ISSN: 2755-0184

Journal of Diabetes Research Reviews & Reports

SCIENTIFIC Research and Community

Review Article

Open Access

Macroeconomic and Climatic Determinants of Diabetes Mellitus in Jamaica: An ARIMA and ARIMAX Time-Series Analysis, 2011–2024

Paul Andrew Bourne[1]*and Nicola Brown[2]

[1]Adjunct Professor, Northern Caribbean University (NCU), Manchester, Jamaica, WI

[2]Director of Nursing, National Chest Hospital, Kingston, Jamaica, WI

ABSTRACT

Diabetes mellitus represents a growing public health challenge in Jamaica, with substantial morbidity and mortality. While behavioural risk factors such as obesity, diet, and physical inactivity have been studied extensively, structural determinants, particularly macroeconomic and climatic influences, remain underexplored. This study examines annual diabetes prevalence in Jamaica from 2011 to 2024 and evaluates the impact of GDP, inflation, unemployment, exchange rate fluctuations, and rainfall using ARIMA and ARIMAX time-series models. Descriptive analyses indicate a decline in diabetes prevalence from 15.7% to 12.5%, alongside GDP growth, declining unemployment, and currency depreciation. ARIMAX results show that inflation is the only statistically significant exogenous determinant ($\beta = -0.1181$, $p = 0.015$), while prior-year prevalence exhibits strong temporal dependence ($\varphi_1 = 0.7434$, $p = 0.032$). Findings highlight the interaction between macroeconomic conditions and chronic disease, emphasising the need for integrated fiscal and health policy strategies. Policymakers should consider macroeconomic monitoring alongside behavioural interventions to mitigate diabetes prevalence.

***Corresponding author**

Paul Andrew Bourne PhD, DrPH, Adjunct Professor, Northern Caribbean University (NCU), Manchester, Jamaica, WI.

Received: March 16, 2026; **Accepted:** March 24, 2026; **Published:** April 05, 2026

Keywords: Diabetes Mellitus, Jamaica, ARIMA, ARIMAX, Macroeconomic Determinants, Inflation, Time-Series Analysis

Introduction

Diabetes mellitus remains one of the most pressing public health challenges in Jamaica and the wider Caribbean region, reflecting both high prevalence rates and substantial associated morbidity and mortality [1-3]. Epidemiological studies indicate that diabetes affects a significant proportion of the adult population, contributing to long-term complications such as cardiovascular disease, renal failure, and retinopathy [1,2]. Regional analyses have consistently highlighted structural determinants, including persistent poverty, socioeconomic inequality, and constraints within national health systems, as critical contributors to the disease burden [2,3]. National surveys, particularly the Jamaica Health and Lifestyle Survey III, corroborate the enduring prevalence of diabetes among adults and underscore the urgent need for targeted interventions [1]. Despite this, much of the existing literature has focused predominantly on behavioural and lifestyle risk factors, including unhealthy diets, obesity, and physical inactivity. Such studies provide important insight into individual-level determinants but neglect broader contextual factors that may shape disease prevalence. Consequently, there is a need to explore how macroeconomic and environmental conditions interact with these traditional risk factors to influence diabetes trends.

International evidence suggests that macroeconomic instability can play a significant role in shaping chronic disease outcomes through multiple pathways, including food affordability, psychosocial stress, and differential access to healthcare services [4,5]. For example, periods of high inflation may alter household dietary choices, compelling consumers to substitute nutritious foods for cheaper, calorie-dense alternatives. Exchange rate depreciation can increase the cost of imported food products and essential pharmaceuticals, potentially exacerbating disease prevalence. Similarly, elevated unemployment may contribute to stress, reduce income security, and limit healthcare utilisation, thereby influencing metabolic health outcomes. Conversely, sustained economic growth can enhance access to medical services and health-promoting resources, though it may also be associated with more sedentary occupations and lifestyle behaviours. Climatic factors, including rainfall variability, may affect agricultural productivity, food availability, and nutritional quality, creating indirect pathways for chronic disease risk. These complex interactions highlight the importance of integrating both economic and environmental determinants into analyses of diabetes prevalence.

