Granular Fiscal Risk and Tax-Base Concentration: Evidence from Macau's Gaming Industry*†

Nikolai Sheung-Chi **Chow** ‡ Hyungsuk **Lee** § Sam **Ng** ¶

Abstract

We document granular fiscal risk in the Macau Special Administrative Region of China: the non-diversifiable component of public-finance risk that arises when government revenues depend on a highly concentrated tax base. To quantify this exposure, we construct firm-level revenue residuals, decompose them into sector-wide and firm-specific components, and aggregate them using lagged Domar-style weights that reflect fiscal relevance. We examine how these shocks relate to macroeconomic and fiscal outcomes using static regressions, nonlinear specifications, and impulse responses estimated with Bayesian Vector Autoregressions and Local Projections. We find that sector-wide shocks are closely associated with movements in the mean of macro-fiscal outcomes. Firm-specific shocks, in contrast, are primarily linked to macroeconomic and fiscal volatility. These results indicate that tax-base concentration shapes not only the average macro-fiscal outcomes but also the underlying risk.

JEL codes: E62, H63, L83
Keywords: Granular fiscal risk; Tax-base concentration; Fiscal volatility; Sectoral and firm-specific shocks; Bayesian VAR.

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‡City University of Macau. Email: scchow@cityu.edu.mo
§Bank of Korea. Email: hslee0120@bok.or.kr
¶University of Macau. E-mail: iengmanng@um.edu.mo

1 Introduction

Many governments—especially small open economies, subnational jurisdictions, and sector-dependent states—finance themselves with highly concentrated tax bases. In such economies, the fiscal authority effectively holds an undiversified portfolio of a few highly correlated private cash-flow streams. This raises a central question: *when an economy relies on a concentrated tax base, how do shocks to dominant firms propagate to macroeconomic and fiscal outcomes?*

To address this question, we build on the granular hypothesis of Gabaix (2011) and extend its logic to the study of public finance. We term this channel *granular fiscal risk*: the non-diversifiable component of public-finance risk induced by concentration in the private tax base. When government revenues hinge on a small set of dominant firms or a single sector, firm-level shocks need not wash out in aggregation; instead, they become risks to fiscal stability.

Our results point to two distinct channels of fiscal risk in concentrated tax-base economies. Sector-wide shocks are associated with movements in the mean of macro-fiscal outcomes, including economic growth and fiscal surpluses. Idiosyncratic firm-specific shocks, in contrast, are primarily associated with volatility (movement around that mean). Dynamic estimates from Bayesian Vector Autoregressions (BVAR), and, as a robustness check, local projections (LP), reinforce this pattern: negative sector-wide shocks are followed by persistent declines in real GDP growth and fiscal surpluses, whereas firm-level shocks exhibit limited aggregate propagation. These findings suggest that sectoral comovement influences macro-fiscal levels, while firm-level shocks are more closely linked to macro-fiscal volatility.

We validate this framework in the Macau Special Administrative Region of China (Macau), an economy with a highly concentrated tax base. The casino gaming industry consists of six operators that generate essentially all gross gaming revenue (GGR). These firms account for a large share of economic activity and the majority of government revenue. Public revenue maps almost linearly to GGR through a statutory gaming duty supplemented by earmarked levies, yielding an effective tax rate near 40% in normal times. This institutional structure provides a clean environment to separate sector-wide shocks from idiosyncratic firm-specific shocks. Our sample (2010Q1–2025Q2) includes large, policy-relevant shocks, such as the post-2014 contraction in VIP gaming activity and the 2020–2022 collapse during pandemic border closures—episodes in which tax-base concentration is particularly salient.

To measure granular fiscal risk, we use quarterly firm-level revenue data for the six operators together with macro-fiscal indicators for Macau. For each firm, we purge common macroeconomic conditions, seasonality, and pandemic effects to obtain firm-level revenue. We decompose the resulting revenue into sector-wide and idiosyncratic firm-specific components and aggregate them using lagged Domar-style weights based on revenue shares to nominal

GDP (Domar, 1961; Hulten, 1978; Carvalho and Gabaix, 2013), yielding the sectoral residual Γ_t^{s}, the idiosyncratic residual Γ_t^{id}, and their sum Γ_t^{tot}.

Using this data, we examine how granular shocks relate to both the levels and the volatility of macro-fiscal outcomes through static time-series regressions, nonlinear specifications, and impulse responses estimated with BVARs and, as a robustness check, LP (Jordà, 2005; Plagborg-Møller and Wolf, 2021; Montiel Olea and Plagborg-Møller, 2021). This empirical design operationalizes a framework applicable to other economies where fiscal authorities face concentrated taxpayer portfolios.

This paper makes three contributions. First, we introduce the concept of *granular fiscal risk*—the non-diversifiable component of public-finance risk that arises when government revenues depend on a concentrated private tax base—and provide a tractable measurement framework based on Domar-weighted firm-level residuals. While the granular hypothesis has been applied to real activity and asset pricing (Gabaix, 2011; Gabaix and Koijen, 2014), its fiscal dimension has received comparatively little attention. We show that the standard fiscal-risk literature's focus on macroeconomic shocks and contingent liabilities (International Monetary Fund, 2009) misses an important micro-level channel when the tax base is narrow.

Second, we provide the first firm-level granular decomposition of fiscal risk in a highly concentrated economy, distinguishing empirically between sector-wide disturbances and idiosyncratic firm-specific shocks. Our central finding is a sharp levels-versus-risk split: sector-wide shocks are associated with movements in the *mean* of macro-fiscal outcomes, whereas idiosyncratic shocks are primarily linked to movements around that mean—that is, to fiscal volatility. This distinction has direct implications for how fiscal authorities should monitor and respond to different sources of revenue uncertainty.

Third, we develop an operational toolkit for fiscal surveillance in tax-base-concentrated systems. The framework—combining a high-frequency granular residual with a slow-moving fundamental-volatility measure—can be implemented with standard firm and national-accounts data, and is portable to other fiscally concentrated jurisdictions, including resource-dependent economies, excise-heavy sectors, regulated concessions, and tourism hubs.

The remainder of the paper is organized as follows. Section 2 describes Macau's gaming industry and fiscal structure. We present the empirical strategy and results in Sections 3 and 4. We then conclude in Section 5.

1.1 Literature Review

Our paper sits at the intersection of (i) the granular origins of aggregate fluctuations, (ii) growth accounting and aggregation with intermediate inputs, and (iii) fiscal-risk measurement and macroeconometric identification of dynamic effects.

The starting point is the granular hypothesis: when firm sizes are fat-tailed and a small

set of firms accounts for a meaningful fraction of economic activity, idiosyncratic firm shocks need not diversify away and can move aggregates Gabaix (2011). This insight has been developed in production-network models where input-output linkages amplify micro shocks and generate comovement across sectors and firms Acemoglu *et al.* (2012). Empirically, a range of studies document that granular shocks account for a material share of aggregate fluctuations in output and productivity, and related work extends the logic to macro-finance settings, including asset pricing and tail risk (Gabaix and Koijen, 2014; Black *et al.*, 2022). We build on this literature but shift the object of interest from real activity alone to *public finances*: when the tax base is concentrated in a few dominant private entities, granularity manifests directly in revenues and fiscal balances.

A key practical issue is how to aggregate firm-level shocks into an empirically meaningful macro-fiscal disturbance. Growth accounting with intermediate inputs implies that the relevant aggregation weights are *Domar weights*—gross-output shares that need not sum to one—so micro shocks can be amplified through intermediate-input use (Domar, 1961; Hulten, 1978). Building on these ingredients, Carvalho and Gabaix (2013) define *fundamental volatility*, the Domar-weighted variance of micro shocks, and show that low-frequency movements in aggregate volatility track shifts in economic composition (Domar weights), holding micro shock variances approximately fixed. Our empirical design mirrors this dual perspective. The high-frequency object is a *granular residual* that aggregates realized firm-level innovations with lagged Domar-style weights; the low-frequency object is a composition-based fundamental-volatility measure that isolates how changing concentration moves exposure to micro risk.

The fiscal-risk literature emphasizes macroeconomic shocks, contingent liabilities, and correlated exposures, with comparatively less attention to idiosyncratic shocks hitting a dominant private tax base International Monetary Fund (2009). This gap is consequential for concentrated fiscal systems: even if macro conditions are stable, large taxpayers can generate sizable revenue surprises when the tax base is narrow. Our paper contributes by (i) defining granular fiscal risk as the non-diversifiable micro component of revenue risk induced by concentration, (ii) offering a measurement framework that can be implemented with standard firm and national-accounts data, and (iii) distinguishing empirically between *sector-wide* disturbances (systematic risk in the fiscal portfolio) and *idiosyncratic* dispersion (volatility and tail-risk signal).

To map granular shocks into macro-fiscal outcomes, we combine static regressions with dynamic impulse responses. Local projections Jordà (2005) provide horizon-specific estimates without imposing a full-system VAR and are robust to certain forms of misspecification. Recent results clarify that, under standard identification schemes, LPs and VARs estimate the same impulse responses Plagborg-Møller and Wolf (2021), and that lag-augmented

LPs deliver more reliable inference in persistent and small-sample settings Montiel Olea and Plagborg-Møller (2021). In parallel, Bayesian Vector Autoregressions are attractive in short samples because shrinkage stabilizes estimation in multi-equation systems; see Chan (2020) and Chan (2024) for comprehensive treatments of Bayesian VAR estimation with shrinkage priors. Our empirical strategy therefore uses a BVAR as a baseline for propagation and LPs as a robustness check, with harmonized shock scaling and lag structure.

Relative to the granular macro literature, the novelty here is the fiscal channel and an operational decomposition that separates sector-wide from firm-specific sources of fiscal risk in a concentrated tax base. Relative to the fiscal-risk literature, the novelty is a micro-founded measurement of shocks and exposure, using the Domar-weighted granular residual and a composition-based volatility metric, and an explicit mapping of these objects into both expected fiscal outcomes (levels) and uncertainty (realized volatility and nonlinear large-shock effects). Macau serves as a clean identification environment rather than the substantive endpoint. Its six-firm concession structure and near-linear tax mapping allow us to validate a general toolkit that can be applied in other settings where fiscal authorities face concentrated taxpayer portfolios, such as resource royalties, excise-heavy sectors, regulated concessions, and tourism hubs.

A growing body of applied work documents the economic and fiscal significance of Macau's gaming sector but stops short of a firm-level granular analysis. Sheng and Gu (2018) document that GGR accounted for over half of GDP at its peak, making the gaming industry the dominant engine of growth. Gu and Li (2009) analyze the economic properties of Macau's gaming tax, which levies a statutory 35% on GGR plus supplementary contributions, producing an effective burden near 40%. Liu (2006) traces the structural evolution from monopoly to oligopoly after the 2002 concession liberalization, and Zhou *et al.* (2022) and Luo and Song (2025) examine, respectively, the demand contraction triggered by China's anti-corruption campaign and the more recent push toward non-gaming diversification. From a macro-fiscal perspective, Wan *et al.* (2022) study Macau's urban resilience during COVID-19, showing that the casino-dependent fiscal structure simultaneously provided the resources for crisis response and created structural vulnerability. Abdallah and Cerisola (2020) construct a cross-country tax-revenue diversification index and find that diversified tax structures lower fiscal volatility—a result whose limiting case is precisely the extreme concentration observed in Macau. Finally, Humphreys and Matheson (2010) show that gaming revenues can reduce budget volatility in U.S. states where the tax base is diversified; by contrast, when gaming *is* the tax base, the relevant risk is no longer a portfolio-diversification question but a granular one. Despite this extensive literature, no study has applied a firm-level granular decomposition to Macau's gaming sector or traced the transmission of idiosyncratic concessionaire shocks to the fiscal balance. Our paper fills this gap.

2 Macau's Gaming Industry and Granular Fiscal Risk

This section provides an overview of the evolution and key characteristics of Macao's gaming sector, with a particular focus on its profound implications for fiscal risk. In this context, fiscal risk refers to the extreme sensitivity of public finances to the cyclical conditions of the gaming industry, arising from the government's heavy reliance on gaming-related duties as its primary revenue source. By tracing the sector's development, we illustrate how Macao's budgetary stability has become inextricably linked to the performance and regulatory environment of a few dominant casino operators.

2.1 Overview and Evolution of Macau's Gaming Industry

The gaming sector is the key engine of Macau's economy and fiscal system. It generates the vast majority of government revenue and accounts for a substantial share of aggregate economic activity. According to data from the Financial Services Bureau of Macau, gaming taxes represented approximately 83.1% of total government revenue in the first nine months of 2024. This fiscal structure implies that the territory's public spending and macroeconomic stability are tightly linked to the performance of a single regulated dominant industry.

