Journal of Korea Trade Vol. 27, No. 2, April 2023, 96-114
https://doi.org/10.35611/jkt.2023.27.2.96
ISSN 1229-828X

JKT 27(2)

Received 30 December 2022
Revised 28 March 2023
Accepted 9 April 2023

Rare Disaster Events, Growth Volatility, and Financial Liberalization: International Evidence*

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Abstract

Purpose – This paper elucidates a nexus between the occurrence of rare disaster events and the volatility of economic growth by distinguishing the likelihood of rare events from stochastic volatility. We provide new empirical facts based on a quarterly time series. In particular, we focus on the role of financial liberalization in spreading the economic crisis in developing countries.

Design/methodology – We use quarterly data on consumption expenditure (real per capita consumption) from 44 countries, including advanced and developing countries, ending in the fourth quarter of 2020. We estimate the likelihood of rare event occurrences and stochastic volatility for countries using the Bayesian Markov chain Monte Carlo (MCMC) method developed by Barro and Jin (2021). We present our estimation results for the relationship between rare disaster events, stochastic volatility, and growth volatility.

Findings – We find the global common disaster event, the COVID-19 pandemic, and thirteen country-specific disaster events. Consumption falls by about 7% on average in the first quarter of a disaster and by 4% in the long run. The occurrence of rare disaster events and the volatility of gross domestic product (GDP) growth are positively correlated (4.8%), whereas the rare events and GDP growth rate are negatively correlated (−12.1%). In particular, financial liberalization has played an important role in exacerbating the adverse impact of both rare disasters and financial market instability on growth volatility. Several case studies, including the case of South Korea, provide insights into the cause of major financial crises in small open developing countries, including the Asian currency crisis of 1998.

Originality/value – This paper presents new empirical facts on the relationship between the occurrence of rare disaster events (or stochastic volatility) and growth volatility. Increasing data frequency allows for greater accuracy in assessing a country's specific risk. Our findings suggest that financial market and institutional stability can be vital for buffering against rare disaster shocks. It is necessary to preemptively strengthen the foundation for financial stability in developing countries and increase the quality of the information provided to markets.

Keywords: Bayesian MCMC, Financial Liberalization, Growth Volatility, Rare Disaster Events, Stochastic Volatility,

JEL Classifications: E21, E22, O47, G17

1. Introduction

The link between economic growth and volatility has long concerned macroeconomists. According to this theory, macroeconomic volatility dampens the investment demand more than the motivation for precautionary savings, thereby hampering economic growth. Following Ramey and Ramey's (1995) seminal work, a substantial body of work has provided

* This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2022S1A3A2A01088589).

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empirical evidence of a negative correlation between volatility and growth rate. In particular, many contributions have demonstrated the determinant of such a negative link. The literature on the finance–growth nexus explored growth volatility and its relationship with financial market development (Levine et al., 2000; Aghion et al., 1999; Aghion et al., 2005; Aghion et al., 2010; Braun and Larrain, 2005; Raddatz, 2006), while other studies have focused on institutional development (Acemoglu et al., 2003; Hnatkovska and Loayza, 2004) and exposure to trade shocks (Blattman et al., 2007). Although most research has found a negative correlation between aggregate volatility and economic growth, the growth benefits of financial or institutional development come at the expense of increased economic volatility. Financial liberalization can be a process of paying the cost of the transition stage of economic development. For example, financial liberalization encourages foreign banks or investors to enter the market and take risks in their lending resources to earn higher returns; however, in financially underdeveloped countries, large capital inflows can cause a rapid increase in bank lending, which can result in a financial crisis if the lending goes to unworthy borrowers. Growth volatility can be exacerbated when rare events affect such a vulnerability; however, the link between rare disaster events and growth volatility has received less attention.

Rare events are extremely uncommon but have severe and far-reaching consequences. Historically, such events encompass natural phenomena (such as earthquakes, tsunamis, hurricanes, floods, and anthropogenic hazards), wars and terrorism, industrial disasters, economic crises, financial and commodity market crashes, and mixed causes, such as epidemics and climate change. The topic of rare disasters has attracted renewed interest as their likelihood might explain the equity premium puzzle. For example, Barro (2006) presents evidence that the model of rare disasters explains a high observed-equity premium in reality. When unexpected rare events arrive in the economy, financial market instability amplifies a feedback mechanism between asset and goods markets, raising growth volatility. In such contexts, decomposing causes of growth volatility into rare disasters and financial market instability are important.

This paper investigates the relationship between rare events and economic growth volatility by distinguishing the likelihood of rare disasters causing a significant decline in consumption per capita from financial market instability. It is difficult to estimate the frequency of a rare event; the word itself is “rare.” We used the Bayesian Markov chain Monte Carlo (MCMC) method developed by Barro and Jin (2021) to estimate the likelihood of rare event occurrences and stochastic volatility in countries. The stochastic volatility model captures financial market instability and allows the underlying security’s volatility as a random process based on the fundamental asset pricing model, the tendency of volatility to revert to a long-run mean, and the variance of the volatility process itself, among others. As proposed here, Bayesian MCMC is a relatively simple method for estimating a complicated model. The model framework is a proper method to estimate rare disasters because the accident rate is influenced by global disasters (e.g., the COVID-19 pandemic of 2020) and economic crises (e.g., the global financial crisis of 2008). After controlling for a long-term trend, the model allows for the specification of probabilities of rare disasters at both the global and national levels and transitions between normal and abnormal states, with the states’ size, duration, and recovery determined stochastically.

We collect quarterly data on consumption expenditure (real per capita consumption) for 44 countries, including advanced and emerging countries, ending in the fourth quarter (Q4) of 2020. We find the global common disaster event, the COVID-19 pandemic, and 13 country-specific disaster events. Nine countries' economies experienced unique, rare events, such as the Asian currency crisis (India, Indonesia, and Korea), the European debt crisis (Estonia, Greece, Latvia, and Lithuania), the Mexican peso crisis of 1994 (Mexico), and the Russian annexation of Crimea in 2014. The occurrence of rare disaster events and the volatility of GDP growth are positively correlated (4.8%), whereas the rare events and GDP growth rate are negatively correlated (−12.1%). Financial liberalization has played a critical role in exacerbating the adverse impact of both rare disasters and financial market instability on growth volatility.

Specifically, case studies, including the case of Korea, convey insights into the cause of major financial crises in emerging countries, including the Asian currency crisis of 1998. Like many other countries, the COVID-19 pandemic crisis is a common disaster for Korea. Interestingly, the Asian currency crisis of 1998 has also been identified as a rare disaster. Although it seems to be a financial crisis, it might become a disaster event through financial liberalization and government political controls.

