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International uncertainty shocks and central bank quantitative easing under supply shocks

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Abstract. This study examines the impact of shocks to economic instability in countries with quantitative easing policies. We estimate a global VAR with time-varying parameters using Bayesian techniques (TVP-GVAR-FSVM). We estimate Nelson-Siegel, a variable related to the yield curve, and find no significant difference in the results whether it is included or not in the VAR model; as a result of the change from a primarily demand-driven shock before 2020 to a supply shock after 2020, the shock to instability is amplified. Volatility shocks were amplified. We further examined the trends in changes in interest rates, exchange rates, long- and short-term interest rate differentials, and economic instability from three perspectives: first, developing versus non-developing countries; second, resource-exporting versus non-resource-exporting countries; and third, countries like Japan, which employs yield curve control, and other countries Third, whether the type of quantitative easing policy differs from that of other countries, such as Japan, which uses yield curve control. Daily data on exchange rates and long- and short-term interest rate differentials revealed commonalities among resource-exporting countries. The TVP-GVAR-FSVM estimation results also showed that the consumer price index has shown common movements in developing countries, especially resource-exporting countries, in recent years. The effect on the unemployment rate also showed movements specific to developed countries, but no commonalities were found among countries in other variables. Compared to resource-importing countries, resource-exporting countries' increased profits due to higher resource prices after the war in Ukraine served as a cushion due to the instability in the global economy and weakened the negative impact on their economies. However, for developing resource-importing countries, shocks to economic stability caused significant volatility. A common feature of countries that have switched to interest rate policies is that prices have very high rates of increase. In addition, the rise in yield curve variables suppressed consumer prices and raised stock prices. Countries that experienced a sustained narrowing of the long/short interest rate differential theoretically resulted in a flattening of the yield curve but also resulted in currency appreciation.
Keywords. Quantitative easing; International uncertainty shocks; TVP-GVAR-FSVM; Resource countries; Developing countries.
JEL. C52; L25; M14.

1. Introduction

We tested for differences in spillover paths and changes in impact between periods of traditional and unconventional monetary policy by Bayesian estimation of a global VAR with time-varying parameters (TVP-GVAR-FSVM) by Pfarrhofer (2022). We used a global VAR featuring time-varying parameters and factor stochastic volatility in the

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mean. We use a global VAR featuring time-varying parameters and factor stochastic volatility in the mean. Among the countries that introduced quantitative easing policies, the U.S., the largest country, changed to a higher interest rate policy as consumer prices rose in the U.S. The interest rate differential between the U.S. and the U.S. widened. The countries whose interest rate differentials widened between the U.S. and their home countries saw their currencies depreciate. We will examine the impact of these effects on resource-importing and resource-exporting countries.

Forward guidance attempts to change people's inflation expectations through strong messages from central banks, such as the Bank of Japan, about their forward-looking monetary policy (Taehun *et al.,* 2005). However, to control inflation, forward guidance to predict and control inflation expectations did not work well enough (Blinder, 2018). In particular, the high inflation that occurred in the U.S. and Europe in 2022 is widely viewed as a peculiar inflation triggered by the natural disaster COVID-19. The U.S. provided huge cash transfers to households, small and medium-sized businesses, and others as a countermeasure to the recession caused by the spread of the infection. This money was not spent due to restrictions on leaving the house, etc., but when the outbreak of the disease subsided, people began to consume the money at once, resulting in rapid inflation (Cochran, 2022). This type of inflation is not the kind of inflation where prices keep rising and rising and rising, because it ends when the price level rises to some extent. This type of inflation caused by large cash transfers is called fiscal inflation (Cochran, 2022). On the other hand, Barro *et al.* (2020) believe that supply shocks similar to those that occurred during the global epidemic of the Spanish flu at the beginning of the century are the cause of high inflation; during the Spanish flu epidemic at the beginning of the 20th century, inflation was caused by labor shortages due to increased deaths, shortages of goods, and wage increases. This time, too, the spread of infection has caused an increase in the number of people leaving the workforce, a decline in the labor supply, a drop in the supply of goods, and rising wages, resulting in inflation. As with fiscal inflation, this, too, should subside once prices and wages rise to some extent and the level adjustment is complete, and the situation is not likely to lead to even higher inflation (Barro *et al.,* 2020). In some countries, including Japan, prices have risen, especially for energy-related products, and food prices, such as wheat, have also risen, creating a commodity group that is experiencing acute inflation. The situation is complicated by the fact that many of the prices that form the CPI have not moved at all. TVP- GVAR-FSVM to confirm this.

The results of the analysis show that quantitative easing policies directly increase the quantity of money but fail to suppress prices. Instead of increasing labor supply and the supply of goods to solve supply shocks, raising interest rates may have resulted in further increases in the cost of production, further reducing the quantity supplied.

Supply shocks lead to a weaker yen and higher interest rates. A developing country with a very high level of central bank purchases of government bonds at the time of the introduction of quantitative easing policy will further magnify currency depreciation. Countries with high import ratios will also adopt high-interest-rate policies to stop their currencies from depreciating. Countries with a high ratio of exports or countries whose CPI does not rise will maintain a zero-interest-rate policy or a low interest-rate policy. For countries with high export ratios, a weak currency lowers the price of exports, and we will examine the impact on the quantitative easing policies of other countries of the high interest rate policies initiated by the U.S. after April 2022 and the reduction of quantitative easing policies adopted by other countries in 2020, in other words, the reduction of balance sheets.

Japan's quantitative easing policy has different characteristics from those of other countries. In Japan, there are two methods of purchasing JGBs after a zero-interest-rate policy: the first method targets the purchase of a certain amount of JGBs; the second method sets the JGB yield at 0%, rather than the amount of JGBs purchased, to avoid flattening the yield curve. The second is to avoid a flattening of the yield curve by setting the yield on JGBs at 0% instead of the amount of JGB purchases. Thus, there are various types of non-traditional, non-traditional monetary policies such as yield curve control policies. A flattening yield curve is a precursor to inverse yield. An inverse yield means investor uncertainty and subsequently higher interest rates. By including three variables related to the yield curve as variables: Nelson-Siegel level, slope, and curvature, we confirm the impact of the yield curve on economic variables. The results will be compared with those obtained from the variables included in the regular VAR model. The level parameter is expected to reflect the degree of incorporation of expected inflation and short-term interest rates since it has a uniform effect on bond yields over all remaining maturities. The slope multiplied by -1 is a parameter for the difference between long and short term interest rates, a concept that has an affinity with the term premium, and thus is interpreted to reflect the degree of incorporation of inflation, economic growth, and uncertainty. Finally, the curvature is a parameter that expresses the relatively high yield of the medium-term zone compared to the long- and short-term, and is analogous to the butterfly spread (obtained by subtracting the yields on short- and long-term bonds from twice the yield on medium-term bonds). A high value of this parameter is interpreted as incorporating a tighter monetary policy stance, while a low value is interpreted as incorporating an accommodative stance.

The sharp rise in U.S. long-term interest rates and the ensuing economic turmoil that ensued (taper tantrum) began in May 2013 when the Fed chairman mentioned a reduction in the quantitative easing policy. One factor contributing to this was the portfolio rebalancing effect. This effect occurs when a central bank, through its quantitative easing policy, purchases large amounts of government bonds and long-term debt, and the supply-demand balance in a country's bond market tightens because demand is greater than it would be without the central bank's intervention in the market. As a result, the price of government bonds rises above its original level and long-term interest rates fall below their original yields. Financial institutions, which manage funds, move funds into assets other than JGBs because of the low yields in the bond market, which has a positive effect on the economy. However, if the possibility of a reduction in the pace of central bank purchases of government bonds increases, market participants may expect the market to loosen in the future, causing government bond prices to fall and long-term interest rates to rise.

Long-term interest rates will rise, and the market will anticipate what could happen. Through changes in future expectations and their anticipatory behavior, long-term interest rates rose sharply in early 2016, as the previous decline in oil prices ceased, weakening the depressing effect on overall prices. This led to a growing belief in the market that central banks in Japan and Europe, which have adopted ongoing quantitative easing policies since 2016, might be reducing their purchases of government bonds. Japan's monetary policy differs from that of other countries in that it has changed its policy from expanding the monetary base to manipulating the overall yield curve since 2016 to address the side effects of its 2013 quantitative easing policy. Before September 2016, Japan's quantitative easing policy was to increase the amount of government bond holdings by the central bank above a certain amount, which would increase the scarcity of government bonds in the market and thus keep the yield curve flat. Since September 2016, however, the target has been changed to fix the yield on 10-year government bonds at around 0%. This will lock in the shape of the yield curve. The amount of government bond purchases must be adjusted to prevent the yield curve from flattening. In the U.S. tapering, the Fed left the level of long-term interest rates to the market instead of deciding to reduce the volume of long-term bond purchases. The BOJ left the size of the reduction in JGB purchases to the market instead of setting the level of long-term interest rates. In addition, COVID-19 from January 2020 onward will reduce demand and supply not only in the manufacturing sector but also in the service sector, such as travel and accommodation.