Since the liberalization of casino concessions in 2002, Macau has transformed into the world's largest gaming hub. Casino operations are governed by a tightly regulated licensing regime. Only six concessionaires—*Sands China*, *Galaxy Entertainment*, *SJM Holdings*, *Melco Resorts*, *Wynn Macau*, and *MGM China*—are legally permitted to operate. This structure creates an oligopolistic market with substantial market power and high profitability in normal times. However, such a market structure also concentrates fiscal risk: idiosyncratic firm-specific shocks can transmit to aggregate macroeconomic and fiscal outcomes.

Macau's gaming industry has evolved through distinct phases, with Gross Gaming Revenue (GGR) providing a clear summary statistic of the sector's rise, rebalancing, and shock-driven contraction (Figure 1). Following concession liberalization in 2002, and the issuance of concessions/subconcessions from 2003 onward, GGR expanded rapidly. Between 2003 and 2014, GGR increased by more than an order of magnitude. This expansion reflected large-scale capital investment and strong demand from mainland China.

The early gaming boom was primarily driven by the VIP gaming segment. A substantial share of GGR originated from high-roller activity supported by junket intermediation and relatively frictionless cross-border capital flows. This business model began to unwind after 2014. China's anti-corruption campaign and tighter regulatory oversight led to a persistent decline in VIP revenues. The composition of GGR shifted toward the mass-gaming segment. By 2019, total GGR returned to peak levels, but the revenue mix was structurally different from that of the earlier boom.

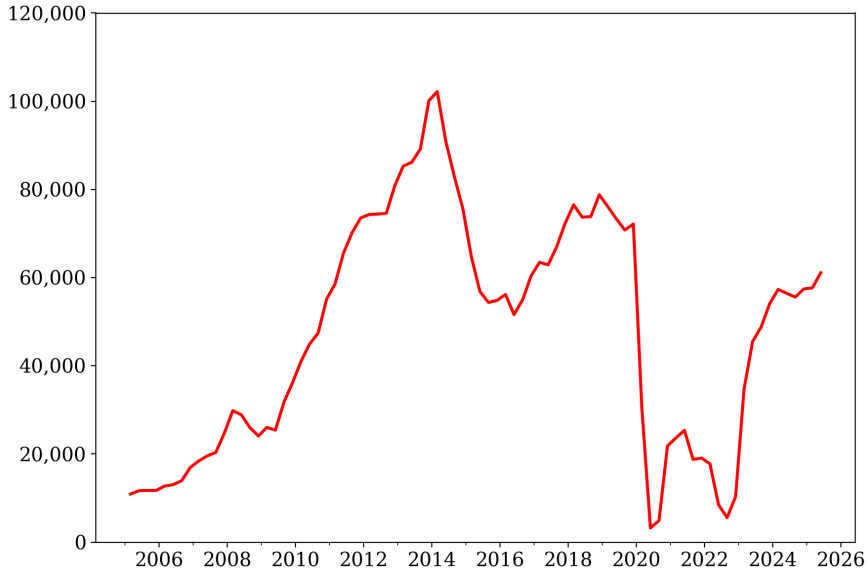


Figure 1: Gross Gaming Revenue in Macau, 2005–2025 (MOP millions)

The 2020–2022 period represents a second structural break. Border closures and the collapse of tourism inflows caused an unprecedented contraction in GGR. Aggregate output of the Macau economy declined sharply in parallel. Following border reopening, GGR recovered gradually. In 2024, GGR reached MOP 226.8 billion, approximately 78% of its 2019 peak. The recovery has been accompanied by structural reorientation toward the mass-gaming segment and non-gaming amenities. Current concession requirements emphasize diversification into conventions, entertainment, retail, and family-oriented attractions.

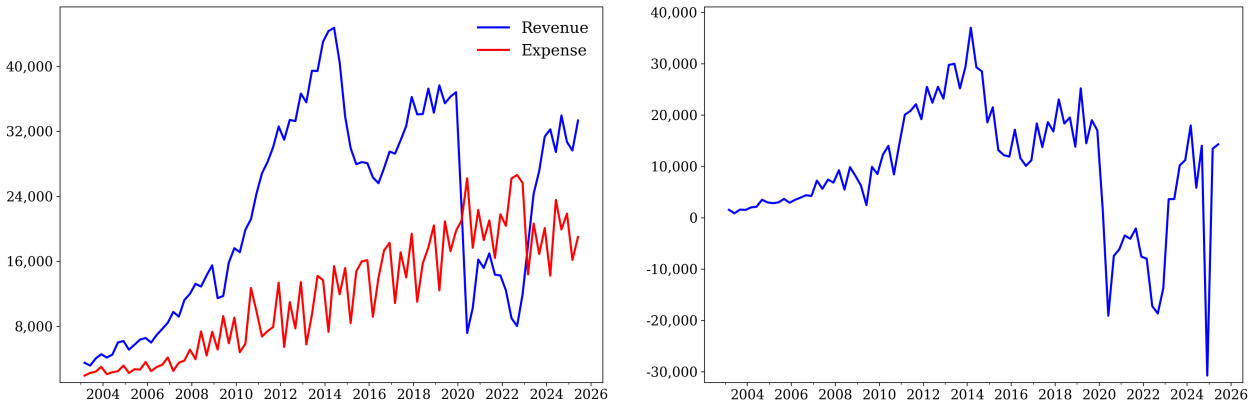
These institutional features, extreme fiscal concentration, oligopolistic market structure, and repeated large shocks, all of which make Macau an informative laboratory to study granular fiscal risk. This helps to understand how sectoral-wide and idiosyncratic firm-level shocks are linked to the overall macroeconomic and fiscal outcomes.

2.2 Fiscal Structure and Dependence on Gaming Revenue

Macau's fiscal system is tightly linked to the performance of the gaming sector. Government revenue depends predominantly on taxes levied directly on gross gaming revenue. We therefore describe the fiscal structure and document the link between gaming activity and fiscal outcomes.

Macau's public finances have historically been strong. The territory's government has consistently maintained budget surpluses for most of the post-liberalization period, underpinned by robust gaming-related revenues. As shown in Figure 2, fiscal revenue has far exceeded expenditure throughout the 2000s and 2010s, allowing the government to accumulate substantial fiscal reserves. The statutory tax on games of fortune is 35% of gross gaming

revenue , supplemented by a 2% community contribution, a 1.6% tourism-promotion levy, and smaller earmarked surcharges, bringing the effective rate close to 39–40%.



(a) Revenue and Expenditure

(b) Fiscal Surplus

Figure 2: Macau Government Revenue, Expenditure, and Surplus, 2003–2025 (MOP millions)

Despite sustained fiscal surpluses, the revenue base is highly concentrated, depending on a dominant sector. Figure 3 shows the share of gaming tax revenue in total government revenue. On average, tax revenue from the gaming sector accounts for approximately 70–80% of total government revenue. This narrow tax base leaves the fiscal position of the Macau government highly exposed to fluctuations in the casino industry.

The COVID-19 pandemic illustrates this exposure. During 2020–2022, border closures led to a collapse in gaming activity. Government revenue fell sharply, while expenditure remained relatively stable. The fiscal balance turned negative in 2020 for the first time in two decades. As gaming activity recovered, fiscal revenues rebounded. This episode highlights the vulnerability inherent in a narrowly concentrated tax base.

2.3 Granular Concentration and Fiscal Transmission

The institutional features described above—extreme industrial concentration and fiscal dependence on a single revenue source—create the conditions of a granular economy in the sense of Gabaix (2011). In such environments, shocks to a small number of dominant firms need not diversify away in aggregation.

In Macau, this mechanism operates primarily through the fiscal channel. Government revenue is a near-proportional function of gross gaming revenue. The six concessionaires generate a majority of the territory's government revenue. Effectively, the fiscal authority holds an undiversified portfolio of a small number of correlated tax revenue streams. As a result, any firm-level shocks could produce substantial movements (both levels and volatility) in the fiscal outcomes of the economy.

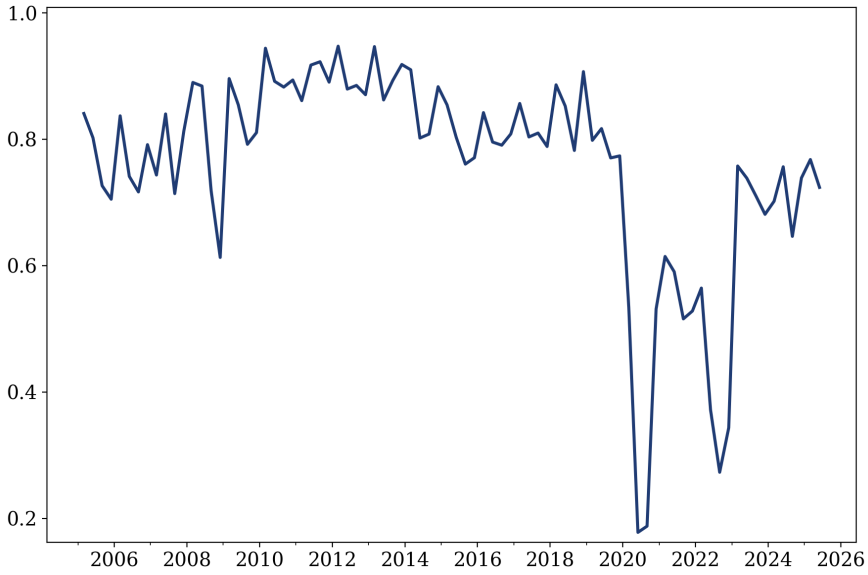


Figure 3: Share of Gaming Tax Revenue in Total Government Revenue, 2003–2025

These features motivate our empirical analysis of *granular fiscal risk*. We quantify the extent to which firm-level revenue, scaled by their economic shares (Domar weights), maps into macroeconomic and fiscal aggregates. The resulting object, which we term the *granular residual*, measures how micro-level shocks in the gaming sector aggregate into macro–fiscal fluctuations. We next construct this granular fiscal risk measure and examine how it relates to macroeconomic performance and fiscal outcomes of the economy.

3 Empirical Methodology

This section outlines how we measure granular risk in Macau by constructing shock series from firm-level revenue fluctuations in the gaming sector and relating them to macroeconomic and fiscal outcomes. Section 3.1 describes the quarterly macro-fiscal and firm-level datasets. Section 3.2 then details the construction of Domar-weighted granular residuals (idiosyncratic vs. sector components) and the measure of fundamental volatility used in the subsequent empirical analysis. Section 3.3 provides descriptive evidence linking our granular-risk measures to fiscal outcomes, documenting a close comovement between fiscal surplus and fundamental volatility that motivates the econometric analysis in Section 4.

3.1 Data

To quantify the granular risk inherent in Macau's gaming sector and its transmission to the aggregate economy, we construct a comprehensive dataset combining firm-level finan-

cial statements of the six licensed concessionaires with Macau's macroeconomic and fiscal indicators.

Firm-level information is obtained from *Compustat Global* (via WRDS) for the six licensed gaming concessionaires operating in Macau: *Sands China*, *Galaxy Entertainment*, *SJM Holdings*, *Melco Resorts*, *Wynn Macau*, and *MGM China*. Firm identifiers (`gvkey`) are standardized, and the dataset is restricted to the post-2010 balanced panel period. *Compustat Global* provides a balanced quarterly panel of firm revenues, operating income, and financial indicators denominated in Macanese patacas (MOP) and adjusted for exchange-rate effects. To align fiscal-year reporting dates across firms, each observation is assigned to the corresponding calendar quarter based on reporting dates. The key variable is firm-level gross revenue, from which we construct quarterly log revenue growth rates at the firm level. All nominal series are converted to real terms using Macau's CPI.

Macroeconomic and fiscal data are quarterly and cover the period 2010Q1–2025Q2. The dataset combines indicators from three official sources: the Statistics and Census Service (DSEC), the Monetary Authority of Macau (AMCM), and the Financial Services Bureau (DSF), as summarized in Table 1. All variables are expressed in natural logarithms or as ratios to GDP, and monetary values are deflated by the consumer price index (CPI). Table 2 reports summary statistics.

