n+4}) + \frac{h^2}{60480}\Big(-594g_n + 54g_{n+1} - 954g_{n+2} \\ &\quad + 1926g_{n+3} + 2124g_{n+4}\Big), \\ y_{n+4} &= y_{n+3} + \frac{h}{720}\Big(-264f_n + 106f_{n+1} - 19f_{n+2} + 251f_{n+3} \\ &\quad + 646f_{n+4}\Big) + \frac{h^2}{60480}\Big(2124g_n - 594g_{n+1} + 54g_{n+2} \\ &\quad - 954g_{n+3} + 1926g_{n+4}\Big). \end{aligned} \tag{6}$$

2.1. EVALUATION OF THE FUNDAMENTAL CONDITIONS OF THE METHOD

Following the basic properties formed by Refs. [18, 19], the convergence and stability of the method are assessed.

2.1.1. Order and error constant

Ref. [18] stated that LMM is said to be of order p if $C_0 = C_1 = \cdots = C_p = 0$ but $C_{p+1} \neq 0$ and C_{p+1} is the error constant.

The order and error constants for equation (4) are obtained as follows: $C_0 = C_1 = C_2 = 0$ but $C_3 \neq 0$. Therefore, equation (4) has order $p = 2$ and error constants, C_3.

Applying the same method to equation (5), we obtained $C_0 = C_1 = C_2 = C_3 = 0$ but $C_4 \neq 0$. Therefore, equation (5) has order $p = 3$ and error constants, C_4.

Following the same process to equation (6), we obtained $C_0 = C_1 = C_2 = C_3 = C_4 = 0$ but $C_5 \neq 0$. Therefore, equation (6) has order $p = 4$ and error constants, C_5.

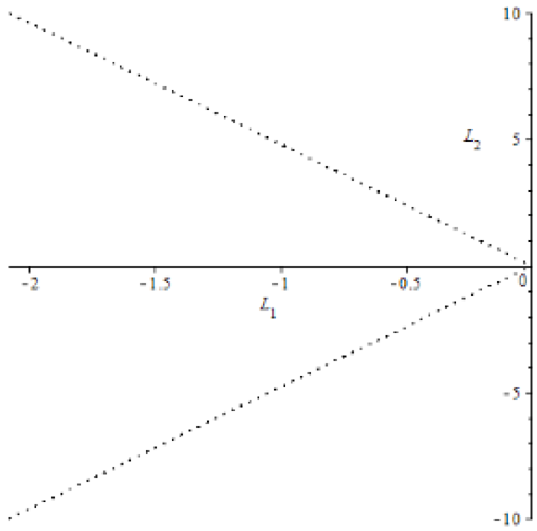

Figure 1. Domain of A-stability (SDBAMM) in equation (4).

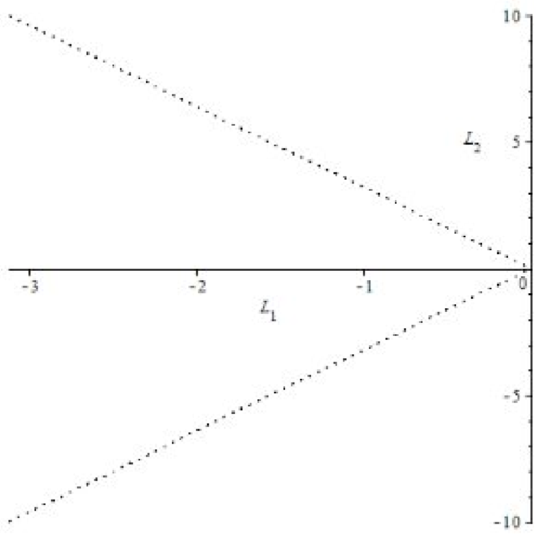

Figure 2. Domain of A-stability (SDBAMM) in equation (5).

2.1.2. Consistency

In Ref. [18], if the order $p \geq 1$, then computational method is consistent. Since the order of SDBAMM as evaluated is $p \geq 1$, hence the method is consistent.

