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Dynamics of Tax Revenue Across Business Sectors and Taxpayer Categories: A Mixed-Design ANOVA Approach

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ABSTRACT

This study examines the dynamics of tax revenue in Banteay Meanchey Prov-ince, Cambodia, by analyzing the effects of business sector, taxpayer category, and their interactions. Using a mixed-design ANOVA, it analyzes tax revenue from small and medium taxpayers in the Industry, Services, and Agriculture sectors during 2017–2024. The results show significant sectoral differences, with Services and Industry generating substantially higher revenue than Agri-culture, reflecting greater formalization, capital intensity, and profit orientation. The taxpayer category effect is nuanced: small and medium taxpayers do not differ significantly in isolation, but after controlling for sectoral composition, small taxpayers contribute significantly less revenue than medium taxpayers, indicating sector-dependent contributions. Interaction effects further reveal that both small and medium taxpayers in Industry and Services outperform their ag-ricultural counterparts, underscoring the amplifying role of sectoral context in revenue generation. Temporal effects are largely insignificant; however, the sharp decline and uneven recovery observed in 2020, associated with the COVID-19 pandemic, highlight the importance of sectoral and taxpayer heter-ogeneity in fiscal resilience. Overall, the findings support a differentiated, sec-tor-sensitive tax policy that prioritizes medium taxpayers in Services and In-dustry as core revenue anchors and incorporates sector–taxpayer interactions.

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INTRODUCTION

Tax revenue constitutes the backbone of public finance and plays a critical role in financing gov-ernment expenditure, promoting economic stability, and supporting sustainable development. In developing economies, mobilizing domestic revenue is particularly vital as it provides a stable funding source for infrastructure and social safety nets while building fiscal buffers against global economic shocks (International Monetary Fund [IMF], 2023). At the subnational level, effective tax collection is essential for local governments to deliver public services and implement development policies tailored to local economic conditions. In Cambodia, provincial tax revenue has become increasingly important following fiscal decentralization reforms, which aim to strengthen local revenue mobilization and enhance public financial management (Asian Development Bank [ADB], 2021). The performance of tax revenue varies across business activities because different sectors such as agriculture, industry, and services have distinct production structures, profitability levels, and degrees of formalization. These structural differ-ences directly influence both taxable capacity and compliance behavior (OECD, 2021). In many developing countries, the agricultural sector is often characterized by small-scale operations and informal practices, resulting in relatively low tax contributions compared to the in-dustry and service sectors, which are generally more formalized and capital-intensive (Morrissey et al., 2016). Analyzing tax revenue by business sector, therefore, provides important insights into the structural composition of the local economy and the effectiveness of sector-specific tax policies. Beyond sectoral differences, taxpayer category commonly classified as small or medium is another important determinant of tax revenue. Medium taxpayers generally contribute a larger share of total revenue due to higher turnover, broader tax bases, and closer monitoring by tax authorities. In contrast, small taxpayers often benefit from simplified tax regimes and lower compliance require-ments. Simplified tax regimes (STRs) are frequently implemented by gov-ernments to address the specific challenges faced by micro and small enterprises (MSEs). These regimes typically involve taxing turnover (gross sales) or using lump-sum payments instead of taxing net profits, which sig-nificantly reduces the administrative burden on businesses that lack extensive transaction records (Wen, 2023). Understanding revenue variations across taxpayer categories is crucial for evaluating the equity and efficiency of the tax system and for designing targeted compliance and enforcement strategies. Tax revenue patterns can also be observed over time, as collection responds to macroe-conomic fluctuations, policy reforms, and external shocks. During 2017–2024, Cambodia experienced significant economic changes, including steady growth before 2020, disruptions caused by the COVID-19 pandemic, and subsequent recovery phases. Observing revenue patterns across years provides insights into trends and structural shifts that may not be evident in cross-sectional analyses (World Bank, 2023). Against this backdrop, this study examines the dynamics of tax revenue across business sectors and taxpayer categories in Banteay Meanchey province, Cambodia, from 2017 to 2024. Specifically, the study assesses the effects of business sector and taxpayer category using a mixed-design analytical framework, treating time as a descriptive dimension rather than an inde-pendent variable. The findings are expected to provide empirical evidence to support provincial tax administration, inform sector-specific tax policies, and contribute to the broader literature on sub-national revenue mobilization in developing economies.

To examine the dynamics of tax revenue across business sectors and taxpayer categories in Banteay Meanchey Province, Cambodia, during the period 2017–2024, and to assess the individual and interaction effects of business sector and taxpayer category on tax revenue.

Based on the research objectives, this study investigates how tax revenue varies across different business sectors and taxpayer categories over the period 2017–2024 in Banteay Meanchey province. In addition, the study examines whether tax revenue differs significantly by sector type and taxpayer category, as well as whether an interaction effect exists between these two factors. Accordingly, the following hypotheses are formulated: H1: There is a significant difference in tax revenue among business sectors (Agriculture, Services, and Industry). H2: There is a significant difference in tax revenue between taxpayer categories (Small vs. Medium). H3: There is a significant interaction effect between business sector and taxpayer category on tax revenue.

METHODS

Research Design

This study employs a quantitative research design to examine the dynamics of tax revenue across different business sectors and taxpayer categories. It utilizes a mixed-design

ANOVA (also known as split-plot ANOVA) to analyze both between-subjects and within-subjects factors. The dependent variable is tax revenue, expressed in US Dollars, collected from small and medium taxpayers across business sectors, including industry, services, and agriculture. The between-subjects factors are taxpayer category (small and medium enterprises) and business sector (industry, services, and agriculture), while the within-subjects factor is time, measured annually from 2017 to 2024. The mixed-design ANOVA allows for the examination of the main effects of taxpayer category, business sector, and time, as well as the interaction effects among these factors, enabling a comprehensive assessment of changes in tax revenue patterns over time.

Data

In this study, tax revenue, expressed in US Dollars, refers to the internal revenue collected from taxpayers categorized as small and medium enterprises. Small enterprises are businesses with an annual turnover ranging from approximately 62,250 USD to 174,300 USD, while medium enterprises have an annual turnover ranging from approximately 174,300 USD to 996,000 USD, according to Cambodian tax regulations (Taxation Law, 2023). These figures represent the revenue collected from three major business sectors industry, services, and agriculture allowing for a sectoral comparison of revenue contributions. Data are obtained from official annual tax reports spanning the period from 2017 to 2024. The reports are collected from Banteay Meanchey Province, Cambodia, providing a comprehensive dataset that reflects both temporal and sectoral variations in tax revenue collection. This dataset enables an examination of trends over time and the identification of differences in revenue patterns between taxpayer categories and business sectors.