Table 1: Variables, Definitions, and Data Sources

Variable	**Definition**	**Source**
`lnRGDP`	Log of real GDP (seasonally adjusted)	DSEC
`lnCPI`	Log of consumer price index (CPI)	DSEC
`GGR_ratio`	Gross gaming revenue as a share of GDP	DSF / DICJ
`Revenue_ratio`	Total government revenue as a share of GDP	DSF
`Surplus_ratio`	Fiscal surplus (or deficit) as a share of GDP	DSF
`lnVisitor`	Log of visitor arrivals (tourism inflows)	DSEC
`ChinaGDP`	Mainland China real GDP growth (%)	CEIC / IMF
`MonetaryBills`	Monetary bills outstanding (proxy for liquidity)	AMCM

3.2 Granular risk in Macau's Gaming Industry

Utilizing the dataset described in Section 3.1, this section constructs the granular residuals and fundamental volatility measures for Macau's gaming sector while characterizing the unique structural features of the industry. We detail the econometric procedures used to isolate idiosyncratic firm-level shocks from sector-wide disturbances and describe how these granular measures capture the inherent risks of a government-sanctioned oligopoly. By mapping these micro-level innovations to the sector's evolution, we provide a quantitative

Table 2: Summary Statistics of Macroeconomic and Fiscal Variables (2010Q1–2025Q2)

Variable	Mean	SD	Min	Max	Obs.
Mainland China Real GDP Growth (`ChinaGDP`, %)	10.48	9.63	-6.77	43.70	70
Monetary Bills Outstanding (`MonetaryBills`)	1.16	1.24	0.11	4.42	70
Gross Gaming Revenue-to-GDP Ratio (`GGR_ratio`)	0.17	0.09	0.01	0.71	70
Government Revenue-to-GDP Ratio (`Revenue_ratio`)	0.09	0.03	0.02	0.31	70
Fiscal Surplus-to-GDP Ratio (`Surplus_ratio`)	0.04	0.05	-0.09	0.22	70
Consumer Price Index (`lnCPI`)	4.46	0.16	4.16	4.61	70
Visitor Arrivals (`lnVisitor`)	14.37	0.80	10.02	15.09	70
Real GDP (`lnRGDP`)	11.44	0.30	10.56	11.90	70

foundation for analyzing the transmission of granular shocks to Macau's aggregate fiscal outcomes.

Granular Residual Construction

The empirical identification of granular fiscal risk begins with the construction of a firm-level measure of idiosyncratic shocks in Macau's gaming industry. We follow the approach of Gabaix (2011) and Carvalho and Gabaix (2013), adapting it to the small, oligopolistic structure of the gaming sector.

For each firm i and quarter t, we compute real revenue growth:

$$g_{it} = \ln(R_{it}) - \ln(R_{i,t-1}),$$

where R_{it} denotes quarterly firm revenue. We then estimate the following firm fixed-effects regression to purge common macroeconomic and seasonal influences:

$$g_{it} = \beta_i + \theta_1 \texttt{ChinaGDP}_{t-1} + \theta_2 \Delta\texttt{lnVisitor}_{t-1} + \theta_3 \Delta\texttt{lnCPI}_{t-1} + \theta_4 \texttt{pandemic}_t + \delta_q + u_{it},$$

where β_i are firm fixed effects, δ_q captures quarterly seasonality, and the macro controls (`ChinaGDP`, visitor growth, and CPI inflation) are included with one-quarter lags. The dummy variable $\texttt{pandemic}_t$ equals one during the COVID-19 period (2020Q1–2022Q4) and zero otherwise. Cluster-robust standard errors are computed at the firm level.

The regression residual u_{it} is the *firm-level residual revenue shock*: it is orthogonal (by construction) to observed macro variables and seasonality, but it can still contain both sector-wide and firm-specific components. To decompose these residual shocks into a sector factor and a purely idiosyncratic component, we first compute the cross-firm average residual in each quarter,

$$\bar{u}_t = \frac{1}{N_t} \sum_{i=1}^{N_t} u_{it},$$

where N_t is the number of concessionaires observed at time t. We then define the firm-specific idiosyncratic shock as

$$\varepsilon_{it} = u_{it} - \bar{u}_t.$$

By construction, ε_{it} is orthogonal to the quarter-specific sector factor $\bar{u}_t$ and has cross-sectional mean zero within each quarter.

To aggregate firm-level shocks into macro-relevant series, we construct *Domar weights* defined as the lagged revenue share of each firm in nominal GDP:

$$s_{i,t-1} = \frac{R_{i,t-1}}{GDP_{t-1}}.$$

Using these weights, we define three granular objects. Our baseline shock series is the *idiosyncratic granular residual*,

$$\Gamma_t^{\text{id}} \equiv \Gamma_t = \sum_{i=1}^{6} s_{i,t-1}\, \varepsilon_{it},$$

which captures the extent to which *firm-specific*, non-sectoral disturbances to the largest concessionaires propagate to the aggregate level.

For comparison, we also construct a *sectoral granular residual* that retains only the common sector-wide movement,

$$\Gamma_t^{\text{s}} = \sum_{i=1}^{6} s_{i,t-1}\, \bar{u}_t = \bar{u}_t \sum_{i=1}^{6} s_{i,t-1}.$$

Finally, using the original residuals u_{it}, we define the *total granular residual* as

$$\Gamma_t^{\text{tot}} \equiv \sum_{i=1}^{6} s_{i,t-1} u_{it} = \Gamma_t^{\text{s}} + \Gamma_t^{\text{id}}.$$

In the empirical analysis below, Γ_t^{id} and Γ_t^{s} serve as the two primary shock measures: the former isolates the Domar-weighted contribution of truly firm-specific disturbances, while the latter captures the common sector-wide component. The total granular residual Γ_t^{tot} is used as a benchmark to gauge the relative importance of each channel. These quarterly series are used in the static regressions and dynamic estimation that follow.

Figure 4 plots the quarterly granular residuals constructed from Macau's six gaming concessionaires, weighted by their Domar shares in nominal GDP. The solid blue line shows the *total* granular residual Γ_t^{tot}, the solid red line plots the *idiosyncratic* component Γ_t^{id}, and the dashed black line shows the *sector* component Γ_t^{s}. Positive values indicate aggregate expansions driven by favorable shocks in the gaming sector, whereas negative values correspond to contractions.

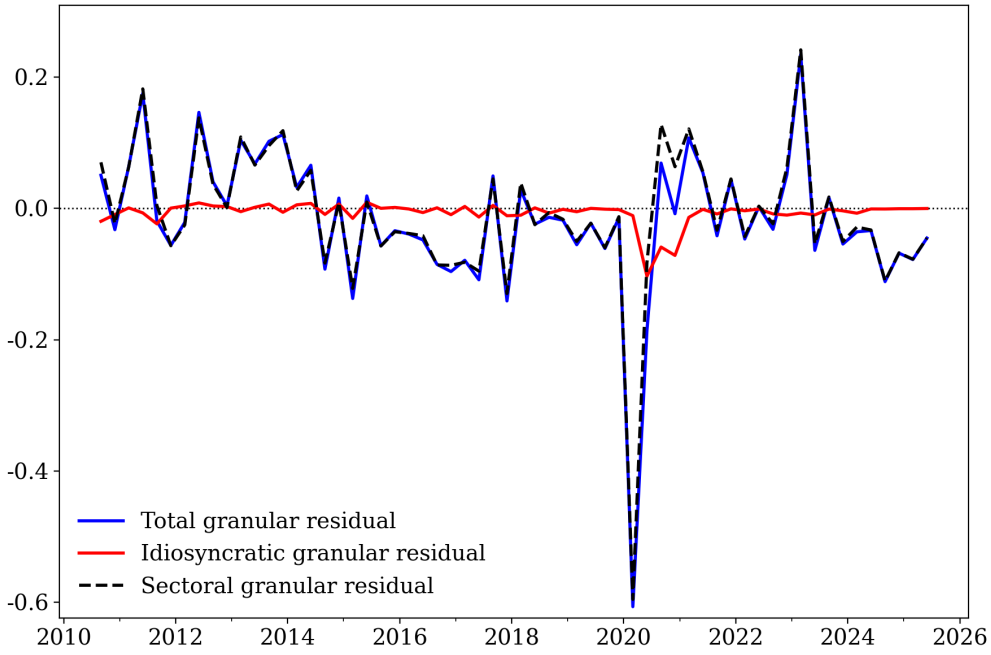


Figure 4: Granular Residual (Γ_t) for Macau's Gaming Sector, 2010Q1–2025Q2

Two features stand out. First, the total granular residual and its sector component are almost indistinguishable over most of the sample, while the idiosyncratic component remains much closer to zero. This pattern confirms that time variation in the Domar-weighted shock is dominated by movements that are common across concessionaires, with firm-specific dispersion playing a secondary but non-negligible role. Second, the decomposition highlights the timing of major sectoral shocks. A modest but persistent decline in Γ_t^{tot} and Γ_t^{s} appears around 2014–2016, in line with the Chinese anti-corruption campaign that curtailed VIP gaming demand. The most dramatic downturn occurs in 2020–2021, when the COVID-19 pandemic and border closures trigger an unprecedented collapse in casino revenues: both the total and sector components plunge to around -0.6, while Γ_t^{id} also turns sharply negative. Around 2020Q2, however, Γ_t^{s} starts to recover while Γ_t^{id} remains below zero, indicating that, even as the sector as a whole begins to rebound, operators differ markedly in their ability to manage and recover from the shock.

Fundamental Volatility

To capture the low-frequency component of aggregate volatility that arises from the underlying composition of firm or sectoral activity, we construct a measure of *fundamental volatility* following Carvalho and Gabaix (2013). The key insight is that aggregate volatility is shaped not only by the volatility of micro-level shocks, but also by how economic activity is distributed across firms. When Domar weights become concentrated, idiosyncratic shocks to

large firms load disproportionately onto aggregate outcomes.

Fundamental volatility at date t is defined as the Domar-weighted aggregation of firm-level idiosyncratic volatilities:

$$\sigma_{F,t}^2 = \sum_i s_{i,t}^2 \, \sigma_i^2,$$

where $s_{i,t} = R_{i,t}/\text{GDP}_t$ is the Domar weight of firm i (the ratio of firm revenue to nominal GDP), and σ_i^2 is the time-invariant variance of its idiosyncratic shock.

Following Carvalho and Gabaix (2013), we treat σ_i^2 as fixed over time, so all variation in $\sigma_{F,t}$ comes from changes in the Domar weights $s_{i,t}$. Because these weights move mainly with slow changes in the sectoral and firm-size distribution, $\sigma_{F,t}$ can be interpreted as a low-frequency, composition-driven component of aggregate volatility, in contrast to the high-frequency granular residual Γ_t.

Figure 5 plots the quarterly series of fundamental volatility, $\sigma_{F,t}$, constructed by aggregating firm-level idiosyncratic shock variances with contemporaneous Domar weights. For each quarter t, we hold the firm-specific variance σ_i^2 fixed and aggregate them using the contemporaneous weights $s_{i,t}^2$, so that changes in $\sigma_{F,t}$ reflect shifts in the distribution of economic activity across firms. The series is expressed in levels and remains strictly positive, reflecting the fact that it measures the concentration-weighted magnitude of idiosyncratic volatility in the economy: higher values indicate that a larger share of aggregate volatility is potentially driven by shocks to a few dominant firms.

From 2010 through the mid-2010s, $\sigma_{F,t}$ exhibits a gradual but persistent decline, suggesting a slow reduction in the economic weight of the largest gaming operators. Beginning in 2019, fundamental volatility drops sharply to its lowest level in the sample. This decline aligns with the contraction of the gaming sector during the regulatory tightening of VIP and junket activity, followed by the dramatic collapse in gaming revenues during the COVID-19 period. During the border-closure years, casino sales cratered: even though Macau's overall GDP also fell, gross gaming revenues shrank by an even larger proportion, so the Domar weights $s_{i,t}$ of the concessionaires dropped markedly. As Domar weights fall, the contribution of large firms to aggregate volatility diminishes mechanically, producing a pronounced reduction in $\sigma_{F,t}$.

After 2022, the series rebounds steadily as gaming activity normalizes and the sector regains economic weight. The post-pandemic recovery of $\sigma_{F,t}$ indicates that as concentration in the gaming industry increases, idiosyncratic shocks at the firm level again carry greater potential to scale into aggregate fluctuations.