The aid package adopted by the U.S. as a countermeasure to COVID-19 led to a temporary increase in demand as usage exploded with the calming of the corona after January 2022. This led to an anticipated increase in the quantity of money, which in turn raised U.S. price levels. As a countermeasure, the FED announced plans to raise interest rates. The depreciation of currencies in various countries caused by interest rate differentials due to the U.S. policy of high interest rates to control inflation has resulted in higher import prices, hurting consumers and manufacturing industries that depend on raw materials from abroad. In addition, Russia's invasion of Ukraine in February 2022 turned Ukraine, a producer, into a war zone, making exports difficult and causing global wheat and palm oil prices to rise.

In addition, through economic sanctions against Russia, imports of natural gas and other Russian products were halted. Sanctions against Russia also led not only to higher resource prices but also to significant changes in future climate change policies.

Price spikes in Ukrainian and Russian wheat and barley, as well as resource prices, occurred throughout the world as a result of reduced supply. In addition, interest rate hikes in the U.S. to counter inflation created interest rate differentials around the world and caused currencies to depreciate around the world. As a result.

With rising import and energy prices, processing industries, service industries that primarily sell to processing industries, and consumers faced higher costs, accelerating the decline in demand.

The decline in supply and demand has become a negative spiral. Normally, when currency depreciation occurs, there is a possibility of shifting production from overseas production sites to domestic production, but this has not been adopted in many industries. The reason is that it is difficult to address the risk of infection in both production and distribution sectors due to the response to COVID-19. Rather than moving production sites to their own countries, supply chains are changing to create production sites near markets with high demand. High interest rates in the U.S., caused by supply shocks from both COVID-19 and the war in Ukraine, have changed the flow of funds around the world. Governments adopted their high interest rate policies to avoid the flight of funds from their home countries caused by the U.S. high interest rate policy. In other words, many countries adopted high interest rate policies to avoid capital flight or to control inflation rather than interest rate levels and policy packages for optimal employment levels. High interest rate policies represent a departure from quantitative easing policies. Essentially, a weaker currency leads to higher exports, which is desirable for exporters because they usually have a larger market to sell to foreign consumers than to domestic consumers. However, the current global infection of COVID-19 will not lead to an expansion of overseas production, and thus to a sufficient increase in exports. Coupled with the introduction of high interest rate policies in the U.S. to curb price increases, global long-term interest rates have begun to rise.

2. Previous review

This paper is related to previous studies on assessing the financial market impact of QE interventions during and after the Great Recession.

Gagnon, Raskin, Remache & Sack (2010) estimate that the Fed's first round of QE in 2008 (QE1) reduced the U.S. term premium by between 30 bps and 150 bps. They also find that it affected other assets not directly targeted, such as corporate bond yields. However, the study considers not only the initial announcement but also all subsequent statements confirming the continuation of the program. Thus, new information about forwarding guidance may be confounded.

Krishnamurthy & Vissing-Jorgensen (2011) examine the effects of JGB and MBS purchase announcements. They examine the effects of treasury and MBS purchase announcements in both the first and second rounds of the Fed's QE intervention in 2008-09. They find that the QE1 announcements reduced MBS yields and spreads; D'Amico & King (2013) analyze the effect of the 2009 Federal Reserve QE1 purchases of Treasuries at the CUSIP level and find a 0.30% decline, and further find that on the day the purchase was made yields on certain bonds fell by 0.035%. On the other hand, announcements of JGB-only purchases in QE2 had a lower impact on the yields of target issues and agency bonds relative to the yields of MBS; Swanson *et al.*, (2011) examined five different announcements of Operation Twist (the Fed's maturity extension program implemented in the 1960s) They examined and compared its impact to that of QE2, finding that the five announcements reduced long-term bond yields by an average of 15 bps cumulatively. Krishnamurthy *et al.*, (2018) analyzed the ECB Securities Markets Program and Outright Monetary Transactions. They find that these programs had a substantial impact on European sovereign yields and boosted equity prices. Dedola *et al.*, (2020), estimated the impact of the Fed and ECB QE operations during the Great Recession. They found that QE operations had a substantial impact on the dollar-euro exchange The estimated effects on the dollar-euro exchange rate were as large as our estimates; Joyce, Lasaosa, Stevens & Tong (2011) studied the UK case and found that: in the two days before and after the six announcements, the average yield on 5- to 25-year gilts fell by a cumulative 1 Greenwood, Hanson, Stein & Sunderam (2020) report the exchange rate impact of 50 pre-COVID-19 QE announcements by the Fed, the BOJ and the UK.

They reported the exchange rate effects of 50 pre-COVID-19 QE announcements by the Fed, the BOJ, and the U.K. After the infectious expansion of COVID-19, the number of countries considered for a quantitative easing policy was expanded to include emerging as well as advanced economies.

The literature on the QE era of COVID-19 focuses primarily on the actions of the Fed and the ECB. Many papers focus on QE programs targeting new asset classes-for example, Haddad, Moreira & Muir (2020), Gilchrist *et al.*, (2020), Barbon & Gianinazzi (2019). Other papers examine the sell-off in government bonds in mid-March 2020 and the associated rise in yields and liquidity. For example, Vissing-Jorgensen (2020) studies the disruption in the Treasury bond market in the early stages of COVID and documents who the institutional sellers were in the early stages of COVID-19 and analyze how subsequent Fed intervention stabilized the market; Bahaj & Reis (2020) study the impact of the Fed's swap line announcement and find that the swap line announcement was effective in reducing the divergence in covered interest rate parity; Cortes, Gao, Silva & Song (2020), among others, compared the impact of the Fed's QE intervention during the Great Recession with that of COVID-19's global QE policy. They did so for several developed and emerging economies. The outcome variable is a measure of disaster risk extracted from asset-specific ETF option prices, suggesting international transmission of the Fed's Quiet Time, which changed during COVID-19, especially in merging markets. This study confirms the importance of controlling for common factors and spillovers. The implementation of QE in emerging economies has received particular attention, with research contributions from major international policy institutions, including the BIS (Hofmann, Shim, Shin, *et al.*, 2020) and the IMF (Sever *et al.*, 2020); the IMF (Sever, Goel, Drakopoulos, Papageorgiou *et al.*, 2020), and the World Bank (Ha & Kindberg-Hanlon, 2020), using daily data to analyze the impact of announcements on bond yields and exchange rates and to examine the rates, as well as the effect of announcements on actual purchases in selected countries. These studies attempted to separate the effects of QE by country from those of the Fed in panel regression models, but did not control for global factors; Hartley *et al.*, (2020) analyzed QE announcements and their integration for these countries, analyzed their effects on a case-by-case basis, and systematic comparison with global factors. Systematic comparisons with QE interventions in advanced economies were also made to assess the long-run effects of policy interventions. The GVAR approach uniquely allows for a discussion of possible substantive effects within a consistent, multi-country empirical framework.

It uniquely allows for discussion of possible real effects within a consistent multi-country empirical framework that takes into account global general equilibrium effects. Possible real effects can be discussed within a consistent multi-country empirical framework that accounts for global general equilibrium effects without making strong assumptions about theoretical identification. Other papers investigate the international transmission of long-term interest rate shocks in the U.S. and euro area interpreted as QE interventions using the GVAR approach (see, for example, Colabella (2020) and references therein). Uncertainty has also been highlighted as a driving force of the business cycle after the experience of economists and policy makers in the aftermath of the Great Recession. A vast literature exists on the measurement of uncertainty and its impact on the economy, including Bloom (2009)

Jurado *et al.*, (2015), Baker *et al.*, (2016), Basu & Bundick (2017), and Carriero *et al.*, (2018b). These studies provide compelling theoretical and empirical evidence suggesting that uncertainty shocks have negative economic consequences. Higher levels of uncertainty significantly reduce economic activity and further reduce the effectiveness of monetary and fiscal policy (Aastveit *et al.*, 2013; Bertolotti & Marcellino, 2019). As a channel of transmission of uncertainty shocks to the macroeconomy, recent papers emphasize real phenomena such as distortions in firms' decision-making. (Bloom, 2009; Alessandri & Mumtaz, 2019).

The econometrics literature increasingly relies on a unified framework for jointly estimating uncertainty and its effects (Mumtaz & Zanetti, 2013; Carriero *et al.*, 2018b; Mumtaz & Surico, 2018). Besides the many contributions that rely on linear speciation, there has been a recent focus on considering the nonlinear relationship between uncertainty and the real and financial economy (Mumtaz & Theodoridis, 2018; Alessandri & Mumtaz, 2019; Mumtaz & Musso, 2019). Furthermore, considering the importance of international linkages in the transmission of macroeconomic shocks (e.g., Canova & Ciccarelli, 2004; Mumtaz & Surico, 2009; Feldkircher & Huber, 2016), a multi-economy modeling framework is proposed by Mumtaz &

Theodoridis (2015), Berger *et al.*, (2016), Crespo Cuaresma *et al.*, (2017), Carriero *et al.*, (2018a), and Mumtaz & Musso (2019). The theoretical justification for empirically evaluating spillover dynamics is provided by Mumtaz & Theodoridis (2017), identified globalization and increased trade openness as the main determinants of international volatility. It should be noted, however, that they rely on factor models or focus on specific variables and do not provide a complete systematic procedure that addresses both real and financial economic sectors on a country-by-country basis. While some papers consider time variability in the relationship between uncertainty and the macroeconomy while others consider country-specific idiosyncrasies due to domestic dynamics or spillover effects, there are limited papers that address both features simultaneously Mumtaz & Musso (2019) treated both features at the same time. However, they are not directly concerned with structural inference based on high-dimensional uncertainty shocks in the cross-section; Pfarrhofer (2022) uses a multi-economy model is introduced. The volatility is allowed to affect the first and second moments of the multivariate dynamic variables. It is a stochastic volatility model at the mean (Koopman & Hol Uspensky, 2002; Chan, 2017).