2.1.3. Zero stability computation

In Ref. [19], an approximate method is zero-stable if the roots $a_i, i = 1, 2, 3, \ldots, \infty$ of the auxiliary equation $S(z)$ developed as $S(z) = \det\left(zR_i^{(n)} - R_i^{(n)}\right)$ is $|z_i| \leq 1$ and the roots $|z_i|$ is simple or distinct where $R_i^{(n)}$ and $R_i^{(n)}$ are the matrices of the auxiliary equation obtained from equations (4), (5), and (6). Following the above, the auxiliary equation for the zero stability of equation (4) is evaluated as:

$$S(z) = \det\left(zR_2^{(1)} - R_1^{(1)}\right) = |zR_2^{(1)} - R_1^{(1)}| = 0. \tag{7}$$

With Maple 18 software application, $S(z) = z(z-1) = 0$. Since $z = 0, 1$, (4) is zero stable.

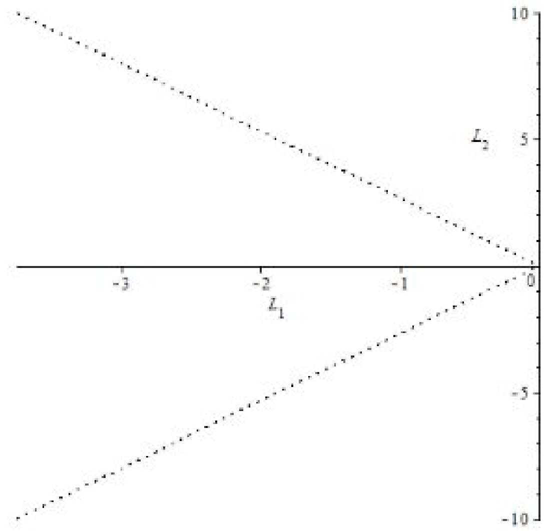

Figure 3. Domain of A-stability (SDBAMM) in equation (6).

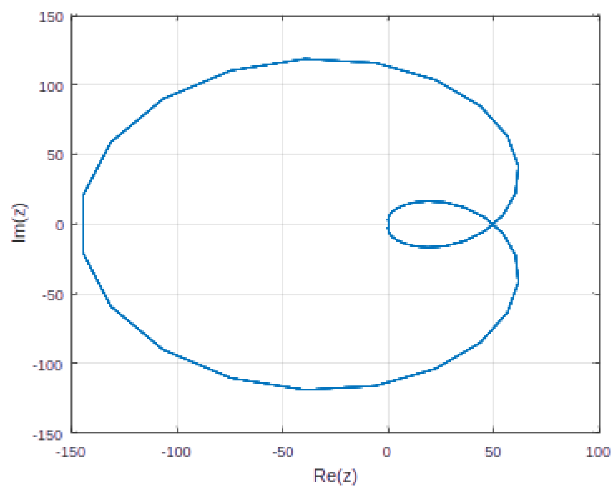

Figure 4. Domain of $A(\alpha)$-stability (SDBAMM) in equation (4).

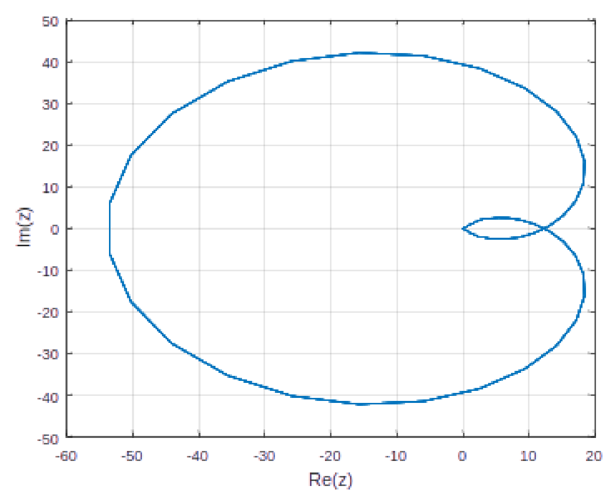

Figure 5. Domain of $A(\alpha)$-stability (SDBAMM) in equation (5).