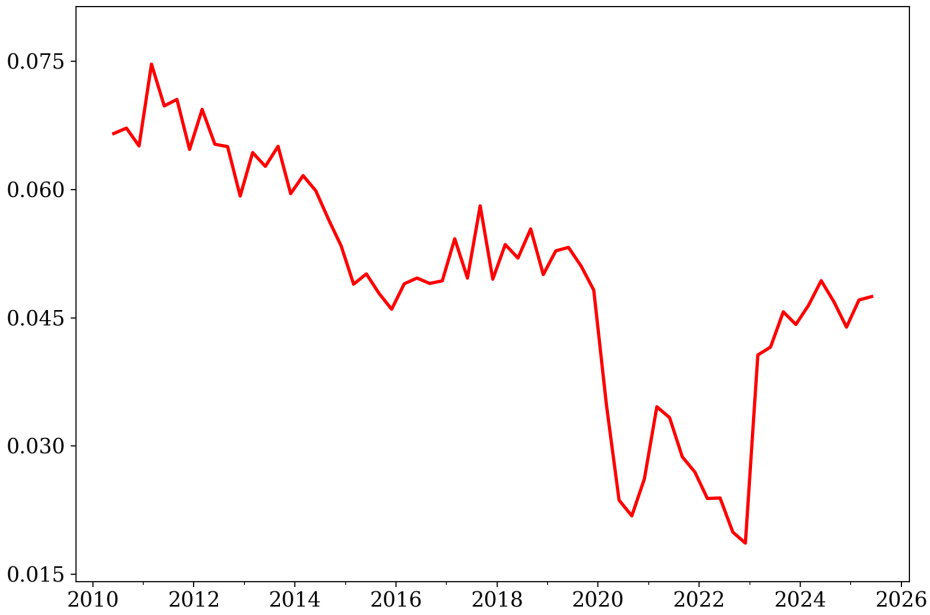


Figure 5: Fundamental Volatility

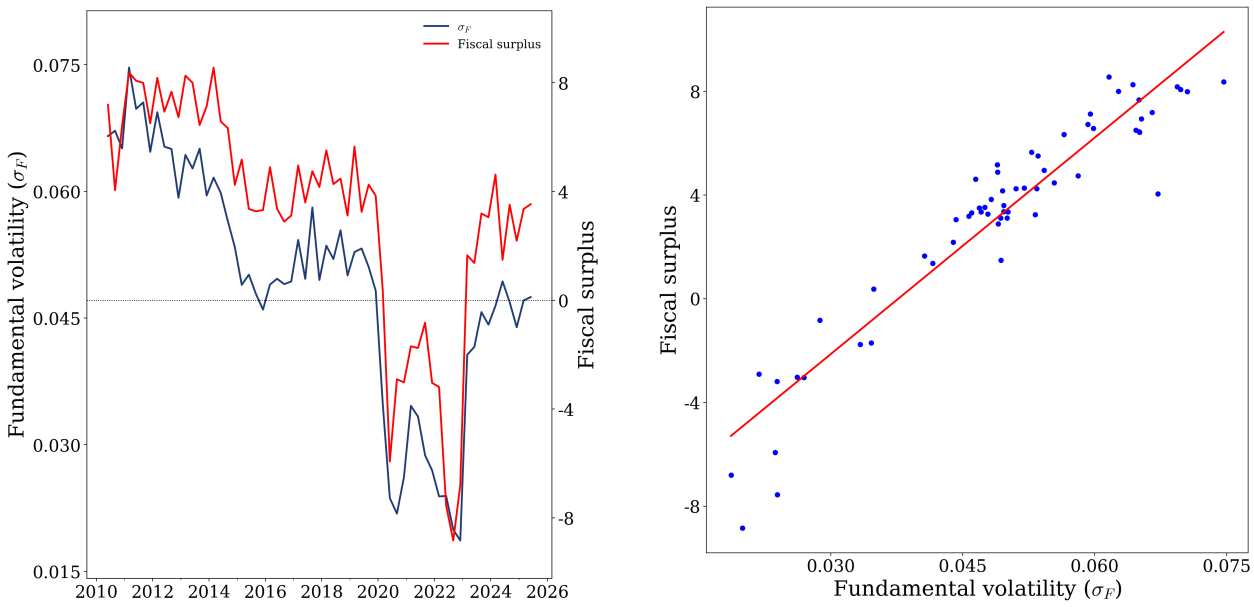
3.3 Descriptive Evidence: The Granular-Fiscal Nexus

We begin by providing descriptive evidence on how our measure of granular risk relates to fiscal outcomes in Macau. A natural object to examine is fundamental volatility, $\sigma_{F,t}$, together with the fiscal surplus. The reason is straightforward: $\sigma_{F,t}$ is constructed from firm-level shocks weighted by Domar shares in nominal GDP, so it moves with the sector's economic weight, while Macau's fiscal position is tightly linked to gaming activity because gaming-related taxes comprise a large share of government revenue. If fluctuations in the size and performance of the gaming sector are an important source of fiscal vulnerability, we should observe these two series moving together in the data.

Figure 6 illustrates this comovement. The left panel plots the time-series evolution of the fiscal surplus and $\sigma_{F,t}$, and the right panel presents their association in a scatter plot with a fitted line. The comovement is particularly pronounced around major disruptions to the gaming sector: both series decline sharply during downturns and recover as activity normalizes. This pattern is consistent with a structural linkage—operating through changes in the sector's economic weight—rather than a direct causal relationship.

The mechanism is intuitive. When gaming revenues collapse—for example, during regulatory tightening or the COVID-19 shutdown—the Domar weights attached to large concessionaires shrink mechanically, lowering $\sigma_{F,t}$. At the same time, the fiscal surplus deteriorates as gaming-related tax revenues fall. As the sector rebounds and regains weight, $\sigma_{F,t}$ rises and fiscal surpluses improve in tandem.

Taken together, these descriptive patterns suggest a tight connection between granular



(a) Time-series evolution

(b) Scatter plot

Figure 6: Fiscal surplus and fundamental volatility $\sigma_{F,t}$. The left panel reports the time-series evolution of fiscal surplus and $\sigma_{F,t}$, and the right panel shows their association in a scatter plot with a fitted line.

risk and fiscal outcomes, as anticipated by the institutional background discussed in Section 2. We now turn to our econometric analysis to quantify this relationship and to assess how granular shocks propagate into macroeconomic activity and the fiscal surplus over time.

4 Empirical Analysis

This section examines how granular shocks from Macau's gaming sector affect fiscal surpluses and economic growth. We combine static and dynamic analyses to identify the contemporaneous impact of granular shocks on macro-fiscal aggregates while tracking their subsequent persistence and propagation over time. Section 4.1 describes the econometric approach used in the analysis, and Section 4.2 reports and discusses the empirical results.

4.1 Empirical Framework

This section describes the empirical framework to analyze the relationship between granular risk, real economic growth, and the fiscal surplus. Section 4.1.1 details the static regression framework used to assess how both granular shocks and fundamental volatility are associated with macroeconomic and fiscal outcomes. We discuss the dynamic effects of these shocks in Section 4.1.2 using Bayesian Vector Autoregressions, and as robustness checks, local projec-

tions.

4.1.1 Static Regression

We analyze both granular shocks and fundamental volatility to distinguish between high-frequency realized innovations that drive outcome levels and the low-frequency risk inherent in the economy's structural concentration.

Granular Risks: Idiosyncratic vs Sectoral Components

We first estimate a set of static time–series regressions that relate granular shocks in the gaming sector to contemporaneous macroeconomic and fiscal outcomes. The goal is to document how much of the variation in growth and fiscal performance is accounted for by the Domar–weighted granular residuals constructed above.

Let Γ_t^{id} denote the idiosyncratic granular residual and Γ_t^{s} the sector component, so that $\Gamma_t^{\text{tot}} = \Gamma_t^{\text{s}} + \Gamma_t^{\text{id}}$. For each quarterly outcome Y_t, we estimate the baseline specification

$$Y_t = \alpha + \beta^{\text{id}}\Gamma_t^{\text{id}} + \beta^{\text{s}}\Gamma_t^{\text{s}} + \boldsymbol{\delta}'\mathbf{X}_{t-1} + \lambda_{q(t)} + \varepsilon_t, \tag{4.1}$$

where $\mathbf{X}_{t-1}$ collects one–quarter lags of mainland China GDP growth, visitor growth, and quarterly CPI inflation, and includes a COVID dummy (equal to one in 2020Q1–2022Q4). The term $\lambda_{q(t)}$ denotes quarter–of–the–year fixed effects that absorb seasonal patterns. We estimate Equation (4.1) with ordinary least squares and Newey–West (HAC) standard errors with four lags. In addition to the "horse–race" regression with both Γ_t^{id} and Γ_t^{s}, we also report restricted specifications that include only one granular term at a time (setting $\beta^{\text{s}} = 0$ or $\beta^{\text{id}} = 0$).

The dependent variable Y_t is rotated across six outcomes: (i) real GDP growth (quarter–on–quarter); (ii) the six–quarter rolling volatility of real GDP growth; (iii) the quarterly first difference of the fiscal surplus-to-GDP ratio; (iv) the six–quarter rolling volatility of that first difference; (v) the quarterly first difference of the government revenue-to-GDP ratio; and (vi) the six–quarter rolling volatility of that first difference. Volatility measures are defined as rolling standard deviations of the corresponding growth rates over a six–quarter window, capturing medium–run fiscal and macroeconomic uncertainty.

To probe the effect of *shock size* on volatility, we also estimate variants that replace the linear granular term in Equation (4.1) with its absolute value, $|\Gamma_t^j|$, or square, $(\Gamma_t^j)^2$, for $j \in \{\text{id}, \text{s}\}$. These specifications are estimated on the full sample and on two subsamples: a pre–COVID sample (up to 2019Q4) and a sample that excludes all COVID quarters (dropping 2020Q1–2022Q4 but retaining pre– and post–COVID observations). Together, these static regressions provide a compact summary of how granular shocks in Macau's gaming sector

co–move with aggregate growth and the level and volatility of fiscal outcomes.

Fundamental Volatility and Fiscal Outcomes

To examine the fiscal implications of concentration-based volatility, we estimate a unified regression specification in which the dependent variable captures either the level of Macau's fiscal position or its fiscal uncertainty. Specifically, we consider

$$F_t = \alpha + \beta\, \sigma_{F,t} + \gamma' X_t + \tau\, t + \varepsilon_t. \tag{4.2}$$

where F_t denotes either (i) the quarterly fiscal surplus as a share of GDP, or (ii) the six-quarter realized fiscal volatility (the rolling standard deviation of the fiscal surplus). The vector X_t contains standard macroeconomic controls, including mainland China's real GDP growth, visitor arrivals, and real GDP, while $\tau\, t$ captures a linear time trend.

This unified framework allows us to evaluate whether fundamental volatility—which reflects changes in the economic footprint of Macau's dominant gaming operators—is systematically associated with both the level and the variability of public finances.

4.1.2 Dynamic Effects

Static regressions are informative about contemporaneous relationships, but they do not reveal the timing, persistence, and dynamic propagation of shocks. We therefore estimate impulse responses to granular shocks using a Bayesian VAR and, as a robustness check, local projections. These dynamic methods discipline the interpretation of Γ_t as a shock and quantify how disturbances originating in the gaming sector transmit to GGR and fiscal outcomes over subsequent quarters.

Bayesian VAR Estimation

To quantify how granular shocks transmit to macroeconomic and fiscal aggregates, we estimate impulse responses using a Bayesian vector autoregression. We adopt a Bayesian approach because our quarterly sample is relatively short, while the system includes multiple macro–fiscal variables whose joint dynamics are central to propagation. Bayesian shrinkage priors improve small-sample inference by regularizing the parameter space and delivering more stable impulse responses than an unrestricted least-squares VAR.

Let y_t be an $M \times 1$ vector of observed variables at quarter t. We estimate the BVAR(p)

$$y_t = c + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t, \qquad u_t \sim \mathcal{N}(0, \Sigma), \tag{4.3}$$

where c is an intercept, A_ℓ are $M \times M$ coefficient matrices, and Σ is the reduced-form innovation covariance matrix.

Our baseline specification includes external demand and tourism conditions, domestic macro and monetary conditions, the granular shock measure, and fiscal and gaming outcomes. Concretely, we use

$$y_t = \big(g_t^{CH},\ \log V_t,\ g_t^{RGDP},\ i_t,\ \Gamma_t,\ GGR_t,\ FS_t\big)', \tag{4.4}$$

where g_t^{CH} is mainland China's real GDP growth (quarterly), $\log V_t$ is the log of visitor arrivals, g_t^{RGDP} is Macau real GDP growth (year-on-year), i_t is the policy rate (base rate), Γ_t is the granular shock (either the sectoral granular shock, Γ_t^{s}, or the idiosyncratic granular shock, Γ_t^{id}, depending on the specification), GGR_t is the gross gaming revenue-to-GDP ratio, and FS_t is the fiscal surplus-to-GDP ratio.[1]

The estimation sample is quarterly and covers 2010Q2-2025Q2, subject to data availability for the granular shock series; we restrict the sample to periods in which Γ_t is observed.

We set the lag order to $p = 2$. With quarterly data and a limited sample, two lags capture the main inertia in macro–fiscal variables while keeping the parameter count manageable. Adding further lags increases the dimensionality of the system quickly and can materially weaken inference in small samples, even under Bayesian shrinkage.

We estimate Equation (4.3) under a Minnesota-type shrinkage prior with hierarchical selection of tightness parameters. The prior shrinks coefficients on longer lags more strongly and shrinks cross-variable lags relative to own lags, reflecting the view that each series is reasonably well-approximated by a persistent univariate process absent strong evidence to the contrary. Following the hierarchical approach, key shrinkage hyperparameters are estimated from the data rather than fixed *ex ante*, which is especially useful in short samples.

Posterior inference is conducted via Markov chain Monte Carlo, and impulse responses are computed from posterior draws of $(A_1, \ldots, A_p, \Sigma)$. We report posterior medians together with credible bands (e.g., 68% and 90%) formed from posterior quantiles.

