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RECEIVED 31 October 2025
REVISED 04 February 2026
ACCEPTED 13 February 2026
PUBLISHED 02 March 2026

CITATION

Alamaren AS, Eyadat AA, Alrjoub AM and
Alhajjeah D (2026) Analysis of the
duration measurement of Jordanian
debt as an effective hedging risk tool.
Front. Appl. Math. Stat. 12:1736648.
doi: 10.3389/fams.2026.1736648

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Analysis of the duration measurement of Jordanian debt as an effective hedging risk tool

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This study evaluates the duration of Jordanian public debt as an instrument for hedging interest rate risk over the period 2008–2020. It provides an analytical examination of public debt concepts and emphasizes the relevance of debt duration as a measure of maturity structure and interest rate sensitivity. The study covers both domestic and external public debt and situates the analysis within the historical context of Jordan's debt evolution, including the 1988 debt crisis and subsequent fiscal adjustments. Using a comprehensive dataset of Jordanian government treasury bonds denominated in Jordanian dinars, the study applies Macaulay Duration and Modified Duration models to assess the effective maturity and interest rate exposure of the public debt portfolio. The results indicate that the estimated Macaulay Duration of Jordanian public debt is approximately 2.514 years, reflecting the weighted average timing of debt cash flows and the horizon of interest rate sensitivity. The Modified Duration is estimated at approximately 2.293 years, indicating a moderate degree of price sensitivity to changes in interest rates. Overall, the findings suggest that Jordan's public debt exhibits a relatively short- to medium-term maturity structure, allowing for refinancing flexibility while maintaining manageable exposure to interest rate risk. The study highlights the usefulness of duration-based indicators as complementary tools for public debt management and risk assessment in emerging economies.

KEYWORDS

duration, hedging, Jordan, Macaulay's duration, modified duration, public debt

Introduction

The economic and political changes that occurred in the region in general and in Jordan, in particular, resulted in an augmentation of the economic and social demands of the growing population, as forced immigration contributed to the population's inflation, which consequently led to growing needs (1, 2). The region's instability led to the accumulation of both external and internal debt; in turn, the extreme scarcity of financial and economic resources inflicted the Jordanian economic crisis (3). The combination of these factors led to a significant reliance on foreign aid and loans, resulting in a persistent fiscal deficit that increased Jordan's debt as the case of the most third-world countries (4). Jordan first resorted to debt in 1949, when it signed an external loan for one million JDs from the British government. Despite the drastic effects of Jordan's economic crisis, there are indicators of the success of the Economic Adjustment Program, which the Jordanian government is implementing with the cooperation of the International Monetary Fund.

During the study period (2008–2020), Jordan's public debt experienced a pronounced upward trajectory, reflecting persistent fiscal pressures and repeated external shocks. According to official data from the Ministry of Finance, total public debt increased from approximately USD 14.4 billion in 2008 to over USD 43 billion by 2020, rising from about 65% of GDP to more than 90% by the end of the period. This expansion was driven by sustained budget deficits, rising public expenditure, regional instability, and the economic impact of hosting large numbers of refugees, in addition to the global financial crisis and its aftermath. While external debt constituted a significant share in the earlier years of the period, domestic debt grew more rapidly over time, indicating a strategic shift toward local currency borrowing to mitigate exchange rate risk. These developments highlight the increasing importance of effective debt management strategies, particularly those concerned with maturity structure and interest rate exposure, which form the core focus of the present study (6–8).

The significance of this study lies in its status as one of the first Jordanian studies to investigate this topic. Its importance also rests on assisting decision-makers of Jordanian financial policies by providing indicators about Jordan's capacity to pay off debt and its susceptibility to changes in interest rates; the study then provides appropriate recommendations to pave the way for further investigation on the subject. Furthermore, the objective of this study is to measure the duration of local governmental debt (in JDs) to figure out the maturity date's duration of these debts and measure the extent to which debt is influenced by the change in interest rates, and the government's capacity to repay debts and obligations during the study's period (2008–2020).

This study aims to determine the duration of the Jordanian government and its ability to repay debt, considering the country's frequent reliance on external or internal debt, which has led to increasing debt amounts. Increasing the sum of debt complicates its reimbursement process with a load of interest accumulation, which affects Jordan's financial security. The primary objective of this study is to examine the hypothesis that the duration of Jordanian debt significantly differs from the average debt duration. The investigation aims to identify distinct characteristics or patterns within Jordan's debt structure that may differentiate it from conventional debt profiles. Such an analysis is crucial for providing insights into the country's financial management strategies and evaluating the potential implications on economic stability and fiscal policy.

Jordan's public debt trajectory dates back to the late 1980s, with the 1988 debt crisis representing a pivotal turning point in the country's fiscal and monetary framework. This crisis was characterized by acute balance-of-payments pressures, a sharp depreciation of the Jordanian dinar, and a rapid accumulation of external debt, which collectively prompted the implementation of IMF-supported stabilization and structural adjustment programs aimed at restoring macroeconomic stability (9, 10).

During the 1990s and the early 2000s, external debt constituted the largest share of Jordan's total public debt, reflecting the country's reliance on concessional financing, bilateral loans, and foreign aid. Over time, however, financial sector reforms and the gradual deepening of domestic capital markets facilitated an increased use of internal debt instruments, particularly government treasury bonds and bills denominated in Jordanian dinars, as part of a broader effort to diversify funding sources and reduce vulnerability to external shocks (11).

From the mid-2000s onward, and more markedly following the global financial crisis of 2008, both internal and external public debt expanded substantially. This expansion was driven by persistent fiscal deficits, heightened regional instability, large refugee inflows, and rising public expenditure. Notably, domestic debt grew at a faster

pace than external debt, reflecting a deliberate policy shift toward local currency borrowing in order to mitigate exchange rate risk and strengthen debt sustainability (12, 13).

This historical evolution provides essential macroeconomic context for the present study and supports the selection of the 2008–2020 period, during which debt accumulation intensified and debt management considerations became increasingly critical. Within this context, the application of duration-based models offers a focused and theoretically grounded framework for evaluating the maturity structure and interest rate risk of Jordan's public debt portfolio.

