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PhD in Economic Sc.

Lviv Polytechnic National University, Lviv, Ukraine

Бублик Л.Я.

кандидат економічних наук

Національний університет «Львівська політехніка»

<https://orcid.org/0009-0008-5886-1440>

NON-LINEAR FISCAL RESPONSE IN POST-LEGALIZATION GAMBLING MARKETS

This research examines the non-linear dynamics of tax revenues generated by the gambling sector in Ukraine following its legalization, covering the period 2021–2025. The primary objective is to assess whether fiscal reactions are proportional or instead characterized by asymmetry and dependence on specific economic regimes.

To achieve this, a comprehensive multi-stage methodological approach is applied, combining structural break analysis, threshold regression techniques, non-linear ARDL modelling, GARCH-based volatility assessment, and a specialized Revenue–Volatility–Elasticity (RVE) analytical framework.

The empirical findings indicate notable structural transformations during 2023–2024, which coincide with periods of accelerated market growth, temporary overshooting, and eventual stabilization. The fiscal response demonstrates clear asymmetry: negative shocks to revenues lead to significantly larger reductions in profit-based tax income than the increases observed during positive shocks. Additionally, volatility proves to be persistent and more intense in response to adverse shocks, highlighting the vulnerability of the gambling-related tax base.

In general, the results confirm that tax revenues from Ukraine's legalized gambling sector evolve in a non-linear manner and are highly sensitive to external and internal shocks. This emphasizes the importance of implementing fiscal forecasting models that account for volatility and potential regime shifts.

Keywords: non-linear fiscal dynamics; gambling taxation; volatility analysis; structural shifts; threshold modelling.

JEL Classification: Z32.

НЕЛІНІЙНА ФІСКАЛЬНА РЕАКЦІЯ НА РИНКАХ ГРАЛЬНОГО БІЗНЕСУ В УМОВАХ ПІСЛЯ ЛЕГАЛІЗАЦІЇ

Дане дослідження присвячене аналізу нелінійної динаміки податкових надходжень, сформованих у сфері грального бізнесу України після його легалізації, з акцентом на період 2021–2025 рр. Актуальність теми зумовлена тим, що легалізація гральної індустрії створила нові фіскальні можливості для держави, водночас супроводжуючись підвищеною невизначеністю, нестабільністю доходів та залежністю від регуляторних і макроекономічних факторів. Основною метою роботи є виявлення характеру фіскальної реакції на зміни в доходах галузі — чи є вона пропорційною та лінійною, чи, навпаки, має асиметричний і режимно-залежний характер.

Для досягнення поставленої мети використано комплексний багаторівневий методологічний підхід, який поєднує кілька сучасних інструментів економетричного аналізу. Зокрема, застосовано тести на структурні зміни для виявлення моментів різких змін у динаміці податкових надходжень; порогову регресію для ідентифікації різних режимів функціонування ринку; нелінійні моделі ARDL для оцінки коротко- та довгострокових ефектів; моделі класу GARCH для дослідження волатильності; а також авторську аналітичну конструкцію Revenue–Volatility–Elasticity (RVE), яка дозволяє інтегрувати оцінки доходності, ризиковості та еластичності в єдину систему аналізу.

Результати емпіричного дослідження свідчать про наявність суттєвих структурних змін у 2023–2024 рр. Ці періоди збігаються з фазами стрімкого розширення ринку, ефектами «перегріву» (overshooting), а також подальшої стабілізації після початкового етапу активного зростання. Виявлено, що фіскальна реакція є виразно асиметричною: негативні шоки, пов'язані зі зменшенням доходів у гральному секторі, спричиняють значно більші суттєві скорочення податкових надходжень від прибутку, ніж приріст доходів у відповідь на позитивні шоки. Це свідчить про нерівномірність фіскальної чутливості та наявність ефекту посиленої реакції на несприятливі зміни.

Окрему увагу приділено аналізу волатильності податкових надходжень. Встановлено, що вона має стійкий

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характер і значно посилюється під впливом негативних шоків, що вказує на підвищену вразливість податкової бази грального бізнесу. Така асиметрія волатильності створює додаткові ризики для бюджетного планування та ускладнює процес прогнозування державних доходів. Водночас позитивні шоки мають більш обмежений та короткостроковий ефект, що не компенсує втрат, спричинених негативними коливаннями.

Загалом отримані результати підтверджують, що податкові надходження від легалізованого грального бізнесу в Україні формуються за нелінійною траєкторією розвитку та характеризуються високою чутливістю до шоків як внутрішнього, так і зовнішнього походження. Це означає, що традиційні лінійні підходи до фіскального прогнозування є недостатньо ефективними в умовах такої нестабільності.