We identify structural shocks using a recursive (Cholesky) scheme that is disciplined by timing assumptions consistent with granular shocks. Specifically, write $\Sigma = PP'$ where P is lower triangular. Structural innovations ε_t are defined by

$$u_t = P\varepsilon_t, \qquad \varepsilon_t \sim \mathcal{N}(0, I_M). \tag{4.5}$$

The key identifying assumption is that the granular shock Γ_t is *predetermined* with respect to within-quarter movements in fiscal and gaming outcomes, while it may respond contempo-

[1] All variables are quarterly. Macro quantities enter either as growth rates (for GDP measures) or as ratios to GDP (for fiscal and gaming variables). Visitor arrivals enter in logs.

raneously to broader macro and monetary conditions that shape the operating environment of large firms. Accordingly, we order the variables as

$$\underbrace{\left(g_t^{CH},\ \log V_t,\ g_t^{RGDP},\ i_t\right)}_{\text{external/tourism, macro, monetary}} \rightarrow \underbrace{\Gamma_t}_{\text{granular shock}} \rightarrow \underbrace{\left(GGR_t,\ FS_t\right)}_{\text{gaming and fiscal outcomes}} . \tag{4.6}$$

Under this ordering, (i) external demand, tourism conditions, real activity, and the policy rate can affect Γ_t contemporaneously, capturing the idea that granular shocks are realized in an economic environment shaped by aggregate conditions; (ii) Γ_t can affect GGR_t and FS_t within the same quarter, consistent with the concentration of Macau's public finances in gaming-related revenues; and (iii) GGR_t and FS_t do not feed back contemporaneously into Γ_t within the quarter, reflecting the assumption that the granular shock is constructed from firm-level innovations that are not mechanically driven by contemporaneous fiscal realizations.

Impulse responses are computed for horizons $h = 0, 1, \ldots, H$ from the posterior distribution implied by (4.3)–(4.5). We focus on responses of real activity and public finance variables—g_t^{RGDP}, GGR_t, and FS_t—to a one-unit innovation in Γ_t.

Local Projections

As a robustness check, we re-estimate the dynamic effects of granular shocks using the local projection (LP) approach. The LP results are reported as impulse responses to a one-standard-deviation shock, constructed by standardizing the shock series (sectoral or idiosyncratic) by its sample standard deviation.

For each horizon $h = 0, 1, \ldots, H$, we estimate

$$Y_{t+h} = \alpha_h + \beta_h \Gamma_t + \sum_{j=1}^{2} \phi_{h,j} Y_{t-j} + \sum_{j=1}^{2} \psi_{h,j} \Gamma_{t-j} + \gamma_h' Z_{t-1} + \kappa_h \texttt{COVID}_{t-1} + \lambda_{q(t)} + u_{t+h}, \tag{4.7}$$

where Y_t denotes the outcome of interest—GGR_t, or FS_t—and Γ_t is the granular shock, measured as either the sectoral component Γ_t^{s} or the idiosyncratic component Γ_t^{id}. We include two lags of the outcome and the shock (i.e., $j = 1, 2$). The vector Z_{t-1} collects lagged macro controls aligned with the BVAR information set, including g_{t-1}^{CH}, $\log V_{t-1}$, lagged CPI inflation, and other lagged conditioning variables used in the implementation. $\texttt{COVID}_{t-1}$ is a lagged pandemic indicator, and $\lambda_{q(t)}$ denotes quarter-of-the-year fixed effects. Standard errors are heteroskedasticity-robust. Impulse responses are reported for a one-standard-deviation shock by scaling $\widehat{\beta}_h$ by the sample standard deviation of Γ_t, i.e., $\widehat{IRF}(h) = \widehat{\beta}_h \cdot \text{sd}(\Gamma)$.

4.2 Empirical Results

We now present our main results in two parts. First, we report the results of the static analysis in Section 4.2.1, using the specification detailed in Section 4.1.1. Next, we present the dynamic results in Section 4.2.2 based on the methodology discussed in Section 4.1.2. We then discuss policy implications in Section 4.3.

4.2.1 Granular Fiscal Risks Matter

This section reports results from the static regressions described in Section 4.1.1. The main message is that in an economy with a concentrated tax base, *sector-wide* shocks move the *level* of macro-fiscal outcomes, whereas *firm-specific* shocks primarily move the *risk* (volatility) of those outcomes. We document this split in three steps. First, we show that the sectoral component of the granular residual loads tightly on real GDP growth and the fiscal surplus. Second, we show that the idiosyncratic component is associated with macro-fiscal volatility, especially through large-shock (non-linear) effects. Third, we show that a concentration-based measure of exposure (fundamental volatility) is linked with the risk in both macroeconomic and fiscal outcomes.

Granular Shocks and Macro-Fiscal Outcomes: Levels and Risks

We focus on the Domar-weighted idiosyncratic residual Γ_t^{id} and the sector component Γ_t^{s} constructed in Section 3. We estimate the baseline specification with lagged macro controls, quarter fixed effects, and a COVID dummy as in Equation (4.1).

Table 3 reports coefficients on Γ_t^{id} and Γ_t^{s} across six outcomes: real GDP growth, a six-quarter rolling volatility of GDP growth, changes in the fiscal surplus-to-GDP ratio and its volatility, and changes in the government revenue-to-GDP ratio and its volatility. Tables 4 –6 report restricted specifications that include either Γ_t^{id} or Γ_t^{s} alone (with and without macro controls), which helps assess whether the results are driven by collinearity or by controls.

Result 1 (Levels): sectoral shocks move GDP growth and the fiscal surplus.

Table 3 shows that macro-fiscal *levels* are primarily associated with the sectoral component Γ_t^{s}. For real GDP growth, the coefficient on Γ_t^{s} is close to unity (0.96 with s.e. 0.09) and highly significant, whereas the coefficient on the idiosyncratic component Γ_t^{id} is economically smaller and imprecisely estimated (-0.55 with s.e. 0.45). The fit is correspondingly high ($R^2 = 0.846$), consistent with the idea that in Macau the common component of the gaming sector behaves like a macro shock.

The same pattern holds for the fiscal surplus. Changes in the surplus-to-GDP ratio load strongly on Γ_t^{s} (0.47 with s.e. 0.10), while Γ_t^{id} remains imprecisely estimated. Restricted

regressions reinforce this interpretation: in Table 4 (Panel A), Γ_t^{s} remains close to one for GDP growth once controls are included, while Γ_t^{id} does not.

Revenue is different. Changes in the revenue-to-GDP ratio load primarily on the idiosyncratic component: Table 3 shows a positive, statistically significant coefficient on Γ_t^{id} (0.70 with s.e. 0.26), while the coefficient on Γ_t^{s} is close to zero and insignificant. Table 6 (Panel A) shows the same conclusion holds when each component enters alone. Taken together, the level results indicate a disciplined split: sectoral comovement matters most for GDP and the fiscal surplus, while firm-specific dispersion matters more for revenue realizations.

Result 2 (Risk): idiosyncratic shocks affect the volatility of tax revenue.

Volatility outcomes exhibit the opposite emphasis. Columns (2), (4), and (6) of Table 3 relate the six-quarter rolling volatility measures to Γ_t^{id} and Γ_t^{s}. Across GDP, fiscal surplus share, and revenue-share volatility, the idiosyncratic component is systematically significant, especially for fiscal volatility outcomes. This is the signature of granular fiscal risk: firm-specific shocks do not consistently produce systematic downturns, but they generate dispersion and uncertainty in fiscal outcomes.

Because rolling volatility tends to spike after large negative realizations (e.g., during the COVID collapse), the signed linear specification can load negatively on Γ_t^{id} even when the underlying mechanism is "large-shock risk." This motivates the nonlinear specifications below (discussed in Section 4.2.1), where we map the *magnitude* of idiosyncratic disturbances into volatility using $|\Gamma|$ and Γ^2.

Table 3: Granular shocks, macro outcomes, and fiscal ratios

	Real GDP		Fiscal surplus		Government revenue	
	Growth	Volatility	Change	Volatility	Change	Volatility
	(1)	(2)	(3)	(4)	(5)	(6)
Γ_t^{id}	-0.550	-1.283***	1.070	-1.105***	0.702***	-0.512***
	(0.448)	(0.487)	(0.841)	(0.405)	(0.260)	(0.152)
Γ_t^{s}	0.959***	0.158*	0.469***	0.218***	-0.004	0.015
	(0.086)	(0.094)	(0.096)	(0.046)	(0.032)	(0.019)
Quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls + COVID	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.846	0.747	0.560	0.690	0.420	0.480
Observations	61	61	61	61	61	61

Notes: Each column reports coefficients from a separate OLS regression with HAC standard errors (4 lags) in parentheses. "Growth" is the quarter–on–quarter log change in real GDP. For fiscal outcomes, "Change" refers to the quarterly first difference of the nominal fiscal ratio (Surplus/NGDP or Revenue/NGDP). "Volatility" is the six–quarter rolling standard deviation of the corresponding series (GDP growth, or the fiscal–ratio change). Γ_t^{id} is the Domar–weighted idiosyncratic granular residual, and Γ_t^{s} is the sector component. Macro controls include lagged China GDP growth, lagged log visitor arrivals, lagged quarterly CPI inflation, and a COVID dummy. The COVID dummy equals one in 2020Q1–2022Q4. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table 4: Restricted granular specifications: Real GDP growth and volatility

	Idiosyncratic granular term only		Sectoral granular term only	
	(1)	(2)	(3)	(4)
Panel A: Real GDP growth				
Γ_t^{id}	0.761	-0.906		
	(1.514)	(0.576)		
Γ_t^{s}			0.885***	0.963***
			(0.160)	(0.084)
Quarter FE	Yes	Yes	Yes	Yes
Macro controls[a]	No	Yes	No	Yes
R^2	0.181	0.422	0.554	0.843
Observations	61	61	61	61
Panel B: Real GDP volatility				
Γ_t^{id}	-3.006***	-1.342***		
	(0.424)	(0.449)		
Γ_t^{s}			0.079	0.168*
			(0.180)	(0.089)
Quarter FE	Yes	Yes	Yes	Yes
Macro controls[a]	No	Yes	No	Yes
R^2	0.293	0.721	0.015	0.711
Observations	61	61	61	61

Notes: HAC standard errors with 4 lags in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels respectively.

[a] Macro controls are lagged China GDP growth, lagged log visitor arrivals, lagged inflation, and a COVID-19 dummy. All specifications include quarter-of-year fixed effects.

Table 5: Restricted granular specifications: Fiscal surplus/NGDP change and volatility

	Idiosyncratic granular term only		Sectoral granular term only	
	(1)	(2)	(3)	(4)
Panel A: Change in fiscal surplus/NGDP				
Γ_t^{id}	1.177	0.896		
	(1.151)	(0.792)		
Γ_t^{s}			0.399***	0.461***
			(0.109)	(0.098)
Quarter FE	Yes	Yes	Yes	Yes
Macro controls[a]	No	Yes	No	Yes
R^2	0.277	0.385	0.377	0.541
Observations	61	61	61	61
Panel B: Volatility of change in fiscal surplus/NGDP				
Γ_t^{id}	-2.152***	-1.186***		
	(0.310)	(0.357)		
Γ_t^{s}			0.151	0.226***
			(0.101)	(0.044)
Quarter FE	Yes	Yes	Yes	Yes
Macro controls[a]	No	Yes	No	Yes
R^2	0.310	0.588	0.060	0.635
Observations	61	61	61	61

Notes: HAC standard errors with 4 lags in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels respectively.

[a] Macro controls are lagged China GDP growth, lagged log visitor arrivals, lagged inflation, and a COVID-19 dummy. All specifications include quarter-of-year fixed effects.

Table 6: Restricted granular specifications: Government revenue/NGDP change and volatility

	Idiosyncratic granular term only		Sectoral granular term only	
	(1)	(2)	(3)	(4)
Panel A: Change in government revenue/NGDP				
Γ_t^{id}	0.684*	0.703***		
	(0.351)	(0.264)		
Γ_t^{s}			-0.021	-0.010
			(0.024)	(0.033)
Quarter FE	Yes	Yes	Yes	Yes
Macro controls[a]	No	Yes	No	Yes
R^2	0.227	0.420	0.099	0.323
Observations	61	61	61	61
Panel B: Volatility of change in government revenue/NGDP				
Γ_t^{id}	-0.688***	-0.517***		
	(0.085)	(0.146)		
Γ_t^{s}			0.009	0.019
			(0.031)	(0.021)
Quarter FE	Yes	Yes	Yes	Yes
Macro controls[a]	No	Yes	No	Yes
R^2	0.353	0.475	0.010	0.348
Observations	61	61	61	61

Notes: HAC standard errors with 4 lags in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels respectively.

[a] Macro controls are lagged China GDP growth, lagged log visitor arrivals, lagged inflation, and a COVID-19 dummy. All specifications include quarter-of-year fixed effects.

Nonlinear Dependence of Volatility on Granular Shocks

To address the sign issue and to allow for potentially nonlinear effects of granular shocks on volatility, we re-estimate the volatility regressions using transformations of the idiosyncratic granular residual. Table 7 replaces Γ_t^{id} with its absolute value $|\Gamma_t^{id}|$, whereas Table 8 uses the square $(\Gamma_t^{id})^2$. In both sets of regressions we retain the full set of macro controls and the COVID dummy, as in Section 4.2.1.

