Time-varying consumption risk-sharing in the era of economic globalization

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Abstract

Purpose – This study aims to examine the time-varying patterns of consumption risk-sharing among 68 representative countries from 1980 to 2023.

Design/methodology/approach – Using the theory of international consumption risk-sharing, this study applies a generalized adaptive model to assess the extent of time-varying risk-sharing across these countries.

Findings – The findings indicate that global consumption risk-sharing patterns have become increasingly heterogeneous. In the context of globalization, the average degree of risk-sharing in both developing and developed countries surpasses that in emerging market countries. The estimated linear trend suggests that risk-sharing in emerging market countries and developing countries exhibits greater stability than in developed countries. Consumption risk-sharing in Southeast Asia, Latin America and Belt and Road countries has not improved, indicating that regional economic integration has not influenced risk-sharing.

Practical implications – Despite ongoing trends of economic globalization, the global allocation of consumption risks remains constrained, highlighting the need for new collaborative mechanisms.

Originality/value – This study advances beyond the constraints of earlier research by using a generalized additive model to investigate the time-varying international consumption risk-sharing. Previous studies primarily depended on linear regression models, which provide static or average estimates and fail to account for temporal variations. To address this limitation, the study adopts a nonparametric estimation approach, enabling a more accurate representation of the dynamic nature of risk-sharing.

Keywords Time-varying coefficient, Consumption risk-sharing, Generalized adaptive model, Emerging market countries

Paper type Research paper

1. Introduction

Economic globalization has spurred trade in goods and services, as well as cross-border capital flows, particularly in emerging market countries and developing countries, thereby strengthening the connection between consumption and output changes in these regions. The theory of international consumption risk-sharing posits that if a country's consumption changes are unrelated to its specific output changes, complete risk-sharing is achieved by decoupling country-specific consumption from country-specific output risks or shocks. This decoupling implies that each country achieves full insurance in consumption, independent of

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changes in its specific output or income. Recent studies have used linear regression models using cross-country panel or time-series data to estimate the level of consumption risk-sharing, thereby determining the average level of risk-sharing over a period or providing only a static point estimation within a sample period (e.g. Obstfeld, 1994; Lewis, 1996; Malik, 2015, among others). However, the dynamic or time-varying patterns of risk-sharing in individual countries have not been comprehensively examined.

Understanding the dynamics of consumption risk-sharing among countries across different periods is essential for two primary reasons. First, this understanding carries substantial practical significance. The impact of financial and trade integration on risk-sharing can be complex (Lane and Milesi-Ferretti, 2018). In addition, economic globalization follows a nonlinear and intricate path, particularly during financial crises or economic recessions. Therefore, assessing the time-varying nature of risk-sharing is essential for grasping the crucial role of economic globalization in this context.

The second rationale for this study is grounded in empirical evidence. While Kose *et al.* (2009) provide extensive evidence of static patterns of consumption risk-sharing among various country groups, the dynamic or time-varying patterns during critical periods, such as the financial globalization of the 1980s and the post-2008 global financial crisis, have remained largely unexamined. Thus, exploring the time-varying nature of risk-sharing can enhance the existing research on its dynamic patterns within the context of economic globalization.

This study examines the time-varying patterns of consumption risk-sharing among 68 countries globally, including 21 emerging market countries, 21 developed countries and 26 developing countries, over 44 years. The study begins by deducing the optimal conditions for consumption risk-sharing and formulating the corresponding reduced-form regression model. Subsequently, the reduced-form model is expanded to include time-varying consumption risk-sharing. This is achieved by applying the generalized additive model (GAM), proposed by Hastie and Tibshirani (1993). The newly developed time-varying risk-sharing regression model exhibits nonparametric properties and features a smooth regression formulation, demonstrating a nonlinear relationship between the independent variables and the response variable.

Furthermore, by adjusting the smoothness of an associated penalty control function (Wood, 2000), we estimate the time-varying consumption risk-sharing coefficients using the reformulated GAM. This methodology offers more robust and efficient estimates of consumption risk-sharing compared to those derived from parametric linear regression models.

We use time-varying coefficients to calculate the average consumption risk-sharing value for each country within the specified period. Deviations from these estimated average coefficients are then used to determine the dynamic consumption risk-sharing patterns for each country. This procedure generates subgraphs for each sample country in each figure, covering the period from 1980 to 2023. In addition, the time-varying consumption risk-sharing coefficients for emerging market countries, developed countries, developing countries and other specific regions are calculated by adding the estimated average coefficient to the respective deviations.

Our analysis reveals that consumption risk-sharing patterns across countries have diversified over the four decades of globalization. Through a global classification of countries, our study indicates that the average level of risk-sharing in developed and developing countries surpasses that in emerging market countries during this period. However, the risk-sharing patterns in emerging market countries and developing countries demonstrate greater stability compared to those in developed countries.

To further enrich our understanding of consumption risk-sharing in a global context, we select Southeast Asia, Latin America and countries along the Belt and Road Initiative (BRI) as representative regions. Examining risk-sharing in these areas provides deeper insights into the effects of regional economic integration on consumption risk-sharing. The risk-sharing levels in these regions are all below the global average of 39.04%. Therefore, during the globalization era, economic integration within these regions has not enhanced risk-sharing.

Our robustness checks, which include residual tests, replacing the restricted maximum likelihood (REML) method with Gaussian process smoothing in GAMs, analyzing variance (ANOVA) between other models and GAMs and validating using a state-space model with the Kalman filter method, further support these findings. To enhance the analysis, we use the dynamic time warping (DTW) method to visualize the alignment paths between consumption and output changes.

This paper is structured as follows. Section 2 reviews the relevant literature. Section 3 introduces international consumption risk-sharing theory and the method for measuring time-varying risk-sharing. Section 4 describes the data. Section 5 presents the empirical results, robustness checks and discussion. Section 6 concludes the paper. The remaining figures and tables are included in the appendix of the supplementary materials.

2. Related literature

International consumption risk-sharing is a critical topic in international finance, attracting extensive research. Obstfeld (1994) and Lewis (1996) are pioneers in measuring the levels of consumption risk-sharing for the G-7 countries using time-series data. Their findings indicate that risk-sharing is relatively low, with changes in each country's consumption highly dependent on output changes. Subsequently, Asdrubali *et al.* (1996) develop a structural model framework to quantify the role of consumption risk-sharing channels in the USA. From an international perspective, Sørensen and Yosha (1998) examine risk-sharing channels among European Community (EC) countries, estimating that approximately 40% of consumption risks were shared between 1966 and 1990. From a micro perspective, Ambrus *et al.* (2014) study risk-sharing within social networks, focusing on how complete risk-sharing could be achieved within local groups in developing countries, while partial risk-sharing occurred across different groups. This micro perspective offers valuable insights into understanding consumption risk-sharing, particularly in recognizing the extent of risk-sharing across various countries and regions.

Building on these findings, subsequent research consistently indicates that international consumption risk-sharing is lower than intra-national risk-sharing (Labhard and Sawicki, 2006; Sørensen and Yosha, 1998). Xu (2008) examines the degree of risk-sharing across China's provinces, US states and Canadian provinces, concluding that the level of risk-sharing within these regions exceeds that among countries. Similarly, Kose *et al.* (2009) document that industrial countries achieve better risk-sharing than emerging market countries and developing countries, as supported by individual country analyses and cross-country panel estimations. Bai and Zhang (2012) argue that during periods of lower financial integration (1970–1986), 43 countries experienced higher levels of risk-sharing compared to periods of higher financial integration (1987–2004). While these studies provide substantial evidence on the static patterns of consumption risk-sharing on average, the dynamic nature of time-varying risk-sharing across individual countries remains insufficiently explored.

Numerous scholars endeavor to understand consumption risk-sharing from a dynamic perspective. For instance, Baxter (2012) argues that high-frequency shocks, such as short-run fluctuations in crop yields, primarily influence short-term risk-sharing, while low-frequency shocks, such as long-term technological progress, affect long-term risk-sharing. Similarly,

Leibrecht and Scharler (2008) find that approximately 30% of idiosyncratic consumption risks are mitigated in the short run, whereas only 10% are shared in the long run, using panel cointegration and vector error-correction model (VECM) methodologies. Asdrubali and Kim (2004) uses a vector auto-regression (VAR) model with structural restrictions to differentiate the responses of consumption changes to permanent and transitory output shocks, further exploring the dynamic relationship between short-term and long-term risk-sharing. Cavaliere *et al.* (2008) use the VECM to investigate the dynamic adjustment process of consumption to its optimal level, aiming to minimize deviations from complete risk-sharing. Asdrubali *et al.* (2023) apply a heterogeneous panel VAR model to analyze the dynamic profiles and channels of risk-sharing across 21 Organisation for Economic Co-operation and Development (OECD) countries.

Moreover, Flood *et al.* (2012) uses the year-rolling window method to discover that risk-sharing has improved on a trend basis since the 1960s for industrial countries and since the 1990s for emerging market countries, though not necessarily at business-cycle frequencies. While this approach effectively captures long-term trends, it may overlook the time-varying nature of consumption risk-sharing. By differentiating the data at three- and five-year horizons, Artis and Hoffmann (2012) find that up to 40% of idiosyncratic consumption risks are shared among industrial countries in the long run. However, their focus on specific horizons may obscure the complexities of consumption risk-sharing under dynamic conditions. Bénétrix (2015) uses dummy variables to represent European integration events, evaluating the effects of financial integration on consumption risk-sharing in Ireland. Similarly, Cimadomo *et al.* (2020) examine the roles of public and private channels in consumption risk-sharing among eurozone countries. Nonetheless, their methodology does not provide precise time-varying risk-sharing coefficients for individual countries, such as the 11 eurozone members.

Foresti and Napolitano (2022) adopt a different approach, applying the Kalman filter to obtain a time series of risk-sharing for individual European Monetary Union (EMU) members. However, the Kalman filter is not a nonparametric estimation method, and the estimated coefficients in their model are largely dependent on the assumption that the process follows a random walk pattern.

Irrespective of the methodology used – whether the rolling window approach, data differentiation or the Kalman filter – these methods typically result in a reduced sample size due to data loss, thereby undermining the accuracy of the estimation. In addition, these approaches predominantly rely on parametric estimates rather than nonparametric ones. Parametric estimation methods depend on the precise configuration of the distribution of the residual terms. For example, if the actual residual terms do not conform to the preset distribution (such as the normal distribution), these estimation methods become unsuitable. To overcome these limitations, our study utilizes the GAM along with an expanded data set to estimate time-varying consumption risk-sharing for 68 selected countries. Notably, we use a nonparametric estimation approach to capture the dynamic nature of risk-sharing. Our methodology does not require restrictive assumptions about the distribution of the residual terms, thereby making the estimation technique more robust compared to previous approaches.

The methodology developed by Antonakis and Scharler (2012), which introduces a time-varying consumption risk-sharing measure based on the dynamic conditional correlation (DCC) model, is closely related to our approach. The DCC model, estimated through a nonparametric procedure, shows optimal performance for high-frequency data analysis (daily, weekly or monthly) (Engle and Sheppard, 2001). However, the annual frequency of the sample data makes the DCC model unsuitable for estimating time-varying risk-sharing

coefficients. In related literature, Fuleky *et al.* (2015) use the commonly correlated effect estimator to examine the cross-sectional heterogeneity of consumption risk-sharing across 158 countries. Everaert and Pozzi (2021) also evaluate dynamic risk-sharing across 15 industrialized countries. They use the encompassing variance ratio method, which produces more robust results compared to earlier studies.

Technically, Zhang *et al.* (2002) discuss a specific model within the GAMs, namely, the semi-varying coefficient model, and its significance in handling coefficients with varying degrees of smoothness. They note that the time trend is increasing rather than seasonal, which is crucial for understanding long-term trends in a country's macroeconomic time series data. In the context of varying coefficient models, it is noteworthy that time-varying generalized additive models (TV-GAMs) retain greater interpretability compared to machine learning approaches, such as boosted decision tree varying coefficient models (Zhou and Hooker, 2022).

Stengos and Zacharias (2006) examine how computer prices vary over time based on quality characteristics. They argue that GAMs and their time-varying coefficient estimation techniques can more flexibly handle nonlinearity and heterogeneity in the data. Consequently, GAMs can effectively capture the dynamic changes in macroeconomic variables over time and under complex conditions. Hu *et al.* (2023) emphasize that the generalized variable coefficient additive model (GV-CAM) can more accurately reflect the dynamic changes and nonlinear relationships of covariates. By modeling both discrete and continuous responses for locally stationary covariates, GV-CAM provides more reliable estimates for time-varying coefficients.

3. Theory and methodology

3.1 International consumption risk-sharing theory

The theory of international consumption risk-sharing suggests that changes in a country's consumption are not directly associated with changes in its output after country-specific or idiosyncratic output shocks have been fully absorbed (Obstfeld, 1994; Rogoff and Obstfeld, 1996). Under the optimal condition, this relationship can be expressed as:

$$\frac{U'(C_{i,t+1}, \theta_{i,t+1})}{U'(C_{i,t}, \theta_{i,t})} = \frac{\lambda_{t+1}}{\lambda_t}, \tag{1}$$

where $U(C_{i,t}, \theta_{i,t})$ is the utility function, satisfying $U' > 0$ and $U'' < 0$. $C_{i,t}$ represents the consumption of country i (where $i = 1, 2, 3, \ldots \ldots, n$) at time t, $\theta_{i,t}$ is a country-specific output shock and λ_t is marginal wealth income in the rest of the world.

Equation (1) indicates that each country's consumption growth rate is not dependent on its output (or income) growth rate but is instead related to the global per capita consumption (or output) growth rate, signifying the optimal situation for risk-sharing. This condition can be interpreted from two distinct perspectives. First, if idiosyncratic output risks within a country are collectively absorbed, any change in its consumption remains unconnected to changes in its output. This principle applies to all countries in all-natural states.

Second, complete risk-sharing implies that changes in consumption for each country remain proportional to global output changes, as determined by the optimal Pareto allocation. Under this allocation, the growth rate of consumption for each country is independent of its country-specific output growth rate and is instead related to the global per capita consumption growth rate. This suggests that through appropriate mechanisms, the consumption risk for residents of each country is fully shared, thereby enabling complete risk-sharing.