This paper is mainly related to rare disaster literature. Since the seminal work of Riez (1988), Barro (2006) provided a general framework to estimate the degree of macroeconomic disasters by capturing the short run cumulative decline in real per capita GDP or consumption above a specific threshold. Nakamura et al. (2013) extended the baseline model to construct disasters as they moved stochastically over time. Other studies have used rare macroeconomic events to analyze disaster risks in assets and foreign exchange markets (Gourio, 2008, 2012; Farhi and Gabaix, 2016). Using a quarterly time series, we reexamine the frequency of rare disaster events in the spirit of Barro (2006); increasing data frequency allows for greater accuracy in assessing a country's specific risk, providing helpful information about rare events' impact on growth volatility and business cycles. As a result, this paper contributes to the presentation of new empirical facts that provide insights into how to prevent economic crises, including the effects of the likelihood of rare disasters.

The rest of this paper proceeds as follows. Section 2 discusses the theoretical model and data, Section 3 presents the empirical results, and Section 4 concludes.

2. Theoretical Models and Data

2.1. The Model

Our model accommodates both rare disasters and normal events with a stochastic process. We use Barro and Jin's (2021) framework to allow two events to have risks from global and country-specific events. The log of actual consumption per capita of each country i at year t, y_{it}, is the sum of three unobserved components:

$$y_{it} = x_{it} + z_{it} + \sigma_{\varepsilon i}\varepsilon_{it} \tag{1}$$

where x_{it} is the permanent (or potential) part; z_{it} is the event gap between y_{it} and its permanent level due to shocks of current and past rare events. The potential of y_{it} and the event gap are each affected by the disaster process. The term $\sigma_{\varepsilon i}\varepsilon_{it}$ is the error term, where ε_{it} is an independent and identically distributed (i.i.d.) standard normal variable. The error term's standard deviation, $\sigma_{\varepsilon i}$, varies across countries. To account for the global financial crisis, $\sigma_{\varepsilon i}$ implemented structural changes in each country, one up to 2007 and another after that. We view $\sigma_{\varepsilon i}\varepsilon_{it}$ as measurement error rather than volatility shock; thus, it is not associated with rare disasters or long run risk.

The model supports a two-dimensional transition from normal to abnormal states. The dummy variable I_{wt} has a value of 1 if an abnormal event for the world at year t occurs; otherwise, it has a value of 0. The country-specific rare events are affected by changes in oversight, institutions, and policies. Similarly, the dummy variable I_{it} has a value of 1 if an abnormal event for a country i at year t occurs and 0 otherwise. We specify the following six disaster probabilities:

$$\Pr\left(I_{wt} = 1 \middle| I_{w,t-1}\right) = \begin{cases} p_0 & \text{if } I_{w,t-1} = 0 \\ p_1 & \text{if } I_{w,t-1} = 1 \end{cases} \tag{2}$$

$$\Pr\left(\left(I_{it} = 1 \middle| I_{i,t-1}, I_{wt}\right) = \begin{cases} q_{00} & \text{if } I_{i,t-1} = 0 \text{ and } I_{wt} = 0 \\ q_{01} & \text{if } I_{i,t-1} = 0 \text{ and } I_{wt} = 1 \\ q_{10} & \text{if } I_{i,t-1} = 1 \text{ and } I_{wt} = 0 \\ q_{11} & \text{if } I_{i,t-1} = 1 \text{ and } I_{wt} = 1 \end{cases} \tag{3}$$

Each component of (1) is constructed as follows. First, the difference in the permanent (or potential) part $\Delta x_{it}(= x_{it} - x_{it-1})$ is the sum of the four components.

$$\Delta x_{it} = \mu_i + I_{it}\eta_{it} + \chi_{i,t-1} + \sigma_{i,t-1}u_{it} \tag{4}$$

where μ_i is the constant long run average growth rate of x_{it}, $I_{it}\eta_{it}$ measures the permanent effect of an abnormal event, $\chi_{i,t-1}$ is the evolving part of the long run growth rate, $\sigma_{i,t-1}$ measures stochastic volatility, and u_{it} is an i.i.d. standard normal variable. The persistent movement of the rare event is measured by $I_{it}\eta_{it}$. In an abnormal state ($I_{it} = 1$), $\eta_{it} < 0$ implies that an abnormal event (i.e., disasters) today lowers the long run level of potential consumption. The long run risk appears in both $\chi_{i,t-1}$ and $\sigma_{i,t-1}u_{it}$. The long run growth $\chi_{i,t-1}$ evolves as follows:

$$\chi_{it} = \rho_\chi \chi_{i,t-1} + \kappa\sigma_{i,t-1}e_{it} \tag{5}$$

where $\rho_\chi \in [0,1)$ is a first-order autoregressive coefficient representing shock persistence. e_{it} is a standard normal variable. The parameter κ measures the ratio of the standard deviation of the shock toχ_{it} the standard deviation of the shock to Δx_{it}. Following Bansal and Yaron (2004), stochastic volatility, σ_{it}, monitors the evolution of an AR(1) process for the variance:

$$\sigma_{it}^2 = \sigma_i^2 + \rho_\sigma\left(\sigma_{i,t-1}^2 - \sigma_i^2\right) + \sigma_{\omega i}\omega_{it} \tag{6}$$

where σ_i^2 is the average of country-specific variance, and $\rho_\sigma \in [0,1)$ is a first-order autoregressive coefficient. The standard normal variable, ω_{it}, derives the shock, multiplied by the country-specific volatility, $\sigma_{\omega i}$.

Finally, the dynamics of event gaps z_{it} follow an autoregressive process:

$$z_{it} = \rho_z z_{i,t-1} + I_{it}(\phi_{it} - \eta_{it}) + \sigma_{vi}v_{it} \tag{7}$$

where $\rho_z \in [0,1)$ is a first-order autoregressive coefficient. The term $I_{it}\phi_{it}$ captures the immediate impact of an abnormal event on consumption levels. Accordingly, $I_{it}(\phi_{it} - \eta_{it})$ measures the temporary movement of the disaster shock. The error term is the product of the standard normal variable, ν_{it}, and the country-specific constant volatility, $\sigma_{\nu i}$.

The standard normal variable ω_{it} derives the shock multiplied by the country-specific volatility $\sigma_{\omega i}$.