The nonlinear results point to a clear "large–shock" channel for volatility. In the fully controlled specification, $|\Gamma_t^{id}|$ enters positively and significantly for GDP volatility (1.415, s.e.

0.490), surplus–share volatility (1.245, s.e. 0.384), and revenue–share volatility (0.543, s.e. 0.159). The squared specification yields the same qualitative conclusion: $(\Gamma_t^{\text{id}})^2$ is positive and statistically significant for all three volatility measures.

These nonlinear specifications clarify the interpretation of the signed linear volatility regressions. The negative coefficients in Tables 3 and 10 (reported in Appendix A.1) reflect the fact that volatility spikes coincide with large negative realizations of Γ_t^{id} (notably around the COVID period). When we condition on the *magnitude* of idiosyncratic shocks in the fully controlled specification, we obtain a robust positive association between large firm–level disturbances and medium–run volatility in both macro and fiscal outcomes.

Table 7: Nonlinear granular effects on volatility: specification with $|\Gamma_t^{\text{id}}|$

	GDP vol.	Surplus vol.	Revenue vol.
	(1)	(2)	(3)
$\lvert\Gamma_t^{\text{id}}\rvert$	1.415***	1.245***	0.543***
	(0.490)	(0.384)	(0.159)
Quarter fixed effects	Yes	Yes	Yes
Macro controls + COVID	Yes	Yes	Yes
R^2	0.723	0.590	0.479
Observations	61	61	61

Notes: Each column reports coefficients from a separate OLS regression of a six–quarter rolling volatility measure on the absolute value $|\Gamma_t^{\text{id}}|$ of the idiosyncratic granular residual. HAC standard errors (4 lags) are in parentheses. GDP vol. is the six–quarter rolling standard deviation of real GDP growth. Surplus–share vol. and revenue–share vol. are the six–quarter rolling standard deviations of Δ(Surplus/NGDP) and Δ(Revenue/NGDP), respectively. Macro controls are lagged China GDP growth, lagged log visitor arrivals growth, lagged inflation, and a COVID-19 dummy; all specifications include quarter-of-year fixed effects. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table 8: Nonlinear granular effects on volatility: specification with $(\Gamma_t^{\text{id}})^2$

	GDP vol. (1)	Surplus vol. (2)	Revenue vol. (3)
$(\Gamma_t^{\text{id}})^2$	14.586***	12.659***	6.011***
	(5.483)	(4.255)	(1.891)
Quarter fixed effects	Yes	Yes	Yes
Macro controls + COVID	Yes	Yes	Yes
R^2	0.716	0.577	0.474
Observations	61	61	61

Notes: Each column reports coefficients from a separate OLS regression of a six–quarter rolling volatility measure on the square $(\Gamma_t^{\text{id}})^2$ of the idiosyncratic granular residual. HAC standard errors (4 lags) are in parentheses. GDP vol. is the six–quarter rolling standard deviation of real GDP growth. Surplus–share vol. and revenue–share vol. are the six–quarter rolling standard deviations of Δ(Surplus/NGDP) and Δ(Revenue/NGDP), respectively. Macro controls are lagged China GDP growth, lagged log visitor arrivals growth, lagged inflation, and a COVID-19 dummy; all specifications include quarter-of-year fixed effects. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Fundamental Volatility: Fiscal Exposure and Fiscal Risk

We next study how concentration-based *fundamental volatility* maps into Macau's fiscal outcomes using equation (4.2). As Section 3.3 suggests, $\sigma_{F,t}$ captures time variation in the Domar-weighted footprint of the dominant gaming operators and thus provides a natural summary measure of *fiscal exposure* in an economy with a highly concentrated revenue base.

Table 9 shows that $\sigma_{F,t}$ predicts both the level and the risk of public finances. In column (1), $\sigma_{F,t}$ loads positively and significantly on the surplus-to-GDP ratio, consistent with fiscal strength when the gaming sector's effective footprint expands. In column (2), $\sigma_{F,t}$ is also positively associated with realized fiscal volatility, implying that the same concentration forces that reinforce the revenue base also amplify exposure to fiscal risk.

These results complement the earlier findings based on *granular shocks*. While our baseline specifications decompose micro-driven movements into an idiosyncratic granular residual Γ_t^{id} and a sectoral component Γ_t^{s}, $\sigma_{F,t}$ captures a slower-moving, concentration-driven component of exposure that is common across operators. The fact that $\sigma_{F,t}$ predicts both the level (surplus) and the risk (volatility) of fiscal outcomes reinforces the interpretation that Macau's fiscal dynamics are tightly tied to the gaming sector—not only through high-frequency firm-level disturbances, but also through time variation in the sector's underlying concentration and economic footprint.

Table 9: Effect of Fundamental Volatility on Fiscal Outcomes

	(1) Fiscal Surplus Surplus_t	(2) Fiscal Volatility sd_Surplus_t
$\sigma_{F,t}$	1.618*** (0.319)	0.651** (0.285)
time_trend	-0.00002 (0.00020)	0.001*** (0.00020)
$\ln(\text{ChinaGDP}_t)$	0.004 (0.003)	0.003 (0.003)
$\ln(\text{Visitors}_t)$	-0.002 (0.004)	0.004 (0.003)
$\ln(\text{RGDP}_t)$	0.049*** (0.018)	-0.034** (0.013)
pandemic_t	-0.012 (0.008)	-0.000 (0.009)
Constant	-0.585*** (0.159)	0.297** (0.120)
Observations	57	55
R-squared	0.940	0.501
F-statistic	238.4	9.57

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Column (1) estimates the effect of fundamental volatility on the fiscal surplus. Column (2) estimates the effect on the six-quarter realized fiscal volatility.

Summary of static analysis

The static evidence reveals a sharp distinction between *levels* and *risk*. Tables 3-6 show that sector-wide granular shocks are primarily associated with macro-fiscal *levels*: adverse movements in the sectoral component are linked to weaker real activity and a deterioration in the fiscal surplus share. This pattern is consistent with the idea that comovements among dominant firms (behaving like a macro shock) directly transmit to aggregate output and public finance outcomes.

The idiosyncratic component plays a different role. Tables 3-6 highlight that firm-specific shocks are less tightly related to the mean of macro-fiscal outcomes, but they are strongly associated with *risk*: higher volatility in government revenue and fiscal outcomes, especially through nonlinearities (Tables 7-8). In parallel, the concentration-based exposure measure $\sigma_{F,t}$ captures a slow-moving component of fiscal vulnerability (Table 9): when the Domar-weighted footprint of dominant operators is larger, both the level of fiscal surplus and realized fiscal volatility tend to be higher.

Taken together, these results highlight the granular fiscal risk in Macau. When government revenues hinge on a small number of dominant firms or a single sector, firm-level shocks need not wash out in aggregation; instead, they become risks to fiscal stability. Specifically, sector-wide shocks are associated with movements in the mean of macro-fiscal outcomes, while firm-specific shocks are associated with movements around that mean.

4.2.2 Dynamic Effects of Granular Shocks on Macro–Fiscal Outcomes

We now examine whether this levels-versus-risk distinction also holds dynamically. Specifically, do sectoral shocks propagate persistently through output, gaming revenue, and the fiscal surplus share, while idiosyncratic shocks exhibit more limited aggregate transmission? We address this question using Bayesian Vector Autoregressions and, as a robustness check, local projections.

Empirical Results from BVARs

We estimate two separate BVAR systems as described in Section 4.1. In the first system, the granular shock is defined as the sectoral component Γ_t^{s}. In the second, it is defined as the idiosyncratic component Γ_t^{id}. In both cases, we focus on the responses to a negative shock, interpreted as an adverse disturbance originating in Macau's gaming sector.

Figure 7 reports impulse responses for three variables: real GDP growth, the gaming revenue-to-GDP ratio, and the fiscal surplus-to-GDP ratio, over a three-year horizon. The left column shows responses to a sectoral shock; the right column shows responses to an idiosyncratic shock. Each panel plots the posterior median (solid line) together with 68% and 90% credible bands (dashed and dotted lines, respectively).

Result 3: Sectoral shocks propagate persistently through output and public finance.

A negative sectoral granular shock produces a pronounced and persistent decline in real GDP growth. The median response remains below zero for several quarters, indicating significant macroeconomic propagation. The gaming revenue-to-GDP ratio falls sharply on impact and remains depressed over the medium run. Fiscal dynamics mirror this pattern: the fiscal surplus-to-GDP ratio deteriorates following the sectoral shock, with significant downside risk concentrated in the first year.

These responses indicate that sectoral comovement among dominant gaming firms behaves like a macroeconomic disturbance that affects the broader economy. The transmission mechanism operates through gaming revenue, which feeds into public finances, reinforcing the finding documented in the static results above.

Result 4: Idiosyncratic shocks exhibit limited aggregate propagation.

In contrast, the responses to an idiosyncratic granular shock are smaller and less precisely estimated. The effect on GDP growth is weaker and less persistent. The gaming revenue ratio responds modestly and briefly, consistent with partial offsetting movements across firms within the sector. The fiscal surplus response is correspondingly muted.

This asymmetry suggests that firm-specific disturbances, when not accompanied by sector-wide comovement, do not generate strong macro-fiscal transmission. Dynamically, the idiosyncratic component behaves less like a macro shock and more like a dispersion shock, consistent with its volatility effects discussed in the static analysis.

We also re-estimate the system with additional lags and alternative Cholesky orderings as robustness checks in Appendix A.2. They yield qualitatively similar impulse responses. Taken together, the BVAR evidence reinforces the central message of the paper: sector-wide granular shocks drive systematic macro-fiscal fluctuations, whereas firm-level shocks do not propagate strongly through aggregate output or fiscal balances.

Robustness check: Empirical Results from LPs

We next estimate local projection impulse responses as a robustness check. Figure 8 reports responses of the gaming revenue-to-GDP ratio and the fiscal surplus-to-GDP ratio to one-standard-deviation negative granular shocks.

The LP results preserve the relative importance of sectoral versus idiosyncratic disturbances. A sectoral shock leads to a pronounced and persistent decline in the gaming revenue ratio as well as the fiscal surplus ratio. In contrast, the idiosyncratic shock produces weaker and less precisely estimated responses, indicating limited macro-fiscal transmission when disturbances are confined to firm-level variation.

Importantly, fiscal responses closely track the gaming-revenue channel in both specifications. Movements in the fiscal surplus ratio co-move with gaming revenue over the medium run, reinforcing the interpretation that granular shocks affect public finances primarily through fluctuations in the gaming-related revenue base.

When real GDP growth is used as the LP outcome variable (reported in Appendix A.3), both sectoral and idiosyncratic shocks produce predominantly negative responses. We interpret these estimates with caution: in small samples, LP estimates for growth rates can be noisy and sensitive to horizon-by-horizon estimation. For this reason, we view the BVAR results as the more informative benchmark for dynamic propagation.

Summary of dynamic analysis

The dynamic evidence aligns with the static distinction between levels and risk. Sector-wide granular shocks propagate persistently through gaming revenue, real activity, and the fiscal surplus. Idiosyncratic shocks, by contrast, exhibit limited aggregate transmission. In a concentrated tax-base economy, sectoral comovement is therefore central for macro-fiscal dynamics, while firm-specific shocks primarily shape fiscal uncertainty rather than systematic downturns.

4.3 Policy Implications

The empirical results in Section 4.2 yield a compact framework for fiscal surveillance in tax-base–concentrated systems. Two canonical stress scenarios emerge. The first is a *sector-wide* shock, defined as a realization of Γ_t^{s}, capturing common demand shifts that propagate through macroeconomic activity and fiscal balances. The second is a *firm-specific* shock, defined by realizations of $|\Gamma_t^{\mathrm{id}}|$ (or $(\Gamma_t^{\mathrm{id}})^2$), capturing dispersion-driven volatility in the revenue base.

Because the estimated impulse responses are persistent, stress tests should be framed as multi-quarter paths rather than one-period impacts. The dynamic responses provide a direct mapping from granular shocks into projected revenue shortfalls and uncertainty bands over 4–12 quarters. For monitoring purposes, trigger rules should depend on the *magnitude* of idiosyncratic realizations rather than their sign, consistent with the empirical link between large firm-level disturbances and subsequent fiscal volatility.

Operationally, the framework can be embedded into routine fiscal monitoring. As new firm-level and aggregate revenue data become available, the sectoral and idiosyncratic components can be recomputed and reweighted using lagged fiscal exposure. This generates updated projections of surplus dynamics and reserve risk conditional on observed shocks. By separating common from firm-specific variation, the approach distinguishes economy-wide downturns from concentration-driven fragility.

The results also clarify a central policy trade-off. A larger gaming footprint strengthens fiscal capacity during expansions, but greater concentration increases sensitivity to sector-wide downturns and to firm-level dispersion. Diversification therefore has a measurable stabilization benefit: it lowers the elasticity of fiscal outcomes to common shocks and reduces exposure as captured by Domar-weighted and fundamental-volatility metrics.