Following Bénétrix (2015) and Artis and Hoffmann (2008), we summarize the first interpretation using the following formula:

$$E\left(\left(\Delta c_{i,t} - \Delta c_t^*\right) \mid \left(\Delta y_{i,t} - \Delta y_t^*\right)\right) = 0, \tag{2}$$

where Δ denotes the difference operator, and E represents the expectation operator conditional on $\{\Delta y_{i,t}, \Delta y_t^*\}$. $c_{i,t} = log\,(C_{i,t})$ and $y_{i,t} = log\,(Y_{i,t})$ are the logarithms of per capita consumption and per capita output for each country i, respectively. $\Delta c_{i,t}$ and $\Delta y_{i,t}$ represent the per capita consumption and output growth rates for each country, while Δc_t^* and Δy_t^* indicate the world per capita consumption and output growth rates. $\Delta c_{i,t} - \Delta c_t^*$ denotes the country-specific components of consumption growth, and $\Delta y_{i,t} - \Delta y_t^*$ denotes the country-specific components of output shocks.

Furthermore, we measure consumption risk-sharing within each country using a coefficient that reflects the relationship between changes in country-specific output and changes in country-specific consumption. This coefficient is derived from the following basic regression model:

$$\Delta c_{i,t} - \Delta c_t^* = \alpha + \beta\left(\Delta y_{i,t} - \Delta y_t^*\right) + \varepsilon_t, \tag{3}$$

where β measures the extent to which consumption risks remain unshared. The degree of risk-sharing is denoted by $1 - \beta$, indicating the extent to which country-specific consumption is disassociated from country-specific output shocks, thereby reducing the correlation between domestic consumption and output. Consequently, the lower (higher) the value of β, the greater (lesser) the extent of risk-sharing. Although complete risk-sharing (or full consumption insurance) is considered an ideal condition, empirically, countries often exhibit incomplete risk-sharing, with $0 < \beta < 1$. When $\beta = 0$, it indicates that full risk-sharing has been achieved, meaning that the country-specific consumption growth rate is uncorrelated with its specific output growth rate. Conversely, when $\beta = 1$, it suggests that no risk-sharing is achieved among countries. α denotes a constant term, and ε_t represents the residual term.

While equation (3) provides an estimate of a country's average risk-sharing, it fails to capture the dynamic aspect of the country's risk-sharing. To address this, we use the following regression model to estimate time-varying consumption risk-sharing:

$$\Delta c_{i,t} - \Delta c_t^* = \alpha + \beta_t\left(\Delta y_{i,t} - \Delta y_t^*\right) + \varepsilon_t, \tag{4}$$

where the coefficient β_t quantifies the unshared consumption risks over time. Consequently, $1 - \beta_t$ represents the measure of time-varying consumption risk-sharing, demonstrating temporal continuity. In contrast to equation (3), which yields different high and low values for various intervals, this approach captures time-varying fluctuations that parametric estimation cannot fully represent [1].

3.2 GAM with time-varying coefficients

The methodology adopted in this study, which uses the GAM and its corresponding nonparametric estimates, offers two distinct advantages. First, the GAM is estimated using a nonparametric procedure, which eliminates the need for restrictive assumptions about the specific distribution of the model. In contrast, most methods used in previous studies rely on parametric estimates, making them highly dependent on model specifications, including the assumption of a normal distribution. Second, the GAM is used to estimate the time-varying consumption risk-sharing coefficient for each country without imposing assumptions about the distribution of the coefficients or residual terms. This approach allows for the use of a sufficiently large sample of observations, thereby enhancing the efficiency of the estimates.

According to Hastie and Tibshirani (1986), the basic GAM differs from the traditional linear regression model, which assumes a linear relationship between the dependent and independent variables, as shown:

$$E\left(Y \mid X_1, X_2, \ldots\ldots, X_p\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots + \beta_p X_p, \tag{5}$$

where Y is the response variable and X_1, X_2, … …, X_p are predictor variables. The coefficients β_0, β_1,… …, β_p can be obtained using ordinary least squares estimation. Unlike the traditional linear model, the additive model does not rely on the assumption of a linear form. Instead, it is represented as:

$$E\left(Y \mid X_1, X_2, \ldots\ldots, X_p\right) = s_0 + s_1(X_1) + s_2(X_2) + \cdots\cdots + s_p(X_p), \tag{6}$$

where $s_j(X_j)$, $j = 1, 2, \ldots \ldots, p$ are smoothing functions ensuring $E(s_j(X_j)) = 0$. These functions are derived using the original back-fitting method proposed by Hastie and Tibshirani (1986). Therefore, the fundamental GAM is an extension of the additive model:

$$g(\mu) = s_0 + s_1(X_1) + s_2(X_2) + \cdots\cdots + s_p(X_p), \tag{7}$$

and:

$$\eta = s_0 + \sum_{j=1}^{p} s_j(X_j), \tag{8}$$

where $\mu = E(Y|X_1, X_2, \ldots \ldots, X_p)$, η is the predictive value and $s_j(X_j)$ are nonparametric smooth functions. These functions can take the form of smooth splines, kernel functions or local smooth functions, thereby capturing the nonlinear effects of the independent variables.

In equations (7) and (8), the basic GAM comprises a random component Y, an additive component η and a link function $g(\cdot)$ that effectively connects Y with η. The random component Y can follow a variety of exponential family distributions, such as the binomial, poisson or gamma distributions.

The time-varying GAM emphasizes that, in the context of the consumption risk-sharing model, time is merely one covariate [2]. Thus, the regression model for time-varying consumption risk sharing is expressed as follows:

$$\Delta c_{i,t} - \Delta c_t^* = \alpha + f(\beta_t)\left(\Delta y_{i,t} - \Delta y_t^*\right) + \varepsilon_t, \tag{9}$$

where $f(\beta_t)$ denotes a smooth function of the time-varying risk-sharing coefficient, $\Delta c_{i,t} - \Delta c_t^*$ is the response variable, β_t is a covariate and ε_t is an independent random variable. The extent of time-varying risk-sharing is then formulated as $1-f(\beta_t)$, evaluated on a country-by-country basis.

Finally, to apply the nonlinear solution technique, we utilize penalized spline estimation (Hastie and Tibshirani, 1993; Ruppert *et al.*, 2003) on a country-by-country basis. This technique involves adjusting the smoothing parameter to balance the fidelity to the actual data and the smoothness of the estimated function (Wood, 2017). Using this method, we determine the estimated time-varying coefficient $f\left(\widehat{\beta}_t\right)$, which includes the estimated average coefficient for each period and its deviation from the average. Consequently, we obtain the time-varying consumption risk-sharing patterns through the computation of $1 - f\left(\widehat{\beta}_t\right)$.

4. Data

This study uses data from two databases, including the Penn World Table 10.01 (PWT 10.01, www.rug.nl/ggdc/productivity/pwt/?lang=en), developed by Feenstra *et al.* (2015) and the World Development Indicators (WDI, https://databank.worldbank.org/reports.aspx?source=2&country=ARE), compiled by the World Bank. These sources collectively provide a comprehensive view of global economic indicators, thereby facilitating a detailed analysis of consumption risk-sharing in the context of economic globalization.

In accordance with the methodology adopted by Kose *et al.* (2009), we systematically select a sample of 21 emerging market countries, 21 developed countries and 26 developing countries worldwide. This diverse sample is detailed in Appendix A, which provides a list of the sample countries and their abbreviations, ensuring clarity and ease of reference for readers. The temporal scope of our study aligns with the onset of economic globalization, beginning in the post-1980s era – a period marked by significant economic transformations, including China's reform and opening-up policy initiated in 1979. Notably, our sample data extends to 2023, covering the most recent four decades, a period characterized by major economic upheavals, particularly two financial crises and the global COVID-19 pandemic.

Our analysis is based on the precise measurement of key variables: total consumption (including household and government expenditure) and output, initially quantified in constant 2017 million dollars. Since household and government consumption data are presented as shares, a conversion process is required to transform these figures into absolute levels. These absolute levels of household and government consumption are then combined to calculate the total consumption for each country. To standardize the data set and minimize the influence of outliers, a logarithmic transformation is applied to these variables. Finally, the first-order differences of the logarithmically transformed figures are calculated, facilitating the analysis of changes in consumption and output at both the national and global levels.

5. Empirical results

5.1 Global dynamics

This section uses the GAM and data from 68 countries from 1980 to 2023 to examine the dynamics of consumption risk-sharing [3]. Figure 1 depicts the evolution of consumption risk-sharing levels among the sampled countries, while Table 1 provides detailed descriptive statistics to complement this analysis.

Over the four-decade period under examination, global consumption risk-sharing increased in the late 1980s and after 2004, 2014 and 2023. Nevertheless, Figure 1 indicates that the overall trend declined from 1980 to 2015. Notably, the period following the global financial crisis is characterized by a reduction in risk-sharing. This finding aligns with the observations of Flood *et al.* (2012), who note that economic globalization does not enhance risk-sharing at the business cycle frequency.

In addition, the global COVID-19 pandemic erupted in 2020. As illustrated in Figure 1, following the outbreak, global consumption risk-sharing experienced a temporary decline. This decline was primarily attributed to the implementation of lockdown measures by numerous countries, including the closure of nonessential stores, travel restrictions and social distancing protocols, which negatively impacted economic connections. Concurrently, businesses witnessed a significant drop in sales and faced heightened risks of bankruptcy, thereby diminishing the market's capacity to absorb consumption risks.

Table 1 shows that the consumption risk-sharing coefficient ranges from 0 to 1, indicating incomplete risk-sharing. In column 1, a higher coefficient suggests greater risk-sharing within a country. This coefficient represents the average value over the observed period. The

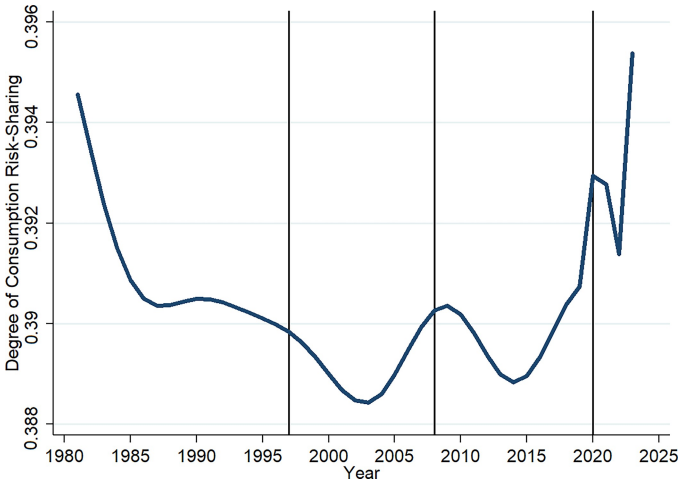


Figure 1. Global time-varying consumption risk-sharing
Note(s): The vertical axis represents the degree of consumption risk-sharing, while the horizontal axis indicates the year. Vertical lines denote the years 1997 and 2008, marking global financial risks. The third vertical line marks the beginning of the global COVID-19 pandemic in 2020
Source: Authors' own work

Table 1. Statistics of consumption risk-sharing

Sample countries	Mean	Sd	Min.	Max.	Median
All countries	0.3904	0.2153	−0.0440	0.9463	0.4158
Emerging market countries	0.2167	0.1570	−0.0591	0.4917	0.2233
Developed countries	0.5553	0.1820	0.1279	0.9138	0.5784
Developing countries	0.4909	0.2291	0.0677	0.8164	0.5613

Note(s): "Sd" represents the unconditional standard deviation. The period of observation spans from 1980 to 2023
Source(s): Authors' own work

analyses suggest that, on a global scale, consumption risks are shared below the halfway point, with a composite score of 0.3904.

From 1980 to 2023, countries are classified according to their average levels of consumption risk-sharing. Argentina, Pakistan and Cameroon reveal an average risk-sharing of less than 10%, while Côte d'Ivoire, Peru, Egypt, Malaysia, Mexico, the USA and China show risk-sharing levels below 30% [4]. In contrast, Norway, the UK, Costa Rica, Honduras, Senegal and Togo collectively share nearly 70% of consumption risks on a global scale. Notably, countries such as Jamaica, Nicaragua and Switzerland show high levels of risk-sharing, although their coefficients are statistically insignificant.

Previous studies, such as those by Bai and Zhang (2012) and Kose *et al.* (2009), measure risk-sharing among various countries. These studies primarily focus on deriving an average level of risk-sharing. However, the current analysis extends this approach by detailing the dynamics of risk-sharing for individual countries. Our results indicate the diversity in risk-sharing levels

worldwide, with values ranging from −0.0440 to 0.9463 and a standard deviation of 0.2153. Moreover, both developed (55.53%) and developing (49.09%) countries display more than twice the level of risk-sharing compared to emerging market countries (21.67%).

Figure 2 illustrates the existence and evolution of risk-sharing across different countries. Specifically, Argentina and Chile show a yearly decline in risk-sharing levels, while Brazil experiences a decrease followed by a recovery after 2000, 2008 and 2018, similar to the annual increase observed in China after 2008. The diversity of these patterns is evident, as many countries, including Malaysia, Pakistan, Mexico, Peru, Ghana, Guatemala, Haiti and Honduras, show a linear change in risk-sharing [5].

Notably, Bénétrix (2015) examines the impact of European integration on Ireland's consumption risk-sharing, focusing on the periods before 1993 and after 1999. This aligns with our findings, which show no significant evidence of dynamic risk-sharing during the European integration process. Unlike methods that use dummy variables to capture linear relationships, GAM can fit nonlinear relationships through smooth functions. Consequently, GAM can directly address the time-varying effects in the relationship between consumption and output without the need for arbitrary time segmentations or numerous dummy variables.

Overall, the extent of dynamic consumption risk-sharing reveals significant variation across countries worldwide. Fuleky *et al.* (2015) use the common correlated effects estimator and find substantial differences in the levels of risk-sharing among countries. However, they do not provide dynamic visualizations of the time-varying risk-sharing for these countries.

The analysis examines two critical financial crises that occurred during the period under review. The first crisis was the Southeast Asian financial crisis of late 1997, which led to a gradual decline in risk-sharing in Thailand, Malaysia, Indonesia and the Philippines starting around 2000. Before the crisis, Thailand's open financial markets had enabled financial institutions and enterprises to raise capital internationally, thereby supporting a robust consumer market. Through channels such as credit consumption and international financing, imports were partially financed, allowing Thailand to share its consumption risks via international financial markets.