Econometric Model

To examine the dynamics of tax revenue across different business sectors and taxpayer cat-egories, two mixed-design ANOVA models are employed. This analytical approach enables the assessment of between-subjects effects, capturing differences across business sectors and taxpayer categories, as well as within-subjects effects, reflecting changes in tax revenue over time. Random intercepts are incorporated to account for unobserved heterogeneity across entities, thereby controlling for time-invariant individual-specific characteristics that could otherwise bias the estimated effects. The first model investigates the effect of business sectors on tax revenue, while the second model evaluates the effect of taxpayer categories on tax revenue. Prior to estimating the mixed-design ANOVA models, several diagnostic tests are conducted to verify the underlying model assumptions. These include Levene's test, the Brown–Forsythe test, and the trimmed-mean test to assess the homogeneity of variances, as well as the Skewness–Kurtosis test to evaluate the normality of the dependent variable and the model residuals. When significant main or interaction effects are detected in the mixed-design ANOVA, post-hoc analyses are performed using Bonferroni-adjusted pairwise comparisons to identify specific group differences. This comprehensive methodological framework provides robust insights into how sectoral characteristics and taxpayer classifications influence both the level and temporal dynamics of tax revenue over the study period. The empirical models employed in this study are specified as follows:

Model 1 – Effect of Business Sectors on Tax Revenue

$$\log(\text{Tax Revenue})_{it} = \mu + \alpha_i + \beta_t + (\alpha \times \beta)_{it} + \delta_i + \epsilon_{it} \quad (1)$$

Where μ represents the overall mean of log(Tax Revenue); $\alpha_i$denotes the effect of the Business Sector; $\beta_t$captures the effect of Year as the within-subjects (repeated-measures) factor; $(\alpha \times \beta)_{it}$represents the interaction effect between Business Sector and Year, indicating whether changes in Tax Revenue over time differ across sectors; δ_i is the random effect associated with the observational unit (such as sector or entity), accounting for unobserved heterogeneity; and $\varepsilon_{it}$is the idiosyncratic error term.

Model 2 – Effect of Taxpayer Category on Tax Revenue

$$\log\,(\text{Tax Revenue})_{it} = \mu + \gamma_j + \beta_t + (\gamma \times \beta)_{jt} + \delta_j + \epsilon_{jt} \quad (2)$$

Where γ_j represents the effect of Taxpayer Category on log(Tax Revenue); β_t denotes the effect of Year as the within-subjects (repeated-measures) factor; $(\gamma \times \beta)_{jt}$ captures the interaction effect between Taxpayer Category and Year, indicating whether changes in Tax Revenue over time differ across taxpayer categories. Other terms in the model, including the overall mean, random effect for the observational unit, and the error term, are defined similarly as in Model 1.

Model 3 – Interaction Effect of Business Sector and Taxpayer Category on Tax Revenue

$$\log\,(\text{Tax Revenue})_{itj} = \mu + \alpha_i + \beta_j + (\alpha \times \beta)_{ij} + \gamma_t + \epsilon_{ijt} \quad (3)$$

Where log $(\text{Tax Revenue})_{ijt}$is the dependent variable for Business Sector i, Taxpayer Category j, at Year t. μ represents the overall mean or intercept. α_i denotes the effect of Business Sector i(a between-subjects factor), while β_j denotes the effect of Taxpayer Category j (a between-subjects factor). $(\alpha \times \beta)_{ij}$represents the interaction effect between Business Sector i and Taxpayer Category j. γ_t denotes the effect of Year t(a within-subjects or repeated-measures factor), and $\varepsilon_{ijt}$is the residual error term capturing unexplained variation.

To formally specify the pre-tests and diagnostic procedures employed in this study, the following mathematical formulations are provided to assess homogeneity of variances (Levene's test, Brown–Forsythe test, and trimmed-mean test), normality (Skewness–Kurtosis test for the dependent variable and residuals), sphericity (Mauchly's test), and post-hoc pairwise comparisons using Bonferroni adjustments when significant main or interaction effects are observed. The corresponding formulas are presented below.

Specifically, the normality of the dependent variable (log (Tax Revenue)) and the residuals $(\hat{\varepsilon}_{it})$ is assessed, as this is a key assumption of ANOVA.

$$Z_{skew} = \frac{\text{Skewness}}{\text{SE(Skewness)}},\ Z_{kurt} = \frac{\text{Kurtosis}-3}{\text{SE(Kurtosis)}},\ \chi^2 = Z_{skew}^2 + Z_{kurt}^2 \sim \chi_2^2 \quad (4)$$

In this test, Z_{skew} represents the standardized skewness, and Z_{kurt} represents the standardized kurtosis. These values are combined to form the chi-square statistic, χ^2, which is used to assess the normality of the data.

To ensure that the variance of the dependent variable is equal across groups (e.g., Business Sectors or Taxpayer Categories), tests for homogeneity of variances, including Levene's test, Brown–Forsythe test, and the trimmed-mean test, are conducted. The corresponding econometric formulations for these procedures are presented below.

a) Levene's Test

Levene's test is the standard procedure for testing the equality of variances. It is less sensitive to departures from normality than the traditional F-test. The test statistic W is defined as:

$$W = \frac{(N-k)}{(k-1)} \cdot \frac{\sum_{i=1}^{k} n_i (Z_{i\cdot} - Z_{\cdot\cdot})^2}{\sum_{i=1}^{k} \sum_{j=1}^{n_1} (Z_{ij} - Z_{i\cdot})^2} \tag{5}$$

Where k is the number of different groups, n_i is the number of observations in group i, and N is the total number of observations. Y_{ij}represents the value of the j-th observation from the i-th group. Z_{ij} is calculated as the absolute deviation from the group mean, $Z_{ij} = | Y_{ij} - \widetilde{Y}_i |$, where $\widetilde{Y}_i$ is the mean of the i-th group. $Z_{i\cdot}$ denotes the mean of $Z_{ij}$for group i, and $Z_{\cdot\cdot}$represents the grand mean of all Z_{ij}across all groups and observations.