Literature review

The duration measurement of Jordanian debt plays a significant role in mitigating risks associated with interest rate fluctuations, particularly during periods of economic uncertainty. According to Al-Momani and Al-Azzam (14), duration serves as a hedging tool by measuring the sensitivity of bond prices to changes in interest rates, thereby helping policymakers and investors manage exposure to interest rate risk. In the context of Jordan, where debt instruments often consist of long-term bonds, aligning portfolio duration with interest rate expectations is critical for minimizing volatility. Studies by Al-Rimawi (15) emphasize the importance of adopting advanced duration-based strategies to enhance financial stability, especially given the growing reliance on domestic and international debt. Furthermore, the application of duration analysis in Jordan mirrors global practices in emerging markets, where hedging tools are tailored to address specific fiscal and monetary challenges (12). Al-Khazaleh (16) highlights that an effective duration management strategy can protect against exchange rate risks, which often compound interest rate volatility in Jordan's debt portfolio. Similarly, Abdelkader and Hamed (17) suggest that central banks in Jordan and the wider MENA region benefit significantly from duration-based risk management frameworks to stabilize sovereign debt. Al-Farhan and Jaber (18) underscore the use of duration tools in aligning debt maturities with fiscal policy goals. Studies by Mohamad et al. (19) and Hamdan (20) provide further insights into how duration is integrated into regional risk management strategies, emphasizing the need for robust financial infrastructure to support these measures in Jordan. Bhattarai et al. (21) studied the time consistency and the duration of debt of the government, using the method of quantitative easing signals that use open market operations to change the average duration of debt influenced by stimuli for central bank services according to the real interest rate. With constant time (Markov-perfect), the fixed pricing model is tied to coordination between fiscal and monetary policy. The drop in the average duration government debt presents an influence for the central bank to hold real interest rates down in the future to avoid capital losses. In addition, the liquidity snare where nominal interest rates in the short term it is higher matched to the nominal ratio of zero bonds. In this study, the researcher used sticky-price model and Markov perfect time pattern and explained the theoretical model for open market operations that decrease the duration of unpaid government debt called "non-quantitative facilities" is not neutral, because the impact on central bank services, as decreasing the average duration of unpaid government debt is the reason for the central bank to hold interest rates short. The time is low in the future to avoid the loss in the balance sheet. Another study (22) highlighted Sudden Stops, Time Inconsistency and the Duration of Sovereign Debt. This study aims to understand the sovereign debt duration taken by the government by a standard model of sovereign

default. The government balances off its debt by raising the duration to decrease risk and duration to relieve the debt dilution dilemma. Furthermore, there are two important results in this study. First, when the government decides the debt duration on a serial basis, the risk suddenly stops will increase the average duration by 1 year. Second, explain the problem of inconsistency time in the choice of sovereign debt duration: governments want to commit to a period of less than 1.7 years than the period they choose when making decisions sequentially. Another study about Properties and Limitations of Duration as a Measure of the Time Structure of Bonds and Interest Rate Risk is presented by Ajlouni (23), the purpose of this study is to analyze the key points of duration as a measure of the time structure of bonds and interest rate risk. The study finds that, as a test of the temporary structure of the bonds, the period has four characteristics: First, the period of the bond is always equal to or less than its due date. Second, the duration of the zero-coupon bond is equal to maturity. Third, the duration increases with the increase in maturity and then decreases in non-linear steps, reaching zero on the date of the final maturity. Fourth with increasing maturity, duration tends to be closed forever. In addition, duration measures the market price elasticity of the asset (liability) about the market discount rate. Also, a study conducted by Bandopadhyaya (24), the Determinants of the Duration of Commercial Bank Debt Renegotiation for Sovereigns, this study aimed to analyze the duration of commercial debt rescheduling for banks. This study explains that the period of the first section of the rescheduling process, in which the major creditor banks and the debtor country participate, is greatly affected only by the size of the rescheduling schedule. Nevertheless, the second part of the process, where all creditor banks participate in the organization, is greatly influenced by maturity and debt / GNP, debt/exports, GNP growth through the renegotiation process, presence of exit bonds and early participation fees.

Tzannatos and Saif (13) assessed the sustainability of Jordan's public debt, highlighting the role of duration in mitigating refinancing and interest rate risks. Similarly, a study on Jordan's fiscal and monetary policy sustainability under a fixed exchange rate regime provided key insights into how duration strategies can enhance policy effectiveness amid persistent budget deficits. The IMF's Extended Quarterly Projection Model for the Central Bank of Jordan (25) further integrates duration concepts into macroeconomic forecasting, improving the country's ability to hedge against rate fluctuations. Globally, emerging research by Zhou et al. (26) on public debt cycles underscores that ignoring financial cycle interactions can distort duration-based debt strategies, while Chen and Lee (27) explored how sovereign debt structure affects inflation and interest rate risk—core variables linked to duration management. Expanding to bond markets, Zhang (28) analyzed the hedging effectiveness of green versus conventional bonds, offering methodological insights applicable to sovereign duration hedging frameworks. In the Jordanian context, the Debt Strategy 2023–2027 (29) explicitly targets improvements in average time to maturity, reinforcing the operational application of duration analysis. Recent public debt quarterly reports (30, 31) provide empirical data on maturity profiles—such as average maturities of 6.1 years for gross debt and 8.0 years for external debt—demonstrating practical progress toward optimized duration management. Finally, The Jordan Times (32) reported a 14.4% rise in debt servicing, signaling the growing importance of effective duration-based hedging to contain fiscal vulnerability. These studies contribute a coherent understanding of how duration measurement is an essential risk management and policy tool in sustaining Jordan's public debt stability.

Synthesis of the literature and research gap

The existing literature on public debt and duration analysis can be broadly classified into three main strands. The first strand focuses on duration as a quantitative tool for measuring interest rate sensitivity and hedging risk in fixed-income portfolios. Studies such as Ajlouni (23), Al-Momani and Al-Azzam (14), and Hamdan (20) emphasize that duration-based measures provide transparent and effective indicators of exposure to interest rate fluctuations, supporting their widespread use in debt and risk management frameworks. A key lesson from this strand is that duration remains a robust and policy-relevant metric, particularly when the objective is to assess maturity structure and interest rate risk rather than long-term macroeconomic sustainability.