We can simplify y_{it} as follows:

$$\Delta y_{it} = y_{it} - y_{i,t-1} = LR + RE + \tilde{\xi} \tag{8}$$

where $LR = \mu_i + \chi_{i,t-1}$,

$$\mathrm{RE} = I_{it}\phi_{it} - (1-\rho_z)I_{i,t-1}\phi_{i,t-1} + (1-\rho_z)I_{i,t-1}\eta_{i,t-1} - \rho_z(1-\rho_z)z_{i,t-2},$$

$$\tilde{\xi} = \sigma_{\varepsilon i}\varepsilon_{it} - \sigma_{\varepsilon i}\varepsilon_{i,t-1} + \sigma_{i,t-1}u_{it}.$$

LR and RE are the long run risks and the shock of rare disasters, respectively. The remainder $\tilde{\xi}$ is a measurement error. Notice that the averages of $\chi_{i,t-1}$ and $\tilde{\xi}$ are zero in the long run.

2.2. The Data

We collected panel data on consumption expenditure (real per capita consumption) from 44 countries, including advanced and emerging countries. The data sources are the Organization for Economic Co-operation and Development (OECD) and the Federal Reserve Bank of St. Louis Economic Data (FRED).[1] All data were quarterly and seasonally adjusted. Table 1 shows the means and standard deviations of quarterly consumption growth by country. The sample periods end in 2020 Q4 but begin at different times of the year. The last column shows the quarter when the rare event occurred, which we discuss further.

Information on prior beliefs is necessary to estimate the model using the Bayesian MCMC method. We follow the specification of the flat prior distribution of Barro and Jin (2021); however, we modify the lower bound to match quarterly data for the parameters p_1, q_{11}, and q_{01}. We can easily solve our model structure using the Gibbs sampler algorithm for random draws of parameters and quantities. Following Nakamura et al.(2014), we run four simulation chains based on the combination of two initial scenarios (i.e., the no-disaster case and all disaster case) and two cases of transition probabilities (i.e., high and low) to obtain accurate estimates and quantities. The Hodrick–Prescott filter is used to detrend consumption expenditure for all event scenarios. We run 2 million iterations for each chain and discard the first million as burn-in to accurately estimate parameters and unknown quantities.

Table 2 shows the main parameters' posterior means and standard deviations of the model. For world disaster events, the estimated probability of transitioning from a normal to an abnormal state (p_0) is 2.2%. The estimated probability of progressing from abnormal to normal (p_1) was 50.2%. If no concurrent disasters affect all countries, the estimated conditional probability of a country transitioning from normal to a disaster state (q_{00}) is 0.7%.

[1] Data sources are OECD (https://data.oecd.org/), FRED (https://fred.stlouisfed.org/) and Philippine Statistics Authority (https://psa.gov.ph/).

The conditional probability that a country remains abnormal from one quarter to the next (q_{10}) is 83.4%. Suppose a global disaster occurs, such as economic shocks or war. Then, the conditional probability of a country transitioning from a normal to an abnormal state (q_{01}) is 5.9%. The conditional probability of one country remaining abnormal from quarter to quarter (q_{11}) was 87.5%.

In the long run, the consumption expenditure is influenced by the permanent part of the shock η, estimated at −0.040. On average, consumption falls by 4% in the long run. Conversely, the estimated mean of the disaster shock, ϕ, is −0.007, indicating that consumption falls by about 7% on average during the first quarter of a disaster. The estimated value of stochastic volatility, ρ_{σ}, is 0.111, and the estimated value of long run growth, ρ_{χ}, is 0.932, indicating that a long run growth rate is consistent over time.

The last column in Table 1 reports the year-quarter in which rare disaster events occurred, i.e., $I_{it} = 1$. For all countries, the COVID-19 pandemic year, 2020, was when a global disaster occurred. The outbreak of COVID-19 brought about an unprecedented global health and economic crisis. Aside from 2020, nine countries' economies experienced their own unique, rare events, such as the Asian currency crisis (India, Indonesia, and Korea), the European debt crisis (Estonia, Greece, Latvia, and Lithuania), the Mexican peso crisis of 1994 (Mexico), and Russia's annexation of Crimea in 2014.

Table 1. The Rare Events in the sample countries

Country		Sample Period		Consumption Growth Rate		Rare Event Years
		Begin	End	Mean	S.D.	
1	Australia	1990Q1	2020Q4	0.009	0.086	2020Q3, 2020Q4
2	Austria	1995Q1	2020Q4	0.009	0.080	2020Q1, 2020Q3, 2020Q4
3	Belgium	1995Q1	2020Q4	0.006	0.038	2020Q1, 2020Q3, 2020Q4
4	Brazil	1996Q1	2020Q4	0.002	0.007	2020Q3, 2020Q4
5	Bulgaria	1995Q1	2020Q4	0.045	0.426	1997Q1, 2020Q1, 2020Q3, 2020Q4
6	Canada	1990Q1	2020Q4	0.002	0.008	2020Q1, 2020Q3, 2020Q4
7	Chile	1996Q1	2020Q4	0.007	0.044	2020Q1, 2020Q3, 2020Q4
8	Colombia	2005Q1	2020Q4	0.009	0.053	2020Q3, 2020Q4
9	Costa Rica	1991Q1	2020Q4	0.006	0.038	2020Q3, 2020Q4
10	Czech	1996Q1	2020Q4	0.008	0.053	2020Q1, 2020Q3, 2020Q4
11	Denmark	1995Q1	2020Q4	0.009	0.075	2020Q1, 2020Q3, 2020Q4
12	Estonia	1995Q1	2020Q4	0.008	0.027	2008Q3, 2020Q3, 2020Q4
13	Finland	1990Q1	2020Q4	0.002	0.008	2020Q3, 2020Q4
14	France	1990Q1	2020Q4	0.001	0.009	2020Q1, 2020Q3, 2020Q4
15	Germany	1991Q1	2020Q4	0.008	0.076	2020Q1, 2020Q3, 2020Q4

Table 1. (Continued)