b) Brown–Forsythe Test

The Brown–Forsythe test is a robust variation of Levene's test. It is particularly useful when the data follows a skewed distribution. The formula remains the same as Levene's W statistic above, but the definition of Z_{ij} changes:

$$Z_{ij} = | Y_{ij} - \widetilde{Y}_i | \tag{6}$$

Where $\widetilde{Y}_i$ represents the median of the i-th group.

c) Trimmed-Mean Test

A trimmed mean is used to calculate Z_{ij} in order to reduce the influence of extreme values (outliers) at the edges of the distribution. The formulation follows the same structure as the tests above, but Z_{ij} is calculated using a p% trimmed mean ($\bar{Y}_{i,p}$).

$$\overline{Y}_{k,trim} = \frac{1}{n_k'} \sum_{i=r+1}^{n_k-1} Y_{ik} \tag{7}$$

This procedure removes rextreme observations from both tails of the distribution. As a result, the adjusted number of observations in group kis given by $n_k' = n_k - 2r$, where n_k is the original number of observations in the group.

Finally, the Post-Hoc Pairwise Comparisons – Bonferroni Adjustment will be conducted. This procedure is used to identify which specific group means differ following a statistically significant main or interaction effect in ANOVA. The Bonferroni adjustment mitigates the increased risk of Type I error associated with multiple comparisons by applying an adjusted significance level to each pairwise test. The adjusted significance level for each comparison is calculated as:

$$\alpha^* = \frac{\alpha}{m} \tag{8}$$

where α^*denotes the Bonferroni-adjusted significance level applied to each individual pairwise comparison, αrepresents the overall (family-wise) significance level, which is typically set at 0.05, and m denotes the total number of pairwise comparisons conducted. The number of pairwise comparisons is calculated as $m = \frac{k(k-1)}{2}$, where kindicates the number of groups being compared in the analysis. This adjustment ensures that the cumulative probability of committing at least one Type I error across all pairwise tests does not exceed the pre-specified family-wise significance level.

RESULTS AND DISCUSSION

Homogeneity of Variances

In mixed-design ANOVA, homogeneity of variances ensures that the variance of the dependent variable is approximately equal across the levels of the between-subjects factor (e.g., business sector or taxpayer category). This assumption is important because unequal variances can distort F-tests and lead to incorrect conclusions about group differences (Ghasemi & Zahediasl, 2012).

Table 1. Test of Homogeneity of Variances for Tax Revenue across Business Sector

Test	F statistic	df1	df2	P-value	Decision
Levene's test (mean-based)	0.7861	2	42	0.4622	Not reject H_0
Brown–Forsythe test (median-based)	0.1502	2	42	0.8610	Not reject H_0
Trimmed-mean test	0.6272	2	42	0.5390	Not reject H_0

Table 1 presents the results of the homogeneity of variances tests for tax revenue across business sectors, using three main procedures: Levene's test (mean-based), Brown–Forsythe test (median-based), and the trimmed-mean test. The results of Levene's test indicate a p-value of 0.4622, which is greater than the 0.05 significance level; therefore, the null hypothesis (H_0) of equal variances is not rejected. Similarly, the Brown–Forsythe test yields a p-value of 0.8610 (> 0.05), suggesting that there are no significant differences in variances across groups. In addition, the trimmed-mean test reports a p-value of 0.5390, further confirming that group variances remain equal even after reducing the influence of extreme values. Overall, as all p-values exceed 0.05, there is insufficient evidence to reject the null hypothesis of homogeneity of variances. These findings confirm that the assumption of homogeneity of variances is satisfied, indicating that the use of a Mixed Design ANOVA for subsequent analysis is appropriate and statistically valid.

Table 2. Test of Homogeneity of Variances for Tax Revenue across Taxpayer Category

Test	F statistic	df1	df2	P-value	Decision
Levene's test (mean-based)	1.9916	1	43	0.1654	Not reject H_0
Brown–Forsythe test (median-based)	1.8449	1	43	0.1815	Not reject H_0
Trimmed-mean test	1.8268	1	43	0.1836	Not reject H_0

Table 2 presents the results of the homogeneity of variances tests for tax revenue across taxpayer categories using Levene's test (mean-based), the Brown–Forsythe test (median-based), and the trimmed-mean test. The results of Levene's test show an F statistic of 1.9916 with a p-value of 0.1654, which is greater than the 0.05 significance level; therefore, the null hypothesis (H_0) of equal variances is not rejected. Similarly, the Brown–Forsythe test yields a p-value of 0.1815 (> 0.05), indicating no statistically significant differences in variances between taxpayer categories. The trimmed-mean test also reports a p-value of 0.1836, further confirming that the variances remain homogeneous even after minimizing the influence of extreme values. Overall, since all p-values exceed 0.05, there is insufficient evidence to reject the null hypothesis of homogeneity of variances. These findings confirm that the assumption of homogeneity of variances is satisfied, supporting the appropriateness and statistical validity of using a Mixed Design ANOVA for subsequent analysis.

Normality Testing of the Dependent Variable

Normality testing assesses whether the dependent variable is approximately normally distributed within each group of the between-subjects factor. This assumption is important for the validity of ANOVA results, as non-normal distributions can affect F-tests and lead to incorrect conclusions.

Table 3. Skewness–Kurtosis Test for Normality of the Dependent Variable

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	Adj.Chi^2(2)	Prob> .Chi^2	Normality
log_revenue	45	0.2206	0.2327	3.11	0.2107	Not rejected

Table 3 reports the results of the Skewness–Kurtosis test for normality of the dependent variable, log_revenue. Based on 45 observations, the test results show that the p-values for skewness (Pr(Skewness) = 0.2206) and kurtosis (Pr(Kurtosis) = 0.2327) are both greater than the 0.05 significance level. In addition, the adjusted Chi-square statistic is 3.11 with an associated p-value of 0.2107. Since the overall p-value exceeds 0.05, the null hypothesis of normality is not rejected. These results indicate that the distribution of log_revenue does not significantly deviate from a normal distribution. Therefore, the normality as-sumption for the dependent variable is satisfied, supporting the appropriateness of applying parametric statistical techniques, including Mixed Design ANOVA, in the subsequent analysis.