The second strand examines public debt maturity structure and debt management strategies, highlighting the trade-offs between refinancing risk, interest rate risk, and borrowing costs. Research by Claessens et al. (12), Broner et al. (33), and Arellano and Ramanarayanan (34) demonstrates that governments actively adjust debt maturity profiles in response to economic uncertainty and market conditions. These studies suggest that managing maturity structure—rather than merely reducing debt levels—is central to effective debt risk management, especially in emerging economies.

The third strand concentrates on debt sustainability and fiscal policy in Jordan and comparable emerging economies. Studies such as Tzannatos and Saif (13) and Abdelkader and Hamed (17) highlight the growing challenges posed by rising debt levels and fiscal pressures, emphasizing the need for improved debt management tools. However, much of this literature relies on macroeconomic sustainability indicators and projection-based frameworks, with limited attention to the time structure and interest rate sensitivity of debt portfolios.

Taken together, literature underscores the importance of combining debt sustainability concerns with maturity-based risk analysis. Despite the richness of existing studies, there remains a noticeable gap in applying duration-based models to a comprehensive national debt portfolio over an extended period. This study addresses this gap by applying Macaulay's Duration and Modified Duration to Jordanian public debt, thereby situating duration analysis as a complementary and policy-relevant tool within the broader debt management and sustainability literature.

The study's hypothesis

This study seeks to test the following main hypothesis:

The Jordanian debt duration differs from the average debt duration.

The purpose and significance of this study

What distinguishes this study is that while all previous foreign studies reviewed the subject of debt in an overall or general view and dealt with the concepts, benefits, and areas of application, in addition to the ways and the model's employment and development, this study addresses all the sensitive aspects of debt.

Moreover, unlike the current study, previous studies did not tackle the subject of a particular state's debt. The latter also differs from other studies' objectives and the problem it handles, being the first in Jordan to investigate such an issue. On top of all, this study is among the first Arab studies in its subject matter, according to the researcher's knowledge.

Data and methodology

The study's sample

The data available during the study period (2008–2020) have been collected from the government treasury bonds in Jordanian Dinars, a total of 398 bonds with different versions compiled during the period.

The study model

Methodological framework and model justification

This study adopts Macaulay's Duration and Modified Duration as its core analytical tools due to their well-established role in measuring interest rate sensitivity and effective maturity in fixed-income instruments. These models are particularly suitable for sovereign debt analysis, as they allow for a time-weighted evaluation of cash flows and provide a direct link between debt structure and interest rate risk exposure. The use of both measures enables a comprehensive assessment, where Macaulay's Duration captures the weighted average time to receive cash flows, while Modified Duration reflects the price sensitivity of debt instruments to changes in interest rates. Together, these models offer a robust and transparent framework for evaluating Jordanian public debt as a hedging tool against interest rate volatility.

The study utilized the following models

The models employed in this study, Macaulay Duration and Modified Duration, are standard tools in fixed-income analysis and sovereign debt management. Macaulay Duration, originally introduced by Frederick Macaulay, measures the weighted average timing of cash flows and is widely used to assess effective maturity and interest rate exposure (23, 35). Modified Duration is derived from Macaulay Duration and provides a linear approximation of bond price sensitivity to changes in yields, making it a commonly applied indicator for interest rate risk management (5, 36). These models have been extensively applied in the analysis of public debt and maturity structure, particularly in emerging economies, due to their transparency and policy relevance (12, 13).

Macaulay's duration: this model measures the percentage change in the value of the bond to the percentage change in its maturity, where the weight of each of the cash flows is determined by dividing the current value of cash flows by the price. The model is named after its inventor Frederick Macaulay, and many portfolio managers use this model to measure debt's duration as a hedging and immunization tool. This model measures as well the degrees of bonds' affectedness on interest rates through Equation 1:

$$D = \frac{\sum_{t=1}^n \frac{t \times Ct}{(1+i)^t}}{\sum_{t=1}^n \frac{Ct}{(1+i)^t}} \tag{1}$$

Whereas:

D: Macaulay duration per year.

n: the number of cash flows.

t: the time to receive the cash flow.

C_t: the cash flow payment.

i: the yield to maturity.

The portfolio's average duration is derived from the individual characteristics of the sampled treasury bonds. Importantly, the duration of a sovereign debt portfolio (D_p) is not calculated as a simple arithmetic mean; rather, it is defined as a weighted average of the durations of the individual instruments composing the portfolio. This relationship is expressed mathematically in Equation 2:

$$D_p = \sum_{j=1}^n w_j \cdot D_j \tag{2}$$

where D_j denotes the Macaulay duration of the j^{th} bond, and w_i represents its relative weight within the total portfolio. The weight is calculated as the ratio of the present value of the bond's cash flows to the total market value of the sovereign debt portfolio:

$$\left(w_i = \frac{PV_i}{\sum PV} \right)$$

This weighting mechanism ensures that bonds with larger outstanding values exert a proportionally greater influence on the portfolio's overall duration, thereby accurately reflecting the government's exposure to interest rate risk. By aggregating these weighted durations across the 398 treasury bonds examined over the 2008–2020 period, the study produces a robust and comprehensive measure of the portfolio's effective maturity. Consequently, this measure captures the functional role of sovereign debt duration as a key instrument for managing interest rate risk and mitigating exposure to market volatility.

Modified Duration is derived from Macaulay Duration by examining the sensitivity of bond prices to changes in the yield to maturity. The price of a fixed-rate bond is given by:

$$P = \sum_{t=1}^n \frac{C_t}{(1+y)^t}$$

Where P denotes the bond price, C_t represents the cash flow (coupon payment or principal repayment) received at time t , y is the yield to maturity, n is the bond's time to maturity, and t denotes the time period in years.

Taking the first derivative of the bond price with respect to the yield to maturity and expressing it in proportional terms yields:

$$\frac{1}{P} \frac{\partial P}{\partial y} = - \frac{1}{1+y} \sum_{t=1}^n \frac{t \cdot C_t}{(1+y)^t} / P$$

The summation term corresponds to Macaulay Duration, which measures the weighted average timing of the bond's cash flows, where the weights are given by the present value of each cash flow relative to the bond price.

Accordingly, Modified Duration is defined as:

$$D_{mod} = \frac{D_{Mac}}{1+y}$$

Where D_{mod} denotes Modified Duration and D_{Mac} denotes Macaulay Duration. Modified Duration provides a linear approximation of the percentage change in bond price resulting from a small change in the yield to maturity and therefore serves as a direct measure of interest rate sensitivity.