Pfarrhofer (2022) extends the vector autoregressive model of Pesaran *et al.*, (2004) so that time-varying parameters and residuals also enter the mean of the process (Crespo Cuaresma *et al.*, 2019). Adopt Bayesian methods and global-local priors for state-space models (Fruhwirth-Schnatter & Wagner, 2010; Belmonte *et al.*, 2014; Bitto & Fruhwirth-Schnatter, 2019; Huber *et al.*, 2019). We focus on models with constant parameter specifications with homogeneous order random errors and homogeneity across countries, but we use hierarchical prior distributions so that they can also have time-varying possibilities and heterogeneous dynamics across economies. Hierarchical prior distributions are associated with a Bayesian treatment of panel data (Verbeke & Lesare, 1996; Fruhwirth-Schnatter *et al.*, 2004).

3. Data

The analysis in Chapter 5 deals with daily data for the period from January 2012 to July 2022. In Chapter 6, we estimate the TVP-GVAR-FSVM using monthly data from January 2002 to July 2022. The monthly data are from International Financial Statistics (IFS) and CEIC (https://www.ceicdata.com/ja). The following 16 economies are used. Israel (ISR), India (IND), Indonesia (IDN), Ukraine (UKR), Croatia (CRO), Colombia (COR), Turkey (TUR), Philippines (PHI), Poland (POL), Mexico (MEX), Romania (ROM), Hungary (HUN), Germany (DEU), Korea (KOR), and Japan (JPN). The countries covered are those that adopted quantitative easing policies after the Corona Disaster. Although the European Central Bank introduced a quantitative easing policy, only Germany is included to account for estimation bias from using all EU member countries. Due to limitations in data availability, India is not included in the estimation in Chapter 6.

Quantitative Easing policy uses unconventional monetary policy instruments in which the central bank purchases government bonds rather than controlling short-term interest rates. A quantitative easing policy is usually employed because a decline in interest rates alone is not expected to increase demand. Alternatively, a decline in U.S. interest rates will result in a change in the interest rate differential between the U.S. and the home country, reducing concerns about asset flight and currency depreciation in the home country. It may have created room for lower interest rates in its own country.

In Chapter 6, we use and analyze the TVP-GVAR-FSVM by Pfarrhofer (2022). The model features a series of monthly data on economic activity: industrial production (FCI). The data set in that section uses monthly data for the period 2002:01 to 2022:07 due to the constraints of IP data acquisition. The following series are employed: unemployment rate (UN), year-on-year consumer price index (CPI), short-term interest rate (SIR), long-term interest rate (LIR), industrial production (INP), the exchange rate (NEX), and stock prices (EQP). To account for cross-national linkages, we estimate cross-section weights. We use annual trade statistics between the two countries. We use annual bilateral trade figures.

Resource-exporting countries were defined as those with a positive trade balance of primary commodities to GDP ratio using the monthly bulletin of Statistics by the United Nations in 2021. Colombia, Indonesia, Mexico, and South Africa are the resource-exporting countries in this study. The developing countries are Colombia, Indonesia, India, Israel, Mexico, the Philippines, and Turkey.

4. Model of TVP-GVAR-FSVM

Let y_{it} denote a k×1 vector of endogeneous variables for $t = 1, \dots, T$ specific to country $i = 1, \dots, N$. It stacks the reduced form shocks to y_{it} in a K×1 vector $\epsilon_t = (\epsilon'_{1t,\dots,}\epsilon'_{Nt})'$, and country-specific endogenous variables K×1 vector $y_t = (y'_{1t,\dots,}y'_{Nt})$ with K=kN. It is a factor stochastic volatility structure on the error term,

$$\epsilon_t = Lf_t + \eta_t,\ f_t \sim \aleph(0, \exp(h_t) \times \Sigma), \eta_t \sim \aleph(0, \Omega_t) \quad (1)$$

f_t is a vector of d × 1 common static factors (with d << K), and η_t an idiosyncratic white noise shock vector of dimension K×1. Latent factors are linked to the errors by the K×d factor loadings matrix L. The factors f_t are Gaussian with zero mean and common time-varying volatility $\exp(h_t)$, scaling a diagonal matrix Σ = I_d, with I_d referring to a d-dimensional identity matrix. The idiosyncratic error components η_t are assumed to follow a Gaussian distribution centered on zero with K× K time-varying covariance matrix.

$$\Omega_t = diag(\exp(\omega_{1t}), \dots, \exp(\omega_{Kt}))$$

we rely on a stochastic volatility model. Here, h_t and $\omega_{ij,t}$ for i = 1,…,N and j = 1,…, k follow independent random walk processes with σ_h and $\sigma_{\omega_{ij}}$ denoting the state-equation innovation variances. It notes that for the case of σ_h and $\sigma_{\omega_{ij}}$ equal to zero, we obtain homoscedastic errors.

$$h_t = h_{t-1} + \zeta_t, \quad \zeta_t \sim ℵ(0, \sigma_t)$$
$$\omega_{ij,t} = \omega_{ij,t-1} + \zeta_t, \qquad \zeta_t \sim ℵ(0, \sigma_{\omega_{ij}})$$

We interpret h_t as the common driving force of the volatilities of all included series, and thus a measurement of uncertainty. It notices that $\mathrm{Var}(\epsilon_t) = \exp(h_t)\mathrm{LL}' + \Omega_t$, and the variance thus discriminates between idiosyncratic shocks and overall movements in international uncertainty.

The dynamic evolution of y_{it} is governed by a vector autoregressive (VAR) process with drifting coefficients and features the common volatility of the factors in the mean. We define the k× 1 intercept vector it and k× k coefficient matrices $A_{ip,t}(p = 1,..,P)$.

$$y_{it} = \alpha_{it} + \sum_{p=1}^{P} A_{ip,t} y_{it-p} + \sum_{q=1}^{Q} B_{iq,t} y *_{it-p} + \beta_{it}\, h_t + \epsilon_{it} \tag{2}$$

The ω_{ij} denote pre-specified weights that capture the strength of the linkages. The process in Eq. (2) is augmented by Q lags of these non-domestic cross-sectional averages $y *_{it}$, with k×k coefficient matrices $B_{iq,t}$ (q = 1,…,Q). The vector β_{it} associated with the log of the factor volatility h_t is of dimension k×1.

Our setup allows for interpreting β_{it} as the contemporaneous impact of uncertainty h_t on the endogenous variables of country i. The structure set forth in Eqs. (1) and (2) implies that shocks to h_t affect both the first and second moments of the system based on common shocks captured by f_t.

In general, structural identification of uncertainty shocks is a challenging task due to various reasons, as suggested in Ludvigson *et al.,* (2019). In principle, the adopted setup would also allow to impose zero restrictions on the contemporaneous responses of lower-frequency real macroeconomic quantities.

we sets the model in standard regression form,

$$y_{it} = C_{it} x_{it} + \epsilon_{it}$$
$$x_{it} = (1, y'_{it}, y'_{it-P}, y^{*'}_{it-1}, \dots, y^{*'}_{it-Q,} h_t)'$$

$$C_{it} = (\alpha_{it}, A_{i1,t}, \dots, A_{iP,t}, B_{i1,t}, \dots, B_{iQ,t}, \beta_{it}) \tag{3}$$

It is convenient to consider the jth equation of country i in Eq. (3) given by

$$y_{ij,t} = C'_{ij,t} x_{it} + \epsilon_{ij,t}$$

We refer to the *j*th row of the matrix C_{it} by $C_{ij,t}$, a vector of dimension $\widetilde{K} \times 1$ with $\widetilde{K}$= k(P + Q) + 2. The state vector is assumed to follow a random walk process with diagonal $\widetilde{K} \times \widetilde{K}$ variance-covariance matrix $\Theta_{ij} = diag(\theta_{ij,1,...,}\theta_{ij,\widetilde{K}})$.

$$C_{ij,t} = C_{ij,t-1} + u_{t,} u_t \sim \aleph(0, \Theta_{ij}) \tag{4}$$

If $\theta_{ij,l}$ equals zero in Eq. (4), the respective coefficient is constant over time as for the stochastic volatility specification. We introduce the non-centered parameterization set which allows to impose shrinkage priors on these innovation variances to test the restriction $\theta_{ij,l}$= 0.