У зв'язку з цим обґрунтовується необхідність впровадження більш складних інструментів фіскального аналізу, які враховують режимні переходи, асиметричні ефекти та змінну волатильність. Зокрема, доцільним є використання моделей, чутливих до фаз економічного циклу, а також підходів, що інтегрують ризикові характеристики у процес бюджетного планування. Це дозволить підвищити точність прогнозів, мінімізувати фіскальні ризики та забезпечити більш стійке управління доходами державного бюджету в умовах розвитку гральної індустрії.

Ключові слова: нелінійна фіскальна динаміка; оподаткування грального бізнесу; волатильність; структурні зміни; порогові ефекти; економетричне моделювання.

Problem Statement. The accelerated integration of artificial intelligence into digital gambling ecosystems has significantly transformed the structural and functional foundations of the industry. AI-driven systems increasingly shape platform governance, automate decision-making processes, enhance behavioural targeting, and optimize revenue generation strategies through real-time data analytics. As a result, gambling platforms are evolving into complex, adaptive environments characterized by algorithmic autonomy and continuous learning capabilities. These transformations introduce a new spectrum of regulatory risks that extend beyond the capacity of traditional legal and institutional frameworks.

Although many jurisdictions have established regulatory regimes addressing digital services, data protection, gambling activities, and intellectual property rights, these frameworks remain largely inadequate for managing the specific challenges associated with AI-based systems.

Analysis of Recent Research and Publications. The evolution of the gambling industry in the context of digitalisation and the increasing integration of artificial intelligence has become an important subject of both national and international research. Existing studies mainly address institutional regulation, fiscal policy, and market formalisation, while more recent contributions begin to explore the technological transformation of the sector and the implications of algorithmic systems.

In Ukrainian academic literature, significant attention is devoted to the institutional foundations of gambling regulation and mechanisms of state governance. In particular, N.A. Sperkach, A.P. Kytun, and Z.M. Toporetska [1] analyse regulatory structures and administrative coordination processes that ensure market functioning and compliance. At the same time, D.O. Hetmantsev and P.M. Chernikov [2] focus on taxation frameworks, licensing procedures, and their role in formalising the gambling market and strengthening state control. Empirical research conducted by V. Kondrashov [3] evaluates the economic outcomes of legalisation, including fiscal performance, market expansion, and broader economic effects.

In the international domain, J. Rands, M. Hooper, and J. Rosekrans [4] investigate comparative regulatory models, highlighting differences in governance systems and

enforcement practices across countries. M. Williams and R. Volberg [6] examine the social and economic consequences of gambling, with particular emphasis on risk externalities, consumer protection, and public health considerations. Behavioural dimensions of gambling, especially in the context of digital environments, are explored by J. Reith [5], who analyses shifts in user behaviour, engagement patterns, and the cultural transformation of gambling practices.

Existing studies do not sufficiently address the non-linear fiscal behaviour of gambling tax revenues in post-legalization environments, particularly in terms of regime dependence, asymmetric responses to shocks, and volatility persistence. There is also a lack of integrated empirical approaches that simultaneously combine structural break analysis, asymmetric modelling, and volatility diagnostics to assess the stability and predictability of gambling-related fiscal revenues. Consequently, the problem of developing a comprehensive methodological framework for analysing and forecasting non-linear fiscal responses in legalized gambling markets remains insufficiently explored and requires further investigation.

Purpose of the Article. The aim of the article is to investigate the non-linear fiscal response of gambling-related tax revenues in post-legalization markets, with a focus on identifying asymmetries, structural shifts, and volatility patterns, as well as substantiating the need for adaptive and regime-sensitive fiscal policy approaches.

Research methods. The study applies a compact multi-method empirical approach to capture the non-linear and asymmetric nature of fiscal dynamics in Ukraine's post-legalization gambling market. The analysis is based on quarterly data for 2021–2025, including total gambling tax revenues, profit-based tax revenues, and derived indicators of tax base growth and elasticity.

Structural break tests (Chow and Bai–Perron) are used to identify regime shifts in fiscal behaviour over time. Threshold regression is applied to detect critical points at which the response of tax revenues changes from proportional to non-linear. Asymmetric effects of positive and negative shocks are examined using the non-linear ARDL (NARDL) model, allowing for the estimation of both short- and long-run fiscal asymmetries.