Modified duration: this model is used to measure the average period of investment to respond to the change in interest rates of the bond, which means price sensitivity, which is the percentage change in price due to the change in the unit of return. This model demonstrates that both interest rates and bond prices move in opposite directions, this model is summed in Equation 3:

$$D = \frac{\text{Macaulay's Duration}}{(1 + y)} \tag{3}$$

Where:

y : the yield to maturity.

Data was collected during the period 2008–2020 and then used in the calculation process, which is done as follows:

- Treasury Bonds during the period 2008–2020.
- Treasury Bonds and both the annual and the weighted average interest rates.

Annual interest rates have been used to find bonds' yields, to calculate bonds' prices, complying with the following steps:

Calculating coupon payment value:

$$\text{Coupon payment} = \text{value of bond}^* \text{ annual interest rate}$$

The analysis is restricted to fixed-rate Jordanian government treasury bonds denominated in Jordanian dinars. Floating-rate or indexed debt instruments are excluded from the sample. This restriction ensures consistency in the calculation of coupon payments and duration measures, as both Macaulay and Modified Duration are most appropriately applied to fixed-coupon securities with predetermined cash flows.

The weighted average annual interest rates reported in Table 1 are used as proxies for bond yields to maturity (YTM) in the pricing and duration calculations. Due to the unavailability of a complete term structure of interest rates for Jordanian government bonds over the study period, the analysis assumes a flat yield curve within each year. Accordingly, the prevailing annual weighted average interest rate is applied as the yield to maturity for all treasury bonds issued in that year when estimating bond prices using Equation 4.

Calculating bond prices separately through the following equation:

$$\text{Bond Price} = \sum_{t=1}^n \frac{C}{(1+i)^t} + \frac{M}{(1+i)^n} \tag{4}$$

C: coupon payment.

i : interest rates (see Table 1).

t : time of period.

TABLE 1 Real rate, or the weighted average in interest rates.

Weighted average interest rates on discounted bills and bonds	Years
8.89%	2008
9.17%	2009
9.41%	2010
9.34%	2011
9.59%	2012
10.13%	2013
9.95%	2014
8.70%	2015
10.42%	2016
10.23%	2017
9.64%	2018
9.55%	2019
8.51%	2020

M : face value (the principal amount repaid at maturity).

n : time to maturity.

In Equation 4, the discount rate i is assigned to the bond level based on the year of issuance. Specifically, all treasury bonds issued within the same year are discounted using the corresponding weighted average annual interest rate reported in Table 1. This rate serves as a common yield-to-maturity proxy for bonds issued in that year, reflecting prevailing market financing conditions. Consequently, while Equation 4 applies to a single discount rate per bond, variation in i arises across years rather than across bonds within the same year. The nominal value M is assumed to be constant across all bonds. This assumption is valid for the sampled Jordanian government treasury bonds, as these instruments are issued with standardized face values determined by the Ministry of Finance. Moreover, the use of a constant nominal value does not affect the estimation of Macaulay or Modified Duration, since duration measures are scale-invariant and depend on the relative timing and present value weights of cash flows rather than on the absolute size of the nominal principal.

The bonds' duration has been calculated, and the following results have been attained:

Results

Using Macaulay's Duration model, the duration of Jordanian debt in 2008 was found to equal 0.015 years. Using the Modified Duration model, it was found to equal 0.014 years, but when calculating the debt's average, it turned out to equal 3.662 years. This means that the Jordanian debt in 2008 was relatively stable and less sensitive to interest rate volatility. The low numerical values of the Macaulay and Modified durations do not indicate short-term borrowing but rather reflect the discounting effect of future cash flows and the weighting structure used in these models. When these durations are aggregated across the entire portfolio, the average duration of 3.662 years provides a more realistic measure of the time-weighted exposure of the government's debt. This level of duration implies that, on average, it

would take approximately 3.7 years for investors to recover the present value of their investment in government debt instruments, confirming that the debt is of a medium-term nature. From a risk management perspective, this duration suggests that Jordan's debt carries a moderate level of interest rate risk long enough to benefit from stable funding conditions, yet short enough to allow periodic refinancing and adaptation to changing market conditions (see Table 2).

In 2009 Jordanian duration debt, using Macaulay's Duration model, was found to equal 0.091 years, and 0.082 when using the Modified Duration model. Yet when counting the average debt duration, it appeared to equal 3.681. This indicates that, although the individual duration measures appear numerically small due to the mathematical weighting of discounted cash flows, the overall debt portfolio maintained a medium-term maturity structure. Economically, this reflects Jordan's strategy to balance interest rate risk and refinancing flexibility, ensuring that the debt portfolio remained stable despite global financial uncertainty. The average duration of about 3.7 years suggests that the government's debt instruments were structured to hedge effectively against sudden changes in interest rates, providing steady debt-servicing conditions and supporting fiscal sustainability. Overall, the 2009 results confirm that Jordan's debt management policy emphasized risk mitigation through duration control, maintaining a sound and moderately sensitive debt profile (see Table 3).

In 2010, the Jordanian duration debt was found 0.038 years using Macaulay's Duration model. Applying the Modified Duration model, it equaled 0.035 years, while when counted, the average debt duration appeared to amount to 4.611 for the same year. This result indicates a clear extension in the overall maturity structure of Jordan's public debt compared with previous years, reflecting a strategic shift toward longer-term borrowing instruments. Economically, the higher average duration signifies that the government aimed to reduce refinancing risk by locking in debt at longer maturities, ensuring greater stability in debt servicing over time. Moreover, the Macaulay and Modified duration values remain low due to their sensitivity to discounting and cash flow timing; the average duration provides a more realistic measure of the portfolio's exposure to interest rate changes. A duration of around 4.6 years implies moderate responsiveness to interest rate fluctuations, allowing the government to benefit from predictable financing costs while maintaining flexibility in managing public liabilities. Overall, the 2010 duration figures demonstrate that Jordan pursued a prudent debt management policy, strengthening the debt's role as an effective hedging tool against long-term interest rate volatility and financial uncertainty (see Table 4).