	Country	Sample Period		Consumption Growth Rate		Rare Event Years
		Begin	End	Mean	S.D.	
16	Greece	1995Q1	2020Q4	0.007	0.066	2009Q1, 2009Q4, 2020Q1, 2020Q3, 2020Q4
17	Hungary	1995Q1	2020Q4	0.007	0.050	2020Q1, 2020Q3, 2020Q4
18	Iceland	1995Q1	2020Q4	0.062	0.575	2020Q3, 2020Q4
19	India	1996Q1	2020Q4	0.010	0.081	1998Q4, 1999Q1, 2020Q1, 2020Q3, 2020Q4
20	Indonesia	1990Q1	2020Q4	0.004	0.014	1993Q2, 1993Q4, 1998Q1, 2020Q3, 2020Q4
21	Ireland	1995Q1	2020Q4	0.009	0.085	2020Q1, 2020Q3, 2020Q4
22	Israel	1995Q1	2020Q4	0.008	0.069	2020Q1, 2020Q3, 2020Q4
23	Italy	1996Q1	2020Q4	0.008	0.067	2020Q1, 2020Q3, 2020Q4
24	Japan	1994Q1	2020Q4	0.008	0.074	2020Q3, 2020Q4
25	Korea	1990Q1	2020Q4	0.003	0.009	1998Q1, 2020Q1, 2020Q3, 2020Q4
26	Latvia	1995Q1	2020Q4	0.007	0.027	2005Q3, 2007Q2, 2008Q4, 2009Q1, 2020Q1, 2020Q3, 2020Q4
27	Lithuania	1995Q1	2020Q4	0.008	0.029	2009Q1, 2020Q1, 2020Q3, 2020Q4
28	Luxembourg	1995Q1	2020Q4	0.010	0.098	2020Q1, 2020Q3, 2020Q4
29	Mexico	1993Q1	2020Q4	0.005	0.053	1995Q1, 2020Q3, 2020Q4
30	Netherlands	1996Q1	2020Q4	0.009	0.081	2020Q1, 2020Q3, 2020Q4
31	New Zealand	1990Q1	2020Q4	0.002	0.008	2020Q3, 2020Q4
32	Norway	1990Q1	2020Q4	0.002	0.007	2020Q1, 2020Q3, 2020Q4
33	Philippines	1998Q1	2020Q4	0.008	0.037	2020Q1, 2020Q3, 2020Q4
34	Poland	1995Q1	2020Q4	0.012	0.089	2020Q1, 2020Q3, 2020Q4
35	Portugal	1995Q1	2020Q4	0.008	0.068	2020Q1, 2020Q3, 2020Q4
36	Romania	1995Q1	2020Q4	−0.007	0.135	2020Q1, 2020Q3, 2020Q4
37	Russia	2003Q1	2020Q4	−0.059	0.535	2014Q4, 2020Q3, 2020Q4
38	Slovakia	1995Q1	2020Q4	0.007	0.043	1999Q3, 2020Q3, 2020Q4
39	Slovenia	1995Q1	2020Q4	0.007	0.052	2020Q1, 2020Q3, 2020Q4
40	Spain	1995Q1	2020Q4	0.008	0.072	2020Q1, 2020Q3, 2020Q4
41	Sweden	1993Q1	2020Q4	0.009	0.073	2020Q1, 2020Q3, 2020Q4
42	Turkey	1998Q1	2020Q4	0.007	0.055	2020Q1, 2020Q3, 2020Q4
43	U. K.	1990Q1	2020Q4	0.001	0.012	2020Q1, 2020Q3, 2020Q4
44	U. S.	1990Q1	2020Q4	0.002	0.006	2020Q1, 2020Q3, 2020Q4

Table 2. Estimated Parameters

Para-meter	Definition	Posterior Mean	Posterior S. D.	5% percentiles	95% percentiles	Dist
p_0	No prior-year world disaster	0.022	0.011	0.006	0.044	U(0, 0.05)
p_1	Prior-year world disaster	0.502	0.211	0.153	0.837	U(0.3/4, 0.9)
q_{00}	No prior-year country disaster, no current world disaster	0.007	0.001	0.005	0.009	U(0, 0.03)
q_{10}	Prior-year country disaster, no current world disaster	0.834	0.038	0.769	0.892	U(0, 0.9)
q_{01}	No prior-year country disaster, current world disaster	0.059	0.027	0.021	0.110	U(0.3/4, 0.9)
q_{11}	Prior-year country disaster, current world disaster	0.875	0.024	0.826	0.898	U(0.3/4, 0.9)
ρ_z	AR(1) coefficient for event gap	0.814	0.002	0.811	0.817	U(0, 0.9)
ϕ	Immediate disaster (abnormal) shock	−0.007	0.003	−0.013	−0.001	U(−0.25, 0)
η	Permanent disaster (abnormal) shock	−0.040	−0.008	−0.025	−0.052	N(−0.025, 0.1^2)
σ_ϕ	SD of ϕ shock	0.051	0.002	0.047	0.054	U(0.01,0.25)
σ_η	SD of η shock	0.106	0.004	0.098	0.112	U(0.01,0.25)
ρ_χ	AR(1) coefficient for LR growth parts	0.932	0.007	0.920	0.942	U(0, 0.98)
ρ_σ	AR(1) coefficient for stochastic volatility	0.111	0.032	0.051	0.163	U(0, 0.98)
κ	Multiple on error term for LR growth rate part	0.075	0.009	0.03	0.086	U(0.1, 10)
μ_i	LR average growth rate	0.0032	0.0001	0.002	0.004	N(0.02, $0.3 \cdot 0.01^2$)
$\sigma_{\varepsilon i}$	SD for a shock to consumption	0.048	0.0015	0.0013	0.0018	U(0.001, 0.15)
${\sigma_i}^2$	Average variance for stochastic volatility	0.0011	0.0002	0.0001	0.0023	TN($\overline{\sigma_{it}^2}$, $0.0004^2; 10^{-8}, 0.$

3. Empirical Results

3.1. Main Findings

This section presents our empirical results on the relationship between the occurrence of rare events (RE), stochastic volatility (STO), and economic variables, such as GDP growth volatility and GDP growth rate, where GDP is quarterly per capita and real GDP. RE and STO are four-quarter lagged posterior medians, indicating that we are interested in the impact of event shocks on the economy in the following year. The correlations with RE or STO and economic variables are shown in Table 3. GDP or industry growth measures are computed using four-period rolling windows in each quarter or year; that is, the volatility of y_t is defined as $\frac{1}{4}\sum_{s=t-3}^{t} \log(y_s)$. Except for the quarterly GDP series, all economic variables are yearly series from the World Bank Deployment Indicator, except for the financial reform index. RE shows a positive correlation with both the GDP and industry growth volatility (4.8% and 5.6%, respectively) and a negative correlation with both the GDP and industry growth rate (−12.1% and −10%, respectively). Similarly, STO is positively correlated with GDP growth volatility (35.7%) but also positively correlated with the GDP growth rate (10.6%), indicating that it may have occurred due to creative destruction through financial market services (e.g., screening successful entrepreneurs) in the short run. STO captures economic uncertainty as time-varying volatility of consumption growth lowers asset prices (Bansal and Yaron, 2004), implying a trade-off between high growth and high volatility and low growth and low volatility. Figures 1 and 2 show the growth volatility plots with RE and STO, respectively. Overall, the growth volatility had been more affected by STO.