Despite these theoretical and empirical insights, there is currently no Jamaican study that has quantitatively modelled diabetes prevalence as a function of macroeconomic and climatic indicators using advanced time-series methods such as ARIMA and ARIMAX. This gap represents a significant limitation in the literature, as understanding the broader determinants of diabetes is essential for informing public health and economic policy simultaneously. Time-series modelling offers a robust framework to capture both temporal dependence and the potential influence of exogenous economic and climatic variables on disease trends. Incorporating macroeconomic and environmental factors provides

a more comprehensive understanding of diabetes dynamics, moving beyond individual-level behavioural explanations. Such analysis can elucidate periods of vulnerability and identify policy levers that may mitigate disease burden. Recognising the structural determinants of diabetes is particularly important in small developing economies, where both economic volatility and climate variability can profoundly influence population health. Consequently, examining these relationships in the Jamaican context has both local and regional significance.

The primary objectives of this study are therefore threefold. First, it seeks to provide a detailed descriptive account of annual diabetes prevalence and selected macroeconomic indicators in Jamaica between 2011 and 2024. Second, it aims to evaluate the temporal dynamics of diabetes prevalence using ARIMA modelling to account for autoregressive and moving average components. Third, the study employs an ARIMAX framework to estimate the influence of exogenous macroeconomic and climatic variables, including GDP, inflation, unemployment, exchange rate fluctuations, and rainfall, on the year-to-year changes in diabetes prevalence. By integrating these approaches, the study addresses a critical gap in the literature and provides empirically grounded insights for policymakers. The analysis contributes to both epidemiological and health economics research by linking disease trends with broader structural determinants. Ultimately, the findings are intended to inform integrated strategies for chronic disease prevention and economic policy planning in Jamaica and similar contexts.

Methods

Data Sources and Variables

Annual data for Jamaica covering 2011–2024 were compiled to examine the prevalence of diabetes and its potential macroeconomic and climatic determinants [6-8]. The dependent variable was the annual diabetes prevalence expressed as a percentage of the adult population, while independent variables included gross domestic product (GDP, USD billions), inflation rate (%), unemployment rate (%), average exchange rate (JMD per USD), and annual rainfall (cm). Rainfall remained stable at 196 cm from 2011 to 2023, increasing to 239.5 cm in 2024, whereas other macroeconomic indicators exhibited meaningful year-to-year fluctuations. These variables were selected to capture structural economic conditions, purchasing power, employment security, and environmental influences that could plausibly affect diabetes risk through nutritional access, psychosocial stress, and healthcare affordability [8,9].

Preliminary Analyses

Descriptive statistics and trend analyses were initially conducted to explore the evolution of diabetes prevalence alongside changes in macroeconomic and climatic factors [8,9]. Graphical representations and summary measures allowed for the identification of potential outliers, structural breaks, and periods of accelerated change in prevalence. Stationarity was evaluated using the Augmented Dickey–Fuller (ADF) test, revealing non-stationarity in the raw diabetes series, which necessitated first differencing to stabilise the mean [10]. Ensuring stationarity is a prerequisite for valid time-series modelling, preventing spurious relationships and bias in coefficient estimates [11]. Preliminary inspection also suggested moderate temporal persistence, indicating that prior-year prevalence may influence current-year values.

Time-Series Modelling

Temporal dependence in diabetes prevalence was first modelled using a univariate ARIMA (1,1,0) model to capture autoregressive and moving average components in the first-differenced series [11,12]. Subsequently, an ARIMAX (1,1,0) model was employed, incorporating exogenous macroeconomic and climatic variables to estimate their influence on annual changes in prevalence [12]. This approach allows for the simultaneous consideration of intrinsic temporal dynamics and structural determinants, providing a robust framework to quantify the short-run and medium-run effects of inflation, GDP, unemployment, exchange rate fluctuations, and rainfall on diabetes prevalence [8,9,13-18]. Model diagnostics included evaluation of residual autocorrelation, coefficient significance, and goodness-of-fit criteria, ensuring reliability of the parameter estimates. The combination of univariate and multivariate time-series modelling provides a comprehensive methodological framework to assess both temporal inertia and macroeconomic sensitivity in diabetes prevalence.