In 2011, using Macaulay's Duration, Jordanian duration debt equaled 0.088 years, and 0.081 years using the Modified Duration

model. However, it occurred that the average debt duration for this year totals 4.267. Economically, an average duration of 4.27 years suggests that the government's debt instruments were structured to minimize exposure to short-term interest rate fluctuations, thereby enhancing financial stability and predictability in debt servicing. This duration level demonstrates Jordan's commitment to prudent debt management, using duration as a risk-hedging mechanism to mitigate the impact of interest rate volatility while maintaining sustainable borrowing conditions within a stable fiscal framework (see Table 5).

In 2012, by using Macaulay's Duration model, the Jordanian Macaulay's duration was estimated at 0.077 years, while by 0.071 years applying the Modified Duration model, and when reckoning the average duration, it turned out to equal 3.397 years for this year. This result indicates a slight shortening in the overall maturity structure of Jordan's public debt compared with the previous year, suggesting a strategic adjustment toward more flexible and cost-efficient borrowing. Economically, the reduction in average duration reflects the government's efforts to balance interest rate risk and refinancing needs, possibly in response to changing market conditions or fiscal pressures. Although the Macaulay and Modified durations remain numerically low due to the discounting effect of near-term cash flows, the average duration provides a more accurate measure of the effective maturity and risk exposure of the debt portfolio. With an average duration of approximately 3.4 years, the portfolio maintained moderate sensitivity to interest rate movements, providing a reasonable hedge against market volatility while preserving liquidity and maintaining refinancing capacity. Overall, the 2012 results illustrate Jordan's pragmatic approach to debt management, emphasizing risk control and financial stability through the careful calibration of debt maturity and duration (see Table 6).

In 2013, Jordanian duration debt was found to amount to 0.071, using Macaulay's Duration model, whilst through applying the Modified Duration model, the result was 0.065 years, but when counting the debt's duration average, the latter turned out to equal 3.299 years. This result indicates a continued moderate decline in the overall maturity profile of public debt compared with the previous year, reflecting a possible government decision to rely more on medium-term instruments amid evolving economic and financial conditions. Economically, the decrease in average duration suggests

TABLE 2 Calculating duration and the average of Jordanian debt for 2008.

Average duration	Modified duration	Macaulay's duration	Year
3.662	0.014	0.015	2008

TABLE 3 Calculating duration and the average of Jordanian debt for 2009.

Average duration	Modified duration	Macaulay's duration	Year
3.681	0.082	0.091	2009

TABLE 4 Calculating duration and the average of Jordanian debt for 2010.

Average duration	Modified duration	Macaulay's duration	Year
4.611	0.035	0.038	2010

TABLE 5 Calculating duration and the average of Jordanian debt for 2011.

Average duration	Modified duration	Macaulay's duration	Year
4.267	0.081	0.088	2011

TABLE 6 Computing the Jordanian Macaulay's duration and average duration for 2012:

Average duration	Modified duration	Macaulay's duration	Year
3.397	0.071	0.077	2012

TABLE 7 Calculating duration and the average of Jordanian debt for 2013.

Average duration	Modified duration	Macaulay's duration	Year
3.299	0.065	0.071	2013

TABLE 8 Calculating duration and the average of Jordanian debt for 2014.

Average duration	Modified duration	Macaulay's duration	Year
1.748	0.095	0.104	2014

TABLE 9 Calculating duration and the average of Jordanian debt for 2015.

Average duration	Modified duration	Macaulay's duration	Year
2.721	0.169	0.185	2015

an effort to enhance flexibility and manage refinancing risk, allowing the government to adjust borrowing costs in response to market changes. The low Macaulay and Modified duration values result from the time-weighting of discounted cash flows, whereas the average duration more accurately represents the actual time horizon of debt obligations. With an average duration of approximately 3.3 years, Jordan's debt portfolio remained moderately exposed to interest rate fluctuations, ensuring stability in debt servicing while maintaining fiscal adaptability (see Table 7).

In 2014, implementing Macaulay's Duration model, the Jordanian Macaulay's duration was determined to amount to 0.104 years. Using the Modified Duration, on the other hand, the result was 0.095 years. Yet, when counting the debt's duration average, it seemed to amount to 1.748 for the same year. This indicates a significant shortening of the overall debt maturity structure compared with previous years, suggesting a strategic shift toward short- to medium-term instruments. The lower average duration implies reduced interest rate risk exposure but increased refinancing frequency, allowing the government more flexibility in managing debt costs. The discrepancy between the individual and average durations reflects the weighting of cash flows, with the average duration providing a more realistic measure of the portfolio's effective maturity and risk profile (see Table 8).

In 2015, Jordanian duration debt was found to equal 0.185 years, while 0.169 years when employing the Modified Duration model. When estimating the average duration, it was determined that 2.721 is a suitable estimate for this year. This indicates a moderate increase in the overall maturity structure compared with 2014, reflecting a shift toward longer-term instruments in the debt portfolio. The higher average duration suggests that the government aimed to balance interest rate risk and refinancing needs, providing greater stability in debt servicing. The difference between the individual and average duration highlights the effect of cash flow weighting, with the average duration offering a more accurate representation of the portfolio's effective maturity (see Table 9).

In 2016, the Jordanian duration debt was found to equal 0.237 years applying Macaulay's Duration model; using the Modified Duration model, it was found to amount to 0.217 years. However, the average debt duration for the same year appeared to equal 2.099. This

TABLE 10 Calculating duration and the average of Jordanian debt for 2016.

Average duration	Modified duration	Macaulay's duration	Year
2.099	0.217	0.237	2016

TABLE 11 Calculating duration and the average of Jordanian debt for 2017.

Average duration	Modified duration	Macaulay's duration	Year
2.289	0.215	0.235	2017

TABLE 12 Calculating duration and the average of Jordanian debt for 2018.

Average duration	Modified duration	Macaulay's duration	Year
2.081	0.339	0.371	2018

resulted in a slight shortening of the overall debt maturity structure compared to the previous year, indicating a government strategy focused on enhancing flexibility and managing refinancing risk. Economically, the lower average duration implies moderate exposure to interest rate fluctuations, allowing the government to maintain stable debt servicing costs while retaining the ability to adjust its debt portfolio to evolving market conditions. The contrast between the individual and average duration highlights the effect of cash flow weighting, with the average duration providing a more realistic reflection of the portfolio's effective maturity and interest rate sensitivity (see Table 10).