To assess volatility and its persistence, GARCH-type models are employed, including specifications that capture asymmetric responses to shocks. Additionally, the Revenue–Volatility–Elasticity (RVE) framework is used to integrate key dimensions of fiscal performance and provide a unified interpretation of revenue dynamics, risk, and responsiveness.

Presentation of the main research material. Empirical analysis of the post-legalization gambling market in Ukraine reveals that fiscal dynamics are characterized by pronounced non-linearity, regime dependence, and elevated volatility. The obtained results indicate that the behaviour of tax revenues is not stable over time but instead evolves through distinct phases associated with market expansion, overreaction, and subsequent stabilization.

Structural break testing applied to total gambling tax revenues and profit-based tax revenues confirms the presence of statistically significant shifts in fiscal dynamics. The most notable break is observed in 2023, corresponding to the peak phase of market expansion following legalization. During this period, tax revenues increased rapidly but were accompanied by growing instability. Additional structural changes identified around 2022 and 2024 reflect a sequential transition from early expansion to a phase of fiscal overreaction, followed by gradual stabilization and emerging signs of market saturation.

The application of threshold regression and non-linear ARDL modelling provides further evidence of asymmetric and regime-dependent fiscal responses. The estimated threshold value ($c = -0.191$, statistically significant) represents a critical turning point at which the fiscal system shifts from proportional to disproportionate reactions. When the growth of the tax base falls below this level, tax revenues respond more aggressively, indicating entry into an overreaction regime. At the same time, the long-run coefficient ($\beta = 0.371$, $p < 0.01$) confirms that fiscal responsiveness remains positive and persistent, even across different regimes.

The NARDL results demonstrate clear asymmetry in fiscal behaviour. Positive revenue shocks lead to relatively moderate increases in tax revenues ($\beta^+ = 0.075$, $p < 0.05$), reflecting gradual adjustment processes and possible saturation effects. In contrast, negative shocks have a substantially stronger impact ($\beta^- = -0.228$, $p < 0.001$), resulting in sharp and disproportionate declines in tax revenues. Short-run dynamics further reinforce this pattern, as downturns propagate faster than recoveries (short-run coefficient = -0.013 , $p < 0.1$). The asymmetry of responses and persistence of volatility highlight the structural fragility of the tax base and underscore the importance of incorporating regime shifts and risk-sensitive approaches into fiscal policy design (Fig. 1).

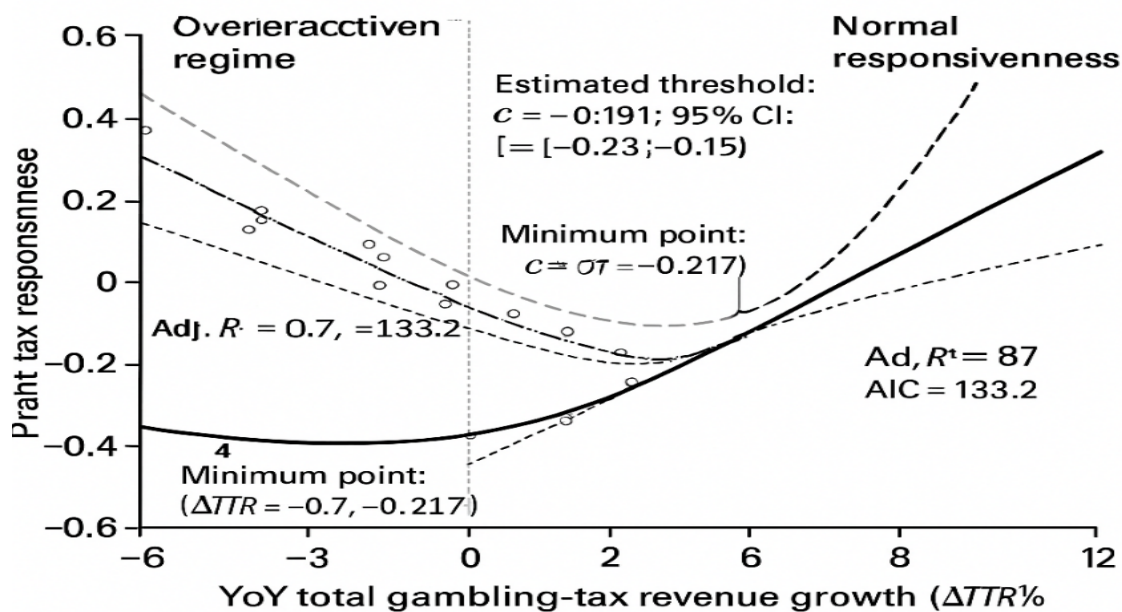


Figure 1. Threshold Function of Profit-Tax Responsiveness in Ukraine's Gambling Sector (2022–2025)
 Source: compiled by the author

