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Government Interventions and Sovereign Bond Market Volatility during COVID-19: A Quantile Analysis

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Abstract: We test the interaction between governments' COVID-19 interventions, COVID-19-induced uncertainty, and the volatility of sovereign bonds. Different from previous literature, we investigate the asymmetric response of bond market volatility to both governmental interventions and COVID-19-induced uncertainty. With a focus on the first waves of the pandemic and using a panel quantile approach and a comprehensive dataset of 31 countries worldwide, we document that containment and closure policies tend to amplify volatility. Furthermore, the price variability is augmented by the spread of the pandemic itself. On the contrary, economic support policies have a substantial stabilizing effect on bond price fluctuations. Both phenomena are not subsumed by additional control variables and are robust to multiple considerations. Our findings may serve financial market participants in their risk management decisions, as well as policymakers to better shape their preparedness for future pandemics.

Keywords: COVID-19; government bond price volatility; government policy responses; international financial markets; containment and closure; economic support; panel quantile regression

MSC: 62P25; 62J02; 62F35

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1. Introduction

A careful mapping of the COVID-19 research shows that much of its efforts and attention has, so far, been focused on the possible impact of government interventions on the equity market [1–19]. To be specific, only a handful of studies focus on the impact of the pandemic on bond yields, prices, liquidity, or term spreads [20–27]. Hence, the primary goal of this study is to improve the understanding of the COVID-19–bond market nexus. Specifically, we scrutinize the effect of the government policy responses to the pandemic and of the COVID-19-induced uncertainty on sovereign bond volatility, showing that this effect is asymmetric, being influenced by the volatility level. Ours is the first paper assessing the asymmetric, nonlinear effect of government interventions on sovereign bond market volatility during COVID-19.

During the COVID-19 outbreak, financial markets have experienced extraordinary levels of uncertainty leading to significant price drawdowns, volatility spikes, and liquidity shortages [28–33]. Importantly, besides the pandemic itself, which generated a specific form of uncertainty associated with the increased number of new infection cases and deaths [34] or with news related to COVID-19 [35], global economies have faced unprecedented government policy responses. These interventions may significantly affect financial market volatility; however, the direction of these forces is far from trivial. On the one hand, any government action may induce additional uncertainty [36], which in turn, leads to an increase in the volatility of government bond markets. On the other hand, several other papers consider government interventions as responsible actions that may curb the adverse effects of crises and uncertainty [37–39], which can also be the case for sovereign debt.

Furthermore, the interventions may take different forms. Some of them include containment and closure policies that are targeted at curbing the spread of the pandemic;

others provide economic support to both enterprises and consumers. The impacts of these very different actions do not need to be identical [38]. If we consider for instance the containment and closure policies, we expect an immediate negative impact of these measures on the real economy. However, these policies limit COVID-19 propagation and might restore investor confidence. In this case, containment policies might reduce bond price volatility. This is also the case with economic support measures which in the short run generate a positive market sentiment but in the long run might be associated with fiscal imbalances, increasing thus the market uncertainty. Consequently, we attempt to shed light on this issue and explore the impact of different government policy responses on government bond volatility.

To this end, we examine the behavior of sovereign bonds in 31 countries during the recent pandemic. Contrary to earlier studies [25,38], we employ Canay's panel quantile regression [40] approach with fixed effects to determine whether the relationship is consistent across several parts of the bond volatility distribution. In other words, we investigate if the impact of interventions on sovereign bond market volatility differs depending on the volatility level.

We, therefore, build upon the work of Zaremba et al. [25] and extend their analysis in three ways. First, we posit that the effect of government interventions on bond market volatility is not linear and is influenced by the level of volatility recorded in each market. More precisely, it is well known that countries with more developed financial markets tend to record a reduced volatility level [41]. These mature markets do not react to news and uncertainty in the same way the emerging financial markets do. Therefore, we expect that the governmental interventions will have a stronger impact on bond price volatility at upper quantiles, that is, for more volatile bond markets. Highlighting the asymmetric effect of governmental interventions on bond market volatility represents the main advantage of a panel quantile approach over the classic panel data models. In addition, a quantile approach has other advantages, including its robustness to non-normality, as well as to heteroscedasticity, skewness, and leptokurtosis, all of which are typical financial data features [40]. The estimated conditional quantile functions provide a much more complete image of the covariates' effect on the location, scale, and shape of the distribution of a response variable [42]. The application of this method to study the relationship between COVID-19 and sovereign bond volatility is uncovered by the extant literature. We demonstrate that both the spread of the infections and the policy measures augment the bond market volatility. As a novel finding, we show that the impact of government interventions increases for upper quantiles, that is, for more volatile markets. The effect is driven principally by containment and closure policies, such as lockdowns or school closings. On the other hand, economic support policies tend to stabilize bond price fluctuations.

Second, we cover the first two waves of the pandemic, while Zaremba et al.'s [25] data span only covers the first wave. We investigate the two waves of the pandemic (for a description, please refer to the work of Duttilo et al. [43]) given the high level of uncertainty and volatility recorded in 2020. Starting with 2021, financial market volatility decreased, pointing in favor of shock accommodation and uncertainty downturn. Moreover, the bond purchase measures (see, for example, the Federal Reserve quantitative easing program) diminished the market volatility. Third, we check for the "Monday effect" of new infection cases. The new infections are reported on the date "t" for the tests performed on the date "t-1" [1]. Given that fewer tests are performed during the weekend, the number of new infection cases is smaller Monday compared with the other days of the week.

In summary, previous literature does not investigate the asymmetric response of bond market volatility to both governmental interventions and COVID-19-induced uncertainty. Starting from this limitation, we derive the following hypotheses for our empirical research:

Hypothesis 1. *Government interventions and new COVID-19 infection cases have different impacts on bond market volatility, depending on the volatility level.*

Hypothesis 2. *The containment measures amplify the volatility by increasing the uncertainty, whereas the economic support policies have a stabilizing effect on bond price fluctuations.*

Hypothesis 3. *The "Monday effect" of new infection cases is significant.*

Our findings contribute to the literature on the effect of the COVID-19 outbreak on bond market volatility [20–22,24] in several ways. Our focus is on sovereign bond market volatility. A concurrent strand of the literature [44–48] investigates the pandemic's effect on sovereign bond risk. In particular, our study is most closely related to the study of Zaremba et al. [25], who applied simple panel regressions to delve into the pandemic–bond volatility nexus. Significantly, our conclusions expand the findings of that study, showing that the impact of interventions is influenced by the bond volatility distribution. Whereas Zaremba et al. [25] only found a link between bond volatility and economic support policies, we also document the essential role of containment and closure interventions, which amplify the price variability. Consequently, while Zaremba et al. [19] find the overall stabilizing effect of government interventions, we demonstrate their detrimental impact.