In 2017, by implementing Macaulay's Duration model, the Jordanian Macaulay's duration was estimated to be 0.235 years and 0.215 years when using the Modified Duration model, yet when counting the average debt duration, it seemed to equal 2.289 years for this same year (see Table 11).

In 2018, utilizing Macaulay's Duration model, Jordanian debt duration resulted in 0.371 years, whereas by applying the Modified Duration model the result was 0.339, but when reckoning the average duration, it turned out to equal 2.081 for the same year. This indicates a slight increase in the overall debt maturity compared with 2016, reflecting a gradual extension of the government's debt portfolio. Economically, the average duration of about 2.3 years suggests that the debt maintained moderate sensitivity to interest rate changes, providing a balance between stable debt servicing and flexibility for refinancing. The low individual Macaulay and Modified durations reflect the weighting of cash flows, whereas the average duration captures the effective maturity and risk exposure of the entire portfolio (see Table 12).

In 2019, by using Macaulay's Duration model, the Jordanian debt duration was found to equal 0.461 years, and 0.419 when applying the Modified Duration model, but when calculating the average of debt duration, the value equalled 2.629 for the same year. This indicates a moderate extension of the debt portfolio's effective maturity compared with previous years, reflecting a strategy to balance interest rate risk and refinancing needs. Economically, the average duration of around 2.63 years suggests that the government maintained moderate exposure to interest rate fluctuations, allowing predictable debt servicing while retaining flexibility in managing public liabilities. The low

TABLE 13 Calculating duration and the average of Jordanian debt for 2019.

Average duration	Modified duration	Macaulay's duration	Year
2.629	0.419	0.461	2019

TABLE 14 Calculating duration and the average of Jordanian debt for 2020.

Average duration	Modified duration	Macaulay's duration	Year
2.721	0.491	0.541	2020

individual Macaulay and Modified durations arise from the weighting of near-term cash flows, whereas the average duration better represents the overall risk profile and maturity structure of the debt portfolio (see Table 13).

In 2020, when operating Macaulay's Duration model, Jordan's Macaulay's duration was found to equal 0.541 years, and it equaled 0.491 years using the model of Modified Duration, but when counting the average of duration, the result of this year was found to equal 2.721. This moderate extension in the debt portfolio's effective maturity reflects the government's response to the economic uncertainty caused by the COVID-19 pandemic, which created volatility in global and domestic financial markets. Economically, the higher average duration suggests that Jordan aimed to lock in financing over a slightly longer horizon to reduce refinancing risk during a period of heightened interest rate and market uncertainty. The low Macaulay and Modified durations result from the weighting of near-term cash flows, whereas the average duration provides a more realistic measure of the portfolio's overall interest rate sensitivity and effective maturity. Overall, the 2020 results indicate that Jordan used duration management as a tool to hedge against pandemic-related financial risks, ensuring stability in debt servicing while maintaining flexibility to respond to evolving economic challenges (see Table 14).

When reckoning the duration of all the years during the period 2008–2020, the following results featured:

- First: through Macaulay's Duration model, the Jordanian debt's duration is equal to 2.514 years, this result indicates that the weighted average timing of the government's debt cash flows is approximately 2.514 years, reflecting the effective maturity and interest rate exposure horizon of the public debt portfolio.
- Second: the Jordanian duration debt, through the Modified Duration, equals 2.293 years, this denotes that the Jordanian government is capable of repaying its debt with a 2.293-year duration during the study's period.
- Third: the Jordanian average duration amounts to 2.501 years, in other words, the Jordanian government is able to repay its debt with an average equivalent of 2.501 years during the study's period.

Thus, applying Macaulay's Duration model and the Modified Duration model during the period 2008–2020 the Jordanian debt duration was figured out.

Also using the two models it appeared that the Jordanian duration debt is greater than the Jordanian average duration, in addition to that, using the Modified Duration model showed that Jordanian debt duration is less than the Jordanian average duration.

Interpretation of duration dynamics and underlying drivers

To strengthen the interpretation of the results, it is important to emphasize that the observed variation in debt duration over time is both mechanically and economically driven by three main factors: (i) the maturity composition of issued debt instruments, (ii) the relationship between coupon rates and market yields, and (iii) shifts in the interest rate environment that affect the discounting of future cash flows. According to duration theory, longer maturities and lower coupon rates generally increase duration, whereas higher yields reduce the present value weight of distant cash flows, thereby compressing duration (36, 37).

Accordingly, years characterized by an extension in the maturity profile—through a higher share of medium- and long-term bond issuance—tend to exhibit higher average duration, reflecting a deliberate debt management strategy aimed at reducing refinancing and rollover risk by securing funding over longer horizons. In contrast, increased reliance on short-term instruments, often motivated by cost considerations or the need for liquidity and flexibility, mechanically lowers duration while heightening refinancing exposure (33, 34).