Using a $\widetilde{K} \times 1$-vector containing the square root of the state innovation variances in Eq. (4) denoted $\sqrt{\Theta_{ij}} = diag(\sqrt{\theta_{ij,1}}_{,...,}\sqrt{\theta_{ij,\widetilde{K}}})$, the reparameterized equation is

$$y_{ij,t} = C'_{ij,0}x_{it} + \widetilde{C'_{ij,t}}\sqrt{\Theta_{ij}}x_{it} + \epsilon_{ij,t} \tag{5}$$

Let $\widetilde{c_{ijl,t}}$ denote a typical element of $\widetilde{C_{ijl,t}}$, then the transformation $c_{ijl,t}$=$c_{ijl,t} + \sqrt{\theta_{ij,l}}\widetilde{c_{ijl,t}}$ yields the corresponding state equation with $\widetilde{C_{ijl,0}} = 0_{\widetilde{K}}$.

$$\widetilde{C_{ij,t}} = \widetilde{C_{ij,t-1}} + v_t, v_t \sim \aleph(0, I_{\widetilde{K}})$$

This procedure moves the square root of the innovation variances to the states into Eq. (5). The resulting state-space representation has the convenient property that the $\sqrt{\theta_{ij,l}}$ can conditionally be treated as standard regression coefficients.

$$\tilde{\eta}_{ij,t} = \sqrt{\Theta_{\omega_{ij,t}}}\widetilde{\omega_{ij,t}} + v_{ij,t,}\ v_{ij,t} \sim ln_{\chi}(1)$$
$$\widetilde{\omega}_{ij,t} = \widetilde{\omega}_{ij,t-1} + \omega_{ij,t,}\ \omega_{ij,t} \sim \aleph(0,1)$$

We obtain a set of unrelated heteroscedastic error terms η_t by the diagonal structure of Ω_t conditional on Lf_t and the full history of the VAR coefficients C_{it}. $\eta_{ij,t}$ indicates the error term of the *j*th equation for country *i*. Squaring and taking logs and using $\omega_{ij,t,} = \sqrt{\Theta_{\omega_{ij,t}}}\widetilde{\omega_{ij,t}}$ yields again moving the square root of the innovation variances from from the state to the

measurement equation. The transformation allows to impose shrinkage priors on these coefficients towards a homoscedastic specification if suggested by likelihood information.

Full conditional posterior distributions obtained from combining the likelihood function with the priors. Most distributions are of well-known form, allowing for a simple Markov chain Monte Carlo (MCMC) algorithm to obtain draws from the joint posterior using a Gibbs sampler. The full history of the TVPs can be drawn by using a FFBS algorithm.

5. Changes in CPI, Exchange rate, long/short interest rate differentials, and economic instability using daily data

5.1. CPI, exchange rate, long/short interest rate differential, economic instability

Interest rates had been increasing in both the long and short term since the supply shock following the Corona disaster, but have increased sharply since the Ukrainian war.

Currencies appreciated in many countries after the Corona disaster, but reversed around the beginning of 2021, depreciating. The trend toward currency depreciation was particularly strong after the Ukrainian war. The magnitude of currency appreciation was greater in developed countries than in developing countries. However, the situation is different for resource-exporting and resource-importing countries. Since the war in Ukraine, resource-exporting countries have changed less than resource-importing countries. This is due to the impact of currency depreciation resulting from the inexpensiveness of their currencies due to the interest rate differential between the home currency and the home interest rate due to the high interest rate policy of the U.S. and the rising prices of imported commodities, offset slightly by the impact of currency appreciation resulting from the increase in the volume of their primary commodity exports.

Like the exchange rate, the CPI also declined briefly after the Corona disaster but has since risen, and has been on a further upward trend since the Ukrainian war.

It is sometimes very high in the U.S., but remains low for most countries except Japan. For both developed and developing countries, the value is almost always below 0.5, except for Japan.

5.2. Relationship between exchange rates and the difference between long- and short-term interest rates

This section uses OLS and ARIMA models to confirm the impact of long- and short-term interest rate differentials on the exchange rate.

Table 1. *Relationship between the exchange rate and the difference between long- and short-term interest rates using daily data*

OLS

CO	*CR*	*HU*	*PO*	*RO*	*ID*	*IN*	*IS*	*JA*	*KO*	*ME*	*PH*	*TU*	*GE*	*UK*
2012m1-2019m12														
0.571***	0.742***	0.364***	0.896***	1.639***	1.306***	0.541***	1.382***	-0.421***	0.041***	1.535***	0.675***	7.669***	6.105***	7.910***
(0.002)	(0.021)	(0.008)	(0.017)	(0.020)	(0.004)	(0.002)	(0.022)	(0.003)	(0.002)	(0.005)	(0.005)	(0.028)	(0.140)	(0.234)
2020m1-2020m6														
0.682***	-0.095	0.368***	0.851***	2.060***	1.130***	0.551***	-0.743***	-0.294***	0.086***	1.789***	0.722***	6.808***	10.600***	26.252***
(0.007)	(0.093)	(0.008)	(0.032)	(0.028)	(0.003)	(0.003)	(0.203)	(0.005)	(0.001)	(0.008)	(0.006)	(0.038)	(0.168)	(0.285)

ARIMA

CO	*CR*	*HU*	*PO*	*RO*	*ID*	*IN*	*IS*	*JA*	*KO*	*ME*	*PH*	*TU*	*GE*	*UK*
2012m1-2019m12														
3.883***	-0.769**	1.511***	1.058***	0.400	3.209***	6.069***	-0.683***	-3.542***	-0.080	3.874***	1.598*	10.782***	-2.275***	9.321
(0.205)	(0.299)	(0.234)	(0.135)	(0.720)	(0.185)	(0.347)	(0.019)	(0.129)	(0.173)	(0.140)	(0.817)	(0.237)	(0.109)	(35.261)
2020m1-2020m6														
7.693***	2.918	2.187***	1.409***	3.550***	3.638***	7.959***	-0.314***	-5.432***	0.405	4.006***	1.080	7.774***	-1.727***	-2.138
(0.414)	(52.275)	(0.359)	(0.310)	(0.631)	(0.652)	(0.405)	(0.030)	(0.235)	(0.366)	(0.214)	(1.325)	(0.521)	(0.226)	(70.987)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Correlation between the logarithm of the inverse of the exchange rate per dollar and the difference between the long- and short-term interest rates using daily data; data are split between after January 2020 and before. A positive sign means that the currency appreciates as the long-short interest rate differential widens; in OLS, the correlation is positive and significant for all countries except Japan before 2019, but it changes to negative for Israel after 2020. Japan remains negative. However, in the ARIMA model, before 2019 it is negative and significant for Croatia, Israel and Japan, and Germany; after 2020 it is negative and significant for Israel, Japan and Germany, except for Croatia. For countries with a positive sign before 2019, the values after 2020 are larger than before 2019, except for Turkey; for countries with a negative sign before 2019, the values after 2020 are larger, except for Japan. The analysis shows that after 2020, currency appreciation reduces the long- and short-term interest rate differentials in Germany, Japan, and Israel. In particular, in Japan, the impact of one unit of currency appreciation on the long- and short-term interest rate differential was more than 1.5 times larger.

6. Estimation

6.1. Measure of uncertainty

The figure below shows an estimate of the common uncertainty to the economic system: The Geopolitical risk (GPR) indicator by Cardara & Iacoviello (2018). The global and country-specific indicators are graphed.

During the period of analysis, 2002-2004, the level of international uncertainty declined. A sharp increase in international volatility is detected starting in late 2007, which signifies the beginning of the U.S. crisis. This period marked the beginning of the crisis in the U.S. subprime mortgage market, which created turmoil in the credit markets. After international volatility declined to pre-crisis levels around 2010, a second, or second peak in international volatility occurred in 2011, after international volatility declined to pre-crisis levels around 2010. This is the European sovereign crisis. The European sovereign crisis continues until late 2013; early 2016 is the peak associated with the Brexit referendum. The peak was associated with the Brexit referendum and the election of Donald Trump as president at the end of 2016.

6.2. Estimation of TVP-GVAR-FSVM

We use a global VAR featuring time-varying parameters and factor stochastic volatility in mean（TVP-GVAR-FSVM) by Pfarrhofer (2022). The non-central parameterization of the state-space model allows TVP-GVAR-FSVM, in principle, to examine the shrinkage of the time-invariant common mean and the shrinkage of the common mean of the time-invariant part of the model and the variance of the corresponding state innovations. Both the covariance and the variance of the corresponding state innovation can be examined. Furthermore, the degree of shrinkage relative to homogeneity can be evaluated. The results show that a large part of the parameter space is directed toward both cross-sectional homogeneity and time-invariance of covariance; the discussion on time-invariance coefficients in Feldkircher *et al.,* (2017) often captures the omitted variable bias in small VARs.

6.2.1. Case of a normal VAR model without Nelson-Siegel as a variable

Fig. 7 displays an overall summary of the dynamic responses for the periods between January 2002 and July 2022, and reports the posterior median of the impulse response functions to the uncertainty shock. Colors refer to the respective period (red indicates early parts of the sample, blue marks later periods). Fig. 8 displays cumulative responses at the three year horizon. Units are scaled as percentages for industrial production, exchange rates and equity prices, while consumer price inflation, unemployment and the Nelson-Siegel factors for level, slope and curvature are in basis points (BPs).