Table 3 also compares RE (or STO) and other variables. Both RE and STO positively correlate with unemployment rates, indicating that unemployment rates increase during depression periods. The current account to GDP ratio and RE are positively correlated, while the current account to GDP ratio and STO are negatively correlated. Both shocks generally cause a fall in the economy's demand.[2] Regarding RE, a decrease in GDP is greater than a decrease in the current account; the opposite results were obtained for STO. The indicator for financial development—private credit to GDP—is negatively correlated with RE and STO. In particular, the correlation coefficients of STO and financial development have statistical significance and are of larger magnitudes. As a country is more financially developed, financial market instability shocks tend to dampen. Financial liberalization has played a significant role in exacerbating the adverse impact of RE and STO on growth volatility. We utilize a financial reform index constructed by Abiad et al. (2010) as a proxy for financial liberalization (1990 to 2005). The financial reform index captures the different dimensions of financial reform: credit controls, interest rate controls, entry barriers, regulations governing financial firms, the dominance of state-owned firms in the financial sector, and restrictions on international financial transactions, including the lack of currency convertibility and the use of multiple exchange rates. The interaction term of the financial reform index and the growth volatility is significantly and positively correlated with RE and STO. This key finding provides insights into the cause of major financial crises in emerging countries, including the Asian currency crisis of 1998.

Table 4 shows the correlations with RE or STO and economic variables in a group of small open developing economies, which is historically more likely to be exposed to negative demand shocks. One of the defining features of small open economies is that households and firms can borrow and lend at an interest rate determined by international markets (Guerron-Quintana, 2013). Our sample includes Bulgaria, Brazil, Chile, Colombia, Costa Rica, Czech Republic, Estonia, Greece, Hungary, India, Indonesia, Italy, Ireland, Korea, Latvia, Lithuania, Mexico, Poland, Philippines, Portugal, Romania, Russia, Slovak Republic, Slovenia, Spain, and Turkey. We exclude advanced countries but include South Korea, Italy, and Russia. In Table 4, RE is positively correlated with GDP growth volatility but negatively correlated with the GDP growth rate. Financial liberalization exacerbated the adverse effect of financial instability on growth volatility as STO is significantly and positively correlated with the interaction term of the financial reform index and the growth volatility.

Table 4 compares the case of South Korea with other small open economies, indicating that

[2] Theoretically, both RE and STO can improve the current account balance and decrease the relative price of tradable goods to nontradable goods.

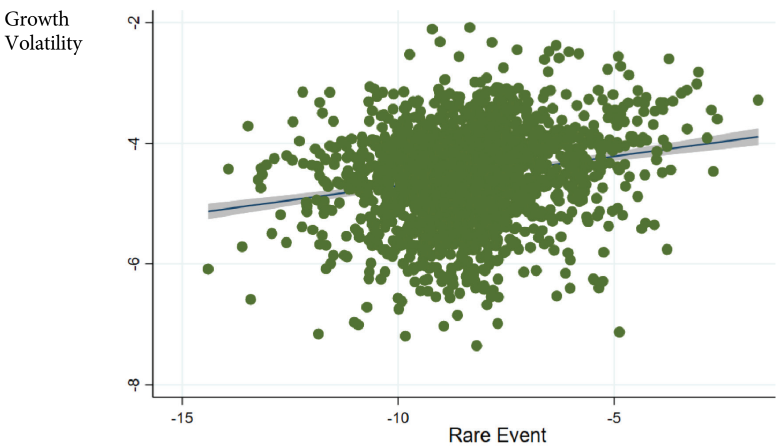
the country is relatively developed but still vulnerable to global financial market risks. Growth volatility is more significantly and positively correlated with STO, implying that financial market stability is crucial to growth sustainability. Interestingly, the GDP deflator (unemployment rate) is significantly and negatively (positively) correlated with RE, representing that a rare disaster shock to South Korea has more adverse effects on the demand side of the economy.

Table 3. Correlation with Economic Variables

	Rare Event	Stochastic Volatility
GDP growth volatility	0.048*	0.357*
GDP growth rate	−0.121*	0.106*
log of GDP	−0.033*	−0.382*
Industry growth	−0.100*	0.078*
Industry growth volatility	0.056*	0.001
GDP Deflator	0.014	0.167
Unemployment rate	0.083*	0.044*
Trade to GDP	−0.008	0.023
Current Account to GDP	0.032*	−0.167*
Private Credit to GDP	−0.015	−0.347*
GDP growth volatility × Financial Reform	0.051*	0.423*

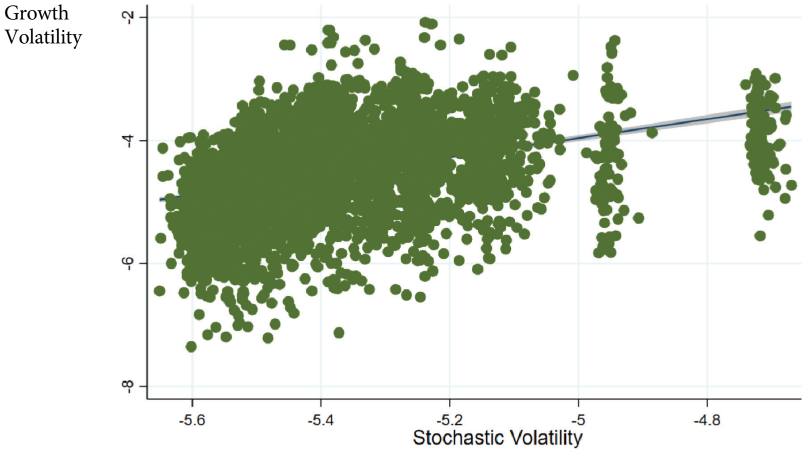
Note: RE and STO are 4-quarter lagged. The World Bank Development Indicators were used to collect all economic variables except for the financial reform index (Abiad. et al., 2010). * indicates statistical significance at the 5% level.

Fig. 1. Rare Events and Growth Volatility



The correlation between growth volatility and the four-quarter lagged rare event occurrence was 0.05, with a 5% significance level.

Fig. 2. Stochastic Volatility and Growth Volatility



The correlation between growth volatility and four-quarter lagged stochastic volatility was 0.36, with a 5% significance level.

Table 4. Correlation with Economic Variables in Small Open Economies

	Rare Event		Stochastic Volatility	
	Small Open	**Korea**	**Small Open**	**Korea**
GDP growth volatility	0.040	0.035	0.223*	0.324*
GDP growth rate	−0.118*	0.164	0.029	0.296*
log of GDP	−0.012	0.032	−0.216*	−0.239*
Industry growth	−0.097*	0.065	0.023	0.083
Industry growth volatility	0.053*	−0.019	0.001	0.099
GDP Deflator	0.010	−0.184*	0.145*	0.167
Unemployment rate	0.102*	0.233*	0.002	0.088
Trade to GDP	0.009	0.017	−0.178*	−0.163
Current Account to GDP	0.083	0.112	−0.120*	−0.061
Private Credit to GDP	0.019	0.001	−0.226*	−0.214*
GDP growth volatility × Financial Reform	0.064	0.023	0.318*	0.171

Note: RE and STO are 4-quarter lagged. The World Bank Development Indicators were used to collect all economic variables except for the financial reform index (Abiad et al., 2010). * indicates statistical significance at the 5% level.

