APPLYING THE HOLT-WINTERS MODEL TO FORECAST STATE BUDGET REVENUE IN CAU GIAY DISTRICT, HANOI

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Abstract: ***This paper applies the Holt-Winters exponential smoothing model to forecast the quarterly state budget revenue of Cau Giay Tax Department for 2025. Using time-series data from Q1/2020 to Q1/2025 and employing IBM SPSS software, the study evaluates forecast accuracy through MAPE and other model fit statistics. The results show a MAPE of 12.636% and R² of 0.791, indicating that the multiplicative Holt-Winters model provides a reliable short-term forecast. These findings can serve as a scientific basis for improving budget planning at the local level.***

• Keywords: *state budget revenue forecast, exponential smoothing, holt-winters, SPSS.*

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1. Introduction

The estimation of state budget revenue (SBR) represents a critical initial step in the budget formulation process, serving as a strategic guideline for resource allocation, fiscal discipline, and policy planning across government levels. An accurate forecast of budget revenue enables regulatory authorities to manage public finances more proactively and minimize discrepancies between projected and actual revenue.

However, in many localities, the current forecasting practices remain heavily reliant on subjective experience, qualitative methods, or manually constructed simulations. Such approaches often lack scientific rigor and fail to adequately capture the dynamics of economic and policy-related fluctuations, resulting in limited forecasting accuracy.

Globally, numerous countries have adopted advanced quantitative models such as time series methods and statistical analysis software to enhance forecasting precision. Among these, the Holt-Winters model, an extension of exponential smoothing techniques, is widely recognized for its effectiveness in handling data exhibiting both trend and seasonal variations.

Motivated by the need to improve the reliability of SBR forecasts, this study applies the multiplicative Holt-Winters model to forecast quarterly revenue for Cau Giay District, Hanoi. Utilizing quarterly budget revenue data from Q1 2020 to Q1 2025, the study employs SPSS software to evaluate the model's fit and forecasting performance. The findings aim to provide a scientifically grounded tool to support more accurate budget planning for local tax authorities.

2. Research methodology

2.1. Literature review

Exponential Smoothing is a popular time series forecasting technique, particularly effective for data with linear characteristics and short cycles. Among its variations, the Holt-Winters model is a suitable choice for time series data that simultaneously exhibits trend and seasonality.

The Holt-Winters model has two main forms:

Additive form: Applied to data where the seasonal amplitude remains relatively stable over time.

Multiplicative form: Suitable for data where the seasonal amplitude varies with the scale of the time series - this is the model used in this study.

Exponential smoothing is a type of linear model that can capture linear characteristics in a time series. One of the fundamental ideas behind exponential smoothing models is to generate future values as weighted averages of past values, where more recent observations are given higher

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weights than observations further in the past. By forming forecasts based on weighted averages, we are using a "smoothing" method. The term "exponential" comes from the fact that exponential smoothing models not only assign decreasing weights over time but do so in an exponential fashion. To apply exponential smoothing models, there are three widely adopted forms for different time series. Simple exponential smoothing (Type I) is used when a time series has no trend and no seasonality. Suppose we have a time series Yt , measured at time points t=1,...,T. The simple exponential smoothing model is defined by the recursive formula as follows:

$$\hat{Y}t+1= \alpha Yt+ (1-\alpha)\hat{Y}t \tag{1}$$

Where Y^t+1 is the forecast value at time t+1, α is the smoothing constant, Yt is the actual data value at time t, and Y^t is the forecast value at time t.

When a trend exists in the time series, the Holt's exponential smoothing model (Type II) can be used. Holt's method requires estimating the current slope and level, and therefore uses two smoothing constants for each estimation formula. These two smoothing constants help calculate the estimated values of the level and slope, which change over time as new observations are incorporated.

$$\hat{Y}t+p= Lt+ pTt \tag{2}$$

$$Lt= \alpha Yt+ (1-\alpha)(Lt-1+ Tt-1) \tag{3}$$

$$Tt= \beta(Lt-Lt-1) + (1-\beta) Tt-1 \tag{4}$$

Where Y^t+p is the forecast value at p periods after time t, Lt is the estimated value of the level at the current time, Tt is the estimated value of the slope at the current time, α is the smoothing constant for the level (0<α<1), and β is the smoothing constant for the slope, i.e., the trend (0<β<1).