Mixed Design ANOVA of Revenue

A mixed-design ANOVA is conducted to evaluate the main effects of business sector and taxpayer category on tax revenue over time, as well as to investigate any potential interaction between these factors while accounting for repeated measures across years.

Table 4. Summary of Mixed Design ANOVA of Revenue by Business Sector

Variable	Effect / Significance	p-value	Decision (10% level)
Sector (ref: Agriculture)	Industry increases Revenue (significant)	0.007	Reject H_0
	Services increase Revenue (significant)	0.000	Reject H_0
Year (ref: Base Year)	2020, 2021, 2024 significant	0.003 / 0.045 / 0.004	Reject H_0
	2018, 2019, 2022, 2023 not significant	others > 0.10	Fail to reject H_0
	Significant interactions:	0.000 / 0.034	Reject H_0 (all

Sector × Year Interaction	Industry × (2020, 2021, 2023, 2024) Services × (2021, 2024)	/ 0.027 / 0.000 0.085 / 0.017	except Industry × 2021, Services × 2021 still significant at 10%)
Constant	Baseline Revenue significant	0.000	Reject H_0
Model Fit	Wald $\chi^2(23)$ → model jointly significant	0.001	Reject H_0
	LR test → Mixed-effects model preferred	0.001	Reject H_0
Random Effects	ID intercept variance = 0.690 Residual variance = 0.456		

Based on the results in Table 4, the mixed design ANOVA shows that Business Sector has a significant effect on Revenue, with both Industry and Services generating higher revenue than Agriculture, indicating that sector type plays an important role in determining revenue levels. Regarding Year effects, only 2020, 2021, and 2024 significantly influence Revenue, while the other years do not, suggesting that revenue fluctuates in specific periods, possibly due to economic conditions or sector-specific events. Several Sector × Year interactions are also significant—particularly for Industry in 2020, 2021, 2023, and 2024, and for Services in 2021 and 2024—indicating that the effect of time on Revenue varies across sectors and that revenue trends differ between Industry and Services compared to Agriculture. The constant term is significant, representing the baseline revenue for Agriculture in the base year. At the model level, the Wald test confirms joint significance, and the likelihood-ratio test shows that the mixed-effects model is preferred to a simple linear regression, highlighting the importance of including both sector-specific fixed effects and random group-level variation. The estimated random-effects variance (ID intercept variance = 0.690) captures differences across groups, while the residual variance (0.456) reflects individual-level deviations, indicating that most variation in Revenue is explained by fixed effects, though some group-level heterogeneity remains. Overall, these findings provide strong and consistent empirical evidence in support of H1, as the significant effect of Business Sector, together with higher revenue in Industry and Services compared to Agriculture, confirms that tax revenue differs significantly among the three sectors. Accordingly, H1 is supported, demonstrating that tax revenue is substantially shaped by sectoral classification even after accounting for time effects, interaction effects, and random group-level variation.

Table 5. Adjusted Mean Tax Revenue by Business Sector and Year

Sector	**2019 (Pre-shock)**	**2020 (Shock)**	**2024 (Post-shock)**	**P-value (2017–2024)**
Agriculture	19.49	16.38	15.99	$p < 0.01$
Industry	20.42	21.59	22.80	$p < 0.01$
Services	23.00	20.19	22.38	$p < 0.01$

Based on Table 5, all adjusted mean tax revenues are statistically different from zero ($p < 0.01$), indicating that the predicted revenue levels for each sector–year combination are both economically and statistically meaningful. Sectoral and temporal differences are formally assessed using mixed-effects regression coefficients and interaction terms, rather than relying solely on marginal mean p-values. The adjusted predictions from the mixed-effects model reveal substantial sectoral heterogeneity in tax revenue dynamics. Throughout the study period, the services sector consistently records the highest predicted marginal tax revenues, with 23.00 in 2019, declining to 20.19 in 2020, and recovering to 22.38 by 2024. The industry sector follows, with predicted marginal revenues of 20.42 in 2019, increasing to 21.59 in 2020, and further rising to 22.80 in 2024. Agriculture exhibits the lowest values, starting at 19.49 in 2019, declining sharply to 16.38 in 2020, and recovering modestly to 15.99 by 2024. A pronounced decline occurs across all sectors in 2020, reflecting a common adverse shock. However, recovery trajectories differ: the industry sector demonstrates the strongest post-2020 rebound, surpassing pre-shock predicted levels by 2024, whereas agriculture experiences a weaker recovery, remaining below its 2019 level.

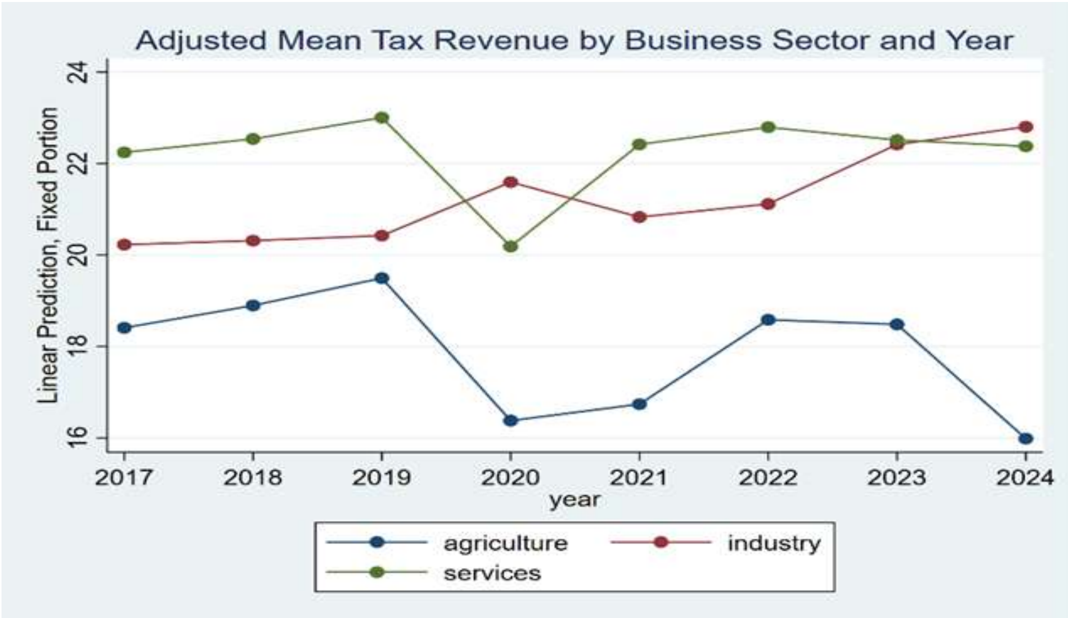

Figure 1. Adjusted Mean Tax Revenue by Business Sector and Year (Mixed-Effects Model).