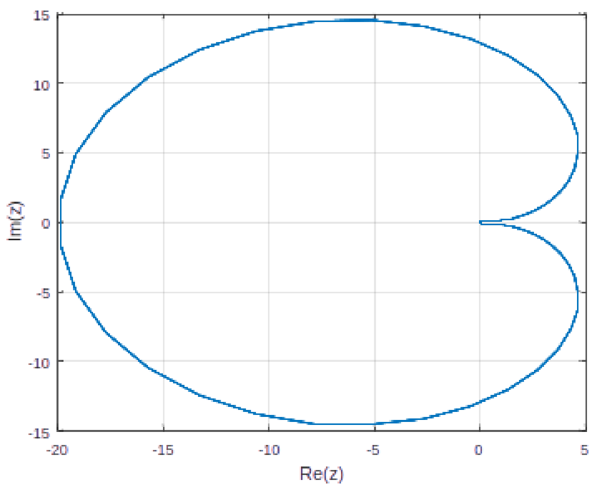

Figure 6. Domain of $A(\alpha)$-stability (SDBAMM) in equation (6).

Table 1. Absolute wave errors (AWEs) of example 2.1 using the SDBAMM for $p = 2, 3$ & 4.

t	$p = 2$ AWEs	$p = 3$ AWEs	$p = 2$ AWEs
1	0.291540982	0.791540982	0.891540983
2	0.282811085	0.782811085	0.882811087
3	0.173634111	0.773812271	0.873812273
4	0.364191634	0.764019094	0.864546566
5	0.453623921	0.653965451	0.853978856
6	0.242802713	0.643653625	0.000057645
7	0.228302782	0.731129213	0.000008536
8	0.117521417	0.51837232	0.000000507
9	0.102672776	0.505385842	0.000915882
10	0.087624845	0.689333246	0.000867949
11	0.007633421	0.573103525	0.005624107
12	0.043054515	0.515670032	0.060187787
13	0.133904025	0.537559191	0.641046655
14	0.114678091	0.618333262	0.722182071
15	0.194680264	0.699302684	0.702514306
16	0.274680462	0.079225254	0.583131758
17	0.35560915	0.005946801	0.664060455
18	0.336630343	0.000408355	0.64508163
19	0.220903362	0.004032602	0.526199585
20	0.205363467	0.008492711	0.507418534
21	0.295689354	0.093214341	0.597744422
22	0.186278882	0.487426545	0.588333953
23	0.118498202	0.481997794	0.579189243
24	0.18398466	0.476858377	0.570312355
25	0.192050426	0.484924132	0.578378107
26	0.204038977	0.593263481	0.686717466
27	0.216482932	0.504187456	0.695328547
28	0.232752377	0.520587497	0.604209415
29	0.352694935	0.739404192	0.824151974
30	0.372657934	0.758320414	0.844114966

CPUT SDBAMM for $p = 2$ is 0.004s, $p = 3$ is 0.003s and $p = 4$ is 0.001s.

Table 2. Absolute wave errors (AWEs) of example 2.2 using the SDBAMM for $p = 2, 3$ & 4.

t	$p = 2$ AVEs	$p = 3$ AVEs	$p = 4$ AVEs
1	0.211970845	0.411553849	0.510817106
2	0.230642093	0.430466516	0.530466516
3	0.348481156	0.547888582	0.741246534
4	0.367736287	0.559329807	1.760830531
5	0.249427561	0.678070967	0.000086211
6	0.197731105	0.309528302	0.000000593
7	1.115122868	0.105861473	0.000000025
8	0.034017997	0.412349265	0.218865224
9	0.043313311	0.339538223	0.412715961
10	0.058763838	1.347236492	0.443478959
11	0.003106765	0.461268684	0.548857587
12	0.000962682	0.473705268	0.561399252
13	0.000025234	0.274797096	0.461978296
14	0.176522995	0.280591847	0.568285831
15	1.100883823	0.384929885	0.461670262
16	0.109611264	0.173929404	1.158621255
17	0.492560409	1.364658549	0.142070374
18	0.476887783	0.000023518	0.400152237
19	0.515942934	0.000003045	0.196982697
20	0.650976935	0.493116715	0.054926433
21	1.005302584	0.060951107	0.02121135
22	0.006469641	0.079107093	1.128960118
23	0.455645303	0.049480563	0.127496534
24	0.229709872	1.107419776	0.055137917
25	1.173595948	0.329409913	0.406365381
26	0.182406654	0.259318268	0.607036408
27	0.562969207	1.237984882	1.818593862
28	0.042449191	0.118049463	0.171223986
29	0.603464021	0.201353987	0.309048938
30	0.682131793	0.283841396	0.028445184

CPUT SDBAMM for $p = 2$ is 0.004s, $p = 3$ is 0.003s and $p = 4$ is 0.001s.