However, the Southeast Asian financial crisis of late 1997 led to a depreciation of the Thai baht. This depreciation exacerbated the foreign debt burden of Thai enterprises, resulting in a surge in corporate bankruptcies. Financial institutions faced severe nonperforming loan issues, and the credit market froze. Residents experienced increased unemployment risks and declining household assets. Imported goods became more expensive, and international investors withdrew their capital, leading to the collapse of risk-sharing mechanisms that had previously relied on international financing channels. Consequently, Thai financial institutions and consumers were left to bear the majority of the risks.

In contrast, countries such as Korea, Japan and China strengthened risk-sharing by implementing strict regulations on short-term capital flows. These measures served as a safeguard against the volatility often associated with rapid capital movements, which can destabilize domestic economies and disrupt consumption smoothing. For instance, Korea adopted policies designed to mitigate risks from external shocks by promoting domestic consumption while restricting speculative foreign capital. This approach not only protects the economy from sudden fluctuations but also fosters a more resilient consumer base, better equipped to withstand consumption-related uncertainties.

The second crisis, which originated in the USA in 2008, underscores the diversity in global risk-sharing. Financially open economies, including the UK, Greece, Norway, Portugal and Korea, underwent a continuous decline in risk-sharing levels. Before the crisis, residents in these countries could easily obtain loans for expenditures, such as housing purchases, due to relatively lenient credit market conditions. Financial innovations, such as

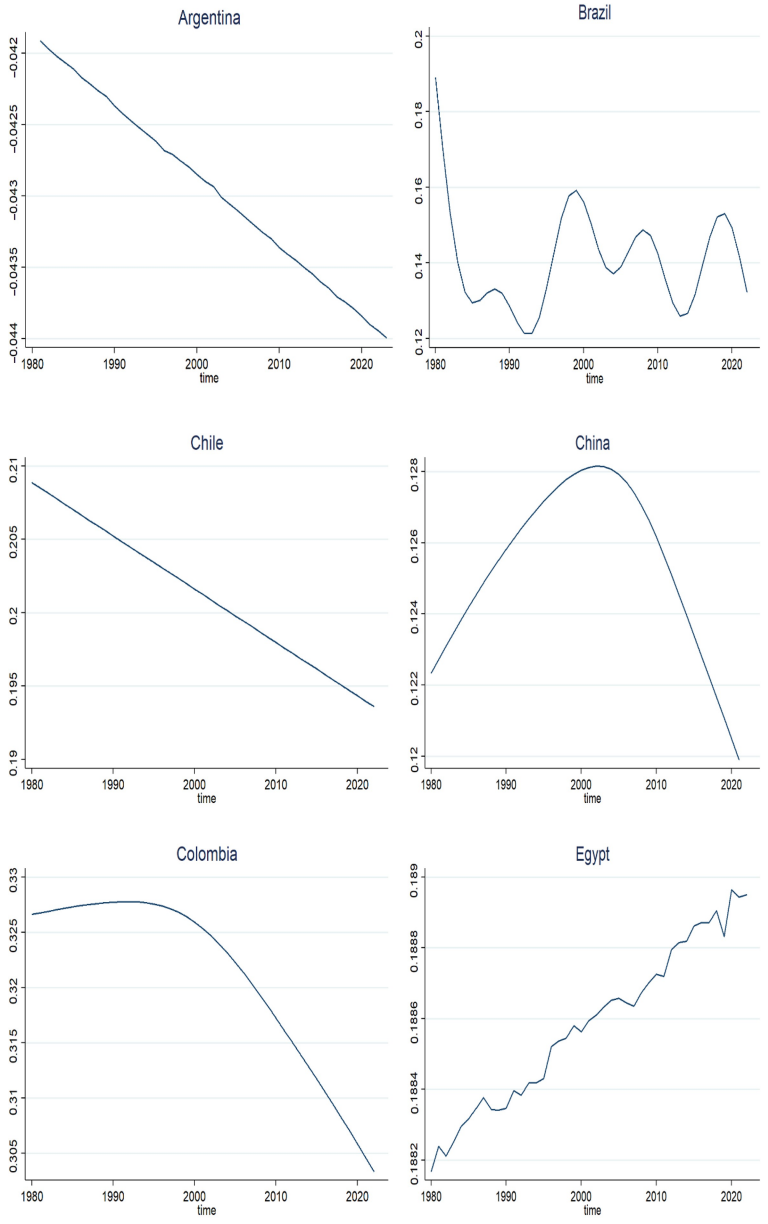


Figure 2. Time-varying consumption risk-sharing for 62 countries

Note(s): The vertical axis represents the degree of consumption risk-sharing, while the horizontal axis indicates the year in each subgraph. Countries with no significant GAM estimates, such as Ireland, Switzerland, Fiji, Gabon, Jamaica and Paraguay, are excluded from the analysis

Source: Authors' own work

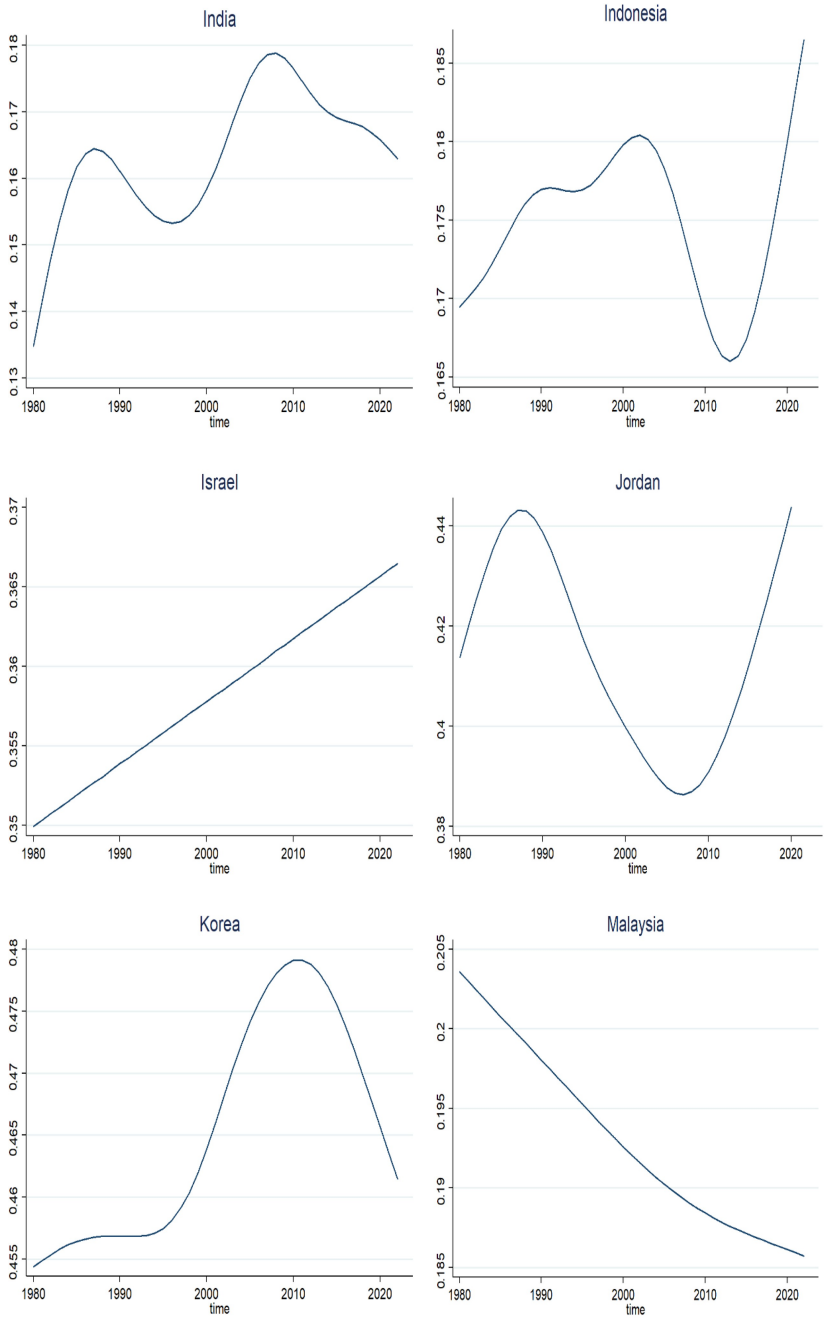
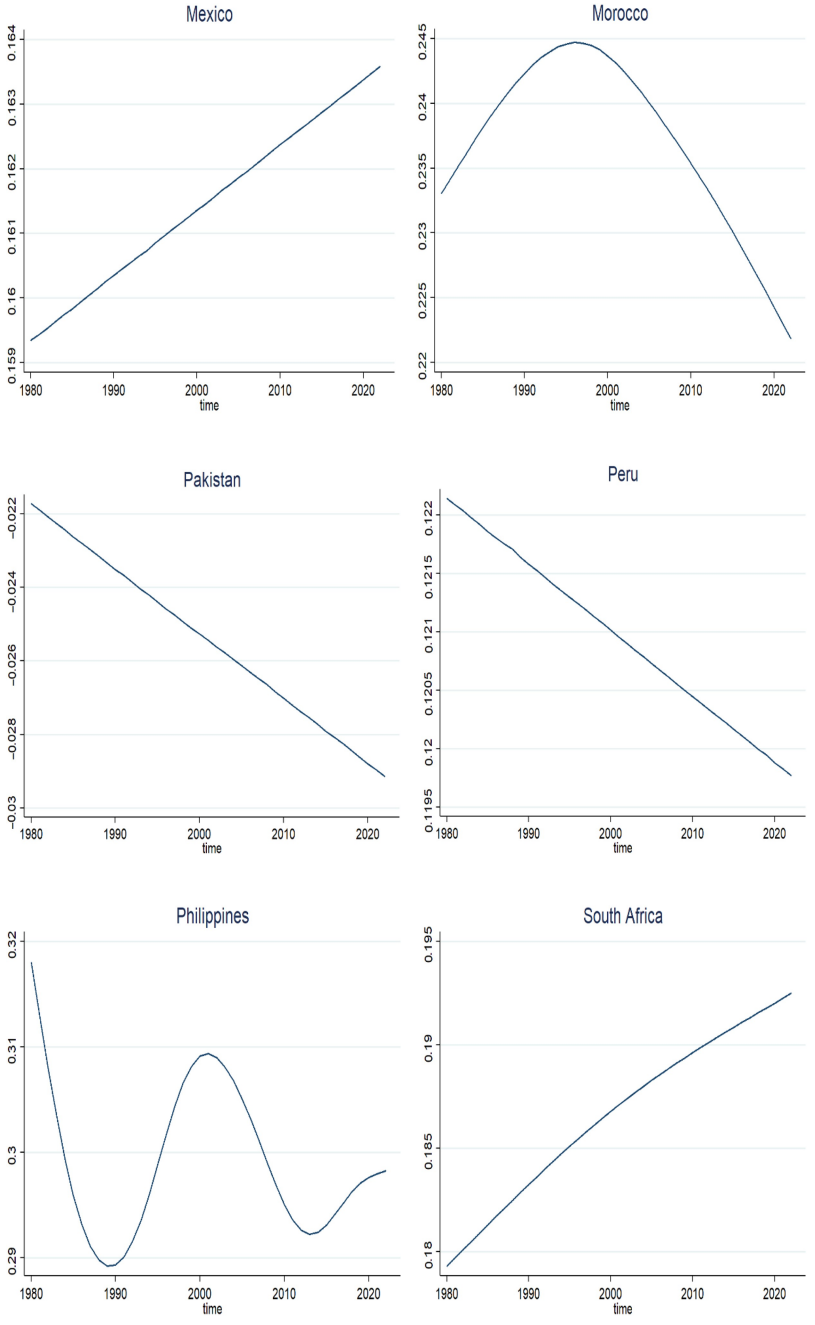


Figure 2. Continued



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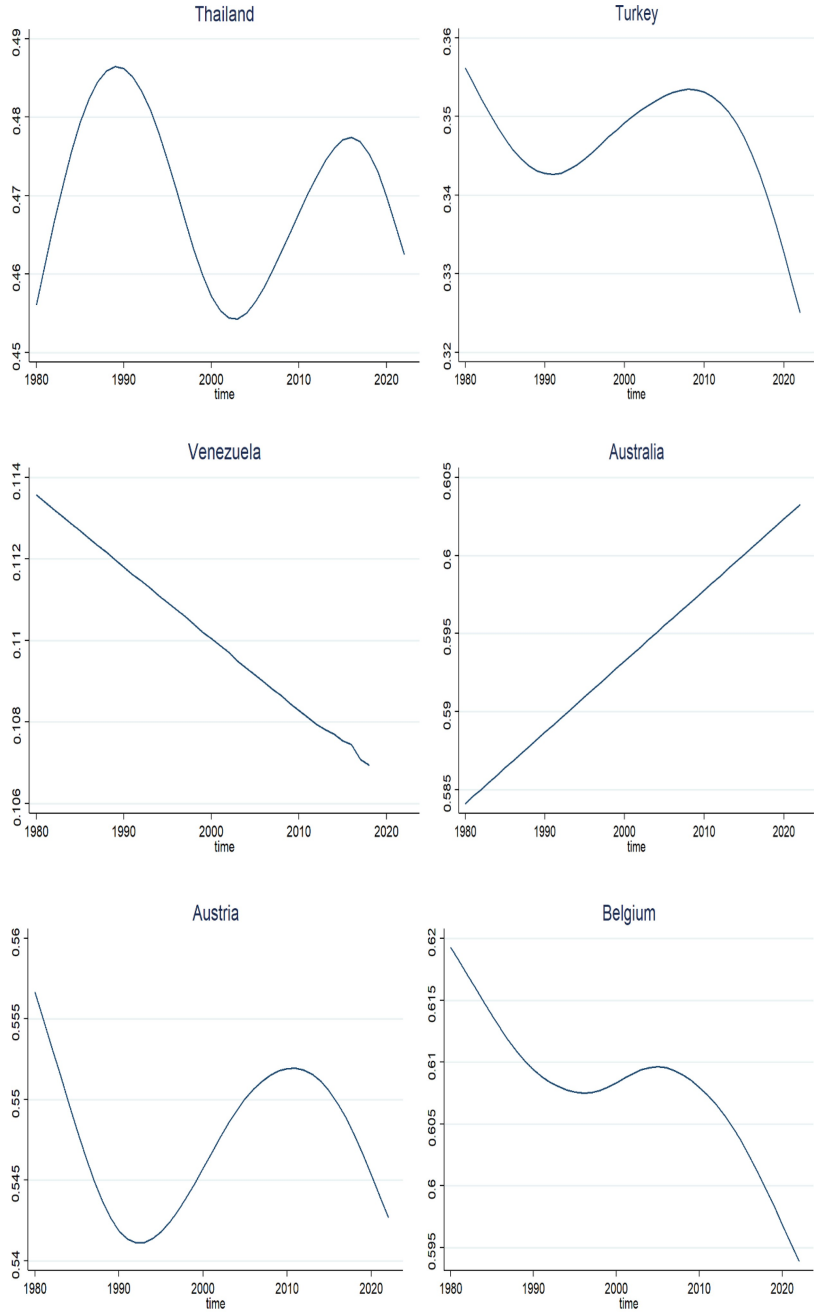