3.2. Five Illustrative Countries

3.2.1. Korea and Indonesia

This section first discusses the case of South Korea as a representative illustration. Fig. 3 depicts the model's detailed dynamics by examining the time evolution of RE and STO for South Korea. The red bar represents the disaster state of $I_{it} = 1$, i.e., the year-quarter identified as the disaster. We compare the event variables to the volatility of GDP growth and the log of GDP, as shown in Fig. 4. Like many other countries, the COVID-19 pandemic crisis is one of the rare disasters. In 2020, the GDP volatility peaked, and the COVID-19 pandemic and the resulting economic fallout caused significant hardship. In the early months of 2020, the GDP volatility peaked. At the end of February 2020, South Korea had the second-highest number of cumulative confirmed cases globally, and the number of new confirmed cases had surged to more than 900 per day (MOEF, 2021). While COVID-19 has had a significant

Fig. 3. Rare Events and Stochastic Volatility in South Korea

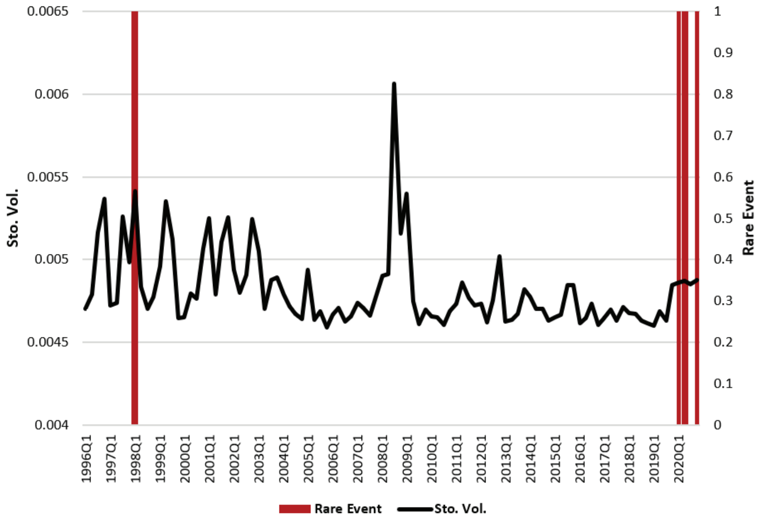
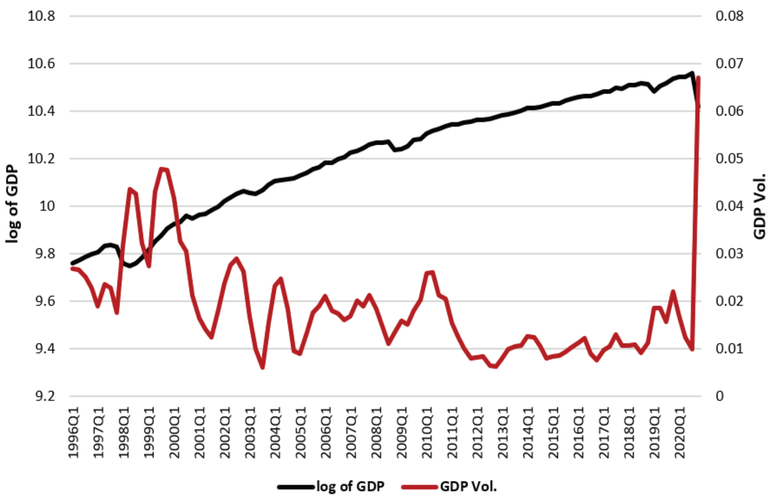


Fig. 4. GDP Volatility and log of GDP in Korea



impact on the global economy, South Korea relatively succeeded in dealing with negative economic shocks by effectively preventing the spread of the disease without a total economic shutdown or intensive quarantine. Korea's GDP fell by 0.7% in 2020, in contrast with the average growth rate of OECD countries, –4.2%. Despite such relative successes, the COVID-19 pandemic is a rare disaster because the cause of the unprecedented crisis went beyond economic shocks.

Interestingly, the Asian currency crisis of 1998 is also identified as a rare disaster, although it appears to be a financial crisis. Before the crisis, South Korea's macroeconomic variables and foreign-debt-related indicators were in good condition, suggesting that it would follow Thailand, Indonesia, Mexico, and other crisis-ridden countries (Cho, 1998). From this context, the unexpected shock might switch the financial crisis into a rare disaster; however, the crisis was marked by a change in the current account after a surplus in 1993. The crisis might be predictable, just unknown to the public. The current account deteriorated continuously until the deficit peaked in 1996. The ratio of foreign reserves to short-term debt started to fall rapidly afterward.

Figs. 5 and 6 are the corresponding figures for Indonesia, which was seriously affected by adverse shocks during the Asian currency crisis of 1998. The Asian region contraction of 1998 is identified as a common adverse rare event for South Korea and Indonesia. The GDP growth rate for the two countries declined by 7% and 9%, respectively. In particular, the Indonesian economy was highly volatile, with RE occurring twice in the early 1990s, demonstrating the negative consequences of extensive banking liberalization with weak institutions between 1990 and 1992. Seemingly, it is unlikely to be the case in South Korea. Cho (1998) suggests that the crisis overly drove South Korea due to the country's macroeconomic environment and structural problems, which led to corporate overinvestment, a highly vulnerable financial structure, and bank mismatches of foreign assets and liabilities. In particular, it resulted from the combined effect of the relaxation of restrictions on foreign loans and lowering an entry