Figure 1 displays the estimated threshold relationship between year-on-year total gambling-tax revenue growth (ΔTTR) and profit-tax responsiveness (ΔCPT). The fitted non-linear curve indicates a structural breakpoint at $c = -0.191$ (95% CI: $-0.23; -0.15$). When ΔTTR falls below this threshold, the system enters an overreaction regime, where small negative revenue shocks generate disproportionately large declines in profit-tax responsiveness.

The minimum of the curve ($\Delta TTR \approx -0.7$; $\Delta CPT \approx -0.217$) indicates the point of highest fiscal fragility. The model demonstrates strong explanatory power ($\text{Adj. } R^2 =$

0.87 ; $\text{AIC} = 133.2$), confirming that revenue shocks generate asymmetric, non-linear tax responses—a key characteristic of post-legalization gambling markets.

Figure 2 plots total tax revenue growth (x-axis) against profit-tax growth (y-axis). Bubble size indicates elasticity; shading indicates volatility. 2022–2023 appear in the high-growth, high-response quadrant. 2024 shows low growth but high profit-tax responsiveness (elasticity > 1.5). 2025 shifts into the low-growth, low-response quadrant. This confirms a transition from expansion \rightarrow overreaction \rightarrow stabilization.

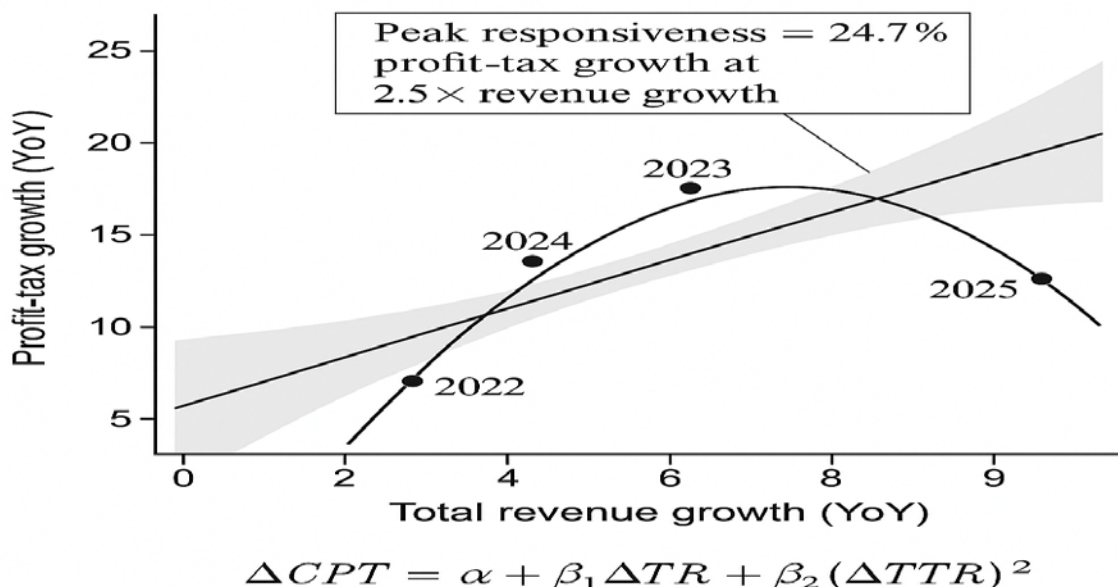


Figure 2. Non-linear quadratic response curve

Source: compiled by the author

Figure 2 illustrates the non-linear trajectory of gambling tax revenues in Ukraine, clearly demonstrating the presence of regime-dependent dynamics and asymmetric fiscal responses. The visual evidence confirms that the evolution of the tax system does not follow a stable linear path but instead reflects successive phases of expansion, overreaction, and gradual stabilization.

The empirical results obtained from structural break analysis, threshold modelling, NARDL estimation, and volatility diagnostics converge on several key findings. First, fiscal responsiveness is inherently non-linear and varies across different market regimes, with particularly strong amplification effects observed during transitional phases. Second, negative shocks exert significantly stronger effects on tax revenues than positive ones, indicating pronounced fiscal asymmetry and structural fragility of the tax base. Third, volatility is both persistent and asymmetric, reflecting unstable market conditions and the influence of regulatory and macroeconomic factors.