Identify differences in endogenous variables across countries. By confirming the trend in response changes, the CPI across countries has the same shape in all countries. For all countries, the late sample period shows decreases in consumer prices, unemployment, industrial production, exchange rates, stock prices, and long-term interest rates. In the first half of the sample, we see cases of increases and cases of larger decreases than in recent years.

It rises once around 2009, but overall, since 2002, the sample period, both developed and developing countries have been declining. In terms of unemployment rates, the U.S. has a similar shape to Mexico and Japan, but the other countries differ. The unemployment rate in the U.S. and all countries except Mexico and Japan have not been as affected. For the long-term interest rate, the U.S. has very large volatility. This contrasts with Germany, which has very small volatility. Stock prices are declining in many countries, as in the U.S., except for Israel, Croatia, and Colombia. Japan, like the U.S., is in a downtrend, but has seen a large comparative increase from 2009 to 2013. Short-term interest rates have increased in many countries in recent years, but have been on a declining trend since 2021. The FCI has been on a marked downward trend since 2010 in Turkey, Romania, Poland, the Philippines, South Korea, Indonesia, and Hungary.

Compared to the case including the Nelson-Siegel variables in the next section, the CPI has a positive portion. However, the other variables show almost the same trend. The short-term interest rate and SIR were added, but the long-term effect of SIR cannot be confirmed.

6.2.2. Cases with Nelson-Siegel as variables

The CPI in Figure 9 is negative in many countries, with the negative range increasing in recent years. Germany has the largest negative range at -0.01, followed by the U.S. and Japan with very small ranges of about -0.08. Fernandez-Villaverde *et al.,* (2015) discussed two channels through which uncertainty shocks affect consumer prices. The first is the aggregate demand channel, which reduces household consumption and thereby leads to an overall decline in prices; the second is the upward price bias channel, in which firms based on profit maximization cause prices to rise. The former dominates the latter, as in the results of Pfarrhofer (2022), since CPI was negative in many countries in this study. Using Figure 10 to examine the time series, the heterodoxy of uncertainty shocks on prices has changed in a hump-shaped pattern, peaking in 2015. The negative size became even larger after 2020, the period during which the quantitative easing policy was introduced. Turkey, Japan, Germany, and Croatia have particularly large negative effects. This means that developing countries, especially resource-exporting countries, have relatively small negative effects.

UNR, both positive and negative, can be observed for many countries in Figure 9. While it increases the unemployment rate in the early years of the sample, an increasing number of countries have seen a decrease in recent years. The exceptions are Japan and Korea, the United States and Croatia. Although Croatia is included, developed countries can be seen as exceptions. Developing countries have seen declining increases in unemployment in recent years. The impact of the impulse response function converges with very short-term impacts. Figure 10 shows that in the time series, all countries except Turkey have a large negative impact in 2020.20 There are a few countries that increase in 21 years, but for most countries, the negative impact is larger than in 2020.

LIR has a positive impact in many countries, but no long-term impact except for Turkey; EQP is positive in many countries the past and negative in recent years; EQP is positive in many countries in the past and negative in recent years; and EQP is positive in many countries in the past and negative in recent years. Long-term impact is significant in the U.S. and Croatia. This means that the long-run variation in the long-term interest rate can be commonly identified regardless of the presence or absence of developing countries, resource-exporting countries, and the type of quantitative easing policy.

The INP is traditionally positive in many countries but has changed to negative in recent years. For the long-run effect, it is positive only for Israel and negative for Korea, Turkey, Poland, and Indonesia; as in Mumtaz & Theodoridis (2018) and Pfarrhofer (2019, 2022), the cumulative effect is decreasing before the global financial crisis. The estimated change in the persistence of uncertainty shocks is shown as a time change. A few years after the global financial crisis, uncertainty shocks began to play an important role for industrial production. This means that the long-run variation to the industrial production index can be commonly identified regardless of the presence or absence of developing countries, resource-exporting countries, and the type of quantitative easing policy.

The FCI of the exchange rate is negative in Figure 9, indicating long-term effects in many countries. Including the U.S., uncertainty shocks cause currency depreciation, despite being denominated in dollars, and the effect has a long-run effect; similar to Mumtaz & Theodoridis (2017) and Pfarrhofer (2019), suggesting that international trade reduces foreign demand and feedback to the domestic economy. International trade plays an important role in the transmission of uncertainty shocks. Figure 10 confirms that uncertainty shocks have also had increasing effects on exchange rates in recent years in Hungary, Germany, Japan, Korea, the Philippines, Romania, Turkey, South Africa, and the United States. In other countries, the negative effects do not increase over time. The long-term effects on exchange rates are commonly confirmed regardless of the presence or absence of developing countries, resource-exporting countries, and the type of quantitative easing policy.

The EQPs of stock prices are small negative, around -0.01 for most countries, with a maximum of -0.03 for Mexico in Figure 9. The effect is positive in the early part of the sample but negative in the late part of the sample. Long-term effects are less common. The country with the longest-run effect is the United States, with a negative peak after about five months. Most countries have a peak after one month. Figure 10 shows that the long-run effect of uncertainty shocks on stock prices increases over time. This means that the long-run variation to stock prices can be commonly confirmed regardless of the three types of countries: with or without developing countries, with or without resource-exporting countries, and with or without the type of quantitative easing policy.

Check the implications for Nelson Siegel regarding the yield curve. The shape of the yield curve indicates economic uncertainty. It is normal for the yield curve to remain unchanged through time. When cross-national heterogeneity occurs, it may be due to international capital moving toward safe capital in response to shocks of uncertainty. The three indicators in Figure 10 have been more negative since the introduction of the quantitative easing policy after 2020, except for Mexico.

The NSL level factor in Figure 9 shows positive values for many countries in recent years. While they were large negatives in the early years of the sample, the magnitude of the negatives has decreased in recent years. Both positive and negative values are present in the sample as a whole. Colombia and Croatia are largely positive in the short term and differ from the other countries. In Figure 10, many countries have large positive increases around 2015. Some countries have changed to a large negative afterwards.

Figure 9 for NSS, the curvature, is positive in the short term and negative in the long term can be observed in several countries. The NSS refers to the slope of the yield curve, and the alternative between positive and negative means that there is a tendency for the curve to flatten. The alternative between positive and negative means that there is a tendency toward flattening. This implies that yield curve control is needed in many countries.

In other words, Figure 10 confirms an upward trend for NSL and a downward trend for NSS, with NSS being the slope factor for NSC in Figure 9, split between positive and both positive and negative countries. Long-term effects are absent except in Croatia and the United States.

A positive response is followed by a negative response in Croatia, Germany, Japan, and Poland. Diebold *et al.*, (2006) find a close relationship between the slope factor and central bank policy. They state that it shows the effect months after the central bank cut the policy rate to counteract the negative economic impact of uncertainty shocks.

Looking at the full set of indicators in Figure 10, the width of the thick black and thick red areas has expanded in recent years for all countries. The only countries that have not expanded in recent years are Croatia for EQP and South Africa for INP. The Nelson-Siegel variable has likewise been expanding in recent years, especially since 2010. This indicates that the volatility of key economic indicators is expanding due to economic instability.

7. Conclusion

This study examines the impact of shocks to economic instability in countries with quantitative easing policies. We estimate a global VAR with time-varying parameters using Bayesian techniques (TVP-GVAR-FSVM).

We estimate Nelson-Siegel, a variable related to the yield curve, and find no significant difference in the results whether it is included or not in the VAR model; as a result of the change from a primarily demand-driven shock before 2020 to a supply shock after 2020, the shock to instability is amplified. Volatility shocks were amplified. We further examined the trends in changes in interest rates, exchange rates, long- and short-term interest rate differentials, and economic instability from three perspectives: first, developing versus non-developing countries; second, resource-exporting versus non-resource-exporting countries; and third, countries like Japan, which employs yield curve control, and other countries Third, whether the type of quantitative easing policy differs from that of other countries, such as Japan, which uses yield curve control. Daily data on exchange rates and long- and short-term interest rate differentials revealed commonalities among resource-exporting countries. The TVP-GVAR-FSVM estimation results also showed that the consumer price index has shown common movements in developing countries, especially resource-exporting countries, in recent years. The effect on the unemployment rate also showed movements specific to developed countries, but no commonalities were found among countries in other variables. Compared to resource-importing countries, resource-exporting countries' increased profits due to higher resource prices after the war in Ukraine served as a cushion due to the instability in the global economy and weakened the negative impact on their economies. However, for developing resource-importing countries, shocks to economic stability caused significant volatility. A common feature of countries that have switched to interest rate policies is that prices have very high rates of increase. In addition, the rise in yield curve variables suppressed consumer prices and raised stock prices. Countries that experienced a sustained narrowing of the long/short interest rate differential theoretically resulted in a flattening of the yield curve but also resulted in currency appreciation.