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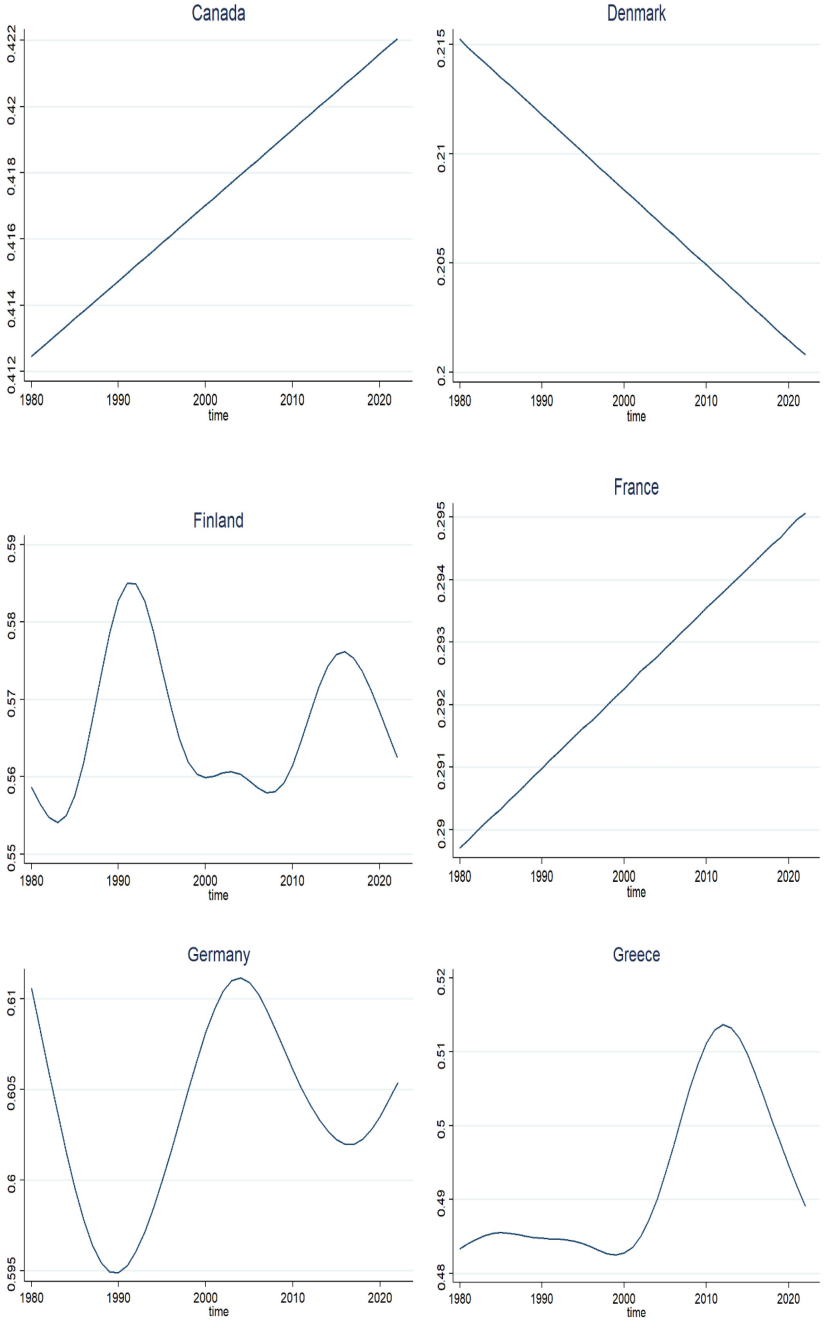

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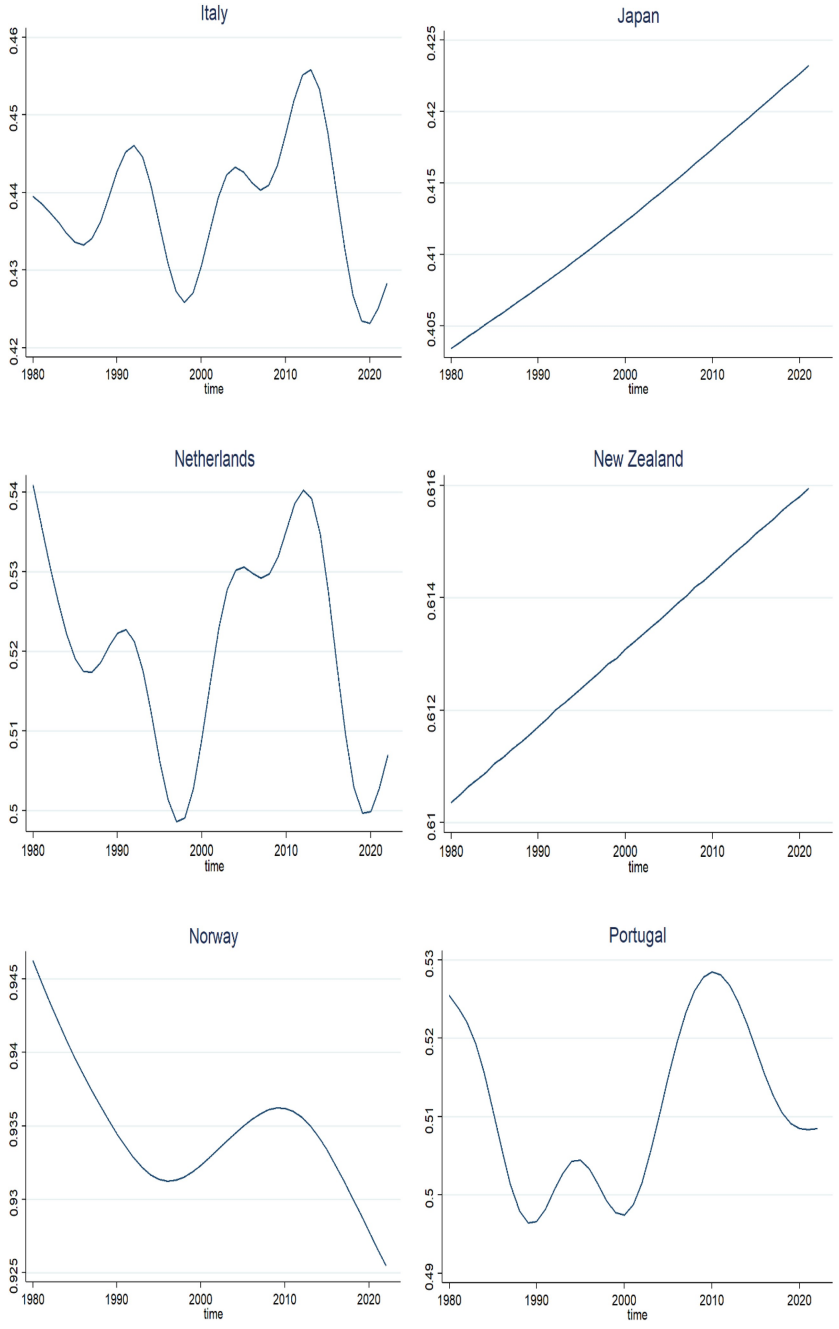

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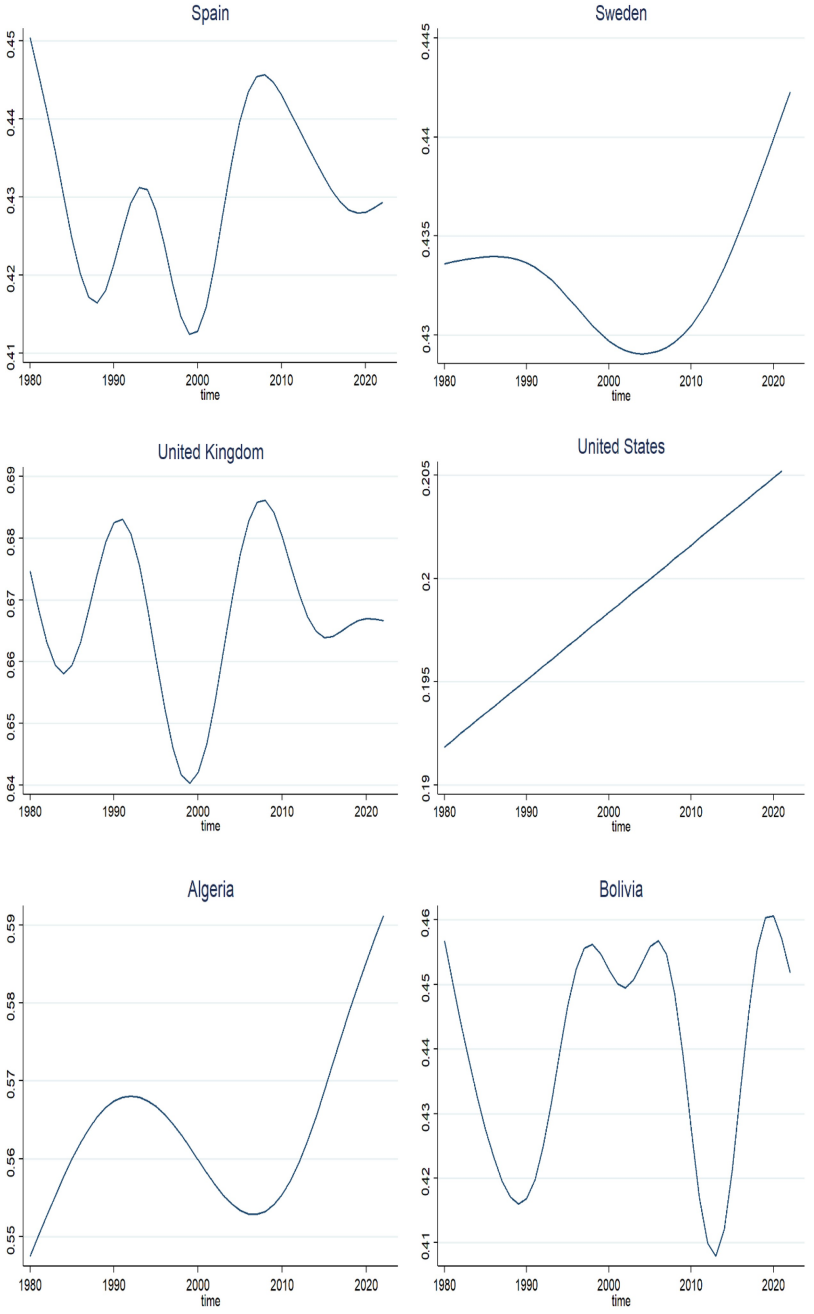

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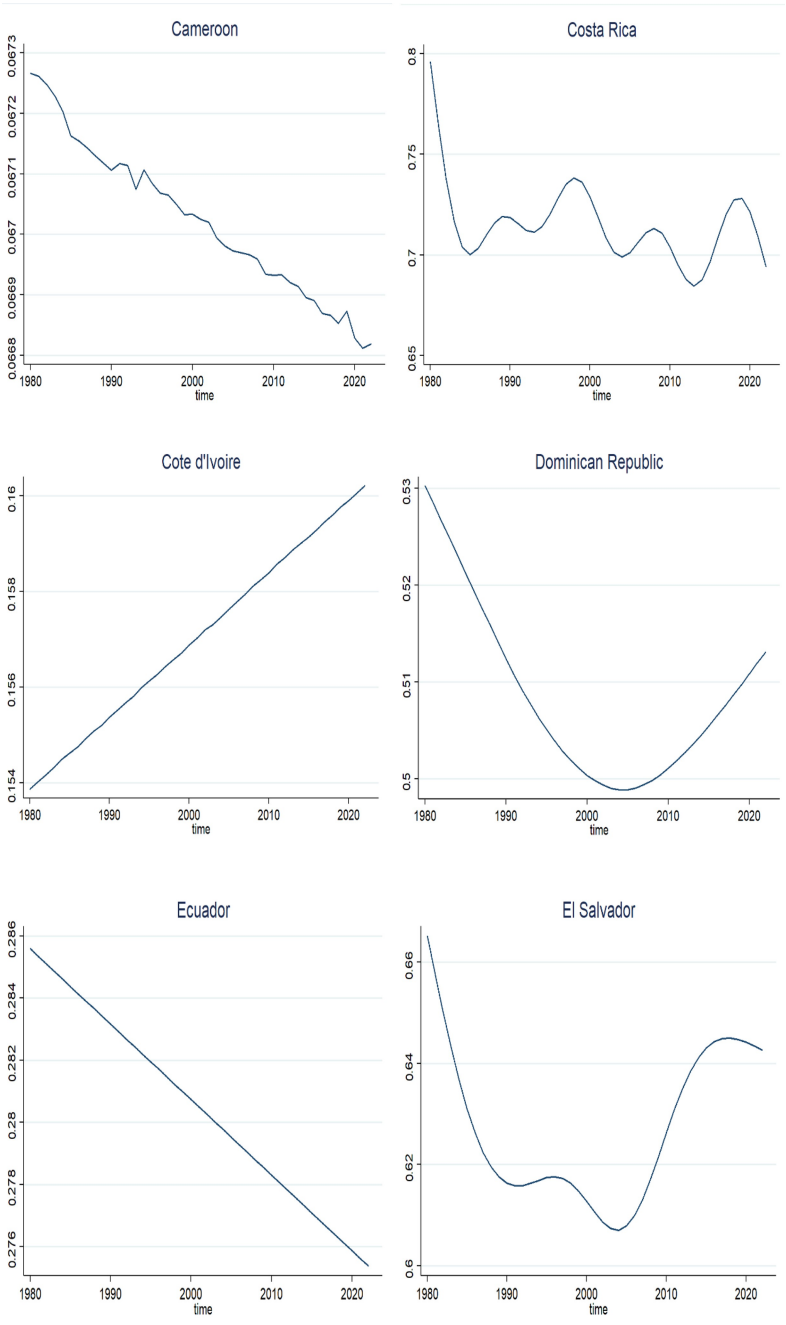