The structure of the paper is as follows: Section 2 describes materials and methods. Section 3 presents the results regarding empirical findings and robustness checks. Section 4 discusses the findings in relation to the research hypotheses, and Section 5 presents conclusions.

2. Materials and Methods

2.1. Materials

As in the work of Zaremba et al. [25], the data consist of information on different policy responses from 31 countries that are covered by Datastream: Australia, Austria, Belgium, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Singapore, South Africa, Spain, Sweden, Switzerland, the United Kingdom, and the United States. This data sample is representative of developed and emerging market economies having adopted complex governmental measures as a response to the COVID-19 public health crisis. All of the bond-related data and variables are derived from the Datastream 10-Year Government Bond Total Returns indices. The 10-year maturities are the primary choice in asset pricing literature due to high liquidity and broad international coverage [49,50]. The sample period encompasses the spread of the pandemic, running from 1 January 2020 through 3 November 2020, covering thus the first two waves of COVID-19. Most of the existing works on this topic focus on the first wave of the pandemic (March–May 2020). In our opinion, the second wave of the public health crisis (September–November 2020) is equally important in studying the impact of COVID-19 on sovereign bond market volatility, given the additional measures imposed by governments to fight against the pandemic. However, the study of the third wave of the pandemic (February–March 2021) should be placed in a totally different context given the start of the vaccination campaign. Following the typical approach in international bond pricing studies [51], we express the market data in U.S. dollars, and the risk-free rate is proxied by the U.S. one-month treasury-bill rate from Kenneth R. French's website [52].

To quantify day-to-day changes in volatility, we build on the work of Antonakakis and Kizys [53], Khalifa et al. [54], and Zaremba et al. [11,25] (all of whom employ absolute measures of daily returns). Furthermore, to extract the country-specific volatility component, free of the impact of systematic risks, we replace the raw returns with residuals from a factor model. To be precise, in order to capture the multidimensionality of bond returns, we utilize the comprehensive seven-factor model originating from Zaremba et al. [25]:

$$\begin{aligned} R_{i,t} = \alpha_i + \beta_i^{MKT}MKT_t^F + \beta_i^{DUR}DUR_t^F + \beta_i^{CRED}CRED_t^F + \beta_i^{SIZE}SIZE_t^F + \\ \beta_i^{MOM}MOM_t^F + \beta_i^{REV}REV_t^F + \beta_i^{CAR}CAR_t^F + \varepsilon_{i,t}. \end{aligned} \tag{1}$$

where $R_{i,t}$ indicates the daily payoff on a country government i on day t, α_i measures the abnormal return, and $\varepsilon_{i,t}$ is the error term. The regression coefficients β_i^{MKT}, β_i^{DUR}, β_i^{CRED}, β_i^{SIZE}, β_i^{MOM}, β_i^{REV}, and β_i^{CAR} reflect the exposures to the market risk (MKT^F), duration (DUR^F), credit risk ($CRED^F$), size ($SIZE^F$), momentum (MOM^F), long-term reversal (REV^F), and carry (CAR^F) risk factors, respectively. A detailed description of factor construction is provided in Table A1 in the Appendix. Indeed, according to Fama and French [55], unexpected changes in the interest rate represent a source of risks and volatility in the bond market. Further, the shift in economic conditions, measured as the difference between the return on a market portfolio and the long-term government bond return, explains the bond price volatility. In addition, the excess return on a value-weighted aggregate market proxy represents another element of risk explaining the financial market volatility [56].

We derive look-ahead bias-free absolute daily residuals by performing the following steps: To begin, for each day t we run the regression (1) using five years of trailing data ending on day t-1. Subsequently, we utilize the coefficient estimates and factor realizations from day t to calculate the expected daily returns. Finally, we compute the residual returns as the difference between the actual return realizations on day t and their expected values implied by the model (1).

Our main explanatory variables are based on the policy response indices from the Oxford COVID-19 Government Response Tracker [57]. The indices aggregate data on different government interventions following the COVID-19 outbreak, such as canceling public gatherings and closing workplaces, social distancing requirements, debt relief, and income support. In our baseline approach, we use three different indices: the Government Response Index (gvt), which incorporates information on all types of policies, as well as the Containment and Health Index (cntm) and the Economic Support Index (eco). The latter two constitute sub-indices of "gvt" and reflect different types of policies. Whereas "cntm" concentrates on containment and closure policies aimed at curbing the pandemic, eco is about economic support to consumers and enterprises during the pandemic.

Besides the primary independent variable, we include a range of additional control variables. These include bond duration (dur), default risk (cred), money market rate (mmr) and convexity (cx), carry (car), momentum (mom), reversal (rev), and "Monday effect" dummy (dummy). The detailed descriptions for all variables are presented in Table A2 in the Appendix A.

Table 1 reports the descriptive statistics for the key variables. Though not reported here, all variables are stationary according to Maddala and Wu's [58], and Pesaran's [59] unit root tests.

Table 1. Summary Statistics.

	Mean	Std. Dev.	Min	Max
R_1	3.392	4.283	0.001	104.7
R_2	5.607	6.966	0.000	125.0
gvt	49.32	24.61	0.000	95.54
cntm	49.28	24.70	0.000	98.96
stg	47.99	26.62	0.000	100.0
eco	49.57	35.21	0.000	100.0
inf	4.578	3.097	0.000	11.49
dur	8.559	1.124	5.390	10.45
cred	4.623	3.663	1.000	13.00
mmr	0.788	1.805	−1.957	7.300
car	0.693	1.107	−1.269	7.623
cx	81.47	20.98	34.86	119.9
size	16.09	0.902	14.13	18.38

Table 1. *Cont.*

	Mean	Std. Dev.	Min	Max
mom	−0.496	0.589	−3.138	3.220
rev	−0.656	1.547	−16.54	3.680

Notes: (i) R_1—daily absolute residuals from a seven-factor model, R_2—daily absolute returns in U.S. dollars, gvt—government response index, cntm—containment and health index, eco—economic support index, stg—original stringency index, inf—new infection cases, dur—duration, cred—credit rating, mmr—money market rate, car—yield-based carry, cx—convexity, size—bond market value, mom—momentum, and rev—reversal; (ii) 6789 observations. The sovereign bond price volatility variables (R_1 and R_2) are adjusted ($|\ln(1 + R)|$) and multiplied by 1000 before running the regression.