Figures

Figure 1-1. *Interest rate (Developing Countries)*

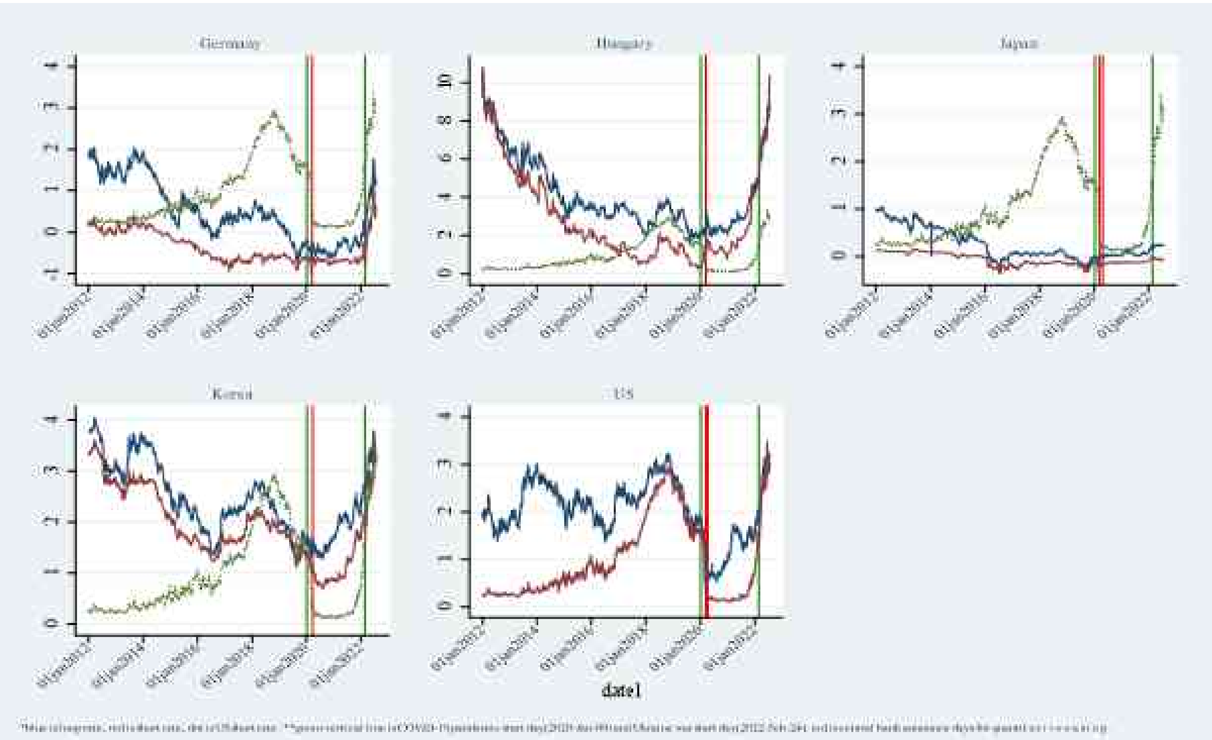

Figure 1-2. *Interest rate (Developed Countries)*

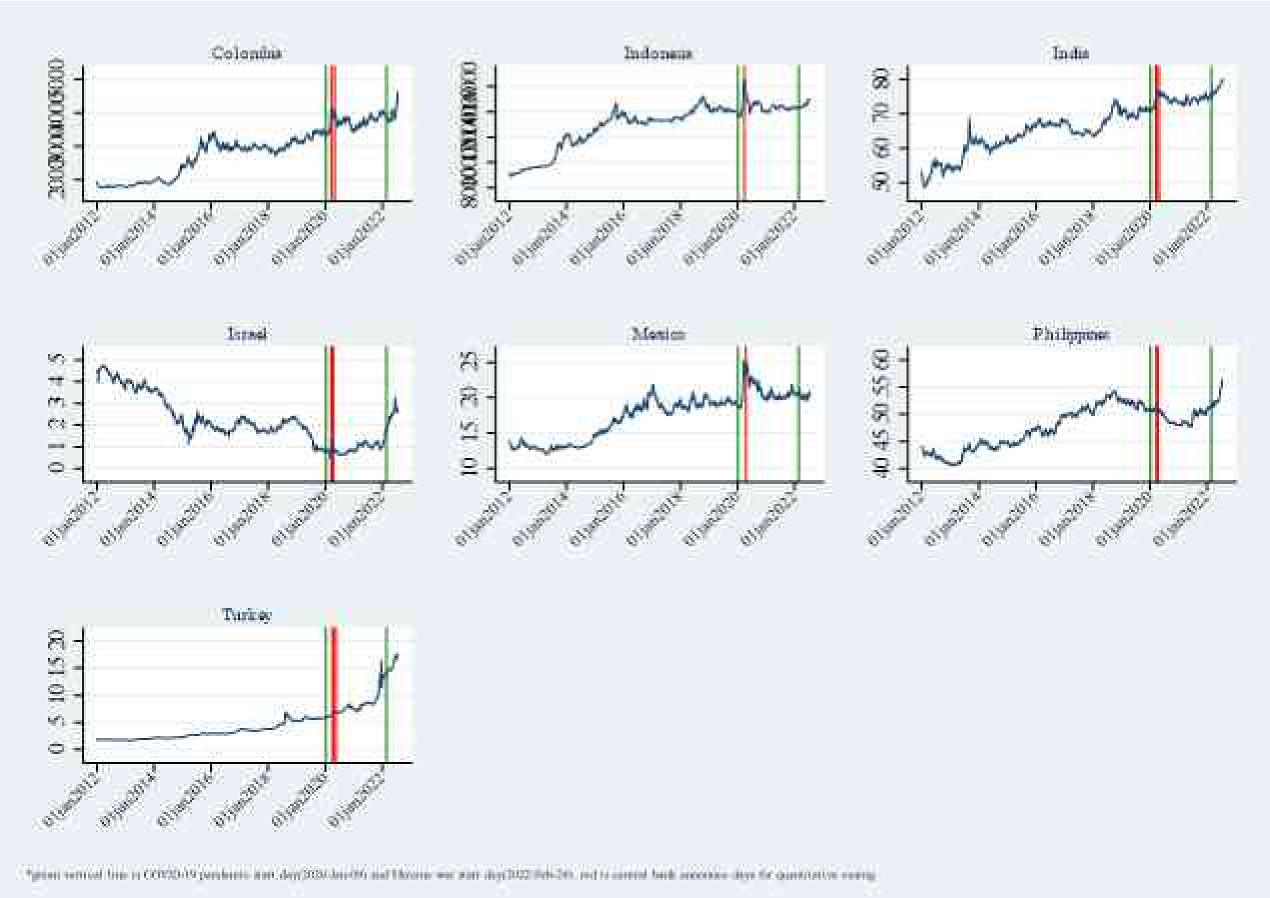

Figure 2-1.*Exchange rate (Developing Countries)*

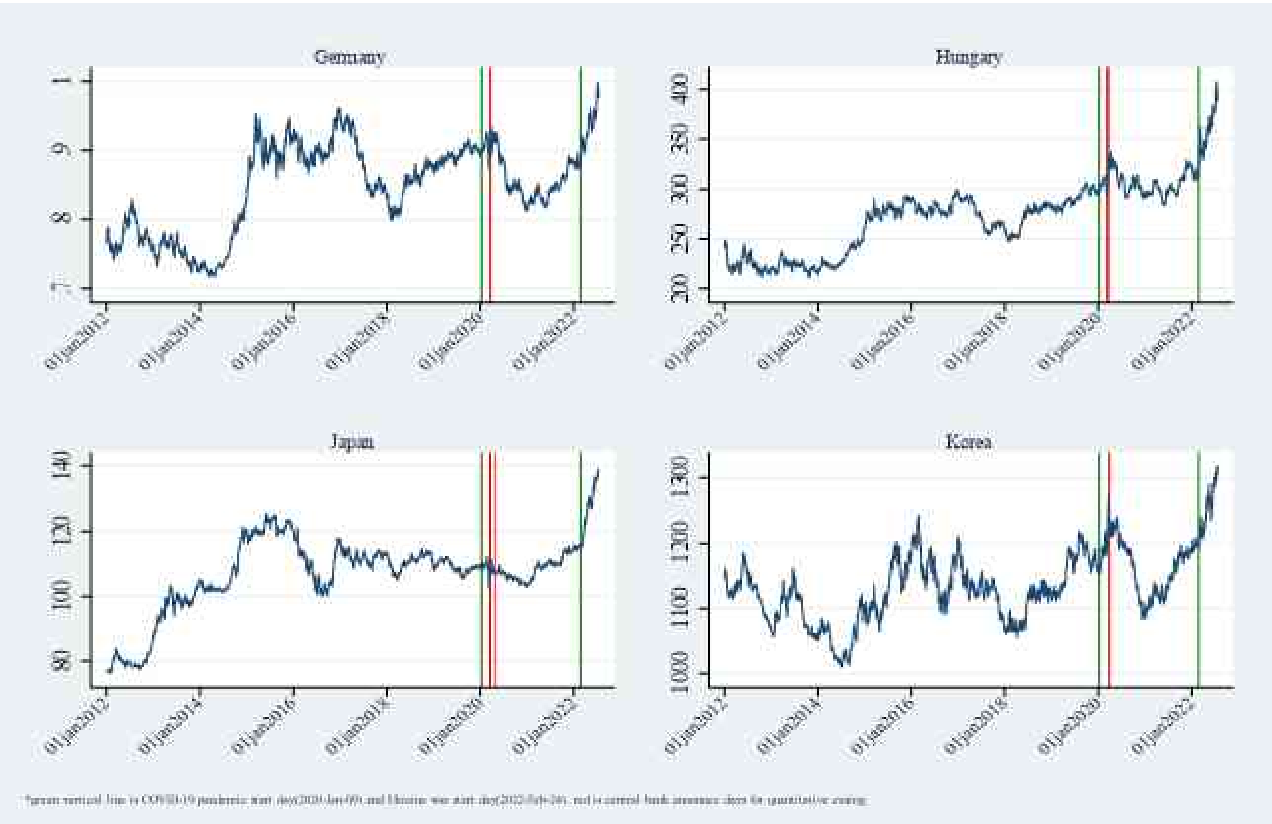

Figure 2-2. *Exchange rate (Developed Countries)*