In Equation (3), the current level (Lt) is calculated by taking a weighted average of two estimated values: one estimate is the current observed value (Yt), and the second estimate is the sum of the previous period's trend value (Tt−1) and the previous period's estimated level value (Lt−1). Equation (2) shows that the forecast value p periods into the future (Y^t+p) is calculated by multiplying the current estimated trend value (Tt) by the number of future periods to forecast (p), and then adding this product to the current estimated level value (Lt).

Holt-Winters is an exponential smoothing method used to forecast time series that exhibit both trend and seasonality (Type III). This method has two versions: Multiplicative Holt-Winters and Additive Holt-Winters.

The four equations in the recursive scheme of the Multiplicative Holt-Winters method are as follows:

$$\hat{Y}t+p= (Lt+ pTt)St-s+p \tag{5}$$

$$Lt= \alpha Yt/St-s+ (1-\alpha) (Lt-1+ Tt-1) \tag{6}$$

$$Tt= \beta(Lt-Lt-1) + (1-\beta)Tt-1 \tag{7}$$

$$St=\gamma Yt/Lt+ (1-\gamma)St-s \tag{8}$$

Where Y^t+p is the forecast value at p periods after time t, Lt is the estimated value of the level at the current time, Tt is the estimated value of the trend at the current time, St is the estimated value of the seasonal component, α is the smoothing constant for the level (0<α<1), β is the smoothing constant for the trend (0<β<1), γ is the smoothing constant for estimating seasonality (0<γ<1), and s is the seasonal length.

If γ equals 0, it means there is no seasonal component in the time series, and the Holt-Winters method becomes the Holt method. If both γ and β equal 0, the model becomes the simple exponential smoothing method. Thus, the Holt-Winters method is the most general model among the three exponential smoothing models. In the multiplicative version of the Holt-Winters method, the seasonality estimate is performed using a seasonal index and is calculated by Equation (8). Equation (8) shows that the current seasonal component, St, is equal to γ multiplied by the seasonal index estimated by the quantity Yt/Lt plus (1−γ) multiplied by the seasonal component at the previous time point, St−s.

2.2. Research methodology

2.2.1. Research data

The study utilizes secondary data on quarterly state budget revenue collected from the Tax Department of Cau Giay District, Hanoi for the period spanning Q1 2020 to Q1 2025. The dataset was obtained from the district's internal tax administration system, which serves as an official repository of local fiscal records.

Prior to model implementation, the data underwent cleaning, normalization, and preprocessing using Microsoft Excel to ensure consistency, completeness, and accuracy. After standardization, the dataset was input into the forecasting model for analysis. The structured time series data formed the basis for applying the Holt-Winters multiplicative exponential smoothing model, facilitating accurate and reproducible revenue projections.

2.2.2. Analytical methods

The study applies the Winters' Multiplicative Exponential Smoothing model, a variant of time series forecasting methods capable of capturing both trend and seasonal components in the data. This model is particularly suited for datasets where seasonal variations are proportional to the overall level of the series.

The forecasting procedure is implemented using SPSS software, with the objective of projecting state budget revenue (SBR) for the remaining quarters of 2025

The use of the multiplicative Holt-Winters model provides a systematic and statistically grounded approach to predicting short-term fiscal inflows, especially where seasonal patterns recur over fixed periods.

The accuracy and performance of the forecasting model are evaluated using standard statistical indicators, including:

MAPE (Mean Absolute Percentage Error): Measures the average absolute percentage difference between the forecasted and actual values. A lower MAPE indicates higher forecasting precision.

R-squared (R^2): Represents the coefficient of determination, reflecting the proportion of variance in the observed data explained by the model. Higher R^2 values indicate a better fit between the model and the actual data.

2.3. Research tools

The estimation and evaluation of the model were carried out using SPSS software, in combination with Microsoft Excel for input data processing and results presentation. SPSS was chosen for its built-in support for exponential smoothing models, as well as its ability to visually present forecasting results in a clear and interpretable manner.