2.2. Methods

Quantile regression models are useful to account for unobserved heterogeneity and asymmetry [40]. In addition, when relying on fixed-effect models, researchers can control for unobserved covariates. A combination of these approaches represents the basis of panel quantile fixed-effect models that are proposed in the literature [42,60–62].

Let us consider the following model:

$$Y_{it} = X'_{it}\theta(U_{it}) + \alpha_i \tag{2}$$

where $t = 1, \ldots, T$; $i = 1, \ldots, n$; Y_{it} and X_{it} represent the observable variables; U_{it} is an unobservable component; X'_{it} includes a constant term; and $\theta(\tau)$ is the parameter of interest.

It is assumed that the function $\tau \to X'\,\theta(\tau)$ is increasing in $\tau \in (0, 1)$. In the case α_i is observable, it follows that:

$$P\left[Y_{it} \leq X'_{it}\theta(U_{it}) + \alpha_i | X_i, \alpha_i\right] = \tau, \tag{3}$$

where $U_{it} \sim U[0, 1]$, conditional on $X_i = \left(X'_{i1}, \ldots, X'_{iT}\right)'$ and α_i.

The challenge is the $\theta(\tau)$ identification, which cannot be accomplished by imposing only covariate quantile restrictions [42]. If $Q_Y(\tau|X)$ is the τ-quantile of a random variable Y conditional on X and $e_{it}(\tau) \equiv X'_{it}[\theta(U_{it}) - \theta(\tau)]$, Equation (2) can be written as follows:

$$Y_{it} = X'_{it}\theta(U_{it}) + \alpha_i + e_{it}(\tau), \tag{4}$$

Canay [40] proves that $\theta(\tau)$ is identified for $T \geq 2$ under independence restrictions and the existence of moments. When we move from identification to estimation, we eliminate the fixed effects under the assumption that α_i is a location shift. Practically, Canay [33] assumes that only $\theta(\tau)$ and $e_{it}(\tau)$ depend on τ and transforms Equation (4) as follows:

$$Y_{it} = X'_{it}\theta\mu + \alpha_i + u_{it},\ E(u_{it}|X_i, \alpha_i) = 0. \tag{5}$$

This way α_i is present in the conditional mean of Y_{it}, allowing Canay [40] to compute the two-step estimator $\hat{\theta}\mu$. First, we obtain a consistent estimator of α_i ($\sqrt{T}$) and $\theta\mu$ ($\sqrt{nT}$), with $\hat{\alpha}_i \equiv E_T\left[Y_{it} - X'_{it}\,\hat{\theta}\mu\right]$. Second, we define $\hat{Y}_i \equiv Y_{it} - \hat{\alpha}_i$, and $\hat{\theta}\mu$ becomes

$$\hat{\theta}\mu \equiv \underset{\theta \in \Theta}{\operatorname{argmin}} \mathbb{E}_{nT}[\rho_\tau(\hat{Y}_{it} - X'_{it}\hat{\theta}\mu], \tag{6}$$

where $\mathbb{E}_{nT}(\cdot) \equiv (nT)^{-1} \sum_{t=1}^{T} \sum_{i=1}^{n} (\cdot)$.

Starting from this framework, similar to Li et al. [63], we use the first lag of explanatory variables to avoid any endogeneity bias. Indeed, some governmental responses to the COVID-19 pandemic have an economic nature (i.e., financial aid, fiscal facilities, etc.). Therefore, the governmental decisions in this line are influenced by the state financing costs, that is, by the bond returns. As a result, we test the following general regression:

$$R_{it} = \alpha_0 + \alpha_1 X_{it-1} + \alpha_2 Z_{it-1} + \mu_i + \gamma_t + \varepsilon_{it}, \tag{7}$$

where R_{it} is the daily measure of sovereign bond volatility in the country i on day t, i.e., the absolute residuals from the model (1); α_0 represents a constant term; X_{it-1} is the vector of COVID-19 variables, represented by new cases of infection and governmental response to the SARS-CoV-2 pandemic; Z_{it-1} is the vector of control variables defined in Section 2; and μ_i are the time-invariant country-specific effects, γ_t are the time-specific effects, and ε_{it} are the error terms.

3. Results

3.1. Empirical Findings

Table 2 reports the results of the quantile regressions that account for the overall role of the policy responses. The positive and highly significant coefficients on "gvt" suggest that government interventions amplify bond market volatility. The effect is robust across the majority of quantiles tested. The impact of policy measures increases when we shift from lower to higher quantiles. In other words, a volatile financial market environment implies a stronger reaction to COVID-19-induced policy measures. The only exception is the most volatile quantile, where the "gvt" does not differ significantly from zero.

Table 2. Panel Conditional Quantile Regression—Government Response Index.