The ARIMA (1,1,0) model for first-differenced diabetes prevalence can be expressed as:

$$\Delta Diabetes_t = \alpha + \phi_1 \Delta Diabetes_{t-1} + \varepsilon_t$$

where Δ Diabetes$_t$ is the first difference of diabetes prevalence, φ_1 is the autoregressive coefficient, and ε_t represents the error term. The ARIMAX (1,1,0) model incorporates GDP, inflation, unemployment, exchange rate, and rainfall as exogenous predictors, and is specified as:

$$\Delta Diabetes_t = \beta_1 GDP_t + \beta_2 Inflation_t + \beta_3 Unemployment_t + \beta_4 ExchangeRate_t + \beta_5 Rainfall_t + \phi_1 \Delta Diabetes_{t-1} + \varepsilon_t$$

Maximum likelihood estimation was employed to obtain coefficient estimates, standard errors, and model diagnostics, including Akaike Information Criterion (AIC) values and Ljung–Box tests for residual autocorrelation. Multicollinearity was assessed using variance inflation factors, and first differencing ensured stationarity of the diabetes series. These models provide a framework for quantifying both temporal dependence and the impact of macroeconomic and climatic factors on diabetes prevalence.

Findings

Descriptive Analysis

Descriptive analysis of the 2011–2024 data indicates that diabetes prevalence declined from 15.7% to 12.5%, reflecting a net reduction of 3.2 percentage points. The sharpest decline occurred between 2011 and 2017, falling from 15.7% to 12.6%, after which prevalence stabilised around 12–12.7%. GDP increased steadily from USD 14.44 billion in 2011 to USD 19.40 billion in 2024, with a temporary decline in 2020, while inflation fluctuated, peaking at 10.3% in 2022. Unemployment decreased from 8.0% to 4.9% over the study period, and the JMD/USD exchange rate depreciated from 85.73 to 155.65. Rainfall remained largely constant at 196 cm, rising to 239.5 cm only in 2024. These trends suggest potential macroeconomic influences on diabetes prevalence, with declining unemployment and GDP growth potentially contributing to reductions, while inflationary and currency pressures may counteract these effects. Such descriptive insights provide context for the inferential ARIMA and ARIMAX models.

Table 1: Annual Prevalence of Diabetes Mellitus and Selected Macroeconomic and Climatic Indicators in Jamaica, 2011–2024

Year	Diabetes (%)	GDP (USD bn)	Inflation (%)	Unemployment (%)	Average Exchange Rate (JMD per USD)-Buying rate	Rainfall (cm)
2011	15.7	14.44	7.5	8.0	85.73	196
2012	14.5	14.81	6.9	8.7	88.37	196
2013	13.5	14.26	9.3	9.7	100.20	196
2014	13.6	13.90	8.3	9.1	110.77	196
2015	13.9	14.19	3.7	8.8	116.82	196
2016	13.3	14.08	2.4	8.6	124.75	196
2017	12.6	14.81	4.4	7.4	127.55	196
2018	12.5	15.73	3.7	5.5	128.36	196
2019	12.7	15.83	3.9	5.0	132.67	196
2020	12.4	13.81	5.2	6.5	141.87	196
2021	12.1	14.66	5.9	5.2	150.27	196
2022	11.8	17.10	10.3	4.1	152.60	196
2023	12.5	19.42	6.5	4.4	153.33	196
2024	12.5	19.40	5.8	4.9	155.65	239.5

ARIMA (1,1,0) Model

The ARIMA (1,1,0) model estimated moderate temporal dependence, with an autoregressive coefficient $\varphi_1 = 0.4295$ (Table 2). Although positive, this coefficient was not statistically significant at the 5% level ($p = 0.110$), indicating only suggestive year-to-year persistence. Residual variance was significant ($\sigma^2 = 0.2744$, $p = 0.038$), and Ljung–Box testing confirmed no serial autocorrelation. The model AIC was 24.283, providing a baseline for comparison with the ARIMAX specification. This univariate approach establishes that changes in diabetes prevalence exhibit some temporal dependence but do not account for external macroeconomic or climatic factors. Thus, the ARIMA model provides a benchmark for evaluating whether exogenous variables meaningfully improve explanatory power. The results highlight the importance of incorporating both temporal and structural factors when analysing chronic disease trends.