In practical terms, fiscal resilience requires both (i) *buffer design*— calibrating reserve targets to the persistence and tail behavior of sector-wide shocks—and (ii) *exposure management*—tracking concentration and fundamental-volatility measures as forward-looking indicators of fiscal fragility. Embedding these metrics into budget scenarios makes transparent the trade-off between higher expected revenues in favorable states and increased downside risk over the medium term.

More broadly, the framework is portable to other fiscally concentrated jurisdictions, including resource-dependent economies, excise-heavy sectors, regulated concessions, and tourism hubs. It provides a structured bridge between firm-level monitoring and macro-fiscal risk assessment in environments where public finances depend on a small number of dominant private actors.

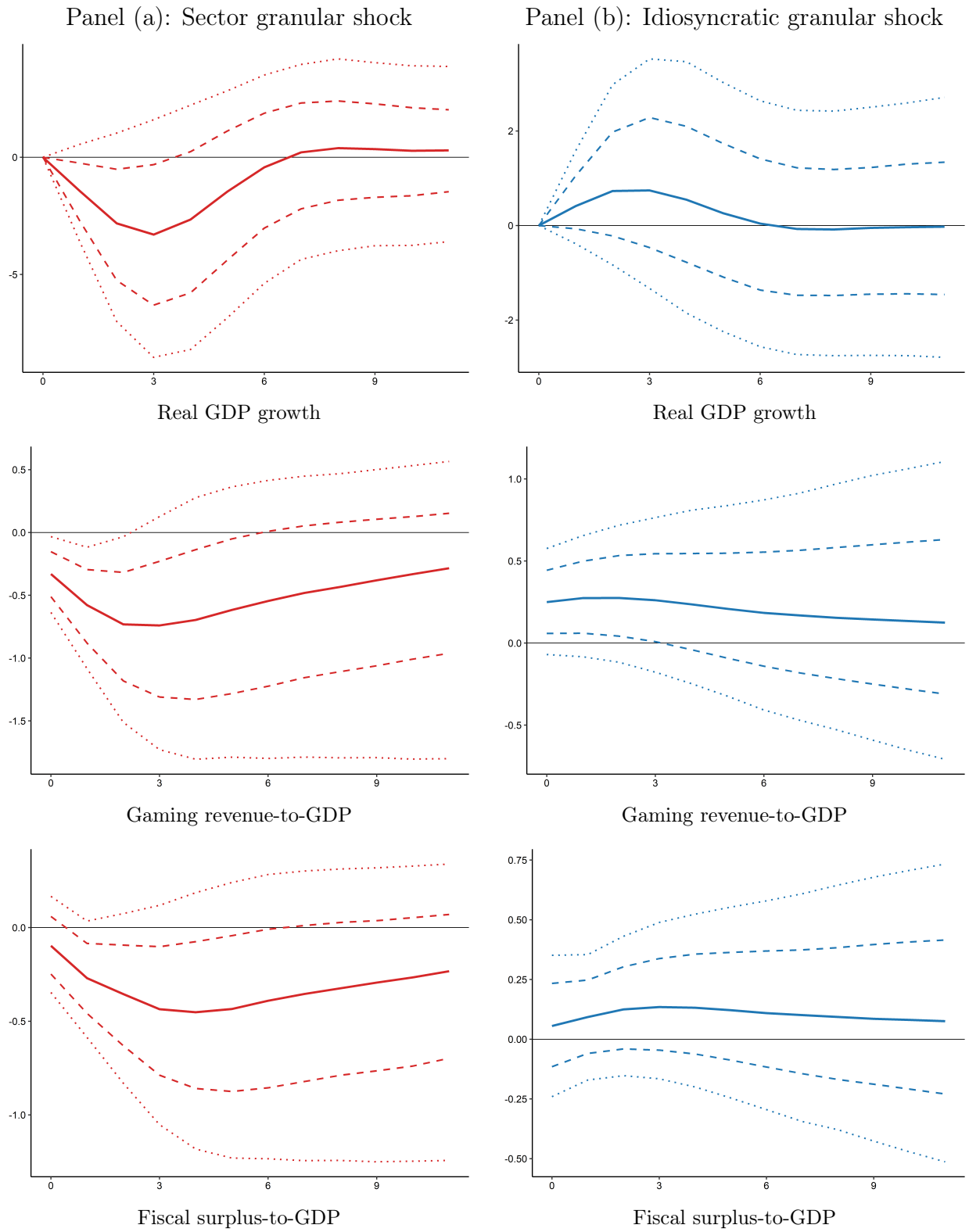


Figure 7: BVAR impulse responses to negative granular shocks: sector vs. idiosyncratic components. Solid lines show posterior medians; dashed and dotted lines report 68% and 90% credible bands.

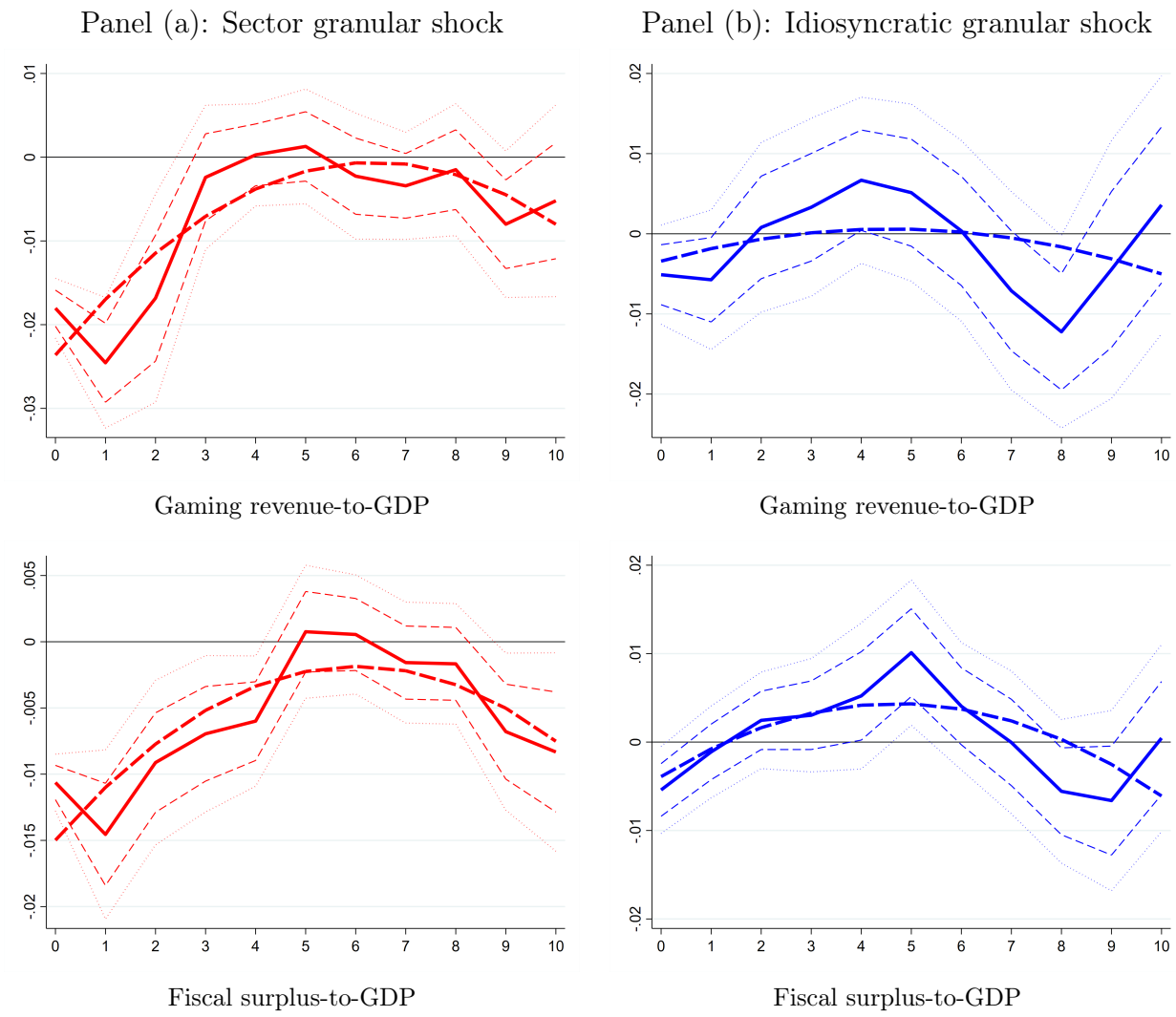


Figure 8: Local-projection impulse responses to one-standard-deviation negative granular shocks: sector vs. idiosyncratic components. Solid lines show point estimates; dashed and dotted lines report 68% and 90% pointwise confidence bands. A thick long-dashed line overlays a quadratic fit to the sequence $\{\widehat{\beta}_h\}_{h=0}^{H}$ to provide a smoothed representation of the medium-run profile.

5 Conclusion

This paper studies *granular fiscal risk*: when government revenues depend on a concentrated tax base, shocks to a small set of dominant private firms—or to the dominant sector as a whole—can propagate to macroeconomic and fiscal outcomes. To quantify it, we develop an implementable framework that decomposes firm-level revenue into (i) a sector-wide component and (ii) an idiosyncratic firm-level component, and aggregates them using lagged Domar-style weights that reflect fiscal relevance.

Macau provides a particularly informative testbed because the mapping from the private tax base to public revenue is almost linear. Gaming duties are levied on gross gaming revenue (GGR), and six concessionaires supply all gaming activity. Across static regressions and dynamic estimates (BVARs and LPs), two robust patterns emerge. First, **sector-wide** gaming shocks behave like aggregate disturbances. They are closely associated with real GDP growth and changes in the fiscal surplus-to-GDP ratio, and they generate persistent impulse responses in both GGR and the fiscal balance. Second, **idiosyncratic** firm shocks operate primarily through a risk channel. The magnitude of the idiosyncratic granular residual (e.g., $|\Gamma_t^{\text{id}}|$ or $(\Gamma_t^{\text{id}})^2$) predicts realized volatility in growth and fiscal ratios, rather than systematic movements in macro-fiscal levels.

Complementing these shocks, the composition-based fundamental-volatility measure isolates how changes in concentration mechanically alter exposure to firm-level risk. When the Domar-weighted footprint of dominant operators expands, fiscal capacity rises—but so does fiscal volatility.

In summary, our results point to two distinct channels of vulnerability in concentrated fiscal systems: sector-wide comovement that shifts the mean of macro-fiscal outcomes, and firm-specific shocks move around that mean. This distinction is central for understanding risk in economies where the public budget is effectively tied to a small number of dominant private actors, and it provides a structured bridge between firm-level monitoring and macro-fiscal risk assessment.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used ChatGPT in order to proofread and improve the language and readability of the manuscript. After using this tool, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article.

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A Robustness Check

This section reports our robustness checks. Section Section A.1 presents the static (OLS) results, Section A.2 reports the BVAR-based impulse responses, and Section Section A.3 provides additional evidence from local projections.

A.1 Granular Regressions without Macro Controls

We start by stripping the static regressions in Section 4.2.1 of all macro controls and the COVID dummy, and re–estimate the horse–race specification with only quarter fixed effects and the two granular terms Γ_t^{id} and Γ_t^{s}. Table 10 reports the results.

Two features stand out. First, for the *level* specifications (columns (1), (3), and (5)), the sectoral granular component continues to load positively on real activity and on the fiscal surplus share even in this parsimonious setup. The coefficient on Γ_t^{s} remains large and highly significant for real GDP growth (0.883, s.e. 0.159) and is also positive and significant for the change in the fiscal surplus share Δ(Surplus/NGDP) (0.394, s.e. 0.113). By contrast, the idiosyncratic component Γ_t^{id} is imprecisely estimated for GDP growth (0.636, s.e. 1.227) and for the surplus share change (1.121, s.e. 1.017). For the revenue share change Δ(Revenue/NGDP) (column (5)), Γ_t^{id} enters positively and is marginally significant (0.687, s.e. 0.360, $p \simeq 0.06$), while Γ_t^{s} is small and statistically insignificant. Overall, once macro controls are removed, the explanatory power of the level regressions declines and the idiosyncratic component becomes less stable, consistent with the interpretation that the controls help isolate granular channels from omitted aggregate conditions.

Second, for the *volatility* measures (columns (2), (4), and (6)), the Domar–weighted idiosyncratic component Γ_t^{id} remains strongly associated with volatility across all outcomes. The coefficients on Γ_t^{id} are large, negative, and highly significant for GDP volatility (-3.019, s.e. 0.402), surplus–share volatility (-2.174, s.e. 0.260), and revenue–share volatility (-0.689, s.e. 0.082). The sectoral term is economically small and statistically insignificant for GDP and revenue volatility, but it is positive and significant for surplus–share volatility (0.159, s.e. 0.078). Taken together, the no–controls regressions reinforce that idiosyncratic firm–level shocks are tightly connected to medium–run volatility, while the interpretation of the level regressions is more sensitive to omitted aggregate factors when controls are excluded.