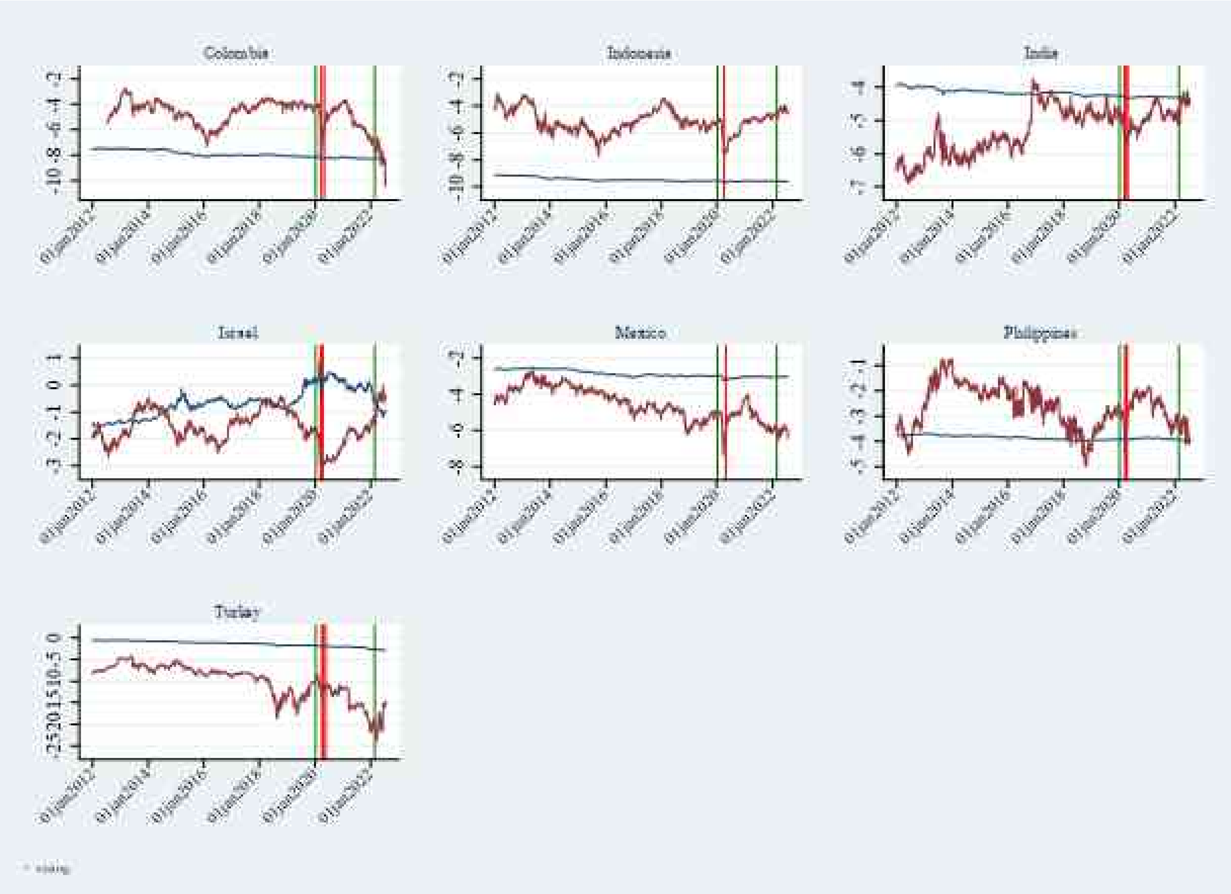

Figure 3-1. *Exchange rate and the Difference between US long interest rate and each long interest rate (Developing Countries)*

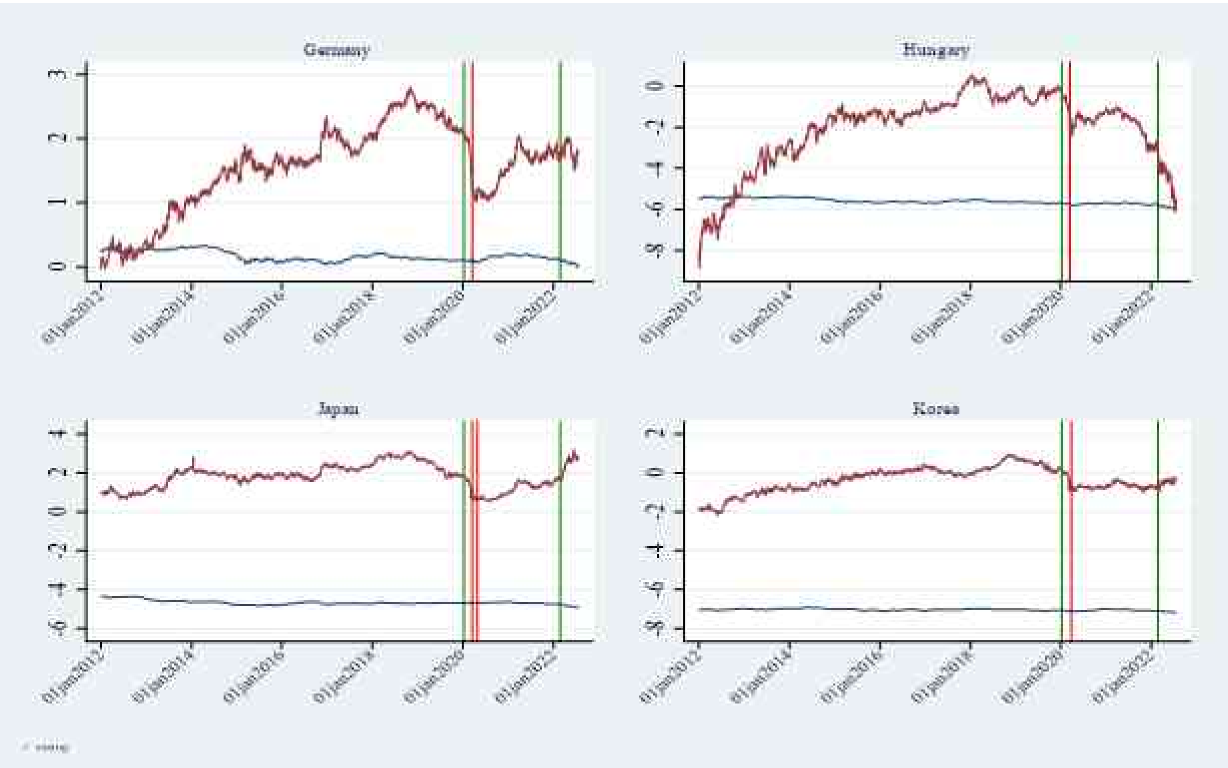

Figure 3-2. *Exchange rate and the Difference between US long interest rate and each long interest rate (Developing Countries)*