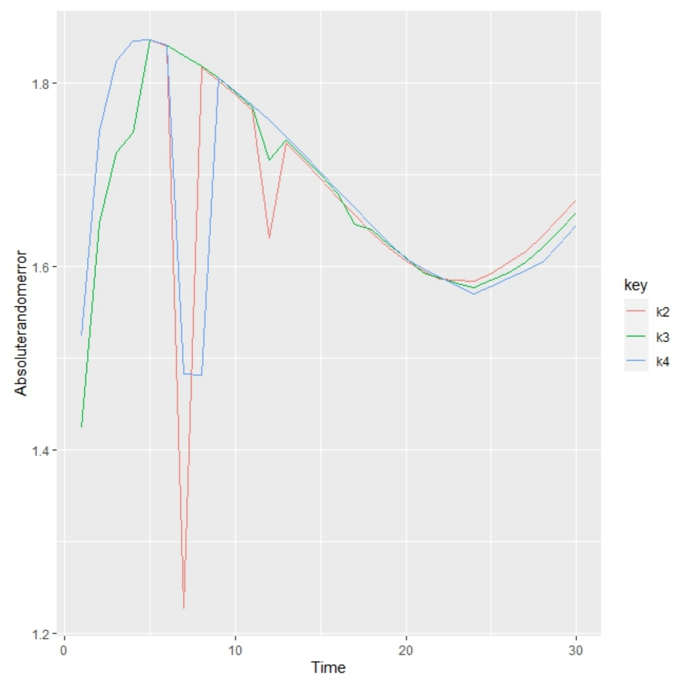

Figure 7. AWEs for example 2.1 using SDBAMM. The coloured-lines represent the wave display of the economic crisis on consumers' purchasing power in Nigeria.

By the same technique, the auxiliary equation for equation (5)

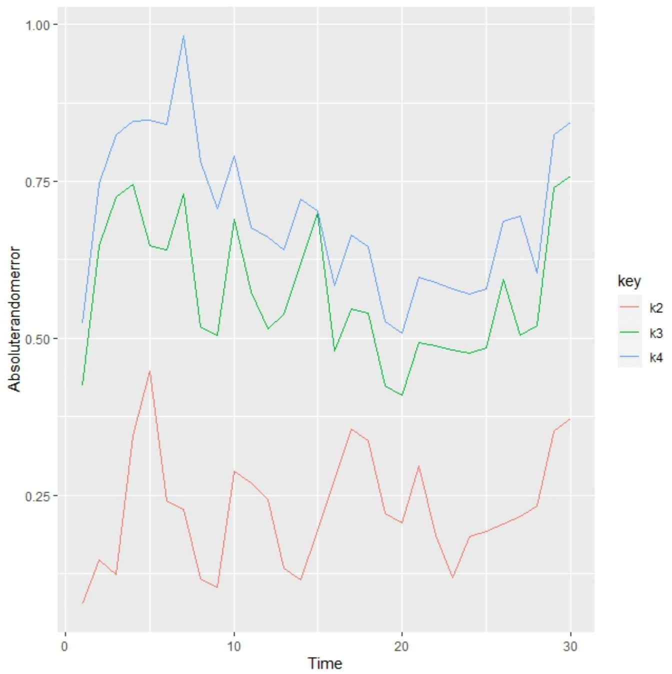

Figure 8. AWEs for example 2.2 using SDBAMM. The coloured-lines represent the wave display of the economic crisis on consumers' purchasing power in Nigeria.

Table 3. Comparing the LAWEs of SDBAMM for $p = 2, 3$ and 4 with [13–15] for fixed step size $h = 0.01$ using example 2.1.