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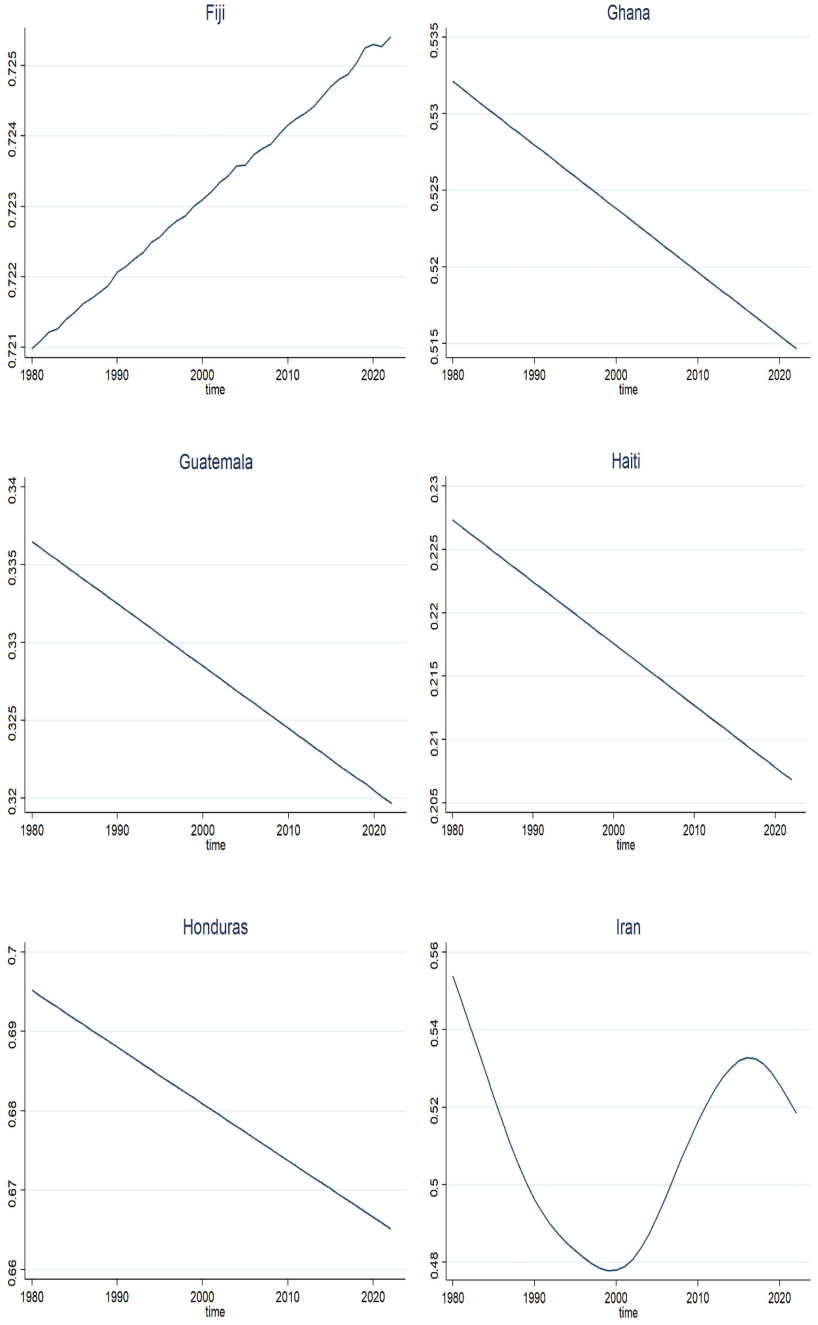

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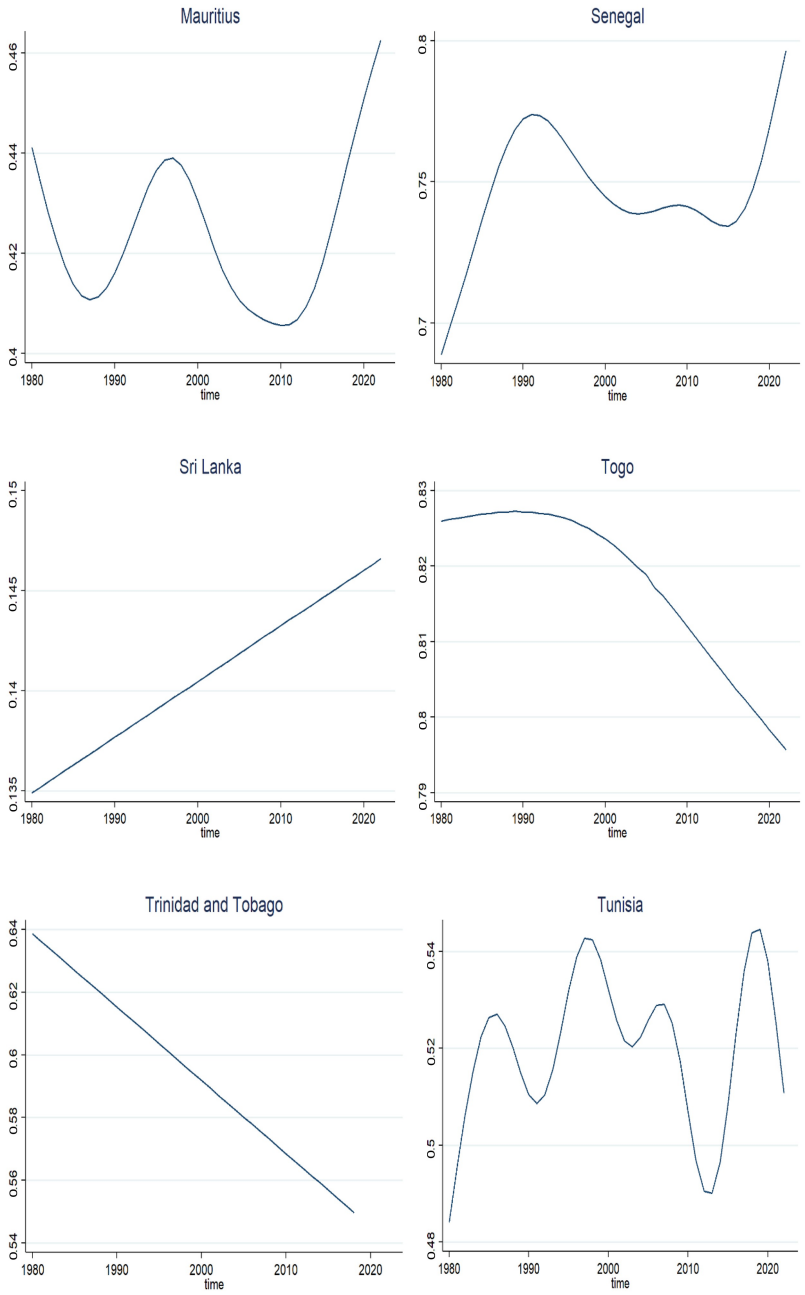

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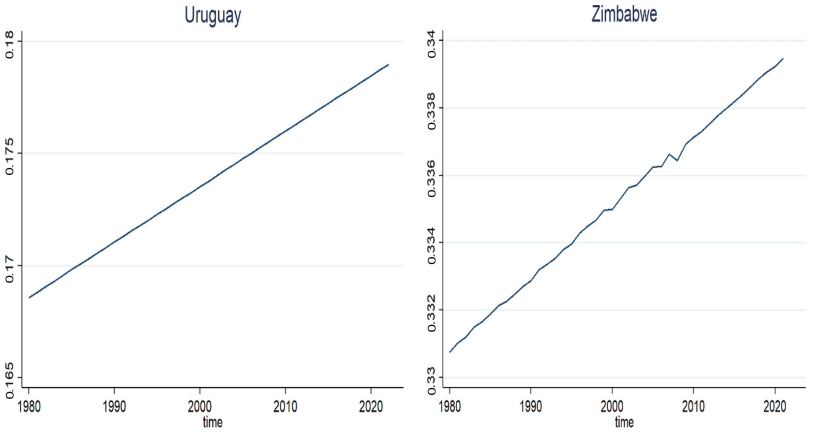

Figure 2. Continued

mortgage-backed securities, also facilitated the dispersion of risks within these countries' financial systems, thereby sharing the risks associated with consumer credit to some extent.

Following the outbreak of the subprime mortgage crisis, financial institutions in the UK, Greece, Norway, Portugal and Korea suffered significant losses, leading to a sharp contraction in the credit market. Many households encountered a substantial decline in property values, and subprime borrowers were unable to repay loans, facing the risk of foreclosure. In response, banks and other financial institutions became more cautious in issuing loans, resulting in a significant decline in consumer credit. This constrained consumption, particularly in the purchase of durable goods such as automobiles and nonessential expenditures like travel.

Moreover, as financial institutions focused on managing their risks, previous risk-sharing mechanisms became ineffective, leading to the concentration of risks on borrowing households. However, countries such as Japan, France and Canada do not exhibit this downward trend. Following the outbreak of the subprime mortgage crisis, the Japanese government proactively adjusted its industrial policies, continuously transforming traditional industries and promoting the diversification of automobile sales and distribution channels.

5.2 Heterogeneous groups of countries

We first categorize 68 countries worldwide into three groups: emerging market countries, developed countries and developing countries. Next, we examine the dynamics of specific regions in Southeast Asia, Latin America and One Belt One Road countries. Table 2 presents the time-varying consumption risk-sharing for these groups.

In emerging market countries, over half of the consumption risks remain unshared, with the average consumption risk-sharing level at 0.2167, lower than the global average [6]. This value aligns with Bai and Zhang (2012)'s average estimate of 0.25, which includes 0.37 for the period 1970—1986 and 0.13 for 1987—2004. Conversely, Argentina, Egypt, India, Mexico, Israel, Pakistan, South Africa and Turkey display linear time-varying patterns, as shown in Appendix E, suggesting that their risk-sharing status remains relatively stable. Notably, Argentina, Brazil, China, Indonesia and Pakistan share less than 10% of their consumption risks. The magnitude of consumption risk-sharing varies across countries and differs from the values presented in Table 2 and Appendix D. For instance, Appendix D indicates that China's

Table 2. Statistics of three groups of countries

Emerging market countries			Developed countries			Developing countries		
Country	Mean	Sd	Country	Mean	Sd	Country	Mean	Sd
All	0.2167	0.1570	All	0.5553	0.1820	All	0.4909	0.2291
Argentina	−0.0565	0.0015	Australia	0.6714	0.0100	Algeria	0.4983	0.0078
Brazil	0.0922	0.0110	Austria	0.6914	0.0053	Bolivia	0.6124	0.0134
Chile	0.2387	0.0025	Belgium	0.6585	0.0064	Cameroon	0.0708	0.0018
China	−0.0414	0.0099	Canada	0.4773	0.0054	Costa Rica	0.6666	0.0148
Colombia	0.4221	0.0073	Denmark	0.1348	0.0041	Côte d'Ivoire	0.2003	0.0002
Egypt	0.1823	0.0027	Finland	0.6342	0.0106	Dominican Republic	0.5642	0.0053
India	0.2416	0.0100	France	0.4217	0.0006	Ecuador	0.2804	0.0030
Indonesia	0.0612	0.0102	Germany	0.7151	0.0061	El Salvador	0.6710	0.0138
Israel	0.2338	0.0068	Greece	0.4470	0.0068	Ghana	0.5806	0.0037
Jordan	0.4530	0.0185	Italy	0.5181	0.0007	Guatemala	0.1183	0.0038
Korea	0.3329	0.0146	Japan	0.3655	0.0037	Haiti	0.1262	0.0060
Malaysia	0.2224	0.0074	Netherlands	0.5768	0.0103	Honduras	0.8046	0.0052
Mexico	0.1150	0.0041	New Zealand	0.6332	0.0004	Iran	0.5095	0.0240
Morocco	0.3021	0.0048	Norway	0.9050	0.0052	Mauritius	0.6362	0.0172
Pakistan	0.0153	0.0011	Portugal	0.5354	0.0057	Nicaragua	0.7220	0.0123
Peru	0.1571	0.0031	Spain	0.4587	0.0076	Senegal	0.7074	0.0253
Philippines	0.3274	0.0100	Sweden	0.6735	0.0081	Sri Lanka	0.4910	0.0088
South Africa	0.1800	0.0065	UK	0.7837	0.0090	Togo	0.8062	0.0092
Thailand	0.4781	0.0097	USA	0.2389	0.0030	Trinidad and Tobago	0.5511	0.0198
Turkey	0.4762	0.0007				Tunisia	0.6614	0.0089
Venezuela	0.1120	0.0001				Uruguay	0.1622	0.0023
						Zimbabwe	0.3622	0.0016

Note(s): Countries with no significant GAM estimates, such as Ireland, Switzerland, Fiji, Gabon, Jamaica and Paraguay, are excluded from the analysis. "Sd" denotes the unconditional standard deviation
Source(s): Authors' own work

consumption risk-sharing level is 12.53%, reflecting risk-sharing between China and the other 67 sample countries. In contrast, Table 2 shows China's level at −4.14%, indicating risk-sharing between China and the other 20 emerging market countries.

Table 2 also shows that most developed countries primarily share their consumption risks with other developed countries, with an average consumption risk-sharing value of 0.5553, exceeding the global average. The G-7 countries collectively share nearly half of consumption risks, with an average of 0.5029 during this period [7]. However, the consumption risk-sharing models of many developed countries exhibit relative instability, as evidenced by the smooth term Edf in the GAM estimation [8].

For developed countries, both Asdrubali and Kim (2004) and Cavaliere *et al*. (2008) indicate long-term risk-sharing among Germany, France, Italy, Spain, The Netherlands, Belgium, Portugal, Austria and the UK using a panel VAR model, though they do not provide specific levels of risk-sharing. Foresti and Napolitano (2022) argue that Italy shows a high level of risk-sharing, which is consistent with our findings. Their study shows that Portugal's risk-sharing is below 10%, whereas our analysis indicates a level of 53.54%. This discrepancy arises because Foresti and Napolitano include Italy, Portugal and the EMU as a collective unit in their sample, while our study considers Italy, Portugal and 19 other developed countries as separate entities.