	Lower Quantiles			**Middle Quantiles**				**Upper Quantiles**		
	0.05	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**	**0.85**	**0.95**
gvt	0.007 ***	0.006 ***	0.005 ***	0.007 ***	0.010 ***	0.012 ***	0.014 ***	0.013 ***	0.011 **	−0.007
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)	(0.005)	(0.012)
inf	0.201 ***	0.188 ***	0.192 ***	0.181 ***	0.163 ***	0.159 ***	0.136 ***	0.135 ***	0.117 ***	0.097
	(0.021)	(0.017)	(0.016)	(0.014)	(0.016)	(0.018)	(0.022)	(0.025)	(0.041)	(0.100)
dur	−2.444 ***	−2.857 ***	−2.373 ***	−2.218 ***	−2.088 ***	−2.034 ***	−1.890 ***	−1.529 ***	−1.482 *	−3.128
	(0.475)	(0.374)	(0.357)	(0.318)	(0.361)	(0.394)	(0.495)	(0.559)	(0.899)	(2.190)
cred	−0.379 ***	−0.382 ***	−0.329 ***	−0.327 ***	−0.326 ***	−0.326 ***	−0.321 ***	−0.328 ***	−0.343 ***	−0.443 ***
	(0.020)	(0.015)	(0.015)	(0.013)	(0.015)	(0.016)	(0.020)	(0.023)	(0.038)	(0.092)
mmr	2.361 ***	2.518 ***	2.535 ***	2.558 ***	2.617 ***	2.689 ***	2.753 ***	2.869 ***	2.946 ***	3.495 ***
	(0.045)	(0.036)	(0.034)	(0.030)	(0.034)	(0.038)	(0.047)	(0.053)	(0.086)	(0.211)
car	2.250 ***	2.422 ***	2.338 ***	2.435 ***	2.484 ***	2.598 ***	2.696 ***	2.879 ***	3.220 ***	4.721 ***
	(0.071)	(0.056)	(0.053)	(0.048)	(0.054)	(0.059)	(0.074)	(0.084)	(0.135)	(0.329)
cx	0.121 ***	0.151 ***	0.127 ***	0.120 ***	0.114 ***	0.114 ***	0.105 ***	0.085 ***	0.083	0.192
	(0.027)	(0.021)	(0.020)	(0.018)	(0.021)	(0.023)	(0.028)	(0.032)	(0.052)	(0.127)
size	−0.445 ***	−0.506 ***	−0.540 ***	−0.621 ***	−0.717 ***	−0.844 ***	−0.936 ***	−1.073 ***	−1.274 ***	−1.568 ***
	(0.054)	(0.042)	(0.040)	(0.036)	(0.041)	(0.044)	(0.056)	(0.063)	(0.102)	(0.248)
mom	−0.534 ***	−0.689 ***	−0.616 ***	−0.673 ***	−0.773 ***	−0.859 ***	−0.930 ***	−1.102 ***	−1.562 ***	−2.664 ***
	(0.082)	(0.065)	(0.062)	(0.055)	(0.062)	(0.068)	(0.086)	(0.097)	(0.156)	(0.381)
rev	0.565 ***	0.482 ***	0.470 ***	0.491 ***	0.494 ***	0.528 ***	0.543 ***	0.519 ***	0.591 ***	0.658 ***
	(0.036)	(0.029)	(0.027)	(0.024)	(0.028)	(0.030)	(0.038)	(0.043)	(0.069)	(0.169)
dummy	0.004	−0.062	−0.087	−0.118	−0.1537	−0.148 *	−0.156	−0.062	0.0663	−0.110
	(0.108)	(0.085)	(0.081)	(0.072)	(0.082)	(0.089)	(0.112)	(0.127)	(0.205)	(0.498)

Notes: The table reports slope coefficients from panel regressions along with the corresponding standard errors. (i) Standard error in parentheses; (ii) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (iii) 6788 observations; (iv) gvt—government response index, inf—new infection cases, dur—duration, cred—credit rating, mmr—money market rate, car—yield-based carry, cx—convexity, size—bond market value, mom—momentum, rev—reversal, and dummy—binary variable that takes value 1 if Monday and 0 for the rest of the weekdays.

Besides the impact of policy responses to the pandemic, our baseline regression analysis uncovers the role of the pandemic itself: growth in the number of new infections translates into an increase in the bond market volatility. This observation matches similar earlier findings from equity markets [3,11,34] showing that COVID-19-induced uncertainty contributes to the instability of stock prices. Interestingly, the COVID-19 figures more strongly influence the sovereign bond prices located at the lower and medium volatility quantiles when compared with high-volatility bonds. Consequently, less volatile financial markets—typically found in developed countries—are more sensitive to changes in COVID-19 figures.

The overall government response index, as examined in Table 2, encompasses various interventions that may exhibit differing economic impacts. Therefore, in the subsequent analysis, we distinguish containment and closure measures from economic support policies. These two categories are measured with "cntm" and "eco", respectively.

Table 3 presents the influence of containment and closure measures on bond market volatility.

Table 3. Panel Conditional Quantile Regression—Containment and Health Index.

	Lower Quantiles			Middle Quantiles				Upper Quantiles		
	0.05	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**	**0.85**	**0.95**
cntm	0.010 ***	0.009 ***	0.007 ***	0.009 ***	0.013 ***	0.015 ***	0.017 ***	0.019 ***	0.019 ***	0.007
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.005)	(0.012)
inf	0.182 ***	0.170 ***	0.174 ***	0.166 ***	0.143 ***	0.135 ***	0.116 ***	0.101 ***	0.075 *	0.001
	(0.021)	(0.017)	(0.016)	(0.014)	(0.016)	(0.017)	(0.022)	(0.025)	(0.041)	(0.101)
dur	−2.209 ***	−2.498 ***	−2.067 ***	−1.858 ***	−1.744 ***	−1.697 ***	−1.596 ***	−1.243 **	−1.115	−2.561
	(0.466)	(0.375)	(0.364)	(0.325)	(0.364)	(0.386)	(0.480)	(0.562)	(0.910)	(2.221)
cred	−0.374 ***	−0.374 ***	−0.317 ***	−0.324 ***	−0.314 ***	−0.322 ***	−0.315 ***	−0.315 ***	−0.329 ***	−0.424 ***
	(0.019)	(0.015)	(0.015)	(0.013)	(0.015)	(0.016)	(0.020)	(0.023)	(0.038)	(0.093)
mmr	2.293 ***	2.470 ***	2.475 ***	2.492 ***	2.538 ***	2.611 ***	2.676 ***	2.791 ***	2.886 ***	3.419 ***
	(0.044)	(0.036)	(0.035)	(0.031)	(0.035)	(0.037)	(0.046)	(0.054)	(0.087)	(0.213)
car	2.170 ***	2.314 ***	2.249 ***	2.345 ***	2.389 ***	2.535 ***	2.608 ***	2.782 ***	3.070 ***	4.610 ***
	(0.070)	(0.056)	(0.054)	(0.049)	(0.054)	(0.058)	(0.072)	(0.084)	(0.137)	(0.334)
cx	0.110 ***	0.131 ***	0.111 ***	0.099 ***	0.095 ***	0.095 ***	0.089 ***	0.070 **	0.062	0.164
	(0.027)	(0.021)	(0.021)	(0.019)	(0.021)	(0.022)	(0.028)	(0.032)	(0.053)	(0.129)
size	−0.453 ***	−0.516 ***	−0.553 ***	−0.625 ***	−0.716 ***	−0.836 ***	−0.936 ***	−1.084 ***	−1.302 ***	−1.535 ***
	(0.052)	(0.042)	(0.041)	(0.036)	(0.041)	(0.043)	(0.054)	(0.063)	(0.103)	(0.251)
mom	−0.521 ***	−0.668 ***	−0.583 ***	−0.642 ***	−0.748 ***	−0.821 ***	−0.878 ***	−1.082 ***	−1.518 ***	−2.690 ***
	(0.080)	(0.065)	(0.063)	(0.056)	(0.063)	(0.067)	(0.083)	(0.097)	(0.158)	(0.385)
rev	0.588 ***	0.493 ***	0.481 ***	0.496 ***	0.508 ***	0.539 ***	0.554 ***	0.531 ***	0.607 ***	0.698 ***
	(0.035)	(0.028)	(0.028)	(0.025)	(0.028)	(0.029)	(0.036)	(0.043)	(0.070)	(0.170)
dummy	−0.012	−0.051	−0.080	−0.131 *	−0.148 *	−0.162 *	−0.161	−0.057	0.044	0.004
	(0.106)	(0.085)	(0.082)	(0.074)	(0.082)	(0.087)	(0.109)	(0.128)	(0.207)	(0.505)