3. Research findings

State budget revenue collected through the centralized tax administration system from Q1 2020 to Q1 2025

Table 1. State budget revenue from Q1 2020 to Q1 2025 (Billion VND)

Period	2020	2021	2022	2023	2024	2025
Quarter 1	1288	1548	1860	1606	2320	2845
Quarter 2	710	1009	1211	1110	1672	
Quarter 3	1151	740	1092	1158	1393	
Quarter 4	1498	1704	1484	1657	2185	

Here's the English translation of the provided text:

Using the Exponential Smoothing - Winter's forecast model, a short-term forecasting model, we've projected quarterly revenue on a local scale. This model considers the impact of both seasonality and trends in tax collection activities (tax payment deadlines for various tax types), yielding relatively accurate quarterly revenue figures. The necessary data for this model includes actual quarterly revenue from Q1 2020 to Q1 2025 to forecast revenue for the remaining quarters of 2025. An evaluation of the forecasting results from the Winter's Exponential Smoothing model against actual revenue from Q3 2024 to Q1 2025 reveals that, despite some upward/downward discrepancies in quarterly forecasts compared to actual collection due to government tax exemption, reduction, and extension policies, the overall domestic revenue forecast using the Exponential Smoothing - Winter's model in SPSS software is 6,817 billion VND. Meanwhile, the actual domestic revenue for Q3, Q4 2024, and Q1 2025 totaled 6,392 billion VND, which is 31 billion VND higher than the forecast, representing a difference of 0.46%. This indicates that the Exponential Smoothing - Winter's model provides relatively accurate forecasts for domestic revenue collection within the province, specifically as follows:

Unit: Billion VND

No.	Quarter	Forecast using Hold - Winter Model	Actual Domestic Revenue Collection	Difference (+;-)
(1)	(2)	(3)	(4)	(5)=(4)-(3)
	Tổng cộng	**6392**	**6423**	**31**
1	Quarter III/2024	1499	1393	-106
2	Quarter IV/2024	2266	2185	-81
3	Quarter I/2025	2627	2845	218

The research data comprises quarterly state budget revenue (NSNN) for the Cau Giay District Tax Team from Q1 2020 to Q1 2025. The revenue data shows a gradual upward trend over time and exhibits clear seasonality among quarters - particularly in Q1 and Q4 each year, which typically coincide with tax finalization deadlines or policy adjustments. The Holt-Winters Multiplicative model was chosen because it's suitable for data displaying both trend and seasonality. The model was built and run using SPSS software. The fit assessment indicators are as follows:

Criterion	Value	Comments
R-squared	0.791	The model explains 79.1% of the variance in the data - a fairly good level.
MAPE	12.636	Relatively low error (<15%) - good accuracy
RMSE	248,4	Mean squared error is consistent with the data scale.
Ljung-Box Q(18)	Sig. = 0.980	Residuals have no autocorrelation - the model is stable.
Số ngoại lệ (Outliers)	0	Clean data, not affected by abnormal values.

Forecasting revenue results through the application of the Exponential Smoothing - Winter's model in SPSS statistical software has established a scientific basis for estimating state budget revenue within the province. This facilitates reasonable revenue management, serving as a foundation for building realistic revenue forecasts and supporting local state budget revenue-expenditure operations. Simultaneously, it addresses the annual recommendations from the State Audit Office regarding the inaccuracy of state budget revenue forecasts. From this, we apply the Exponential Smoothing model to forecast state budget revenue in the upcoming quarters:

Unit: Billion VND

Model		Q2 2025	Q3 2025	Q4 2025
SỐ THU-Model_1	Forecast	1.700	1.600	2.500
	UCL	2.200	2.100	3.100
	LCL	1.200	1.100	1.900

By applying the Exponential Smoothing - Winter's model in SPSS statistical software, we aim to forecast the 2025 domestic revenue collection results. This proactive approach will enhance our ability to manage and build annual budget revenue forecasts, enabling us to promptly implement solutions for mobilizing revenue into the budget. This effort strives to achieve the assigned state budget revenue targets, contributing to the province's economic and social development goals.

4. Result

Forecasting budget revenue plays a pivotal role in the entire state budget estimation process, forming the foundation for setting revenue and expenditure targets that align with actual conditions and socio-economic development orientations. The research findings affirm the feasibility of applying quantitative models in public financial management at the grassroots level, especially in a context where transparency, efficiency, and scientific rigor are increasingly emphasized.

This study applied the Holt-Winters model to forecast state budget revenue at the district level. Empirical results show that the model exhibits a high degree of fit with historical budget revenue data and provides reliable short-term forecasting capabilities. The model helps eliminate subjective factors in estimation and offers a scientific basis to support the budget revenue estimation process.

However, the study also acknowledges some limitations, including a relatively narrow data scope and the exclusion of external influencing factors such as fiscal policies or macroeconomic fluctuations. Therefore, future research should expand the data scale, incorporate socio-economic variables, and compare with other forecasting models to enhance the accuracy and practical applicability of the results.

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