Table 6. Summary of Mixed Design ANOVA of Revenue by Taxpayer Category

Variable	Effect / Significance	p-value	Decision
Taxpayer Category (ref: Medium)	Small taxpayer → no significant effect on Revenue	0.262	Fail to reject H_0
Year (ref: Base Year)	All years (2018–2024) → no significant effect on Revenue	0.246–0.978	Fail to reject H_0
Taxpayer × Year Interaction	All interactions (Small × 2018–2024) → no significant effect	0.404–0.999	Fail to reject H_0
Constant	Significant	0.000	Reject H_0

Model Fit	Wald $\chi^2(15)$ → overall model not significant	0.771	Fail to reject H_0
	LR test → no improvement over linear model	1.000	Fail to reject H_0
Random Effects	ID intercept variance ≈ 0		
	Residual variance = 3.7753		

Based on the results in Table 6, the mixed design ANOVA indicates that Taxpayer Category does not have a significant effect on Revenue, as Small taxpayers show no meaningful difference compared to Medium taxpayers. Similarly, Year effects (2018–2024) are not significant, and the interaction between Taxpayer Category and Year is also not significant, indicating that the effect of time on Revenue does not differ by taxpayer category. The constant term is significant, representing the baseline Revenue for Medium taxpayers in the reference year. At the model level, the Wald test and likelihood-ratio test confirm that the model is not significant, showing that including both taxpayer category fixed effects and random group-level variation does not improve the fit compared to a simple linear regression. The estimated random-effects variance for groups is near zero, while the residual variance remains substantial, indicating that most of the variation in Revenue is unexplained by the model and does not vary across groups. Overall, these findings provide no empirical support for H2, as Revenue appears largely unaffected by Taxpayer Category, Year, or their interaction in this sample. Accordingly, H2 is not supported, demonstrating that tax revenue does not differ significantly between Small and Medium taxpayers even after accounting for time effects, interaction effects, and random group-level variation.

Table 7. Predicted Marginal Tax Revenues by Tax Category and Year.

Taxpayer Category	**2019 (Pre-shock)**	**2020 (Shock)**	**2024 (Post-shock)**	**P-value (2017–2024)**
Medium	22.15	19.34	21.48	$p < 0.01$
Small	19.79	19.43	21.37	$p < 0.01$

Based on the results presented in Table 7, predicted marginal tax revenues from the mixed-effects model indicate that medium firms consistently generate higher revenues than small firms throughout 2017–2024. All predicted values are statistically significant ($p < 0.01$), confirming that these revenue levels are both economically and statistically meaningful. These differences are formally assessed using mixed-effects regression coefficients and interaction terms, rather than relying solely on marginal mean p-values, which is analogous to a mixed-design ANOVA approach that evaluates both within-year and between-group effects. Both firm types experience a pronounced decline in 2020, with medium firms dropping from 22.15 in 2019 to 19.34 in 2020, and small firms from 19.79 to 19.43, reflecting a common adverse shock. Recovery trajectories differ by firm size: medium firms exhibit a stronger post-shock rebound, reaching 21.48 by 2024, whereas small firms recover more gradually, rising to 21.37. These results highlight substantial heterogeneity in tax revenue dynamics, with medium firms contributing disproportionately to total revenue and responding more sensitively to shocks, while small firms show more gradual changes but steady recovery. The findings suggest that firm size is an important determinant of tax revenue patterns, with implications for policy design and targeted revenue collection strategies.

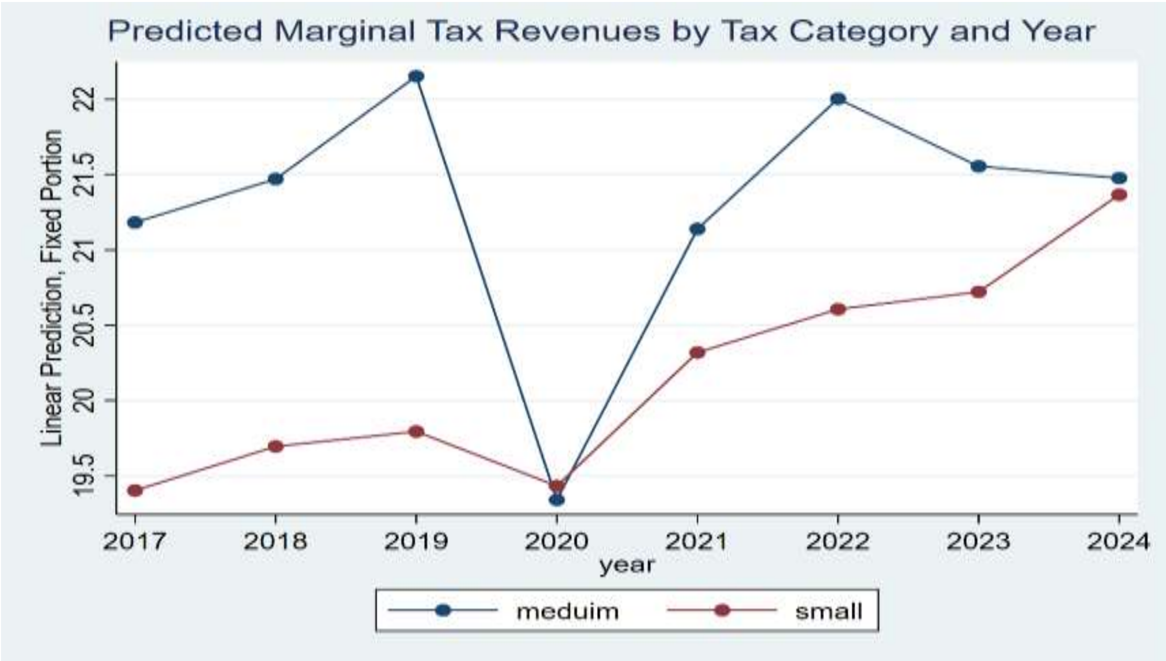

Figure 2. Predicted Marginal Tax Revenues by Tax Category and Year

Table 8. Summary of the Mixed-Design ANOVA of Revenue by Business Sector and Taxpayer Category