Notes: The table reports slope coefficients from panel regressions along with the corresponding standard errors. (i) Standard error in parentheses; (ii) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (iii) 6788 observations; (iv) cntm—Containment and Health Index, inf—new infection cases, dur—duration, cred—credit rating, mmr—money market rate, car—yield-based carry, cx—convexity, size—bond market value, mom—momentum, rev—reversal, and dummy—binary variable that takes value 1 if Monday and 0 for the rest of the weekdays.

This additional analysis unequivocally reveals the underlying source of the impact of government policy responses on market volatility. Highly significant "cntm" coefficients indicate that these containment and closure interventions constitute a major contributor to bond price variability. In accordance with previous results, the policy measures generate a more substantial impact when we test the higher quantiles of the distribution, whereas the spread of the pandemic as measured by the "inf" variable is more powerful in low quantiles. Finally, similar to the previous case, the effect of policy measures (or the spread of the disease) on bond price volatility is not significant for very volatile markets (i.e., the 0.95 quantile).

Let us now turn to the role of the other category of government interventions: economic support policies (eco). Table 4 demonstrates the results of another set of quantile regressions to capture the role of this category of government actions. Our analysis uncovers a negative impact on bond price volatility for lower and upper quantiles, but not for middle quantiles (Table 4). For sovereign bonds with smaller and higher volatility, economic support interventions stabilize the markets. The effect is more substantial for the upper quantiles, which is in line with the impact generated by other policy interventions (see, for example, the results reported in Table 3).

Table 4. Panel Conditional Quantile Regression—Economic Support Index.

	Lower Quantiles				Middle Quantiles				Upper Quantiles	
	0.05	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**	**0.85**	**0.95**
eco	−0.002	−0.004 ***	−0.002 *	−0.001	−0.001	−0.001	−0.001	−0.004 **	−0.010 ***	−0.025 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.007)
inf	0.273 ***	0.255 ***	0.240 ***	0.236 ***	0.239 ***	0.238 ***	0.224 ***	0.243 ***	0.209 ***	0.170 **
	(0.016)	(0.014)	(0.012)	(0.011)	(0.013)	(0.014)	(0.019)	(0.023)	(0.033)	(0.085)
dur	−3.718 ***	−4.251 ***	−3.546 ***	−3.272 ***	−3.264 ***	−3.125 ***	−3.131 ***	−2.733 ***	−2.920 ***	−3.751
	(0.444)	(0.378)	(0.337)	(0.316)	(0.362)	(0.391)	(0.507)	(0.614)	(0.884)	(2.282)
cred	−0.366 ***	−0.370 ***	−0.314 ***	−0.314 ***	−0.325 ***	−0.331 ***	−0.332 ***	−0.348 ***	−0.345 ***	−0.424 ***
	(0.018)	(0.015)	(0.014)	(0.013)	(0.015)	(0.016)	(0.021)	(0.025)	(0.037)	(0.095)
mmr	2.343 ***	2.546 ***	2.572 ***	2.594 ***	2.664 ***	2.721 ***	2.814 ***	2.902 ***	3.006 ***	3.394 ***
	(0.043)	(0.036)	(0.032)	(0.030)	(0.035)	(0.038)	(0.049)	(0.059)	(0.086)	(0.221)
car	2.348 ***	2.463 ***	2.351 ***	2.437 ***	2.555 ***	2.654 ***	2.777 ***	3.006 ***	3.217 ***	4.479 ***
	(0.066)	(0.056)	(0.050)	(0.047)	(0.054)	(0.058)	(0.075)	(0.091)	(0.132)	(0.340)
cx	0.187 ***	0.226 ***	0.191 ***	0.176 ***	0.178 ***	0.172 ***	0.172 ***	0.148 ***	0.161 ***	0.215
	(0.025)	(0.022)	(0.019)	(0.018)	(0.021)	(0.022)	(0.029)	(0.035)	(0.051)	(0.132)
size	−0.331 ***	−0.419 ***	−0.468 ***	−0.544 ***	−0.640 ***	−0.757 ***	−0.840 ***	−0.982 ***	−1.175 ***	−1.347 ***
	(0.050)	(0.042)	(0.038)	(0.035)	(0.041)	(0.044)	(0.057)	(0.069)	(0.100)	(0.258)
mom	−0.542 ***	−0.697 ***	−0.630 ***	−0.660 ***	−0.770 ***	−0.850 ***	−0.928 ***	−1.016 ***	−1.392 ***	−2.258 ***
	(0.077)	(0.066)	(0.059)	(0.055)	(0.063)	(0.068)	(0.089)	(0.107)	(0.155)	(0.399)
rev	0.475 ***	0.388 ***	0.383 ***	0.413 ***	0.416 ***	0.430 ***	0.416 ***	0.377 ***	0.427 ***	0.442 **
	(0.034)	(0.029)	(0.026)	(0.024)	(0.028)	(0.030)	(0.039)	(0.047)	(0.069)	(0.177)
dummy	0.001	−0.068	−0.085	−0.107	−0.196 **	−0.175 **	−0.185	−0.019	−0.012	−0.100
	(0.101)	(0.086)	(0.076)	(0.072)	(0.082)	(0.089)	(0.115)	(0.139)	(0.201)	(0.519)

Notes: The table reports slope coefficients from panel regressions along with the corresponding standard errors. (i) Standard error in parentheses; (ii) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (iii) 6788 observations; (iv) eco—Economic Support Index, inf—new infection cases, dur—duration, cred—credit rating, mmr—money market rate, car—yield-based carry, cx—convexity, size—bond market value, mom—momentum, rev—reversal, and dummy—binary variable that takes value 1 if Monday and 0 for the rest of the weekdays.