The degree of consumption risk-sharing has decreased in more than half of the developed countries since the global financial crisis, as illustrated in Appendix E. This dynamic pattern

aligns with the findings of Antonakis and Scharler (2012). Specifically, the UK's risk-sharing pattern shows an initial increase followed by decreases in 1997 and 2008, maintaining relative stability overall (see Figure 6 in Antonakis and Scharler, 2012), which is consistent with our results presented in Figure E2 of the Appendix. It is important to note that Antonakis and Scharler (2012) focus on consumption risk-sharing among G-7 countries, while our sample includes 21 developed countries. In addition, we must differentiate the degree of risk-sharing between the UK and all countries from that between the UK and developed countries. According to Table D in the Appendix, the level of risk-sharing between the UK and all countries is 66.68%, whereas in Table 2, the level of risk-sharing between the UK and developed countries is 78.37%.

Conversely, consumption risk-sharing in Germany has been on an upward trajectory since the financial transition of the 1990s, driven by increased access to financing instruments for nonfinancial institutions, as detailed in Appendix E [9]. However, the global financial crisis led to a reduction in the level of risk-sharing in Germany. In the UK, risk-sharing has consistently increased since 2000, likely due to the Financial Services and Markets Act of 2000 [10]. This legislation enhances the efficiency of financial regulation, promotes resource allocation efficiency and improves residents' consumption risk-sharing.

Some developing countries, such as Côte d'Ivoire, Tunisia, Mauritius and Guatemala, effectively share consumption risks, as shown in Table 2. In contrast, other developing countries demonstrate relatively low risk-sharing. The average level of risk-sharing in developing countries is 0.4909, which is similar to the figures observed in developed countries. These observations largely align with the conclusions of Kose *et al.* (2009). Notably, on average, developing countries achieve higher levels of risk-sharing than emerging market countries. Furthermore, certain developing countries display linear time-varying patterns in risk-sharing, with the smooth term indicating relative stability in shared consumption risk within these countries.

In short, our analysis reveals significant diversity in consumption risk-sharing patterns among grouped countries. A detailed comparison between emerging market countries and developed and developing countries provides two key insights. First, developed and developing countries collectively share approximately half of the consumption risks, while emerging market countries account for only a quarter. This finding is consistent with Hevia and Servén (2018), who observe that the global risk-sharing gap has widened over time. Second, consumption risk-sharing patterns in emerging and developing countries display greater stability compared to those in developed countries. This highlights the marked differences in consumption risk-sharing mechanisms among these grouped countries.

Table 3 and Figures 3–5 illustrate the dynamics of consumption risk-sharing in specific regions. According to Table 3, the average degree of risk-sharing among four representative Southeast Asian countries is 38.03%. Thailand reveals the highest risk-sharing with other Southeast Asian countries, at 71.86%, while Indonesia has the lowest, at 12.02%. Figure 3 indicates that risk-sharing in Southeast Asia increased annually from 1980 to 2007, even during the 1997 East Asian financial crisis, suggesting effective regional risk allocation during economic globalization. However, after 2008, risk-sharing began to decline annually, likely due to the global financial crisis. Since 2020, the region has shown an upward trend in risk-sharing.

The average degree of risk-sharing in Latin America is 35.52%, with substantial dispersion across countries within the region. For example, Paraguay exhibits a high degree of risk-sharing at 82.17%, while another country has a very low degree at 3.33%. This suggests that the efficiency of consumption risk allocation among Latin American countries is relatively low. Figure 4 illustrates that the dynamics of risk-sharing in the region are complex, generally

Table 3. Three specific regions

Southeast Asia			Latin America			One Belt One Road		
Country	Mean	Sd	Country	Mean	Sd	Country	Mean	Sd
All	0.3803	0.2170	All	0.3552	0.2555	All	0.3470	0.1964
Indonesia	0.1202	0.0077	Mexico	−0.0092	0.0031	Iran	0.5383	0.0254
Philippines	0.3103	0.0104	Argentina	0.0333	0.0012	Indonesia	0.1745	0.0029
Thailand	0.7186	0.0104	Brazil	0.0799	0.0050	Malaysia	0.3112	0.0080
Malaysia	0.3720	0.0017	Chile	0.3822	0.0025	Philippines	0.2553	0.0097
			Colombia	0.4631	0.0084	Thailand	0.5567	0.0127
			Ecuador	0.3638	0.0021	Pakistan	0.0728	0.0044
			El Salvador	0.5787	0.0148	Egypt	0.2048	0.0019
			Guatemala	0.1485	0.0015	Turkey	0.3692	0.0138
			Honduras	0.6339	0.0156	Chile	0.2749	0.0071
			Paraguay	0.8217	0.0152	Fiji	0.7737	0.0014
			Dominican Republic	0.4115	0.0068	New Zealand	0.3877	0.0001
						Australia	0.5040	0.0052
						China	0.0829	0.0047

Note(s): "Sd" represents the unconditional standard deviation
Source(s): Authors' own work

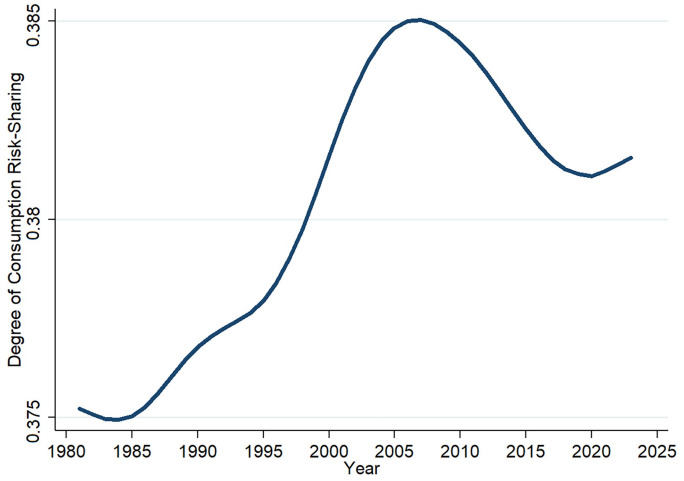

Figure 3. Southeast Asia time-varying consumption risk-sharing
Note(s): The vertical axis represents the degree of consumption risk-sharing, while the horizontal axis indicates the year
Source: Authors' own work

fluctuating around 35.50%. Overall, consumption risk-sharing has been lower after 2000 compared to before 2000, indicating a decline in the degree of risk-sharing during economic globalization.

The average degree of consumption risk-sharing among countries along the Belt and Road is 34.70%, which is lower than that in Southeast Asia and Latin America. China's risk-sharing with these countries is only 8.29%, while countries such as Fiji, Thailand, Iran and

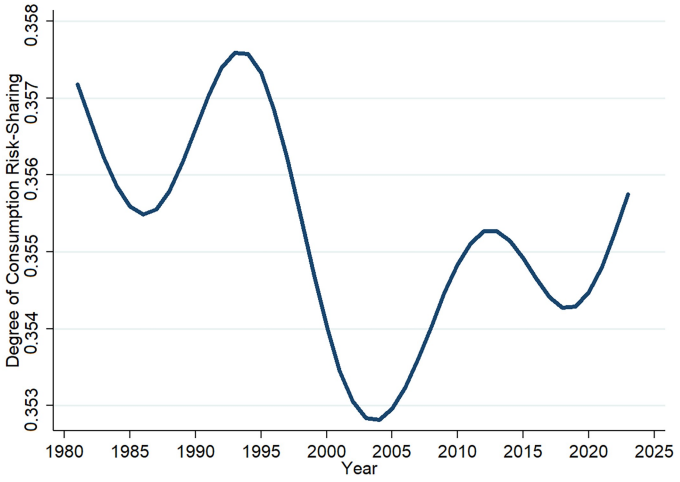

Figure 4. Latin America time-varying consumption risk-sharing
Note(s): The vertical axis represents the degree of consumption risk-sharing, while the horizontal axis indicates the year
Source: Authors' own work

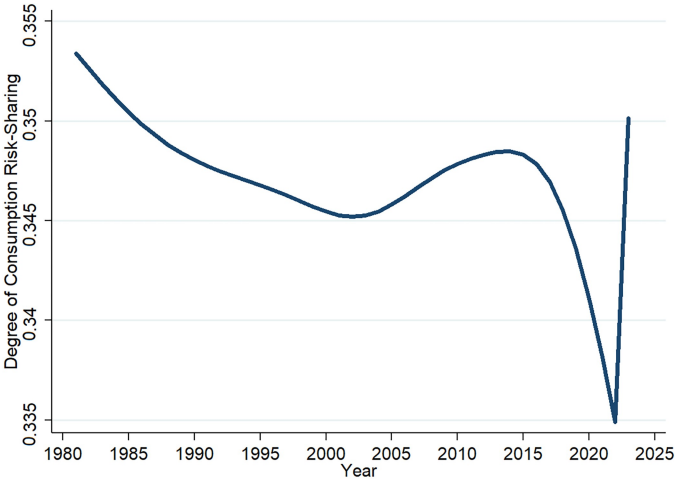

Figure 5. One Belt One Road time-varying consumption risk-sharing
Note(s): The vertical axis represents the degree of consumption risk-sharing, while the horizontal axis indicates the year
Source: Authors' own work

Australia share more than 50% of the consumption risk from this region. As illustrated in Figure 5, risk-sharing in the Belt and Road region has been declining since 1980, decreasing to 34.52% by 2002. The Chinese government launched the Belt and Road Initiative in September and October 2013; however, since 2014, risk-sharing among these countries has

continued to decline rapidly, reflecting the potential imbalanced economic impact of the initiative.

In summary, the degree of consumption risk-sharing in Southeast Asia, Latin America and countries along the Belt and Road is below the global average of 39.04%. Economic integration within these regions has not effectively promoted risk-sharing.

5.3 Robustness checks

To support the findings presented in the preceding sections, we conduct a series of robustness checks. Firstly, we perform post-estimation residual tests, including the Shapiro–Wilk and Shapiro–Francia tests for normality (N-test) and the portmanteau test for white noise (Q-test). If the GAM specification is correct, the residuals should show no serial correlation and be normally distributed. Table 4 presents the results of these tests for 62 sample countries (excluding 6 with insignificant coefficient estimates). The results confirm that the residuals are free from serial correlation and are normally distributed across these countries.

Second, each country's sample data comprises 44 data points. When using the generalized cross-validation (GCV) method for estimation, small sample sizes may increase the risk of overfitting (Reiss and Ogden, 2009; Wood, 2017). To enhance the reliability of our findings, we use the REML method. In addition, we examine two representative countries, the USA and China. Table 5 presents the estimation results using these methods. The results are consistent for both countries, regardless of the method used. Furthermore, the Q-test and

Table 4. Residual analysis

Emerging market countries			Developed countries			Developing countries		
Country	Q-test	N-test	Country	Q-test	N-test	Country	Q-test	N-test
Argentina	0.5601	0.4757	Australia	0.1203	0.1585	Algeria	0.5406	0.5208
Brazil	0.3967	0.1825	Austria	0.6546	0.6332	Bolivia	0.9267	0.0370
Chile	0.7458	0.0036	Belgium	0.4729	0.3142	Cameroon	0.8463	0.9717
China	0.6294	0.8468	Canada	0.6747	0.0003	Costa Rica	0.3902	0.9826
Colombia	0.5531	0.8670	Denmark	0.5252	0.3145	Côte d'Ivoire	0.5072	0.8780
Egypt	0.8049	0.1843	Finland	0.2565	0.5630	Dominican Republic	0.8753	0.0042
India	0.0656	0.2935	France	0.0658	0.4469	Ecuador	0.9167	0.0006
Indonesia	0.4875	0.0027	Germany	0.8036	0.1285	El Salvador	0.5428	0.6335
Israel	0.9684	0.0018	Greece	0.8610	0.2654	Ghana	0.5226	0.6750
Jordan	0.0036	0.5716	Italy	0.2326	0.3415	Guatemala	0.9098	0.9914
Korea	0.3308	0.5992	Japan	0.2260	0.2084	Haiti	0.4408	0.0727
Malaysia	0.8892	0.4801	Netherlands	0.0464	0.9568	Honduras	0.1421	0.0180
Mexico	0.6606	0.1148	New Zealand	0.2446	0.0003	Iran	0.9122	0.8322
Morocco	0.7231	0.0652	Norway	0.4529	0.1246	Mauritius	0.0893	0.0567
Pakistan	0.2375	0.1506	Portugal	0.9090	0.3853	Nicaragua	0.1544	0.2404
Peru	0.4984	0.5156	Spain	0.0277	0.9117	Senegal	0.4475	0.0739
Philippines	0.4729	0.1437	Sweden	0.9589	0.0003	Sri Lanka	0.0000	0.5510
South Africa	0.0241	0.4944	UK	0.0479	0.5213	Togo	0.0513	0.0991
Thailand	0.4537	0.4777	USA	0.9759	0.0004	Trinidad and Tobago	0.7383	0.0027
Turkey	0.7338	0.1750				Tunisia	0.5888	0.8371
Venezuela	0.8509	0.0049				Uruguay	0.0168	0.9442
						Zimbabwe	0.9753	0.0000

Note(s): Countries without significant GAM estimations, such as Ireland, Switzerland, Fiji, Gabon, Jamaica and Paraguay, are excluded from the analysis. "Sd" denotes the unconditional standard deviation. The Q-test is a portmanteau test for white noise, while the N-test denotes the Shapiro–Wilk and Shapiro–Francia tests for normality

Source(s): Authors' own work

Table 5. GCV method and REML method

	GCV		REML	
Variables	I	II	III	IV
$\Delta y_{i,t} - \Delta y_t^*$	0.801*** (6.069)	0.761*** (4.910)	0.801*** (6.069)	0.761*** (4.910)
Cons.	0.002 (0.988)	0.003 (1.164)	0.002 (0.988)	0.003 (1.164)
Adj R^2	0.550	0.409	0.550	0.409
GCV	2.572e-04	2.942e-04		
REML			−105.69	−103.17
Q-test	0.7028	0.9759	0.7028	0.9759
N-test	0.1582	0.0004	0.1582	0.0004

Note(s): "I" and "III" represent U.S. data from the sample of all countries, while "II" and "IV" represent U.S. data from the group of developed countries. The Q-test denotes the portmanteau test for white noise, and the N-test represents the Shapiro–Wilk and Shapiro–Francia tests for normality. "Adj R^2" indicates the model's goodness of fit, and "GCV" stands for generalized cross-validation, used to evaluate model predictions. *** denotes the 99% confidence level, ** denotes the 95% confidence level and * denotes the 90% confidence level
Source(s): Authors' own work

N-test results confirm that the residual sequences are satisfactory. Therefore, the GCV method is reliable for estimation in this context.