Variable	Effect / Significance	p-value	Decision
Sector (ref: Agriculture)	Services increases revenue (significant)	0.005	Reject H_0
	Sector (ref: Agriculture)	0.001	Reject H_0
Taxpayer Type (ref: Medium)	Small taxpayer reduces revenue (significant)	0.000	Reject H_0
Interaction: Sector × Taxpayer Category	Industry × Small: increases revenue (significant)	0.038	Reject H_0
	Services × Small: increases revenue (significant)	0.022	Reject H_0
Year (ref: 2017)	2018, 2019, 2020, 2021, 2022, 2023, 2024 not significant	0.846 / 0.649 / 0.544 / 0.144 / 0.268 / 0.572 / 0.265	Fail to reject H_0
Constant	Baseline revenue significant	0.000	Reject H_0
Model Fit	Wald $\chi^2(15)$ → model jointly significant	0.000	Reject H_0

	LR test → Mixed-effects model vs linear model	1.000	Fail to reject H_0
Random Effects	ID intercept variance ≈ 0		
	Residual variance = 6.700		

According to the results presented in Table 8, the mixed-effects model indicates that Business Sector has a significant effect on Tax Revenue. Specifically, businesses operating in the Industry and Services sectors generate significantly higher tax revenue compared to the Agriculture sector (the reference category), with coefficients significant at the 0.005 and 0.001 levels, respectively. This finding suggests that the type of business sector plays an important role in determining tax revenue levels. Regarding Taxpayer Category, Small taxpayers exhibit a significant negative effect on tax revenue relative to Medium taxpayers (the reference category), with a p-value of 0.000. This indicates that small taxpayers contribute significantly less to tax revenue than medium taxpayers. Accordingly, this result supports Hypothesis 2, which states that there is a significant difference in tax revenue between taxpayer categories (Small vs. Medium). Regarding interaction effects, both Industry × Small and Services × Small show positive and significant effects ($p = 0.038$ and 0.022, respectively), suggesting that the effect of Taxpayer Category on Tax Revenue varies by business sector. Small taxpayers in Industry and Services generate higher Tax Revenue than small taxpayers in Agriculture, highlighting the importance of the combined effect of sector and taxpayer category. The year effects (2018–2024) are not statistically significant (all $p > 0.10$), indicating that annual changes do not meaningfully influence Tax Revenue once sector, taxpayer category, and their interactions are considered. The constant term is statistically significant, representing the baseline Tax Revenue for a Medium taxpayer in Agriculture. At the model level, the Wald $\chi^2(12)$ test confirms that the model is jointly significant ($p = 0.000$), suggesting that the predictors together explain a substantial portion of variation in Tax Revenue. However, the likelihood-ratio test shows that the random intercept for ID is effectively zero (variance ≈ 0), indicating that differences across groups do not meaningfully contribute to variation in Tax Revenue, with most variation captured by the fixed effects. Overall, the results indicate that Tax Revenue is significantly influenced by business sector and taxpayer category, and that the interaction between these two factors is meaningful, while temporal variation across years and group-level effects are negligible. Therefore, H3 is supported, as the significant positive interaction terms demonstrate that the effect of taxpayer category on Tax Revenue depends on the business sector.

Table 9. Predicted Marginal Tax Revenues by Tax Category and Business Sector

Sector × Taxpayer Category	**2019 (Pre-shock)**	**2020 (Shock)**	**2024 (Post-shock)**	**P-value (2017–2024)**
Agriculture – Medium	19.84	18.26	17.50	0.000
Agriculture – Small	14.03	12.44	11.68	0.000
Industry – Medium	23.47	21.89	21.13	0.000
Industry – Small	21.47	19.88	19.12	0.000
Services – Medium	24.32	22.73	21.97	0.000
Services – Small	22.71	21.12	20.37	0.000

Based on the predicted marginal means presented in the table 9, the mixed-effects model indicates that business sector and taxpayer category both play a significant role in shaping tax revenue dynamics across the pre-shock, shock, and post-shock periods. Medium taxpayers consistently generate higher predicted Tax Revenue than small taxpayers within each sector throughout 2019, 2020, and 2024, with all predicted values statistically significant (p = 0.000), confirming that these differences are both economically and statistically meaningful. These differences are formally assessed using mixed-effects regression coefficients and interaction terms, rather than relying solely on marginal mean p-values, which is analogous to a mixed-design ANOVA approach that evaluates both within-year and between-group effects. The data show a pronounced decline in 2020 (shock year) for all sector–taxpayer combinations, reflecting an adverse economic event. For example, the predicted marginal mean for Industry – Medium drops from 23.47 in 2019 to 21.89 in 2020, while Services – Small decreases from 22.71 to 21.12, illustrating the shock's broad impact. Recovery trajectories differ by sector and taxpayer category: medium taxpayers in Industry and Services exhibit a stronger post-shock rebound, with predicted values reaching 21.13 and 21.97 in 2024, respectively, whereas small taxpayers recover more gradually, with predicted means reaching 19.12 and 20.37, highlighting slower recovery among smaller firms. The interaction between sector and taxpayer category is also evident. Small taxpayers in more productive sectors—Industry and Services—generate higher predicted Tax Revenue than small taxpayers in Agriculture, indicating that the negative impact of being a small taxpayer is mitigated in sectors with higher productivity. Overall, these results highlight substantial heterogeneity in tax revenue dynamics, with medium taxpayers contributing disproportionately to total revenue and responding more sensitively to shocks, while small taxpayers show more gradual changes but steady recovery. The findings confirm that both business sector and taxpayer category, along with their interaction, are key determinants of Tax Revenue, providing useful insights for policymakers seeking to implement targeted revenue collection strategies.