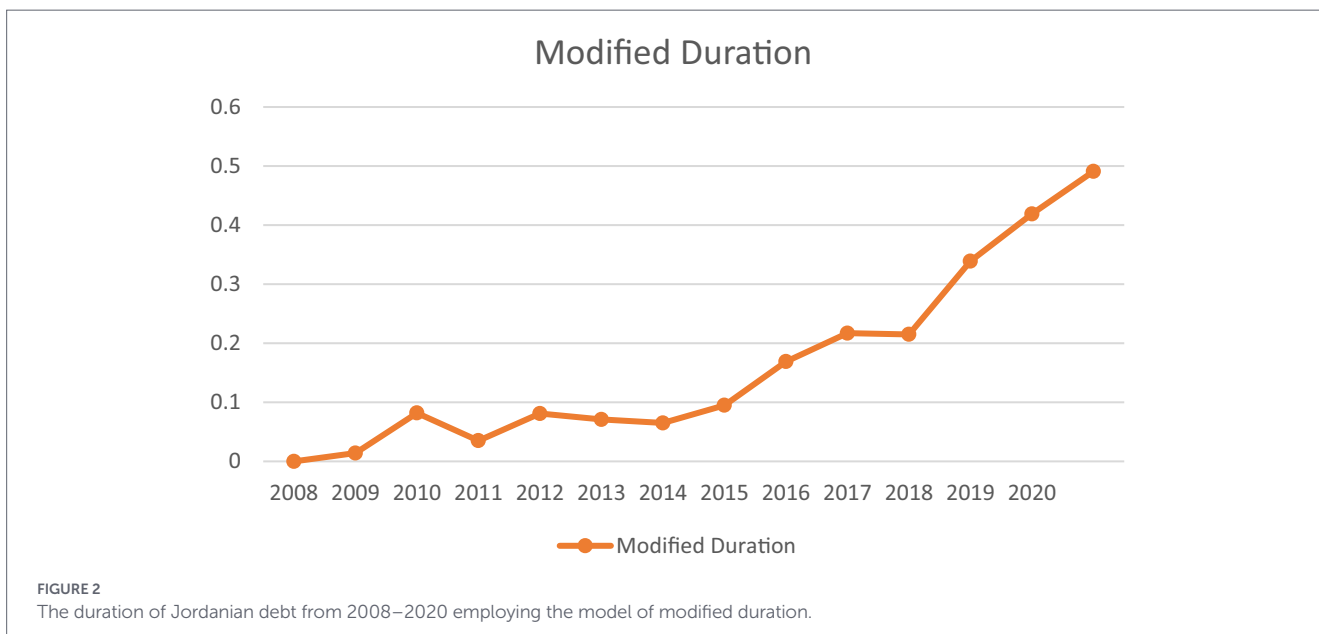
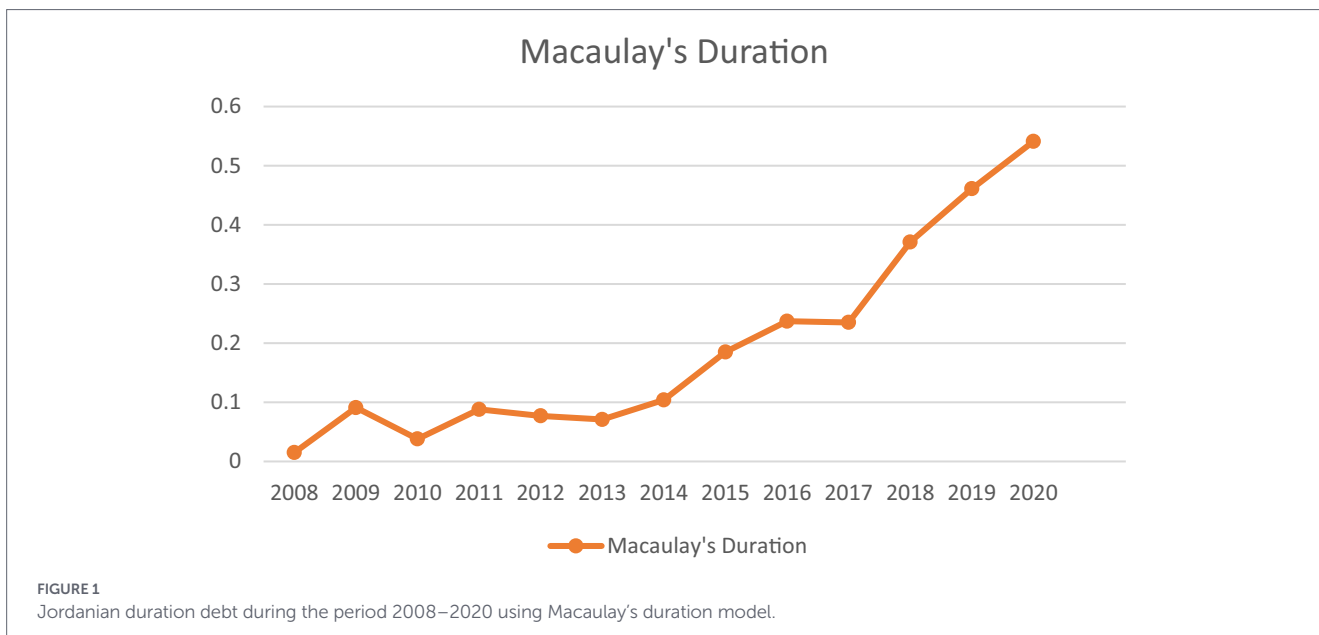
Furthermore, macroeconomic and financial conditions provide an essential causal context for these patterns. In emerging economies, debt maturity structure is frequently adjusted in response to periods of heightened uncertainty, fiscal stress, or external shocks, as governments balance interest rate risk against refinancing risk (12). For instance, the global financial crisis of 2008–2009 and the COVID-19 shock in 2020 increased financing needs and uncertainty, prompting sovereign debt managers to stabilize debt servicing costs and mitigate rollover risk through maturity adjustments consistent with international debt management guidelines (38).

Therefore, the duration estimates presented in this study should be interpreted not merely as numerical outcomes, but as reflections of evolving debt management trade-offs shaped by issuance strategy, refinancing considerations, and the prevailing macro-financial environment.

Figure 1 shows duration using Macaulay's Duration model, where from 2008 the Macaulay's duration gradually began increasing then declined in 2010, and then got back to increasing up to 2020.

Figure 2 clarifies Macaulay's duration using the Modified Duration model. It appears that the Macaulay's duration started to rise from 2008 gradually to decline in 2010, then went up again till 2020.

Figure 3 exhibits the Jordanian debt's average during the period 2008–2020. Where we trace that the lowest average of Jordanian debt was in 2008 with an average of 1.748 years, compared to the average of 2008 which recorded 4.611 years which was the highest one. Compared to 2010, it recorded the highest rate, with an average of 4.611 years. The relatively small numerical values reported on the y-axis in Figures 1, 2 reflect bond-level Macaulay and Modified Duration coefficients rather than average portfolio duration expressed in years. These values arise from the discounting structure of cash flows and the prevailing interest rate environment, which assigns greater weight to near-term payments. Consequently, they should not be interpreted as the effective maturity of public debt. The economically meaningful measure of debt maturity and interest rate exposure is captured by the average duration values reported separately in Figure 3 and Table 15.