Table 10: Granular shocks, macro outcomes and fiscal shares (no controls)

	Real GDP		Fiscal surplus		Government revenue	
	Level	Volatility	Level	Volatility	Level	Volatility
	(1)	(2)	(3)	(4)	(5)	(6)
Γ_t^{id}	0.636	-3.019***	1.121	-2.174***	0.687*	-0.689***
	(1.227)	(0.402)	(1.017)	(0.260)	(0.360)	(0.082)
Γ_t^{s}	0.883***	0.091	0.394***	0.159**	-0.023	0.012
	(0.159)	(0.152)	(0.113)	(0.078)	(0.029)	(0.024)
Quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Macro controls + COVID	No	No	No	No	No	No
R^2	0.560	0.303	0.407	0.368	0.232	0.357
Observations	61	61	61	61	61	61

Notes: Each column reports coefficients from a separate OLS regression with HAC standard errors (4 lags) in parentheses. For real GDP, "Level" is quarter–on–quarter real GDP growth (log difference), and "Volatility" is the six–quarter rolling standard deviation of that growth rate. For fiscal outcomes, "Level" refers to the quarter–to–quarter change in the nominal fiscal share (Surplus/NGDP or Revenue/NGDP), and "Volatility" is the six–quarter rolling standard deviation of the corresponding share change. Γ_t^{id} is the Domar–weighted idiosyncratic granular residual, and Γ_t^{s} is the sector component. Regressions include only the granular variables and quarter fixed effects; no macro controls or COVID dummy are included. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

A.2 Robustness check: Bayesian VAR

We conduct two robustness checks for our BVAR impulse responses. First, to allow for richer dynamics, Figure 9 re-estimates the BVAR with **four lags** (instead of the baseline lag length), keeping the remaining settings unchanged. Second, to assess sensitivity to the recursive identification, Figure 10 modifies the Cholesky ordering by moving the granular shock Γ_t *earlier in the system*, so that it is ordered before the macro–fiscal outcome block. Accordingly, the alternative ordering used in Figure 7 is

$$(g_t^{CH}, \log V_t) \;\rightarrow\; \Gamma_t \;\rightarrow\; (g_t^{RGDP}, i_t, GGR_t, FS_t).$$

Across both exercises, the impulse responses remain qualitatively similar to the baseline in terms of sign and overall dynamic profile, indicating that our main conclusions are robust.

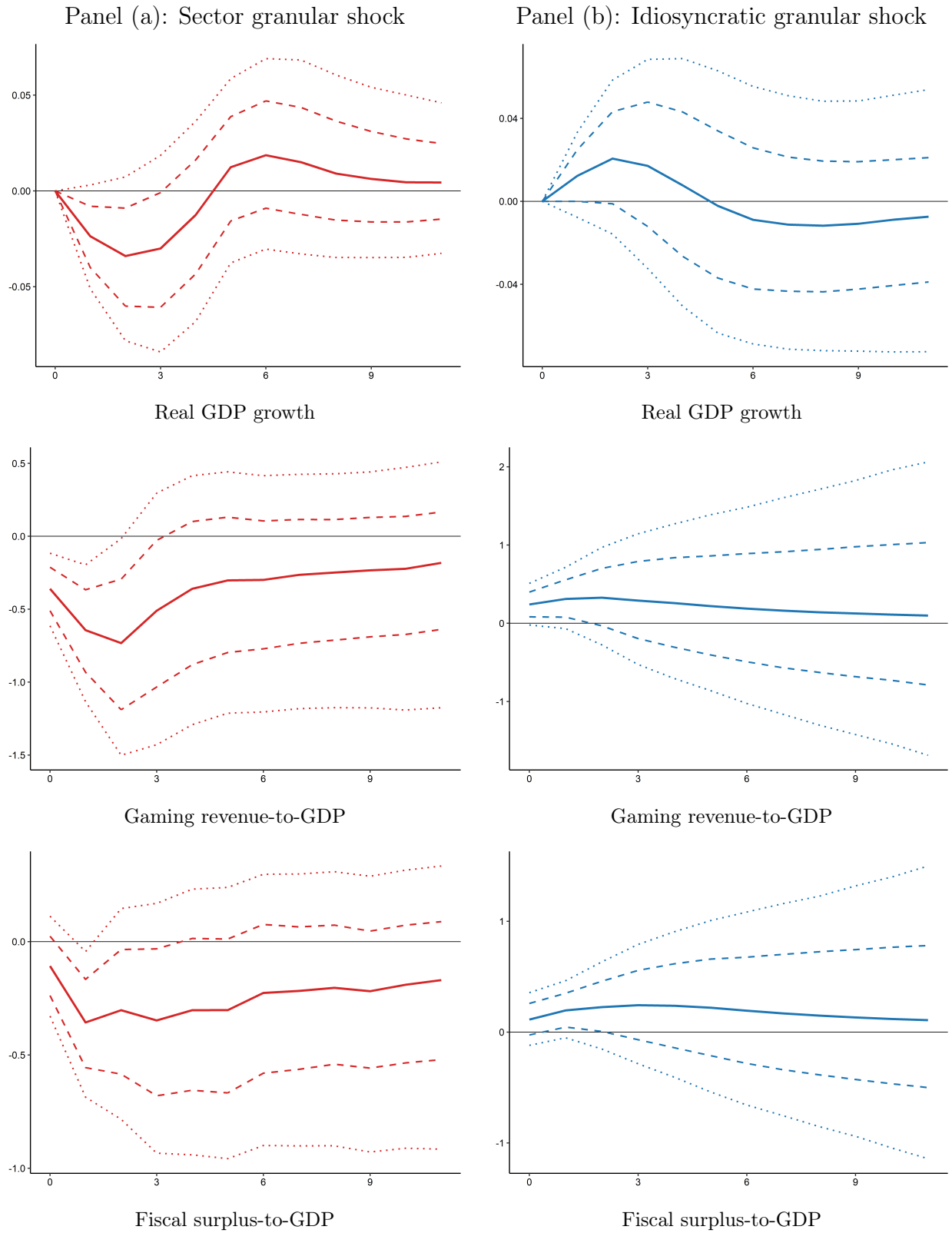


Figure 9: Impulse responses to negative granular shocks: sector vs. idiosyncratic components. Solid lines show posterior medians; dashed and dotted lines report 68% and 90% credible bands.

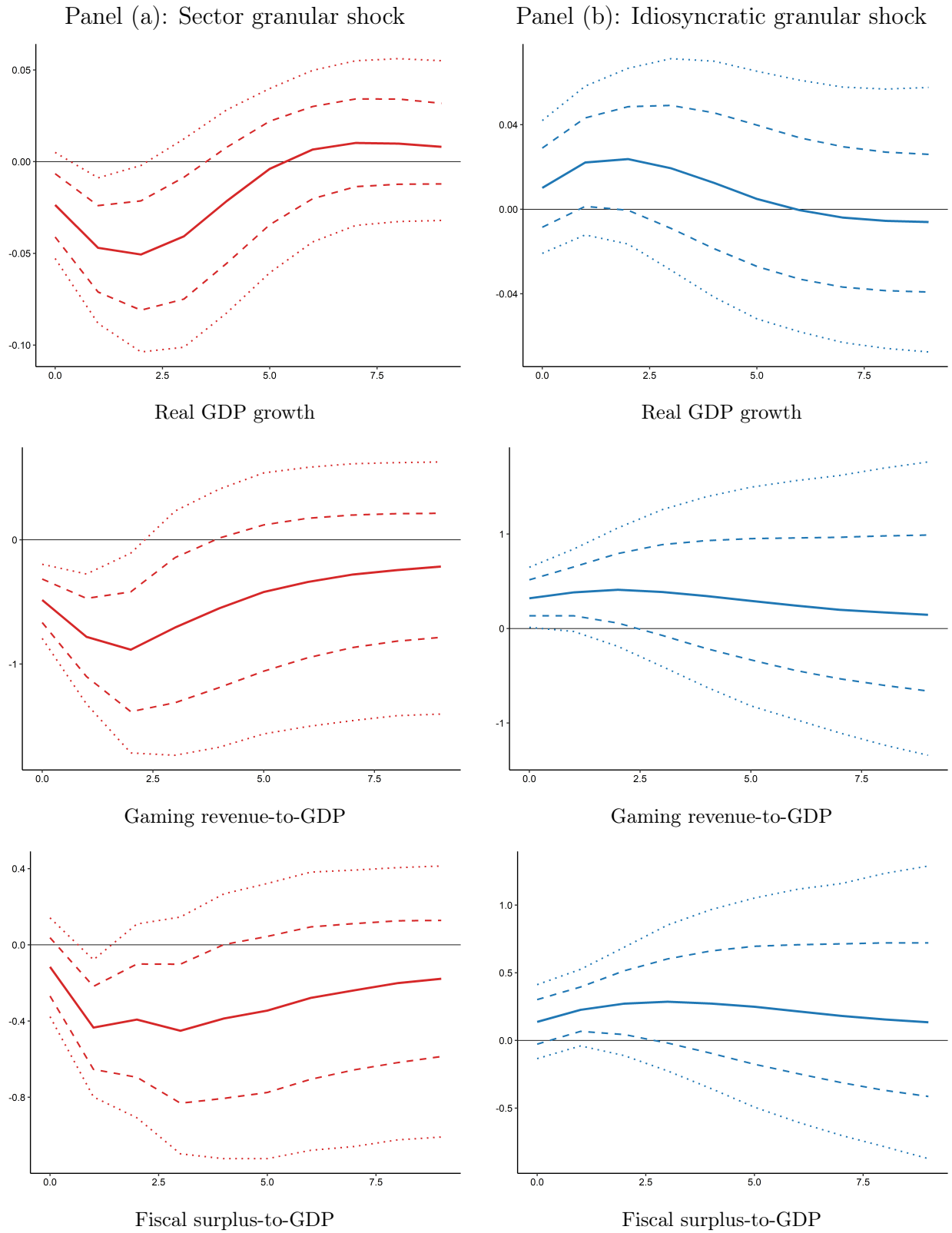
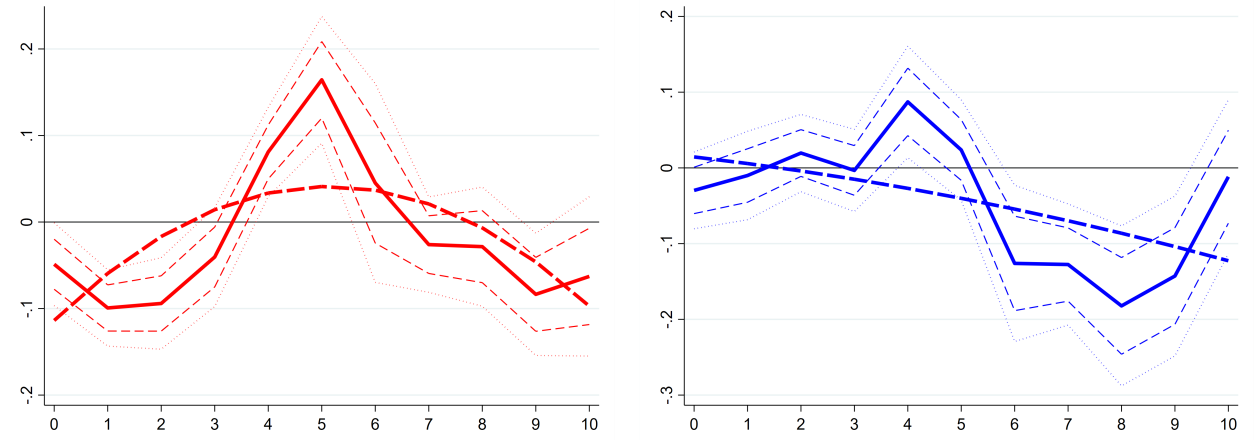


Figure 10: Impulse responses to negative granular shocks: sector vs. idiosyncratic components. Solid lines show posterior medians; dashed and dotted lines report 68% and 90% credible bands.

A.3 Additional Results: Local Projection

This subsection reports additional evidence based on local projections (LP), focusing on the response of real GDP growth to granular shocks, as in Section 4.2.2. Figures 11b–11a plot the estimated impulse responses of real GDP growth (year-on-year) to a one–standard-deviation shock in the idiosyncratic granular component and the sectoral granular component, respectively, together with 68% and 90% confidence bands.

Overall, when real GDP growth is used as the outcome variable, the LP-based responses are negative in both cases. We briefly note that this pattern may reflect small-sample issues that are more pronounced in LP estimation, especially at longer horizons, and thus we interpret these LP results as complementary to (rather than a replacement for) our baseline BVAR evidence.



(a) Sectoral granular shock

(b) Idiosyncratic granular shock

Figure 11: Local-projection impulse responses of real GDP growth to one–standard-deviation granular shocks