To sum up our considerations, we find that market volatility is affected by containment and closure restrictions as well as economic support policies; however, the directions of the impacts are opposite. Whereas the first category tends to boost market fluctuations, the latter helps to stabilize the market.

3.2. Robustness Checks

To assure the validity of our findings, we run a number of additional robustness checks. First, we use a different metric to compute the sovereign bond price volatility, relying on absolute raw returns rather than on risk-adjusted returns (residuals). In an unreported analysis, we also consider different nested models. The major results remain unaffected. These results are reported in Table 5 and are very similar to those reported in Section 3.1.

Table 5. Panel Conditional Quantile Regression—Robustness Analysis Using Daily USD Returns as a Proxy for Bond Price Volatility.

	Lower Quantiles				Middle Quantiles				Upper Quantiles	
	0.05	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**	**0.85**	**0.95**
gvt	0.002	0.019 ***	0.020 ***	0.023 ***	0.030 ***	0.033 ***	0.032 ***	0.034 ***	0.029 ***	−0.036 *
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.006)	(0.009)	(0.020)
inf	0.310 ***	0.264 ***	0.246 ***	0.238 ***	0.203 ***	0.195 ***	0.217 ***	0.217 ***	0.249 ***	0.349 **
	(0.033)	(0.026)	(0.025)	(0.024)	(0.027)	(0.031)	(0.037)	(0.049)	(0.076)	(0.165)
dur	−5.950 ***	−4.269 ***	−4.197 ***	−4.576 ***	−5.363 ***	−6.754 ***	−8.351 ***	−9.593 ***	−12.41 ***	−16.18 ***
	(0.734)	(0.576)	(0.545)	(0.529)	(0.589)	(0.674)	(0.805)	(1.066)	(1.655)	(3.604)
cred	−0.330 ***	−0.340 ***	−0.363 ***	−0.360 ***	−0.357 ***	−0.342 ***	−0.320 ***	−0.313 ***	−0.235 ***	−0.257 *
	(0.031)	(0.024)	(0.023)	(0.022)	(0.024)	(0.028)	(0.034)	(0.045)	(0.069)	(0.152)
mmr	3.716 ***	3.965 ***	4.187 ***	4.258 ***	4.309 ***	4.432 ***	4.540 ***	4.782 ***	5.056 ***	6.006 ***
	(0.070)	(0.055)	(0.052)	(0.051)	(0.056)	(0.065)	(0.077)	(0.102)	(0.159)	(0.347)
car	3.341 ***	3.305 ***	3.543 ***	3.693 ***	3.887 ***	4.119 ***	4.290 ***	4.455 ***	4.791 ***	6.643 ***
	(0.110)	(0.086)	(0.082)	(0.079)	(0.088)	(0.101)	(0.121)	(0.160)	(0.249)	(0.542)

Table 5. *Cont.*

	Lower Quantiles			Middle Quantiles				Upper Quantiles		
	0.05	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**	**0.85**	**0.95**
cx	0.323 ***	0.233 ***	0.231 ***	0.254 ***	0.300 ***	0.388 ***	0.479 ***	0.556 ***	0.726 ***	0.972 ***
	(0.042)	(0.033)	(0.031)	(0.030)	(0.034)	(0.039)	(0.046)	(0.062)	(0.096)	(0.210)
size	−0.560 ***	−0.689 ***	−0.734 ***	−0.867 ***	−0.946 ***	−1.107 ***	−1.278 ***	−1.531 ***	−1.995 ***	−2.608 ***
	(0.083)	(0.065)	(0.061)	(0.060)	(0.066)	(0.076)	(0.091)	(0.121)	(0.187)	(0.408)
mom	−0.371 ***	−0.609 ***	−0.791 ***	−0.904 ***	−0.947 ***	−1.046 ***	−1.117 ***	−1.175 ***	−1.770 ***	−3.300 ***
	(0.127)	(0.100)	(0.095)	(0.092)	(0.102)	(0.117)	(0.140)	(0.185)	(0.288)	(0.627)
rev	0.846 ***	0.812 ***	0.721 ***	0.799 ***	0.878 ***	0.939 ***	1.006 ***	1.121 ***	1.322 ***	1.588 ***
	(0.057)	(0.044)	(0.042)	(0.041)	(0.045)	(0.052)	(0.062)	(0.082)	(0.128)	(0.279)
dummy	−0.101	−0.188	−0.312 **	−0.319 ***	−0.375 ***	−0.330 **	−0.423 **	−0.413 *	−0.134	−0.458
	(0.167)	(0.131)	(0.124)	(0.120)	(0.134)	(0.153)	(0.183)	(0.243)	(0.377)	(0.821)

Notes: The table reports slope coefficients from panel regressions along with the corresponding standard errors. (i) Standard error in parentheses; (ii) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (iii) 6788 observations; (iv) gvt—government response index, inf—new infection cases, dur—duration, cred—credit rating, mmr—money market rate, car—yield-based carry, cx—convexity, size—bond market value, mom—momentum, rev—reversal, and dummy—binary variable that takes value 1 if Monday and 0 for the rest of the weekdays.

Second, we work with alternative sets of control variables, and we show a similar effect of governmental interventions and COVID-19-related uncertainty (Table 6).

Table 6. Panel Conditional Quantile Regression—Robustness Analysis Using a Different Set of Control Variables.