Fig. 5. Rare Events and Stochastic Volatility in Indonesia

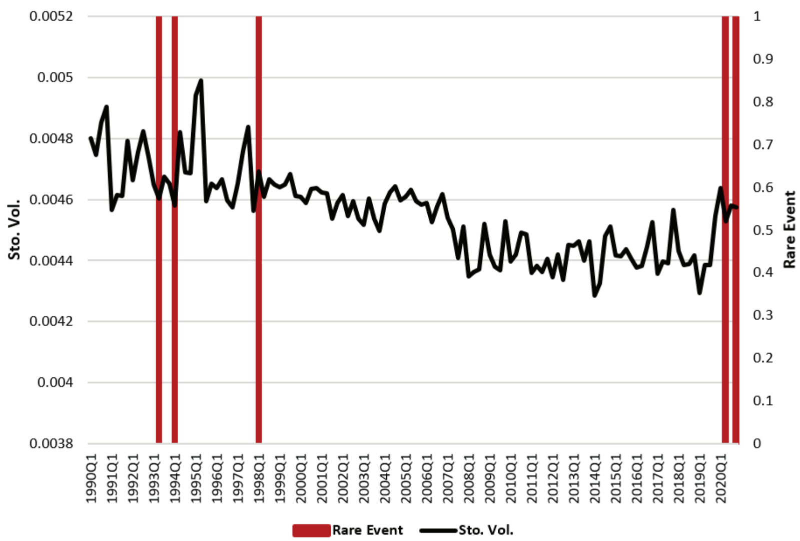
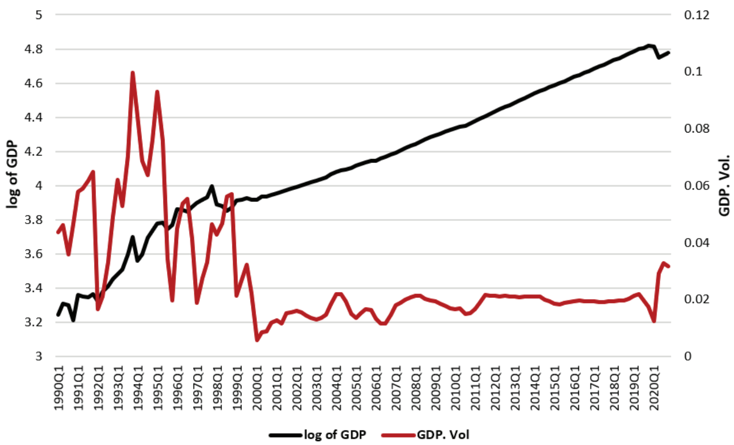


Fig. 6. GDP Volatility and log of GDP in Indonesia



barrier to financial institutions, facilitated by financial liberalization in the early 1990s. More seriously, government political control over both firms and financial institutions for an extended period implicitly guaranteed that it would not allow the chaebol (conglomerates) to go bankrupt. Consequently, South Korea was in the same situation as Indonesia and other Asian countries affected by the crisis.

3.2.2. The United States, the United Kingdom, and Brazil

In the Appendix, Figures A1, A3, and A5 depict the model's detailed dynamics by examining the time evolution of RE and STO for the United States, the United Kingdom, and Brazil. Figures A2, A4, and A6 depict the dynamics of GDP volatility and the log of GDP.

For the United States and the United Kingdom (Figures A1 and A3), the COVID-19 pandemic crisis is only a rare disaster, and in 2020, the GDP volatility peaked. The two countries' GDP growth rates declined by 9% and 23%, respectively. The COVID-19 pandemic was a global disaster that affected all countries, whereas economic crises, such as the global financial crisis of 2008, are closely related to the STO. Brazil experienced several economic crises, including the 1994 Mexican peso crisis, the 1999 sharp depreciation of the newly adopted Brazilian Real (BRL) currency, the 2008 global financial crisis, and the 2014 Great Recession. Interestingly, these economic crisis shocks are closely related to STO, implying that financial market instability primarily caused the shocks. In other words, we can interpret that the financial crisis was caused by the failure to rebalance the financial market, not due to an unexpected rare disaster.

4. Conclusion

This paper investigated the relationship between rare disaster events and growth volatility. We used quarterly data on consumption expenditure from 44 countries to estimate the likelihood of rare event occurrences and stochastic volatility for each country. By decomposing a fall in consumption into RE and stochastic volatility, we provide new empirical facts on a quarterly data basis. We find that the global common disaster event, the COVID-19 pandemic, and thirteen country-specific disaster events harm economic growth and fluctuations. Consumption falls by about 7% on average in the first quarter of a disaster and by 4% in the long run. Moreover, the occurrence of rare disaster events is positively correlated with GDP growth volatility, whereas the occurrence of rare disaster events negatively correlates with the GDP growth rate. Our findings shed light on the RE impact on growth volatility and business cycles.

Economic growth generally comes at the expense of increased economic volatility, such as through creative destruction. Therefore, economic reform processes, such as financial liberalization, naturally pay the cost of expanding economic volatility; if a rare disaster occurs, the economic crisis can seriously escalate.

This paper provides insight into what can be done to reduce the likelihood of future crises. Historically, rare disasters inevitably occur; the problem is how to mitigate the impact of a disaster. Our findings suggest that financial market and institutional stability can be vital for buffering against rare disaster shocks. It is necessary to preemptively strengthen the foundation for financial stability in developing countries and the desirability to improve the quality of the information provided to markets. Such actions will inevitably be necessary for preventing crises and mitigating the consequences of rare disasters.

Finally, it would be interesting to investigate how RE and stochastic instability affects economic fluctuations via a well-designed demand–supply structure. We leave this exploration for future work.