Conclusion

Through the study that has been presented, the researcher finds that from 2008 to 2020, the Jordanian debt has been constantly increasing. Nonetheless, being a part of the Gross Domestic Product, the Jordanian debt's actual level has significantly decreased at the period's beginning, then risen slightly in recent years due to the global financial crisis. Therefore, calculating debts of duration can be used as a risk hedging tool, and also to predict prohibitions because it informs us about the required period, so we can calculate the rate of change in the value of the asset and the change's percentage in the maturity date, thus hedging the risk of volatility of interest rates. According to the previous results, we find that the Macaulay's duration using Macaulay's Duration model equals 2.514 years, and applying the Modified Duration equals 2.293 years. These are economically good indicators for the Jordanian

government. Since it is also considered a short period and not a long period, this is a good indicator in terms of hedging the risks of increasing debt and duration debt. The researcher also sees that Jordanian experts must interfere to reduce the debt rate and resort to alternative local sources to minimize Jordan's fiscal deficit. They should also look for other revenue to resolve the problem. The findings of this study carry important policy implications for public debt management in Jordan. The estimated duration measures provide policymakers with clear indicators of interest rate risk exposure and refinancing horizons, enabling more informed decisions regarding debt maturity structuring. A moderate debt duration, as observed in the study period, suggests that the government can balance cost efficiency with refinancing flexibility. Moreover, duration analysis can be integrated into debt strategy frameworks to support hedging against interest rate volatility, enhance fiscal sustainability, and improve the predictability of debt servicing costs.

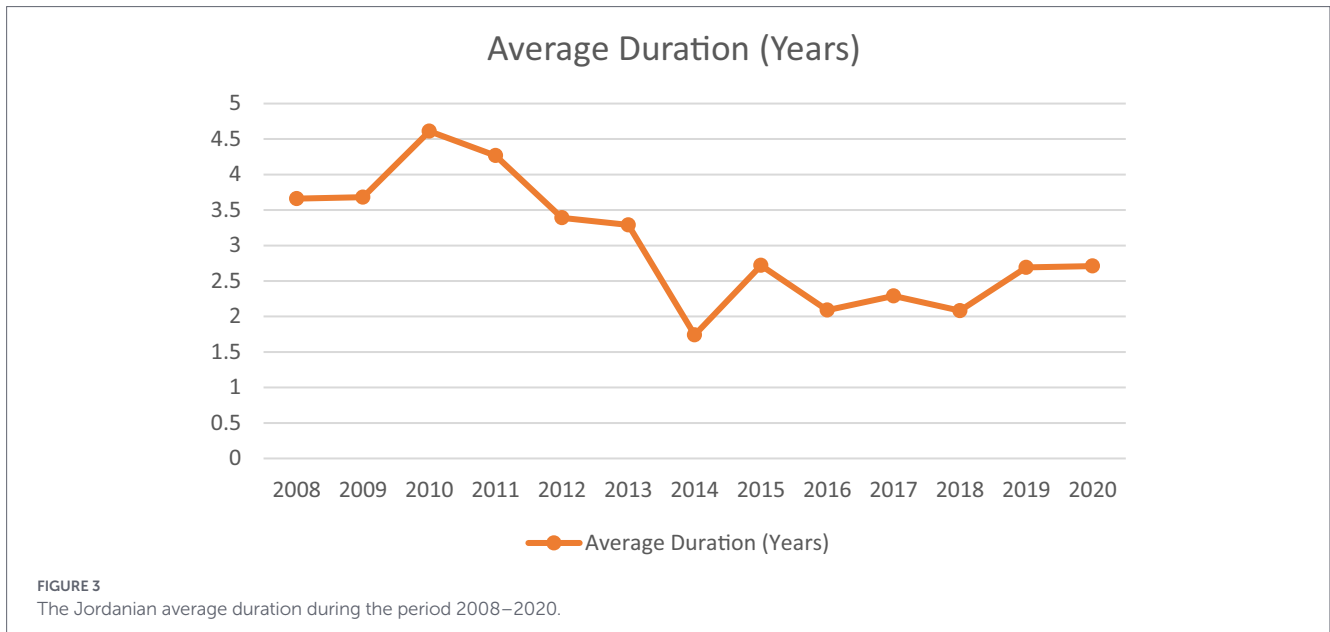


TABLE 15 determining the Jordanian debt duration and the average for 2008–2020.

Average duration	Modified duration	Macaulay's duration	Year
2.501	2.293	2.514	2008–2020

Accordingly, incorporating duration-based indicators into Jordan's debt management policies can strengthen risk mitigation and long-term financial stability.

Limitations of the study

Despite the robustness of the duration-based approach, this study is subject to certain limitations inherent in the employed models. First, Macaulay's and Modified Duration assume fixed cash flows and relatively stable interest rate structures, which may not fully capture nonlinear dynamics or sudden market shocks. Second, the analysis focuses on government treasury bonds denominated in Jordanian Dinars, excluding external debt instruments and exchange rate fluctuations. Finally, the study does not account for convexity effects, which may influence price sensitivity under large interest rate movements. These limitations, however, do not undermine the validity of the results; rather, they define the analytical scope of the study and align it with standard practices in sovereign debt duration analysis. The derivation of Modified Duration from Macaulay Duration in this study follows the standard linear approximation, which assumes relatively small changes in interest rates and therefore does not explicitly account for convexity effects. While convexity becomes relevant under large and non-linear interest rate movements, its exclusion does not materially affect the validity of duration-based risk assessments within the scope of moderate rate fluctuations considered in this analysis. The duration estimates reported in this study are deterministic measures derived directly from observed cash flows, interest rates, and maturities of government bonds. As such, they do not rely on statistical estimation procedures that would naturally yield standard errors or confidence intervals. Consequently, no formal error analysis or confidence

bands are reported. While incorporating stochastic interest rate models or simulation-based approaches could provide probabilistic assessments of duration, such extensions are beyond the scope of the present study and represent a potential avenue for future research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AmA: Supervision, Investigation, Writing – review & editing, Data curation, Software, Methodology, Visualization, Writing – original draft, Funding acquisition, Validation, Resources, Formal analysis. AE: Methodology, Data curation, Conceptualization, Writing – review & editing, Formal analysis, Funding acquisition. AsA: Visualization, Validation, Writing – review & editing, Conceptualization. DA: Investigation, Writing – review & editing, Methodology.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that Generative AI was used in the creation of this manuscript. Declaration of generative AI and AI-assisted technologies in the writing process during manuscript preparation, the authors used ChatGPT (OpenAI) and Trinka AI to improve the clarity and fluency of the English language. Subsequently, the authors reviewed and edited the content as needed and take full responsibility for the content of the manuscript.

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