	Lower Quantiles			Middle Quantiles				Upper Quantiles		
	0.05	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**	**0.85**	**0.95**
gvt	0.009 ***	0.015 ***	0.014 ***	0.012 ***	0.012 ***	0.016 ***	0.018 ***	0.018 ***	0.011 **	−0.002
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.005)	(0.012)
inf	0.095 ***	0.060 ***	0.042 ***	0.046 ***	0.043 ***	0.031 *	0.018	0.017	0.026	−0.133
	(0.025)	(0.017)	(0.016)	(0.014)	(0.016)	(0.017)	(0.022)	(0.028)	(0.044)	(0.102)
dur	−0.126 **	−0.223 ***	−0.200 ***	−0.168 ***	−0.182 ***	−0.158 ***	−0.166 ***	−0.188 ***	−0.188 *	−0.084
	(0.055)	(0.039)	(0.035)	(0.031)	(0.036)	(0.038)	(0.050)	(0.063)	(0.097)	(0.227)
cred	0.153 ***	0.205 ***	0.225 ***	0.252 ***	0.258 ***	0.262 ***	0.273 ***	0.261 ***	0.284 ***	0.218 **
	(0.022)	(0.015)	(0.014)	(0.012)	(0.014)	(0.015)	(0.020)	(0.025)	(0.039)	(0.090)
car	0.036	−0.067	−0.052	0.006	0.138 ***	0.232 ***	0.396 ***	0.702 ***	1.044 ***	2.473 ***
	(0.071)	(0.050)	(0.045)	(0.040)	(0.046)	(0.048)	(0.064)	(0.081)	(0.125)	(0.290)
size	−0.801 ***	−0.876 ***	−0.881 ***	−0.929 ***	−1.008 ***	−1.139 ***	−1.232 ***	−1.352 ***	−1.615 ***	−1.762 ***
	(0.061)	(0.043)	(0.039)	(0.034)	(0.040)	(0.042)	(0.056)	(0.070)	(0.108)	(0.252)
mom	0.967 ***	0.924 ***	0.935 ***	0.851 ***	0.734 ***	0.599 ***	0.470 ***	0.260 **	−0.348 **	−1.264 ***
	(0.091)	(0.064)	(0.058)	(0.051)	(0.059)	(0.062)	(0.083)	(0.104)	(0.160)	(0.371)
rev	1.242 ***	1.138 ***	1.140 ***	1.102 ***	1.125 ***	1.190 ***	1.211 ***	1.249 ***	1.364 ***	1.473 ***
	(0.037)	(0.026)	(0.023)	(0.020)	(0.024)	(0.025)	(0.033)	(0.042)	(0.065)	(0.151)
dummy	0.007	−0.036	−0.092	−0.091	−0.126	−0.141 *	−0.116	−0.061	0.112	0.080
	(0.124)	*(0.087)*	*(0.080)*	*(0.070)*	*(0.080)*	*(0.085)*	*(0.113)*	*(0.142)*	*(0.218)*	*(0.507)*

Notes: The table reports slope coefficients from panel regressions along with the corresponding standard errors. (i) Standard error in parentheses; (ii) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (iii) 6788 observations; (iv) gvt—government response index, inf—new infection cases, dur—duration, cred—credit rating, car—yield-based carry, size—bond market value, mom—momentum, rev—reversal, and dummy—binary variable that takes value 1 if Monday and 0 for the rest of the weekdays.

Third, in an unreported analysis, we employ a modified measure of the strictness of government policies, namely the Stringency Index, which is also sourced from the Oxford COVID-19 Government Response Tracker. None of these extra robustness checks materially affect our findings. Our overall conclusions remain unaffected.

4. Discussion

The novelty of our analysis consists in investigating the asymmetric, nonlinear effect of government interventions and COVID-19-induced uncertainty on bond price volatility. Our first hypothesis points in favor of a nonlinear impact of government interventions and new COVID-19 infection cases on bond market volatility. The empirical findings confirm this hypothesis. More specifically, we have shown that government interventions and new COVID-19 infection cases have different impacts on bond market volatility, depending on the volatility level. Indeed, the governmental interventions' effect is less strong at lower quantiles, that is, for less volatile markets. Consequently, the intervention impact is influenced by the bond volatility distribution. This result thus validates the first hypothesis of our empirical exercise and can be explained by the fact that the government interventions during the pandemic were stronger in the developed countries, generating a higher uncertainty and thus amplifying the bond price volatility. On contrary, the financial markets had a stronger reaction to new infection cases in more developed countries. This is an original result, never reported by the previous literature.

Making the differentiation between containment and economic measures, our second research hypothesis posits that containment measures amplify volatility, whereas economic measures have the opposite effect. This is because the travel restrictions generate additional uncertainty which amplifies the volatility, while the economic measures are designed to restore investor confidence. Indeed, we have shown that the containment measure amplified the volatility whereas the economic measures reduced the bond price volatility level. However, the positive impact the containment and closure measures have on the volatility level cannot be compensated by the stabilizing effect of economic measures. Similar to the main results, the containment measures' impact is stronger at upper quantiles, whereas the impact of economic measures is significant only at lower and upper quantiles, but not at middle quantiles. This finding brings some clarification to the previous results reported in the empirical literature, showing a mixed effect of government interventions on financial market volatility. Our findings contrast those reported by Zaremba et al. [25], who reported an overall stabilizing effect of government interventions. We, therefore, validate our second research hypothesis.

Lastly, we partially validate the third hypothesis of our research. Indeed, the "Monday effect", associated with fewer reported infection cases, is significant at middle quantiles only.

5. Conclusions

We examine the impact of government interventions and COVID-19 numbers on the volatility of sovereign bonds. We apply quantile regressions to a sample of 31 countries to scrutinize the importance of different types of policy responses during the first two waves of the pandemic. We show that the impact of COVID-19 on sovereign bonds is influenced by the level of market volatility, which represents an original result of our analysis.

Our findings demonstrate that the direction of the effect on government bond return volatility depends strongly on the type of interventions. Confinement and closure restrictions increase market uncertainty and, in consequence, drive the return volatility up. In contrast, economic support measures tend to calm the volatility level in trading and enhance market stability. Further, we show that the impact of COVID-19-induced policy measures and related uncertainty is higher in the case of less volatile markets (i.e., at lower quantiles).