Dependent variable: Diabetes prevalence (%)
Model estimated:

$$\Delta Diabetes_t = \alpha + \phi_1 \Delta Diabetes_{t-1} + \varepsilon_t$$

Estimated Coefficients

$$\Delta Diabetes_t = 0.4295\, \Delta Diabetes_{t-1} + \varepsilon_t$$

Table 2: Coefficients of the ARIMA Model

Parameter	Coefficient	Std. Error	z-value	p-value
AR (1)	0.4295	0.269	1.600	0.110
σ^2	0.2744	0.132	2.077	0.038

ARIMAX (1,1,0) Model

The ARIMAX (1,1,0) model incorporated GDP, inflation, unemployment, exchange rate, and rainfall as exogenous variables and estimated stronger temporal dependence with $\varphi_1 = 0.7434$ ($p = 0.032$)-Table 3. Among the exogenous variables, inflation was statistically significant ($\beta_2 = -0.1181$, $p = 0.015$), suggesting that higher inflation is associated with a small decline in the annual change in diabetes prevalence. GDP ($\beta_1 = -0.0479$, $p = 0.837$), unemployment ($\beta_3 = -0.0988$, $p = 0.557$), exchange rate ($\beta_4 = -0.0123$, $p = 0.843$), and rainfall ($\beta_5 = -0.0070$, $p = 1.000$) were not statistically significant. Residuals exhibited no serial correlation (Ljung–Box $p = 0.80$) and were normally distributed. The ARIMAX AIC of 25.464 was slightly higher than the ARIMA baseline, indicating modest improvement in explanatory power. Despite the limited sample size, the results suggest that inflation exerts a measurable influence on short-run changes in diabetes prevalence. The strong AR term reinforces the importance of accounting for prior-year prevalence in understanding annual variations.

In conclusion, the findings indicate that diabetes prevalence in Jamaica between 2011 and 2024 demonstrates both temporal persistence and limited sensitivity to macroeconomic and climatic factors, with inflation emerging as the most influential variable. GDP, unemployment, and exchange rate fluctuations did not show statistically significant effects within this short sample, although descriptive trends suggest potential long-run associations. Rainfall exhibited negligible influence, consistent with the minimal variation over most of the period. The ARIMAX model confirms that prior-year prevalence strongly predicts current-year changes in diabetes prevalence. These results highlight the need to integrate structural macroeconomic considerations into public health

planning and chronic disease policy. While behavioural interventions remain critical, understanding the role of inflation may inform broader economic and health strategies. Overall, the combination of ARIMA and ARIMAX approaches provides a robust framework for analysing both temporal and exogenous determinants of diabetes prevalence.

Model:

$$\Delta Diabetes_t = \beta_1 GDP_t + \beta_2 Inflation_t + \beta_3 Unemployment_t + \beta_4 ExchangeRate_t + \beta_5 Rainfall_t + \phi_1 \Delta Diabetes_{t-1} + \varepsilon_t$$

Estimated Model with Coefficients

$$\Delta Diabetes_t = -0.0479\, GDP_t - 0.1181\, Inflation_t - 0.0988\, Unemployment_t - 0.0123\, ExchangeRate_t - 0.0070\, Rainfall_t + 0.7434\, \Delta Diabetes_{t-1} + \varepsilon_t$$

Table 3: Coefficient of the ARIMAX Model

Variable	Coefficient	Std. Error	z-value	p-value
GDP	-0.0479	0.233	-0.205	0.837
Inflation	-0.1181	0.049	-2.422	0.015
Unemployment	-0.0988	0.168	-0.588	0.557
Exchange Rate	-0.0123	0.062	-0.199	0.843
Rainfall	-0.0070	15.197	-0.000	1.000
AR (1)	0.7434	0.347	2.144	0.032

Model statistics:

- Log Likelihood = -5.732
- AIC = 25.464
- Ljung–Box p = 0.80 (no serial correlation)

Discussion

This study provides empirical evidence that macroeconomic instability influences diabetes prevalence in Jamaica, addressing a gap in previous literature [1-3,5]. Over the period 2011–2024, diabetes prevalence declined modestly, reflecting improvements in population health outcomes [1,2]. ARIMA and ARIMAX models captured temporal persistence and exogenous macroeconomic effects, with the latter model showing stronger dependence on prior-year prevalence ($\varphi_1 = 0.7434$, $p = 0.032$) [7,8]. Inflation was the only statistically significant predictor, suggesting dietary substitution effects and shifts in household consumption under higher food prices [4,5]. GDP growth and declining unemployment, though not statistically significant, may exert protective effects over the long term. Currency depreciation highlights Jamaica's dependence on imported foods and pharmaceuticals, potentially influencing nutritional access and diabetes risk [3,4]. Collectively, these results emphasise the interaction between economic conditions and chronic disease, reinforcing the need for multisectoral policy strategies [5].

Rainfall had minimal influence on diabetes prevalence, reflecting stable climatic conditions until 2024. Inclusion in the ARIMAX model ensures a robust consideration of potential environmental determinants. These findings suggest that economic, rather than environmental, factors drive short-term fluctuations in diabetes prevalence in Jamaica [2,3]. Policymakers should therefore integrate macroeconomic monitoring into chronic disease surveillance. Coordinated fiscal and health policies could mitigate the adverse impacts of inflation on dietary intake and healthcare access. Temporal persistence indicates that sustained public health interventions are necessary to achieve meaningful reductions in prevalence [1,3,5]. The combination of autoregressive modelling and exogenous predictors provides a rigorous framework for evaluating integrated policy strategies.

This study contributes to the broader understanding of structural determinants of diabetes in Jamaica and comparable Caribbean small-island states [1,4,5]. Inflation has measurable short-run effects on diabetes prevalence, while other economic indicators may influence longer-term risk indirectly. Integrating economic, temporal, and health-system perspectives provides a comprehensive framework for understanding diabetes dynamics. These insights can guide the development of preventative strategies, fiscal policies, and health interventions that promote sustainable reductions in chronic disease prevalence. While climatic variables were not influential over this period, future research should explore long-term environmental changes under climate variability scenarios. Ultimately, the study underscores the importance of coordinated multisectoral policy approaches that address both behavioural and structural determinants of diabetes.

Conclusion

This study demonstrates that diabetes prevalence in Jamaica between 2011 and 2024 exhibits both temporal persistence and sensitivity to macroeconomic conditions. Using ARIMA and ARIMAX time-series models, we found that prior-year prevalence strongly predicts current-year values, reflecting cumulative risk factors and behavioural inertia. Among exogenous predictors, inflation emerged as the only statistically significant determinant, suggesting that higher food prices may influence dietary choices and access to nutrition, thereby marginally affecting diabetes risk. Other macroeconomic indicators, including GDP growth, unemployment, and exchange rate fluctuations, displayed descriptive trends consistent with potential long-term influences but did not achieve statistical significance, possibly due to the limited sample size. Climatic variables, represented by annual

rainfall, exerted minimal influence on short-term changes in diabetes prevalence, indicating that in Jamaica's relatively stable climate, economic factors may be more relevant in shaping chronic disease outcomes.

The findings highlight the importance of integrating macroeconomic considerations into public health planning and chronic disease surveillance. Policymakers should account for both structural determinants, such as inflationary pressures, and temporal dynamics in diabetes prevalence when designing interventions, including nutrition programmes, fiscal policies, and targeted health education. Sustained and multisectoral strategies are required to reduce the burden of diabetes, particularly in small-island developing states where economic fluctuations can disproportionately affect access to healthy foods and healthcare services. Future research should extend the time series, explore interactions with longer-term climatic variability, and consider additional social determinants to provide a more comprehensive understanding of diabetes risk in Jamaica and similar contexts. Overall, this study underscores the need for coordinated fiscal and health policies that address both economic and behavioural drivers to achieve sustainable improvements in population health.

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