Normality Test of Residuals

The normality of residuals is tested to ensure that the differences between observed and predicted tax revenue values are approximately normally distributed. This assumption is essential for the validity of F-tests in mixed-design ANOVA, as non-normal residuals can affect the reliability of statistical inferences.

Table 10. Normality Test of Residuals from Mixed Model

Variable	**Obs**	**Pr(Skewness)**	**Pr(Kurtosis)**	**Adj. Chi^2(2)**	**Prob>.Chi^2**	**Normality**
Model 1(Business Sectors on Tax Revenue)	45	0.9902	0.8750	0.02	0.9876	Not rejected
Model 2 (Taxpayer Category on Tax Revenue)	45	0.0258	0.9355	4.92	0.0856	Not rejected

Model 3 (Sector & Taxpayer Interaction)	45	0.3821	0.5779	1.12	0.5703	Not rejected

According to the results in Table 10, the normality of residuals from the mixed-effects models is assessed using the Skewness/Kurtosis test at the 95% significance level ($\alpha = 0.05$). For Model 1, which analyzes the effects of business sectors on tax revenue, the joint test yields $\chi^2(2) = 0.02$, Prob > $\chi^2 = 0.9876$, indicating that the residuals are approximately normally distributed. For Model 2, which examines the effects of taxpayer category on tax revenue, the joint test yields $\chi^2(2) = 4.92$, Prob > $\chi^2 = 0.0856$. Although the skewness component is slightly below 0.05 ($p = 0.0258$), the overall test suggests that the residuals are still approximately normal. These results indicate that the normality assumption of residuals is satisfied for both models, supporting the validity of the mixed-design ANOVA analyses. For Model 3, which examines the interaction effect of business sector and taxpayer category on tax revenue, the Skewness/Kurtosis test for normality of residuals shows the following results: $\chi^2(2) = 1.12$, Prob > $\chi^2 = 0.5703$, with individual p-values for skewness = 0.3821 and kurtosis = 0.5779. Since the joint p-value (0.5703) is greater than 0.05, the null hypothesis of normality cannot be rejected. This indicates that the residuals for Model 3 are approximately normally distributed. Consequently, the normality assumption of residuals is satisfied, supporting the reliability of statistical inferences from the mixed-effects model for the sector–taxpayer interaction analysis.

Post Hoc Pairwise Comparisons Following Mixed Design ANOVA

Post hoc pairwise comparisons are conducted to identify specific differences between group means after a significant mixed-design ANOVA result. These comparisons help determine which sectors or taxpayer categories differ significantly in tax revenue, while controlling for Type I error.

Table 11. Post Hoc Pairwise Comparisons of Sector Means Following Mixed Design ANOVA

Comparison	**Contrast**	**Std. Err.**	**95% CI Lower**	**95% CI Upper**	**Decision**
Industry vs. Agriculture	3.344	0.263	2.828	3.859	Reject H_0
Services vs. Agriculture	4.387	0.263	3.872	4.903	Reject H_0
Services vs. Industry	1.044	0.239	0.576	1.512	Reject H_0

Table 11 presents the results of post hoc pairwise comparisons of sectors following the mixed-design ANOVA. The comparisons indicate that all three sectors differ significantly from each other. Specifically, Industry has a significantly higher mean than Agriculture, with a mean difference of 3.344 (Std. Err. = 0.263, 95% CI [2.828, 3.859]), while Services outperform Agriculture by 4.387 (Std. Err. = 0.263, 95% CI [3.872, 4.903]). Additionally, Services have a significantly higher mean than Industry, with a mean difference of 1.044 (Std. Err. = 0.239, 95% CI [0.576, 1.512]). The confidence intervals for all comparisons do not include zero, and the null hypothesis is rejected in each case, confirming that the differences are statistically significant and not due to random variation. These results indicate a clear ranking of sector performance: Services > Industry > Agriculture, with Services leading slightly above Industry and Agriculture lagging behind both. Overall, the findings highlight meaningful differences in performance across sectors, with Services performing the best, Industry performing moderately, and Agriculture performing the least.

Discussion

This study examines the determinants of tax revenue by focusing on business sector, taxpayer category, temporal effects, and their interactions using a mixed-design ANOVA and mixed-effects modeling framework. Prior to estimation, key statistical assumptions—including homogeneity of variances and normality—were rigorously tested and satisfied, ensuring the validity of subsequent parametric analyses. The findings provide strong and consistent empirical support for Hypothesis 1 (H1), which posits that tax revenue differs significantly across business sectors. Across multiple model specifications, both the Industry and Services sectors generate significantly higher tax revenue than Agriculture, the reference category, with post hoc pairwise comparisons con-firming that all inter-sectoral differences are statistically significant. This establishes a clear performance ranking of Services > Industry > Agriculture and aligns with the structural characteristics of these sectors. Services and Industry tend to be more formalized, capi-tal-intensive, and profit-oriented, resulting in greater taxable capacity and higher compliance, whereas Agriculture is often dominated by small-scale and informal activities, limiting its contribution. Importantly, the business sector variables remain statistically significant both when estimated independently and when included alongside the Taxpayer Category variable, indicating that the sectoral effect is not driven by taxpayer classification but reflects funda-mental structural differences. These results are consistent with Optimal Tax Theory, which emphasizes sectoral heterogeneity (Kaplow, 2022); the Slippery Slope Framework and Tax Incidence Theory, which explain compliance and tax burden differences across sectors (Paleka & Vitezić, 2023; McKenzie & Ferede, 2017); and Sectoral Public Finance and Structural Transformation theories, which predict higher revenue from formalized industrial and service sectors (Bird & Zolt, 2014; OECD, 2022). Empirical studies similarly demonstrate that formal sectors consistently generate higher revenue than agriculture and that sectoral effects remain significant even when controlling for taxpayer category (Bird & Zolt, 2014; OECD, 2019; Allingham & Sandmo, 1972; Torgler, 2007). Collectively, these theoretical and empirical in-sights provide robust verification of H1.