Computational method	Compared LAWEs with [13–15]
SDBAMM LAWE $p = 2$	7.63E-03
SDBAMM LAWE $p = 3$	4.08E-04
SDBAMM LAWE $p = 4$	5.07E-07
CSSEMM LAWE $p = 2$ [13]	3.51E-02
CSSEMM LAWE $p = 3$ [13]	7.22E-03
CSSEMM LAWE $p = 4$ [13]	3.45E-02
EMM LAWE $p = 2$ [14]	2.91E+01
EMM LAWE $p = 3$ [14]	4.23E-02
EMM LAWE $p = 4$ [14]	5.64E-02
BSM LAWE $p = 2$ [15]	4.03E-03
BSM LAWE $p = 3$ [15]	6.04E-02
BSM LAWE $p = 4$ [15]	5.05E-03

Table 4. Comparing the LAWEs of SDBAMM for $p = 2, 3$ and 4 with [13–15] for fixed step size $h = 0.01$ using example 2.2.

Computational method	Compared LAWEs with [13–15]
SDBAMM LAWE $p = 2$	0.25E-05
SDBAMM LAWE $p = 3$	0.30E-06
SDBAMM LAWE $p = 4$	0.25E-08
CSSEMM LAWE $p = 2$ [13]	5.39E-03
CSSEMM LAWE $p = 3$ [13]	6.45E-02
CSSEMM LAWE $p = 4$ [13]	3.14E-02
EMM LAWE $p = 2$ [14]	4.62E+01
EMM LAWE $p = 3$ [14]	3.56E-03
EMM LAWE $p = 4$ [14]	5.22E-02
BSM LAWE $p = 2$ [15]	8.15E-03
BSM LAWE $p = 3$ [15]	3.26E-02
BSM LAWE $p = 4$ [15]	2.17E-03

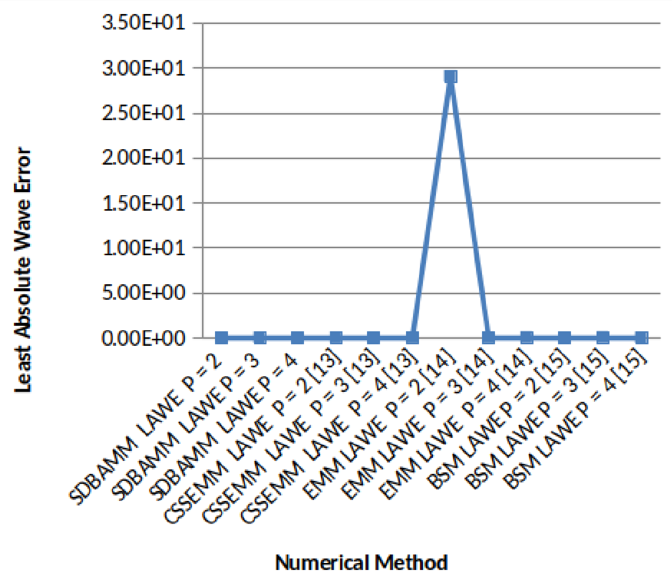

Figure 9. Compared LAWEs of SDBAMM for $p = 2, 3$ and 4 with LAWEs of Refs. [13–15] for example 2.1.

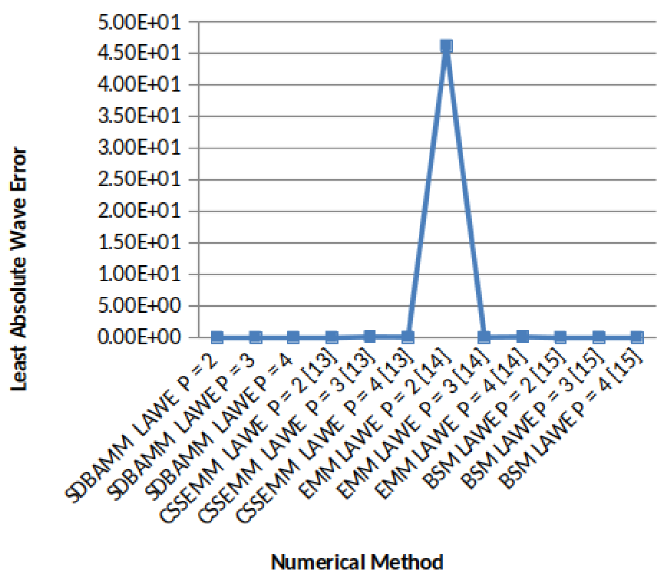

Figure 10. Compared LAWEs of SDBAMM for $p = 2, 3$ and 4 with LAWEs of Refs. [13–15] for example 2.2.