The conclusions from this study yield clear, practical implications. Since confinement and closure restrictions amplify volatility, our results imply that governments should be transparent and clear with their plans about this type of intervention in the short and longer terms. The COVID-19 period is characterized by increased uncertainty, and government interventions may amplify this uncertainty. Hence, providing information publicly as soon as possible may calm the adverse effect of closures. In addition, even though economic interventions seem to be associated with positive responses, this does not mean that transparency about economic steps is not needed, especially if such supportive actions are expected to increase the fiscal deficit.

The findings also imply that investors can exploit this information to better shape their investment decisions. They should be aware that non-economic interventions, which are not directly related to financial markets, may spill over to capital markets and are not limited to the equity markets. Therefore, investors, particularly those operating in the fixed-income markets, should monitor the changes in government policy and make the required adjustments to their portfolios. More precisely, to anticipate the volatility dynamics, they need to analyze the type of interventions and the sovereign bond markets' characteristics.

Our research has several limitations and can be extended in the following ways: First, our analysis covers only the first two waves of the pandemic. Although governmental interventions and COVID-19-induced uncertainty were vitally important in 2020, a different set of measures was adopted in 2021 during the third and fourth waves of the pandemic. Second, in the context of the high volatility recorded by the bond markets in the post-pandemic period, it is recommended to investigate the sources of this volatility. On the one hand, COVID-19 might change investor behavior for a long period. On the other hand, other elements of uncertainty, represented by the energy crisis or the Russo-Ukrainian War, can explain the volatility level. Third, additional robustness analyses can be performed using alternative approaches to derive the day-to-day changes in volatility, relying on Fama and French's [55] three-factor model or on Carhart's [56] four-factor model.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Construction of the Cross-Sectional Asset Pricing Factors.

Symbol	Factor	Description
MKT^F	Market risk factor	MKT^F is the excess return on the market, i.e., the value-weighted return of all the bond indices in the sample at the end of month t minus the risk-free rate, i.e., the one-month T-Bill return.
DUR^F	Duration factor	The factor is represented by a long–short zero-investment portfolio that buys (sells) the value-weighted portfolio comprising 30% of bond indices with the highest (lowest) adjusted duration.
$CRED^F$	Credit risk factor	The factor is represented by a long–short zero-investment portfolio that buys (sells) the value-weighted portfolio comprising 30% of bond indices with the highest (lowest) adjusted credit risk score. The credit risk score for each market is calculated as the average numerical rating from three major rating agencies: Moody's, S&P, and Fitch. To obtain the numerical ratings, we convert all the ratings linearly so that the top rating (AAA/Aaa) is associated with 1 and the bottom rating (C) is associated with 21.
$SIZE^F$	Size factor	The factor is represented by a long–short zero-investment portfolio that buys (sells) the value-weighted portfolio comprising 30% of bond indices with the highest (lowest) market value of the relevant bond basket.
MOM^F	Momentum factor	The factor is represented by a long–short zero-investment portfolio that buys (sells) the value-weighted portfolio comprising 30% of bond indices with the lowest (highest) change in yield-to-maturity from t-12 to t-1. This corresponds with going long (short) bonds with the highest (lowest) return induced by the change in YTMs.

Table A1. *Cont.*

Symbol	Factor	Description
REV^F	Reversal factor	The factor is represented by a long–short zero-investment portfolio that buys (sells) the value-weighted portfolio comprising 30% of bond indices with the highest (lowest) change in the yield-to-maturity (YTM) from t-60 to t-13. This corresponds with going long (short) bonds with the lowest (highest) return induced by the change in YTMs.
CAR^F	Carry factor	The factor is represented by a long–short zero-investment portfolio that buys (sells) the value-weighted portfolio comprising 30% of bond indices with the highest (lowest) lowest carry. The carry variable is measured as the difference between the yield-to-maturity on 10-year government bonds and the 3-month interbank interest rate.

Notes: The table displays the procedures used to calculate the returns on asset pricing factors used in this study.

Table A2. Major Variables Used in the Study.

Symbol	Variable	Description
		Panel A: Dependent variables
R_1	Daily absolute residuals from a seven-factor model	R_1 represents the residuals from the seven-factor model (1), computed as $\lvert \ln(1 + R) \rvert$.
R_2	Daily absolute returns in U.S. dollars	R_2 represents the daily returns computed as $\lvert \ln(1 + R) \rvert$.
		Panel B: Explanatory variables of interest
gvt	Government Response Index	COVID-19 government policy response index aggregating all types of policies and rescaling them to create a score between 0 and 100 on day *t*
cntm	Containment and Health Index	COVID-19 containment and health index aggregating only containment, closure, and health policies and rescaling them rescaled to create a score between 0 and 100 on day t.
stg	Stringency Index	COVID-19 containment and health index aggregating only containment and closure policies and rescaling them rescaled to create a score between 0 and 100 on day t.
eco	Economic Support Index	COVID-19 economic support index aggregating only the goverment policy responses targeting and providing economic support and rescaling them to create a score between 0 and 100 on day t.
inf	New infections	The new cases of infection are computed as $\ln(1 + \Delta INF')$, where INF′ is the number of infected cases.
		Panel C: Control variables
dur	Duration	Average adjusted duration of the bond market index on day t-1.
cred	Quantified credit rating	Numerical sovereign rating of the government bonds in the index on day t-1. The credit risk score for each market is calculated as the average numerical rating from three major rating agencies: Moody's, S&P, and Fitch. To obtain the numerical ratings, we convert all the ratings linearly, so that the top rating (AAA/Aaa) is associated with 1 and the bottom rating (C) is associated with 21.
mmr	Money market rate	Three-month interbank rate that is available in a given country at t-1.
car	Carry	The difference between the yield-to-maturity on 10-year government bonds and the 3-month interbank interest rate.
cx	Convexity	Average adjusted convexity of the bond market index on day t-1.
size	Market value	Natural logarithm of the market value of the bond index portfolio expressed in U.S. dollars on day t-1.
mom	Momentum	Change in the yield-to-maturity level on the government bond index in months t-12 to t-1.
rev	Reversal	Change in the yield-to-maturity level on the government bond index in months t-60 to t-13.
dummy	"Monday effect" dummy	The variable takes the value 1 if the day of the week is Monday and 0 otherwise.

Notes: The table presents the variables that are used in the study.

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