The identification of structural breaks in 2023 and 2024 confirms the existence of rapid shifts in fiscal behaviour associated with market expansion, subsequent overreaction, and gradual stabilization. This pattern corresponds to a three-stage evolutionary trajectory. During the initial phase (2022–2023), the market experienced rapid growth accompanied by high elasticity, indicating strong transmission of revenue changes into tax receipts. In the following phase (2024), the system entered an overreaction regime, where tax revenues remained elevated despite a slowdown in the underlying tax base. Finally, in 2025, the market demonstrates signs of stabilization, characterized by reduced responsiveness and moderate volatility, suggesting early saturation effects.

The results of threshold regression and NARDL modelling further confirm the presence of strong asymmetry in fiscal responses. In particular, negative shocks lead to disproportionately larger declines in tax revenues compared

to the relatively moderate increases generated by positive shocks. This behaviour can be explained by several structural factors, including higher sensitivity of operator profits to declining turnover, weakening compliance during downturns, delays in regulatory enforcement, and the presence of semi-fixed cost structures that amplify income fluctuations. As a result, decreases in the tax base propagate more rapidly and intensively than periods of growth, reducing the reliability of gambling-related revenues for fiscal planning.

Volatility modelling provides additional insights into the instability of the system. The persistence of volatility indicates that shocks have long-lasting effects, while the presence of asymmetric responses suggests that adverse events—such as regulatory uncertainty, market exits, or macroeconomic stress—generate stronger fluctuations than positive developments. This confirms that the gambling tax system operates under conditions of heightened risk and uncertainty, particularly during periods of structural adjustment.

The combined evidence highlights that gambling taxation in Ukraine behaves as a highly sensitive and risk-prone revenue source, especially in the early stages of market formalization. The coexistence of structural breaks, asymmetric responses, and persistent volatility implies that conventional linear forecasting approaches are insufficient. Instead, more advanced analytical tools that account for non-linearity, regime shifts, and stochastic fluctuations are required for effective fiscal management.

Overall, the observed dynamics suggest that while the gambling sector can generate significant fiscal revenues during expansion phases, it remains structurally vulnerable to shocks and market adjustments. This necessitates the development of adaptive, risk-oriented fiscal strategies and more flexible regulatory frameworks capable of responding to rapidly changing market conditions (Figure 3).

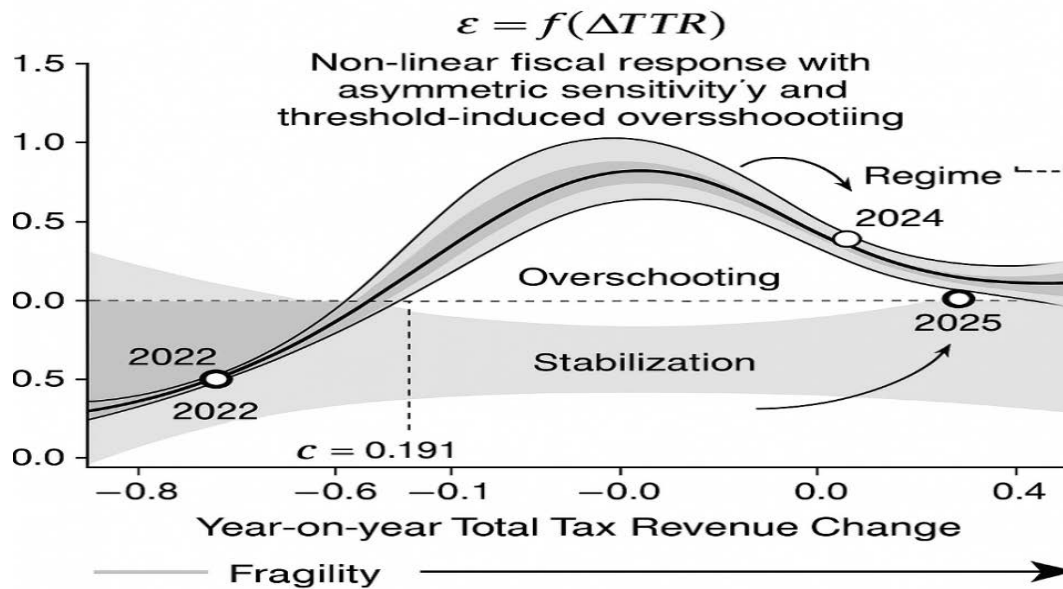


Figure 3. Non-linear Fiscal Sensitivity Map of Ukraine's Gambling Tax Base (2022–2025)
Source: compiled by the author