The effect of Taxpayer Category varies across model specifications, highlighting the importance of controlling for sectoral composition. In the model that includes only taxpayer category and year effects, no significant difference is observed between Small and Medium taxpayers, leading to a rejection of Hypothesis 2 (H2) in that specification. This suggests that, when considered in isolation, taxpayer size alone does not sufficiently explain variation in tax revenue. However, once Business Sector is incorporated into the model, the effect of taxpayer category becomes negative and statistically significant, with Small taxpayers contributing significantly less tax revenue than Medium taxpayers. This shift indicates that taxpayer category is correlated with business sector, and omitting sectoral controls masks the true relationship between firm category and tax revenue. Therefore, the results from the full model suggest that H2 is conditionally supported, as meaningful differences between Small and Medium taxpayers emerge only after accounting for sectoral heterogeneity. These findings highlight the risk of omitted-variable bias and demonstrate that taxpayer category effects cannot be interpreted independently of sectoral context. The results align with theoretical perspectives emphasizing taxpayer heterogeneity (Kaplow, 2022), differential compliance (Paleka & Vitezić, 2023), sectoral capacity to bear taxes (McKenzie & Ferede, 2017), and structural differences between formalized and informal sectors (Bird & Zolt, 2014; OECD, 2022). Empirical evidence further supports the conditional nature of taxpayer effects, showing that small taxpayers generally exhibit lower compliance and contribute less revenue, whereas Medium taxpayers in formal sectors show higher contributions, particularly after controlling for sectoral differences (Al-lingham & Sandmo, 1972; Torgler, 2007; Bird & Zolt, 2005; OECD, 2019). Furthermore, the observation that administrative reforms may differentially affect revenue from small versus medium taxpayers over time aligns with the empirical evidence presented by Jensen et al. (2024).

Analysis of interaction effects provides clear support for Hypothesis 3 (H3), which posits that the effect of taxpayer category on tax revenue depends on business sector. Positive and statistically significant interaction terms for Industry × Small and Services × Small indicate that small taxpayers in Industry and Services generate higher tax revenue than small taxpayers in Agriculture. This demonstrates that tax revenue dynamics are shaped by the combined influence of firm size and sector, rather than by either factor alone. Theoretical frameworks reinforce this finding: Optimal Tax Theory emphasizes taxpayer heterogeneity (Kaplow, 2022), the Slippery Slope Framework highlights sector-dependent compliance variation (Paleka & Vitezić, 2023), and Tax Incidence Theory explains sectoral differences in the capacity to bear tax burdens (McKenzie & Ferede, 2017). Sectoral Public Finance and Structural Transformation theories further predict higher revenue from formalized, capital-intensive sectors, shaping the observed relationship between taxpayer category and revenue (Bird & Zolt, 2014; OECD, 2022). Empirical studies corroborate these insights, showing that formal sectors consistently generate higher revenue and that while small taxpayers generally contribute less, small firms operating in formal sectors outperform their agricultural counterparts (Allingham & Sandmo, 1972; Torgler, 2007; Bird & Zolt, 2005; OECD, 2019). Additionally, research highlights the importance of sector-year and category-year interactions in shaping revenue dynamics over time, especially in response to macroeconomic shocks and structural changes (Chenery et al., 1986; IMF, 2023; Jensen et al., 2024). Together, these findings provide robust support for H3, confirming that the impact of taxpayer category cannot be fully understood without ac-counting for sectoral context.

Year effects are largely insignificant in the fully specified models, indicating that once sectoral composition, taxpayer category, and their interactions are controlled for, annual var-iation does not independently drive tax revenue. Nonetheless, predicted marginal means reveal a pronounced decline across all sectors and taxpayer categories in 2020, followed by heterogeneous recovery paths. This pattern likely reflects an economy-wide adverse shock, such as the COVID-19 pandemic, with Industry and Medium taxpayers demonstrating relatively stronger post-shock recovery compared to Agriculture and Small taxpayers. These results underscore the importance of sectoral and taxpayer heterogeneity in mediating the resilience and recovery of tax revenue in response to extraordinary shocks, highlighting that external factors can produce significant short-term fluctuations even when year effects are otherwise statistically insignificant.

CONCLUSION

This study provides a comprehensive empirical analysis of tax revenue dynamics in Banteay Meanchey Province, Cambodia, during 2017–2024, focusing on the effects of business sector, taxpayer category, and their interactions. The findings provide robust support for Hypothesis

1, confirming that tax revenue differs significantly across sectors, with Services and Industry generating higher revenue than Agriculture. This difference reflects the higher formalization, capital intensity, and profit orientation of non-agricultural sectors, which increase taxable capacity and compliance. The effect of taxpayer category is nuanced, providing conditional support for Hypothesis 2: when considered alone, small and medium taxpayers do not differ significantly in revenue contribution, but once sectoral composition is controlled, small tax-payers generate significantly less revenue than medium taxpayers, indicating that taxpayer contributions are sector-dependent. Hypothesis 3 is also confirmed, as interaction effects show that small and medium taxpayers in Industry and Services contribute more revenue than their counterparts in Ag-riculture, highlighting that sectoral context amplifies the revenue potential of different taxpayer categories. Temporal effects are generally insignificant; however, the sharp decline and heterogeneous recovery of tax revenue in 2020 due to the COVID-19 pandemic underscore the importance of sectoral and taxpayer heterogeneity in mediating resilience and fiscal stability. Overall, the results emphasize that understanding tax revenue dynamics requires an integrated approach considering both business sector and taxpayer category, as well as their interactions, providing critical insights for effective tax policy, revenue fore-casting, and management. The findings from Banteay Meanchey Province suggest that effective tax policy must explicitly account for both business sector and taxpayer category. Services and Industry emerge as the primary revenue-generating sectors, with Medium taxpayers in these sectors functioning as key revenue anchors and contributing disproportionately to fiscal stability; therefore, they should be prioritized through en-hanced compliance management and risk-based monitoring. In contrast, Small taxpayers—particularly in Agriculture—exhibit structurally limited revenue capacity, indicating the need for simplified tax regimes and gradual formalization rather than uniform enforcement. The conditional significance of taxpayer category confirms that Medium taxpayers generate significantly higher revenue than Small taxpayers once sectoral composition is controlled, underscoring the importance of sector-sensitive taxpayer segmentation. More-over, significant sector–taxpayer interaction effects imply that both Small and Medium tax-payers in formal sectors outperform their agricultural counterparts, highlighting the value of incorporating these interactions into revenue forecasting and fiscal planning. Overall, the re-sults emphasize that a differ-entiated, evidence-based approach is essential for strengthening revenue mobilization and fiscal resilience at the provincial level.

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