Third, the GAM approach can use the Gaussian process smooths. Therefore, we compare the estimation results of the Gaussian process smooths with the spline smooths in Table 6. For the USA, the results using Gaussian process smooths are identical to those using spline smooths. For China, although there are slight differences between the two methods, the overall results remain largely consistent. In addition, the residuals from both methods demonstrate white noise stability and a lack of autocorrelation. Consequently, the spline methods for estimation under our GAM approach are reliable.

Fourth, while the GAM is suitable for estimation, it is essential to investigate whether simpler models, such as linear models or other models would yield similar results given the type of data set. To highlight the advantages of the GAM and the importance of incorporating both time-varying parameters and nonparametric specificity, we conduct analysis of variance (ANOVA) comparisons with alternative models. The ANOVA results are presented in Tables 7 and 8. Table 7 compares the simple linear model with the GAM, showing $Pr(>F) < 0.05$, which indicates that the GAM significantly enhances the explanatory power of data variability compared to the linear model. Table 8 compares the dynamic generalized linear model (DGLM, as suggested by West *et al.*, 1985) with the GAM, also resulting in $Pr(>F) < 0.05$. Therefore, the estimation of the GAM outperforms that of the DGLM for the given data set. This analysis underscores the GAM's ability to capture both temporal changes and underlying distributions.

Fifth, Table 9 presents the estimation results using the State Space Model (SSM) with the Kalman filter method. Despite the highly significant coefficient estimates in the state equation in all cases, the results from this method differ substantially from those obtained using the GAM. We also compare the residual test results after SSM and GAM estimation. In all cases, the residuals from the Kalman filter method show autocorrelation, rejecting the null hypothesis at the 0.05 level, and are not normally distributed. In contrast, the GAM residuals are white noise, stationary and show no autocorrelation for both the USA and China. These findings indicate that regression estimation using the Kalman filter method results in residual issues.

Table 6. Gaussian process smooths and splines smooths

	USA				China			
Variables	I	II	III	IV	I	II	III	IV
$\Delta y_{i,t} - \Delta y_t^*$	0.761*** (4.910)	0.761*** (4.910)	0.801*** (6.069)	0.801*** (6.069)	1.040*** (8.448)	1.041*** (8.443)	0.938*** (9.233)	0.875*** (8.574)
Cons.	0.003 (1.164)	0.003 (1.164)	0.002 (0.988)	0.002 (0.988)	−0.010 (−1.647)	−0.010 (1.650)	−0.006 (−1.200)	−0.004 (−0.765)
Adj R^2	0.409	0.409	0.550	0.550	0.653	0.653	0.691	0.639
GCV	2.492e-04	2.942e-04	2.572e-04	2.572e-04	1.033e-03	1.036e-03	8.834e-04	9.101e-04
Q-test	0.976	0.976	0.703	0.703	0.639	0.629	0.102	0.626
N-test	0.000	0.000	0.158	0.158	0.835	0.847	0.484	0.535

Note(s): "I" and "II" represent Gaussian process smooths, while "III" and "IV" represent spline smooths. For the Q-test, the null hypothesis is the absence of serial autocorrelation; for the N-test, the null hypothesis is that the data conform to a normal distribution. A p-value below 0.05 indicates the rejection of the null hypothesis. Values in parentheses are t-values
Source(s): Authors' own work

Table 7. Linear model and GAM

Variables	I	II	III	IV
$\Delta y_{i,t} - \Delta y_t^*$	0.801*** (6.069)	0.801*** (6.069)	0.761*** (4.910)	0.761*** (4.910)
Cons.	0.655 (1.561)	0.002 (0.988)	0.495 (1.135)	0.003 (1.164)
Adj R^2	0.572	0.550	0.438	0.409
F-statistic	0.108		0.433	
Pr(>F)	1.137e-06		1.601e-06	

Note(s): "I" and "III" represent linear models, while "II" and "IV" represent GAMs. Values in parentheses are *t*-values. *** denotes the 99% confidence level, ** denotes the 95% confidence level and * denotes the 90% confidence level. Pr(>F) represents the *p*-value associated with the F-statistic. A Pr(>F) value below 0.05 suggests significant differences among the group means
Source(s): Authors' own work

Table 8. DGLM And GAM

Variables	I	II	III	IV
$\Delta y_{i,t} - \Delta y_t^*$	0.801*** (6.069)	0.801*** (6.069)	0.761*** (4.910)	0.761*** (4.910)
Cons.	0.655 (1.561)	0.002 (0.988)	0.495 (1.135)	0.003 (1.164)
Adj R^2	0.572	0.550	0.438	0.409
AIC	−226.19		−220.55	
F-statistic	0.108		0.433	
Pr(>F)	1.137e-06		1.601e-06	

Note(s): "I" and "III" represent dynamic generalized linear models (DGLMs), while "II" and "IV" represent GAMs. Values in parentheses are *t*-values. *** indicates the 99% confidence level, ** indicates the 95% confidence level and * indicates the 90% confidence level. Pr(>F) denotes the p-value associated with the F-statistic. A Pr(>F) value below 0.05 suggests significant differences in the means among the groups
Source(s): Authors' own work

Compared to the Kalman filter, the Unscented Kalman Filter (UKF) is a powerful tool for state estimation in nonlinear systems. The UKF's performance hinges on the careful tuning of parameters such as the scaling parameter, process noise covariance and observation noise covariance. These parameters are critical, and their optimal values can vary based on the specific application and system dynamics. Without prior experience or empirical data to guide the tuning, there is a risk of misconfiguration, which can lead to suboptimal performance or filter divergence. Therefore, we omit the UKF method from our analysis.

Finally, we examine the issue of group dynamics. For this purpose, we select DTW as the clustering method, as it effectively handles nonlinear variations in time series data. DTW measures the similarity between two time series, such as consumption and output, by allowing for nonlinear time alignment. This method addresses issues related to inconsistent lengths and temporal distortions, thereby automatically aligning time series even when delays or distortions occur during certain periods.

Figures 6 and 7 depict the visual alignment paths for the USA and China, respectively. These paths show how each point in the consumption change aligns with the corresponding points in the output change. The alignment path for the USA is convoluted in certain years, indicating that consumption and output changes are not synchronized during those periods. In contrast, China's alignment path is mostly linear throughout the years, suggesting that consumption and output changes are synchronized or display similar temporal rhythms.

Table 9. State space model with Kalman filter method

	USA				China			
Variables	I	II	III	IV	I	II	III	IV
$\Delta y_{i,t} - \Delta y_t^*$	−0.060 (—)	0.761*** (4.910)	−0.060 (—)	0.801*** (6.069)	−0.060 (—)	1.041*** (8.443)	−0.060 (—)	0.875*** (8.574)
Cons.	0.176 (—)	0.003 (1.164)	0.176 (—)	0.002 (0.988)	0.176 (—)	−0.010 (1.650)	0.176 (—)	−0.004 (−0.765)
μ_{t-1}	0.791*** (8.120)		0.966*** (22.470)		0.957*** (16.110)		0.915*** (14.760)	
Q-test	0.000	0.976	0.000	0.703	0.000	0.629	0.000	0.626
N-tset	0.268	0.000	0.009	0.158	0.287	0.847	0.004	0.535

Note(s): In the Kalman filter method, the observation equation is $\Delta c_{i,t} - \Delta c_t^* = \mu_t + \beta(\Delta y_{i,t} - \Delta y_t^*) + \varepsilon_t$, and the state equation is $\mu_{t+1} = \mu_t + \eta_t$. "I" and "II" denote state-space models (SSMs), while "III" and "IV" denote GAMs. For the Q-test, the null hypothesis is the absence of serial autocorrelation; for the N-test, the null hypothesis is that the data conform to a normal distribution. A p-value below 0.05 indicates rejection of the null hypothesis. Values in parentheses are t-values; a hyphen (—) indicates no reported value
Source(s): Authors' own work

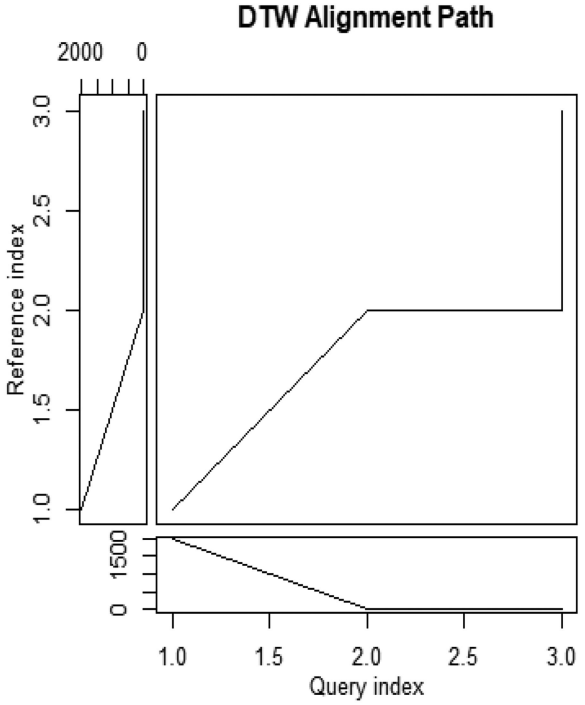

Figure 6. DTW alignment path for the USA

Note(s): The query index represents the position of each point in the time series of consumption changes, whereas the reference index corresponds to the position of each point in the time series of output changes. US data are derived from a group of developed countries

Source: Authors' own work

It is important to note that a straight alignment path indicates temporal synchronization. However, this does not imply that the consumption and output time series for each country are numerically correlated. Time alignment refers to the one-to-one correspondence of points at each time point.

5.4 Discussion

A substantial body of research explains incomplete risk-sharing. Bai and Zhang (2012) and Hevia and Servén (2018) argue that financial markets exhibit frictions and financial contracts have imperfections. These factors, combined with limitations in the commitment and execution of such contracts, contribute to incomplete risk-sharing. For example, many Latin American countries defaulted on sovereign debts in the 1980s, hindering their ability to borrow abroad and impeding the sharing of consumption risk. Bai and Zhang (2012) highlight that while debt defaults are rare in OECD countries, they are common in developing countries, particularly those classified as emerging market countries. Defaulting countries are more likely to face higher financing costs, severe fiscal pressures and slower economic growth than nondefaulting countries.

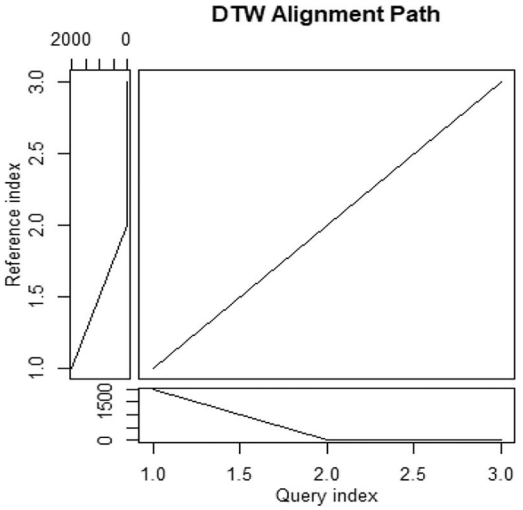

Figure 7. DTW alignment path for China

Note(s): The query index indicates the position of each point in the time series of consumption changes, while the reference index reflects the position of each point in the time series of output changes. China's data are obtained from a group of emerging market countries

Source: Authors' own work

It is essential to highlight that the liberalization of capital accounts or unrestricted capital flows is not the primary factor behind reduced risk-sharing. Kose *et al.* (2009) contend that even with capital account liberalization, risk-sharing in developing and emerging market countries remains relatively limited. Following China's accession to the WTO (2001—2008), the country pursued a cautious approach to capital account openness, primarily encouraging long-term capital movements. However, our study identifies a consistent decline in China's level of risk-sharing. Therefore, it is critical to distinguish between the effects of short-term and long-term capital flows in this context.

Many scholars observe that long-term risk-sharing exceeds short-term risk-sharing, a phenomenon supported by empirical evidence. Flood *et al.* (2012) argue that financial globalization does not enhance risk-sharing, attributing the improvement to the convergence of long-term consumption growth across countries rather than to the synchrony of short-term consumption fluctuations. Baxter (2012) demonstrates that shocks at low and medium frequencies facilitate risk-sharing to a greater extent, indicating a higher degree of long-term risk-sharing. This finding contradicts theoretical expectations, which suggest that short-term or high-frequency income shocks should be more dispersed compared to long-term or low-frequency shocks.

A crucial distinction should be made between long-term and short-term risk-sharing and the time-varying risk-sharing examined in our study. High-frequency shocks, such as short-run fluctuations in crop yields, affect short-term risk-sharing, whereas low-frequency shocks, like long-run technological progress, influence long-term risk-sharing (Baxter, 2012). Therefore, the time-varying consumption risk-sharing investigated in our study contributes to the discussion on dynamic risk-sharing. Moreover, while Cavaliere *et al.* (2008), Antonakis and Scharler (2012) and Everaert and Pozzi (2021) use multiple methods to

examine dynamic risk-sharing, their analyses are limited to a small group of industrialized countries.

Finally, we propose three potential research directions by expanding our findings. First, a deeper analysis is required to understand the causes of the decline in global risk-sharing, particularly in the post-COVID-19 era characterized by ongoing trade tensions. Assessing the impact of the pandemic and trade wars on consumption risk-sharing in these new circumstances would be highly meaningful.

Second, future research should investigate whether the issuance of central bank digital currencies (CBDCs) will cause significant fluctuations in nominal exchange rates, thereby affecting resident consumption risk-sharing. In addition, the introduction of CBDCs has triggered demand for safe-haven assets, which may influence consumption risk-sharing.