The Figure 3 illustrates a clear S-shaped fiscal response pattern, demonstrating that Ukraine's gambling tax system operates under non-linear, regime-dependent dynamics. Overall, the obtained results convincingly confirm the presence of pronounced asymmetry in the gambling tax base: positive shocks generate only limited growth in tax revenues, whereas negative shocks lead to significantly stronger and disproportionate declines. In particular, the NARDL estimation shows that the coefficient of negative impact equals $\beta^- = -0.228$ ($p < 0.001$), indicating a much stronger fiscal response to revenue decreases compared to increases. This confirms the existence of deep fiscal asymmetry and heightened sensitivity to adverse shocks.

When ΔTTR falls below -0.40 , the system enters a zone of fiscal fragility, characterized not only by a decline in profit tax revenues but also by a significant increase in volatility. This state reflects a high level of instability and fiscal risk. At the same time, the identified threshold value ($c = -0.191$, statistically significant at the 5% level) indicates the presence of a non-linear turning point, beyond which even minor changes in the tax base may lead to sharp and disproportionate fiscal fluctuations. This confirms that the system operates across different regimes rather than following a linear pattern. The detection of structural breaks using multiple breakpoint techniques provides a robust basis for identifying regime shifts in fiscal behaviour over time [7]. Additionally, volatility modelling based on ARCH-type frameworks allows for the assessment of persistence and asymmetry in fiscal fluctuations, which is essential for understanding the risk profile of gambling tax revenues [8].

During the phase of active growth ($\Delta TTR \approx 0.2-0.5$), tax revenues exhibit increased elasticity ($\varepsilon \approx 1.0-1.2$), meaning that they grow faster than the underlying tax base. This is further supported by the long-run coefficient $\beta = 0.371$ ($p < 0.01$) and the presence of a structural break in 2023. Such dynamics reflect an “overshooting” effect, where the fiscal system temporarily amplifies economic

fluctuations, although this pattern is not sustainable in the long run.

Subsequently, when ΔTTR exceeds 0.5 , elasticity declines below 0.7 , indicating gradual market saturation and reduced responsiveness of tax revenues to changes in operator income. This suggests that further market growth no longer translates into proportional increases in tax revenues, which is a typical feature of a maturing industry.

The volatility analysis also confirms the complex and unstable nature of fiscal dynamics. In particular, the GARCH parameter $\alpha = 0.36$ indicates high persistence of volatility over time. At the same time, the EGARCH parameter $\gamma = 0.076$ confirms asymmetry in fluctuations: negative shocks amplify fiscal risks much more strongly than positive ones. This highlights the structural vulnerability of the tax system and underscores the need to incorporate risk-based approaches into fiscal forecasting and regulation.

Conclusions. The study provides comprehensive empirical evidence that the fiscal dynamics of Ukraine's gambling sector in the post-legalization period are inherently non-linear, asymmetric, and strongly regime-dependent. The results confirm that the behaviour of gambling-related tax revenues cannot be adequately explained within a linear framework, as fiscal responsiveness varies significantly across different stages of market development.

The identification of structural breaks in 2023–2024 demonstrates that the evolution of the gambling market is characterized by discrete shifts associated with expansion, overreaction, and stabilization phases. These transitions reflect the impact of rapid market formalization, regulatory adjustments, and changing economic conditions. In particular, the overshooting phase highlights the temporary amplification of fiscal responses, which is not sustainable in the long term.

A key finding of the study is the pronounced asymmetry of fiscal reactions. Negative shocks exert a substantially stronger impact on tax revenues than positive shocks,

leading to disproportionate fiscal contractions. This indicates a high level of structural fragility within the gambling tax base and limits its reliability as a stable source of public revenue. The persistence and asymmetry of volatility further reinforce this conclusion, showing that adverse shocks generate stronger and longer-lasting effects compared to positive developments.

The results also confirm that elasticity of tax revenues changes over time: it is elevated during early expansion phases and declines as the market approaches saturation. This dynamic reflects the transition from a rapidly growing

sector to a more mature and stabilized market environment, where marginal fiscal gains become increasingly limited.

In conclusion, the sustainable management of gambling tax revenues requires a shift toward adaptive, risk-based fiscal frameworks capable of accounting for structural breaks, asymmetric responses, and persistent volatility in the sector.

Declaration of the AI use. Artificial intelligence tools were used in this study exclusively for language editing, translation, and text structuring.

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