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Appendix / Appendices

Fig. A1. Rare Event and Stochastic Volatility in the United States

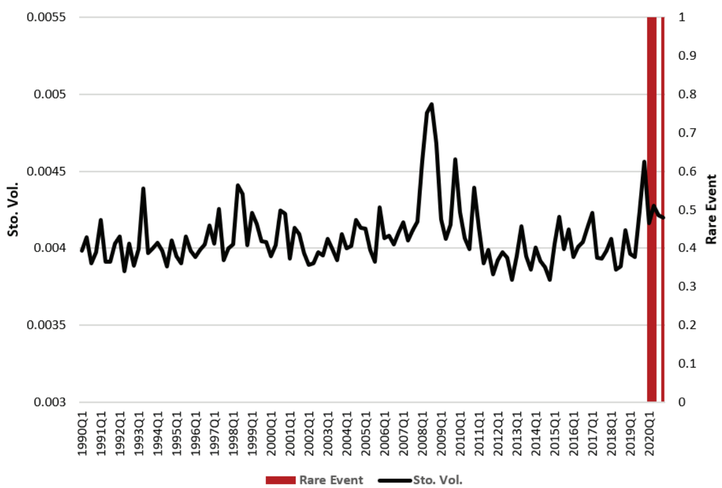

Fig. A2. GDP Volatility and log of GDP in the United States

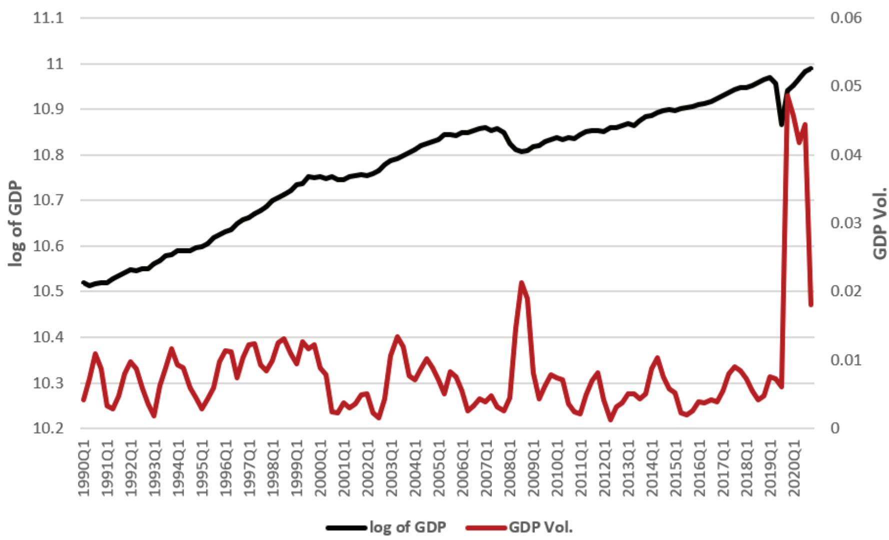

Fig. A3. Rare Event and Stochastic Volatility in the United Kingdom

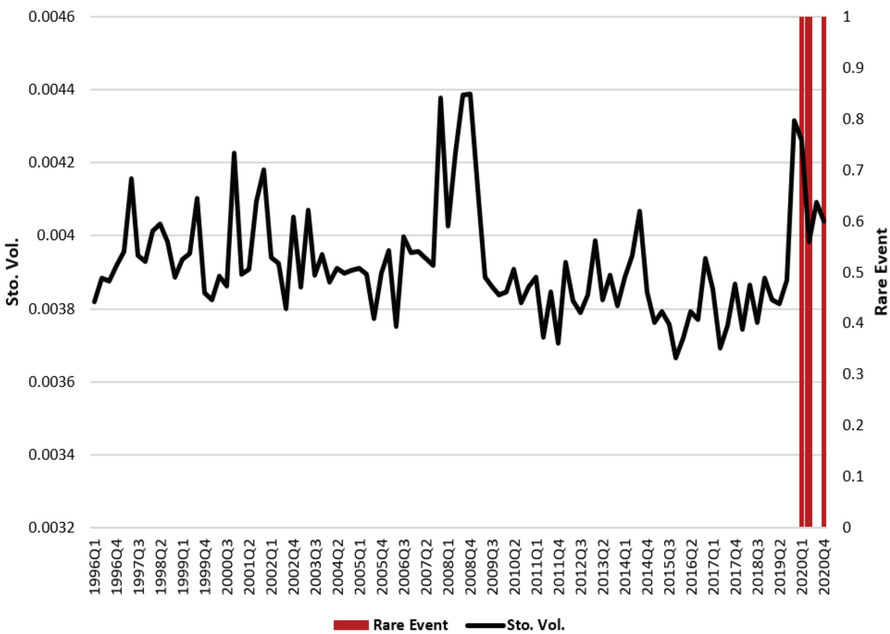

Fig. A4. GDP Volatility and log of GDP in the United Kingdom

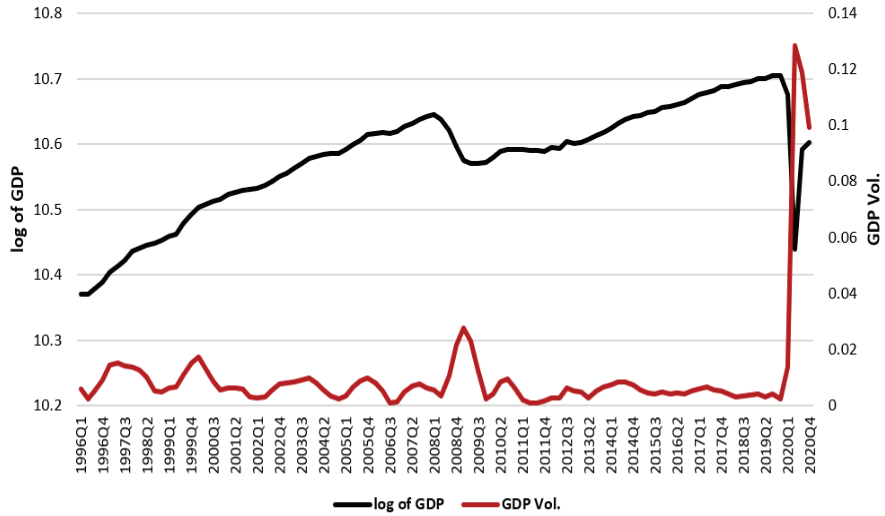

Fig. A5. Rare Event and Stochastic Volatility in Brazil

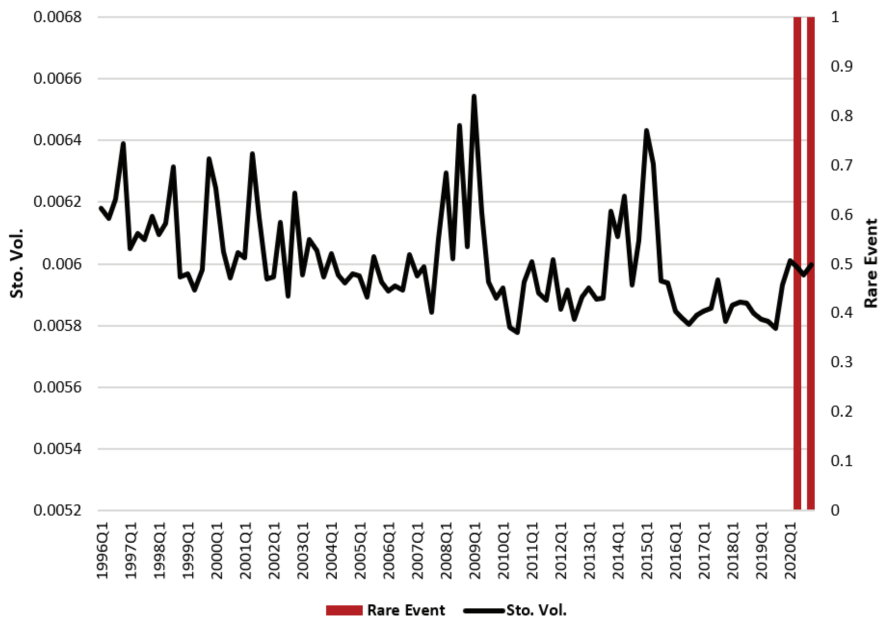

Fig. A6. GDP Volatility and log of GDP in Brazil