Third, the impact of regional trade agreements on risk-sharing should be evaluated. For example, China's Belt and Road Initiative, launched in 2013, has promoted increased interactions in trade, foreign direct investment and bank lending among countries along the route, potentially influencing consumption risk-sharing among residents. Exploring whether these agreements facilitate more effective risk-sharing is highly relevant.

6. Conclusion

This study investigates time-varying consumption risk-sharing patterns across 68 representative countries from 1980 to 2023 using the GAM. During this period, global patterns display increasing diversity. Notably, developed and developing countries share approximately half of the consumption risks in the era of economic globalization, whereas emerging market countries share less than a quarter. The GAM estimation manifests that most emerging market countries and developing countries show a linear time-varying pattern, indicating relatively stable dynamic risk-sharing throughout economic globalization. In contrast, developed countries show unstable patterns, despite some achieving high levels of risk-sharing. Regional analysis further suggests that economic integration has not enhanced consumption risk-sharing.

Of utmost significance, despite the advancements in economic globalization, risk-sharing remains minimal and incomplete due to inefficient risk allocation. This issue is particularly pronounced after the financial crisis, during which many developed countries saw a decrease in risk-sharing. In contrast, certain emerging market countries maintained consistent levels of risk-sharing. Notably, Southeast Asian countries experienced a decline in risk-sharing following the 1998 financial crisis. In addition, the level of global consumption risk-sharing also decreased during the COVID-19 pandemic from 2020 to 2022.

This research underscores the vital role of governments in improving trade and financial cooperation. Such efforts are essential to reduce the consumption risks for residents in the age of economic globalization. This imperative stems from the growing interdependence of national economies, which necessitates a more collaborative and innovative mechanism for managing macroeconomic risks.

This novel mechanism can be achieved through several strategic initiatives, including the elimination of bilateral trade frictions, the reduction of political and economic uncertainties to protect investors' rights, the establishment of a global disaster early warning and response mechanism to mitigate the impact of natural disasters on consumption and the leveraging of big data and artificial intelligence technologies to proactively address potential economic risks. Furthermore, significant potential exists for economic policy coordination among diverse groups of countries – developed, developing and emerging market countries – to enhance the efficiency of consumption risk allocation.

Notes

1 Artis and Hoffmann (2012) investigate the time profile of consumption risk-sharing using a regression model, which is essentially a linear regression with OLS estimation. They perform multiple differencing on the data in their model. However, this method may lead to a substantial loss of observations and could reduce the accuracy of the estimates due to data manipulation.

2 Wood (2000; 2017) extends the structure of the basic GAM by introducing a flexible specification of the response of dependent variables to covariates. The enhanced GAM prioritizes the use of "smooth functions" to assess the relationship between dependent and independent variables, thereby moving away from complex parametric relationships.

3 The estimation results of the GAM, which highlight deviations from the average coefficient, are presented in Appendices B and C. Appendix B illustrates the smoothing functions used for the time variable in the GAM estimation, along with the fitting results for the smoothing terms. Appendix C presents the overall estimation results of the GAM.

4 Appendix D provides statistics on time-varying risk-sharing for each country.

5 The implementation of sum-to-zero constraints precisely specifies that the straight line must pass through zero, resulting in a zero-width point in the interval. This visualization shows a straight line with residual bands that narrow to zero for countries demonstrating such a relationship (Wood, 2017). In addition, the application of sum-to-zero constraints effectively resolves the identification problem associated with the penalized piecewise linear basis used to represent each smooth function.

6 We calculate the unweighted average change in output and consumption for emerging market countries. Specifically, consumption risk-sharing for each country is defined as the risk-sharing between that country and the entire group of emerging market countries.

7 The countries included are the United States (0.2389), Japan (0.3655), the United Kingdom (0.7837), Germany (0.7151), France (0.4217), Italy (0.5181) and Canada (0.4773).

8 For further exploration, readers can refer to the point estimates for these countries in Appendix C. The significant results for the time-varying coefficients indicate the presence of a time-varying effect. A higher "Edf" value suggests that the smoothing term captures more nonlinear features, while a lower "Edf" value indicates that the smoothing term is closer to linearity. If the "Edf" is near 1, the smoothing term approximates a linear relationship.

9 Since the 1990s, German authorities have initiated a comprehensive transformation of the financial system. For example, the business model shifted from relationship-based housekeeping banks to distance-funded transaction and investment banks.

10 In the 1990s, risk-sharing in the UK declined, as detailed in Appendix E. This decline may be attributed to the establishment of the Financial Services Authority, a highly centralized single regulator that narrowed the business scope of financial intermediaries.

References

Ambrus, A., Mobius, M. and Szeidl, A. (2014), "Consumption risk-sharing in social networks", *American Economic Review*, Vol. 104 No. 1, pp. 149-182, doi: 10.1257/aer.104.1.149.

Antonakis, N. and Scharler, J. (2012), "Has globalization improved international risk sharing?", *International Finance*, Vol. 15 No. 2, pp. 251-266, doi: 10.1111/j.1468-2362.2012.01304.x.

Artis, M.J. and Hoffmann, M. (2008), "Financial globalization, international business cycles, and consumption risk sharing", *The Scandinavian Journal of Economics*, Vol. 110 No. 3, pp. 447-471, doi: 10.1111/j.1467-9442.2008.00546.x.

Artis, M.J. and Hoffmann, M. (2012), "The home bias, capital income flows and improved long-term consumption risk sharing between industrialized countries", *International Finance*, Vol. 14 No. 3, pp. 481-505, doi: 10.1111/j.1468-2362.2011.01293.x.

Asdrubali, P. and Kim, S. (2004), "Dynamic risk sharing in the United States and Europe", *Journal of Monetary Economics*, Vol. 51 No. 4, pp. 809-836, doi: 10.1016/j.jmoneco.2003.09.002.

Asdrubali, P., Kim, S., Pericoli, F.M. and Poncela, P. (2023), "Risk sharing channels in OECD countries: a heterogeneous panel VAR approach", *Journal of International Money and Finance*, Vol. 131, p. 102804, doi: 10.1016/j.jimonfin.2023.102804.

Asdrubali, P., Sørensen, B.E. and Yosha, O. (1996), "Channels of interstate risk sharing: United States 1963—1990", *The Quarterly Journal of Economics*, Vol. 111 No. 4, pp. 1081-1110, doi: 10.2307/2946708.

Bai, Y. and Zhang, J. (2012), "Financial integration and international risk sharing", *Journal of International Economics*, Vol. 86 No. 1, pp. 17-32, doi: 10.1016/j.jinteco.2011.08.009.

Baxter, M. (2012), "International risk-sharing in the short run and in the long run", *Canadian Journal of Economics*, Vol. 45 No. 2, pp. 376-393, doi: 10.1111/j.1540-5982.2012.01699.x.

Bénétrix, A.S. (2015), "International risk sharing and the Irish economy", *The Economic and Social Review*, Vol. 46 No. 1, pp. 29-49, available at: www.esr.ie/article/view/290/102

Cavaliere, G., Fanelli, L. and Gardini, A. (2008), "International dynamic risk sharing", *Journal of Applied Econometrics*, Vol. 23 No. 1, pp. 1-16, doi: 10.1002/jae.968.

Cimadomo, J., Ciminelli, G., Furuna, O. and Giuliodori, M. (2020), "Private and public risk sharing in the euro area", *European Economic Review*, Vol. 121, p. 103347, doi: 10.1016/j.euroecorev.2019.103347.

Engle, R.F. and Sheppard, K. (2001), "Theoretical and empirical properties of dynamic conditional correlation multivariate GARCH", *NBER Working Paper*, No. 8554, doi: 10.3386/w8554.

Everaert, G. and Pozzi, L. (2021), "Encompassing measures of international consumption risk sharing and their link with trade and financial globalization", *Journal of Applied Econometrics*, Vol. 37 No. 2, pp. 433-449, doi: 10.1002/jae.2876.

Feenstra, R.C., Inklaar, R. and Timmer, M.P. (2015), "The next generation of the Penn World Table", *American Economic Review*, Vol. 105 No. 10, pp. 3150-3182, doi: 10.1257/aer.20130954.

Flood, R.P., Marion, N.P. and Matsumoto, A. (2012), "International risk sharing during the globalization era", *Canadian Journal of Economics/Revue Canadienne D'économique*, Vol. 45 No. 2, pp. 394-416, doi: 10.1111/j.1540-5982.2012.01700.x.

Foresti, P. and Napolitano, O. (2022), "Risk sharing in the EMU: a time-varying perspective", *Journal of Common Market and Studies*, Vol. 60 No. 2, pp. 319-336, doi: 10.1111/jcms.13217.

Fuleky, P., Ventura, L. and Zhao, Q.X. (2015), "International risk sharing in the short and in the long run under country heterogeneity", *International Journal of Finance and Economics*, Vol. 20 No. 4, pp. 374-384, doi: 10.1002/ijfe.1524.

Hastie, T.J. and Tibshirani, R.J. (1986), "Generalized additive models", *Statistical Science*, Vol. 1 No. 3, pp. 297-318, doi: 10.1214/ss/1177013604.

Hastie, T.J. and Tibshirani, R.J. (1993), "Varying-coefficient models", *Journal of the Royal Statistical Society: Series B*, Vol. 55 No. 4, pp. 757-796, doi: 10.1111/j.2517-6161.1993.tb01939.x.

Hevia, C. and Servén, L. (2018), "Assessing the degree of international consumption risk sharing", *Journal of Development Economics*, Vol. 134, pp. 176-190, doi: 10.1016/j.jdeveco.2018.05.011.

Hu, L.X., Tang, Y.M. and Xu, Q.F. (2023), "Generalized varying-coefficient additive model for locally stationary time series", *Journal of Statistical Computation and Simulation*, Vol. 93 No. 8, pp. 1337-1354, doi: 10.1080/00949655.2022.2135708.

Kose, M.A., Prasad, E.S. and Terrones, M.E. (2009), "Does financial globalization promote risk sharing?", *Journal of Development Economics*, Vol. 89 No. 2, pp. 258-270, doi: 10.1016/j.jdeveco.2008.09.001.

Labhard, V. and Sawicki, M. (2006), "International and intranational consumption risk sharing: the evidence for the United Kingdom and OECD", Bank of England Working Paper, No. 302. RUL, available at: www.bankofengland.co.uk/-/media/boe/files/working-paper/2006/international-and-intrantional-consumption-risk-sharing.pdf

Lane, P.R. and Milesi-Ferretti, G.M. (2018), "The external wealth of nations revisited: international financial integration in the aftermath of the global financial crisis", *IMF Economic Review*, Vol. 66 No. 1, pp. 189-222, doi: 10.1057/s41308-017-0048-y.

Leibrecht, M. and Scharler, J. (2008), "Reconsidering consumption risk sharing among OECD countries: some evidence based on panel cointegration", *Open Economies Review*, Vol. 19 No. 4, pp. 493-505, doi: 10.1007/s11079-007-9052-6.

Lewis, K.K. (1996), "What can explain the apparent lack of international consumption risk sharing?", *Journal of Political Economy*, Vol. 104 No. 2, pp. 267-297, doi: 10.1086/262025.

Malik, S. (2015), "Financial-integration thresholds for consumption risk-sharing", *International Review of Economics and Finance*, Vol. 38, pp. 73-93, doi: 10.1016/j.iref.2015.01.004.

Obstfeld, M. (1994), "Are industrial-country consumption risks globally diversified?", in Leiderman, L. and Razin, A. (Eds), *Capital Mobility: The Impact on Consumption, Investment and Growth*, Cambridge University Press, Cambridge, pp. 13-44. RUL, available at: www.cambridge.org/gb/universitypress/subjects/economics/macroeconomics-and-monetary-economics/capital-mobility-impact-consumption-investment-and-growth?format=HB&isbn=9780521454384

Reiss, P.T. and Ogden, R.T. (2009), "Smoothing parameter selection for a class of semiparametric linear models", *Journal of the Royal Statistical Society Series B: Statistical Methodology*, Vol. 71 No. 2, pp. 505-523, doi: 10.1111/j.1467-9868.2008.00695.x.

Rogoff, K. and Obstfeld, M. (1996), *Foundations of International Macroeconomics*, MIT Press. RUL, available at: https://mitpress.mit.edu/9780262150477

Ruppert, D., Wand, W.P. and Carroll, R.J. (2003), *Semiparametric Regression*, Cambridge University Press, Cambridge, doi: 10.1017/CBO9780511755453.

Sørensen, B.E. and Yosha, O. (1998), "International risk sharing and european monetary unification", *Journal of International Economics*, Vol. 45 No. 2, pp. 211-238, doi: 10.1016/S0022-1996(98)00033-6.

Stengos, T. and Zacharias, E. (2006), "Intertemporal pricing and price discrimination: a semiparametric hedonic analysis of the personal computer market", *Journal of Applied Econometrics*, Vol. 21 No. 3, pp. 371-386, doi: 10.1002/jae.828.

West, M., Harrison, P.J. and Migon, H.S. (1985), "Dynamic generalized linear models and Bayesian forecasting", *Journal of the American Statistical Association*, Vol. 80 No. 389, pp. 73-83, doi: 10.1080/01621459.1985.10477131.

Wood, S.N. (2000), "Modelling and smoothing parameter estimation with multiple quadratic penalties", *Journal of the Royal Statistical Society Series B: Statistical Methodology*, Series B, Vol. 62 No. 2, pp. 413-428, doi: 10.1111/1467-9868.00240.

Wood, S.N. (2017), *Generalized Additive Models: An Introduction with R*, Taylor and Francis Group: CRC Press, doi: 10.1201/9781315370279.

Xu, X.P. (2008), "Consumption risk-sharing in China", *Economica*, Vol. 75 No. 298, pp. 326-341, doi: 10.1111/j.1468-0335.2007.00606.x.

Zhang, W.Y., Lee, S.Y. and Song, X.Y. (2002), "Local polynomial fitting in semivarying coefficient model", *Journal of Multivariate Analysis*, Vol. 82 No. 1, pp. 166-188, doi: 10.1006/jmva.2001.2012.

Zhou, Y.C. and Hooker, G. (2022), "Decision tree boosted varying coefficient models", *Data Mining and Knowledge Discovery*, Vol. 36 No. 6, pp. 2237-2271, doi: 10.1007/s10618-022-00863-y.

Supplementary material

The supplementary material for this article can be found online.

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