is presented as:

$$S(z) = \det(zR_2^{(2)} - R_1^{(2)}) = 0. \tag{8}$$

Using Maple 18 software application, we obtain $S(z) = z^2(z - 1) = 0$. Since $z = 0, 0, 1$, equation (5) is zero stable.

Following the same technique for equation (6), the auxiliary equation is presented as:

$$S(z) = \det(zR_2^{(3)} - R_1^{(3)}) = 0. \tag{9}$$

With Maple 18 software application, we obtain $S(z) = z^3(z - 1) = 0$. Since $z = 0, 0, 0, 1$, equation (6) is zero stable.

2.1.4. Convergence of the proposed method

Following the consistency and zero-stability of the derived discrete schemes in equations (4), (5), and (6) of SDBAMM above, the method is convergent.

2.1.5. Stability domain

A- and $A(\alpha)$- stability domain of equations (4), (5), and (6) are plotted using the software's of Maple 18 and MATLAB and are presented in Figures 1 to 6.

2.2. NUMERICAL EXPERIMENT

Some examples of the modeled equation of this study are solved using SDBAMM with the help of the sequences developed by Ref. [16] for delay and uncertainty term evaluations to obtain the computational solutions of absolute wave errors of consumers' purchasing power in Nigeria modeled in equation (5).

2.2.1. Numerical examples

Example 2.1.

$$dCBB(t) = \cos(t)\,[(dCBB(t)(dCBB(t)-2)]\ \ dt + ((dCBB(t)(dCBB(t)-2))\,d|\varepsilon_i|(t), \quad 0 \leq t \leq 30. \tag{10}$$

$CBB(t) = (1+\sin(t))d|\varepsilon_i|(t), t \geq 0$ is the wave of the exact solution.

Example 2.2.

$$dCBB(t) = 1000\,(dCBB(t) - dCBB(t)\,(t - (\ln(1000-1))))\,dt + (dCBB(t) - dCBB(t)\,(t - (\ln(1000+1))))\,d|\varepsilon_i|(t), \quad 0 \leq t \leq 30. \tag{11}$$

$CBB(t) = (e^{-t})d|\varepsilon_i|(t), t \geq 0$ is the wave of the exact solution where $dCBB(t)$ representing the differential transformation of consumers' purchasing power in Nigeria.

3. RESULT AND DISCUSSION

3.1. GRAPHICAL PRESENTATION OF ABSOLUTE WAVE ERRORS

With the help of softwares of R and R-studio, the graphs of AVEs of SDBAMM for examples 2.1 and 2.2 above in Tables 1 to 2 are plotted and presented as Figures 7 and 8.

3.2. COMPARATIVE ANALYSIS OF FINDINGS

Comparing the least absolute wave errors (LAWEs) of the method with other methods in Refs. [13–15]:

3.3. GRAPHICAL PRESENTATION OF THE COMPARATIVE ANALYSIS OF FINDINGS

The comparative analysis of findings are shown in Figures 9 and 10.

4. CONCLUSION

This study has analyzed that SDBAMM is suitable for evaluating some examples of the modeled equation. Following the comparative analysis of the findings of the obtained results with other results of the applied numerical methods in evaluating the modeled equation, the discrete schemes of SDBAMM performed better by giving the most least absolute wave errors (MLAWEs). This study recommends that the adopting stronger monetary policy tools by the Nigerian government to manage tariff uncertainty, inflation and exchange rate waves will improve consumers' purchasing power and reduce economic fluctuations in the Nigerian markets.

DATA AVAILABILITY

The data will be available on request from the corresponding author.

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