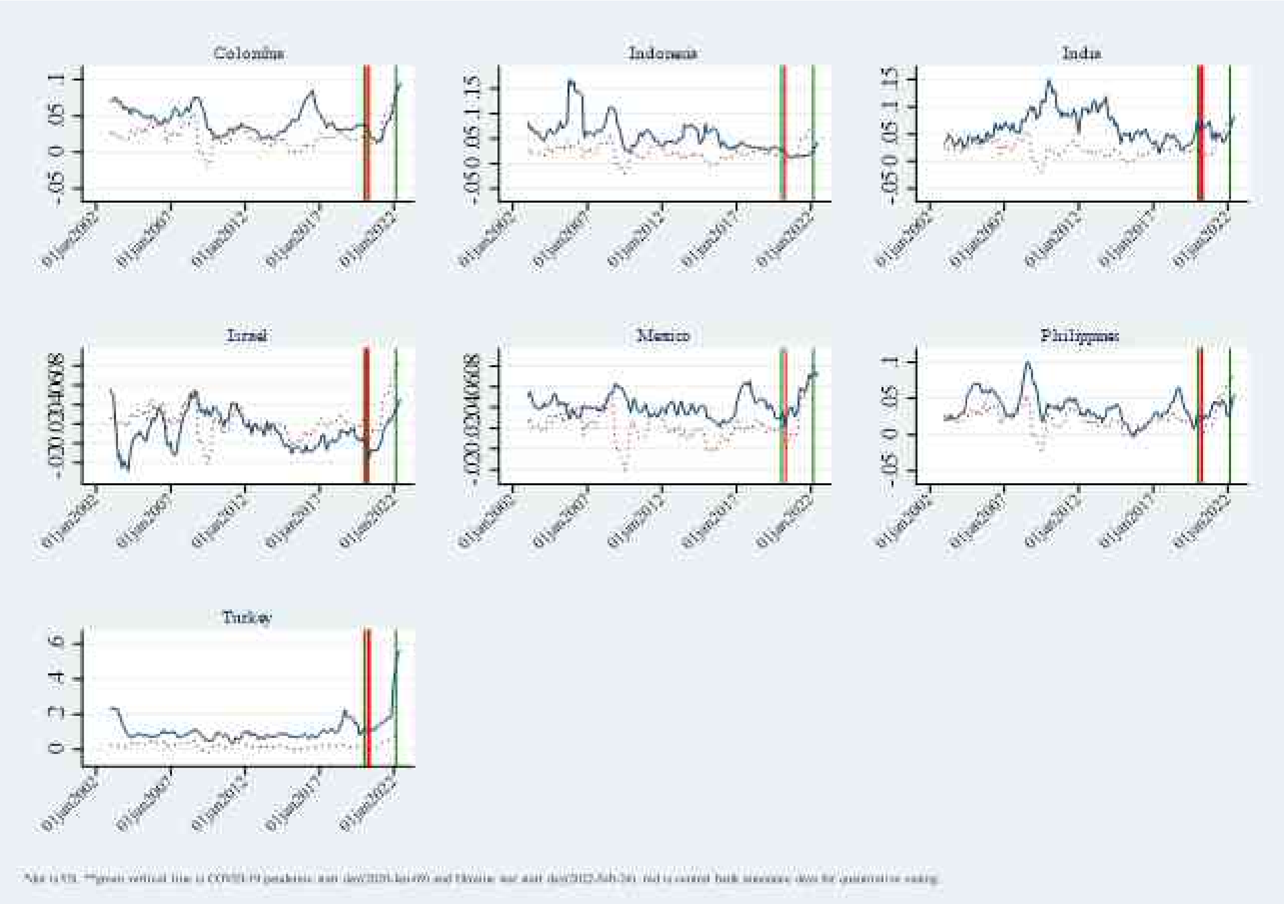

Figure 4-1. *CPI (Developing Countries)*

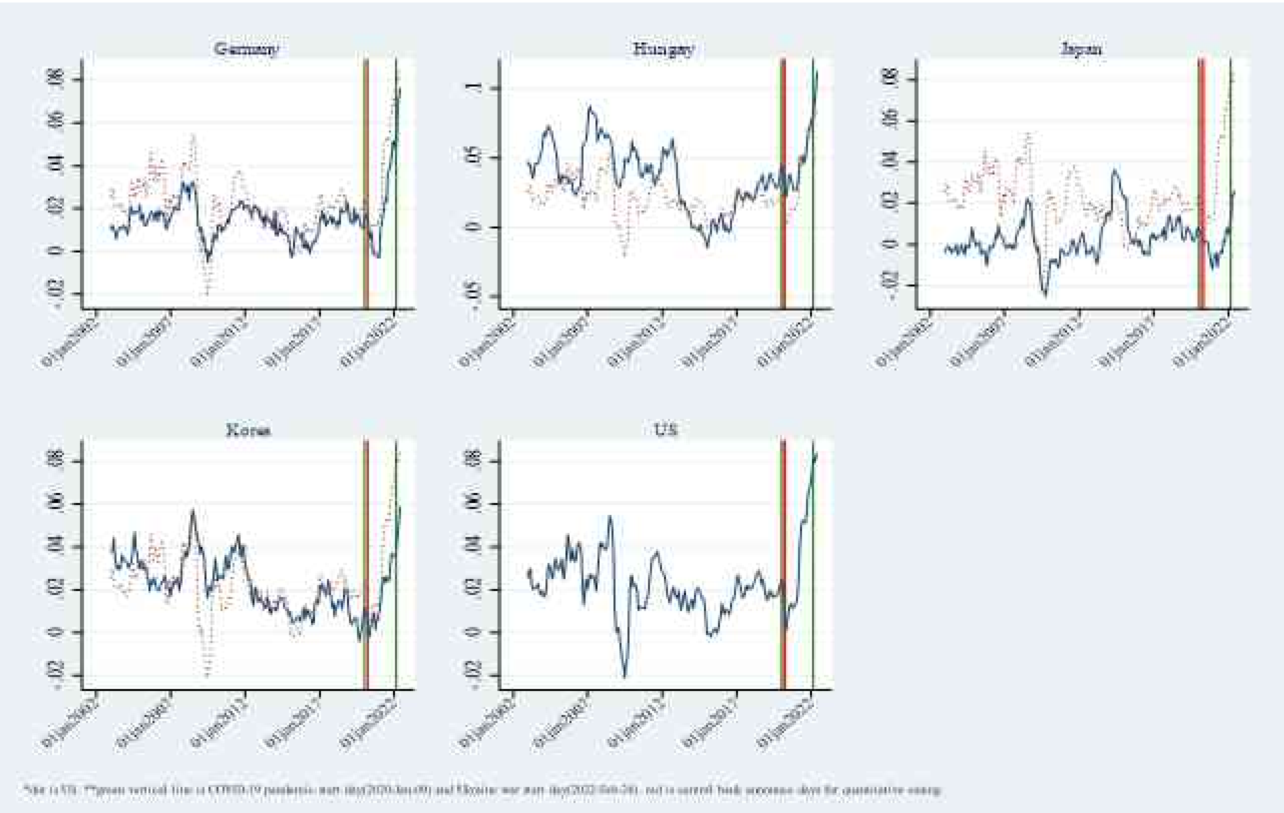

Figure 4-2.*CPI (Developed Countries)*

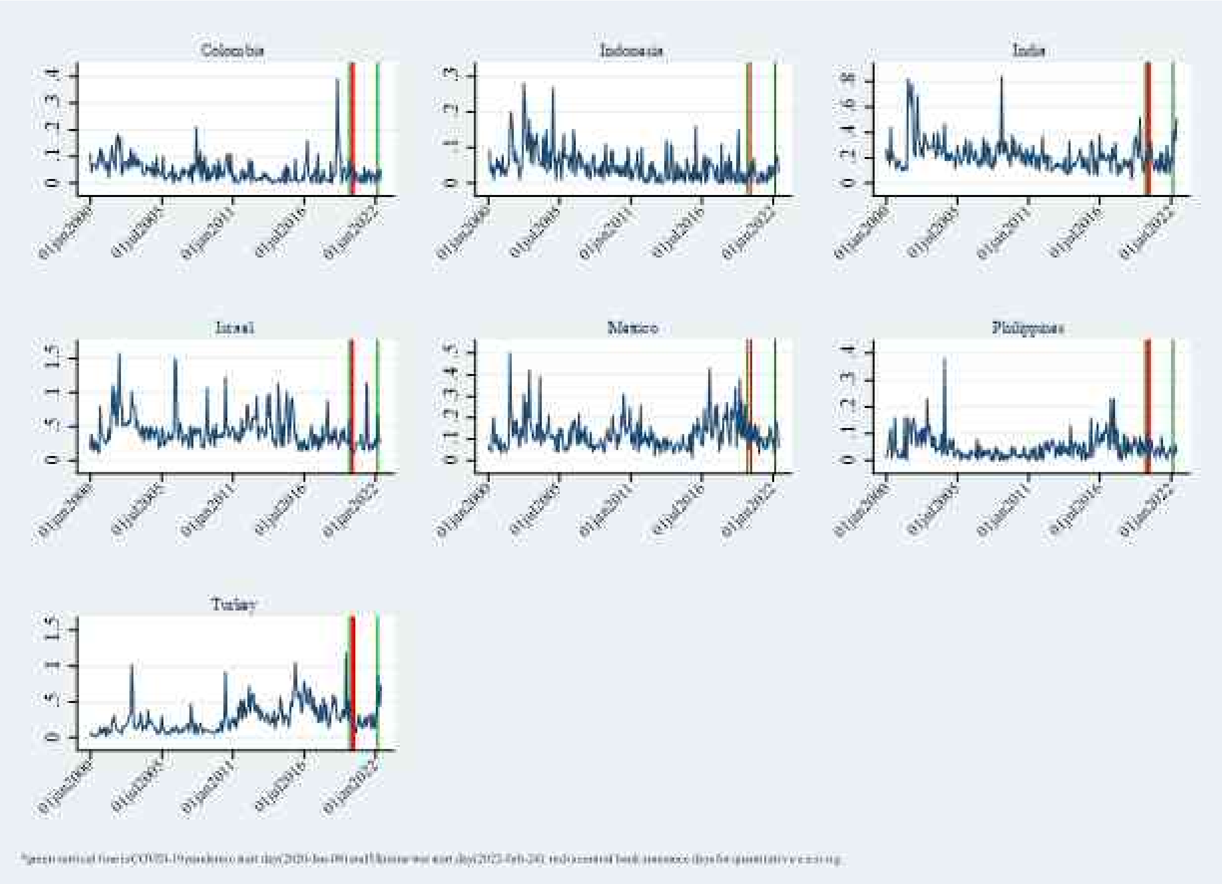

Figure 5-1. *Economic Instability (Developing Countries)*

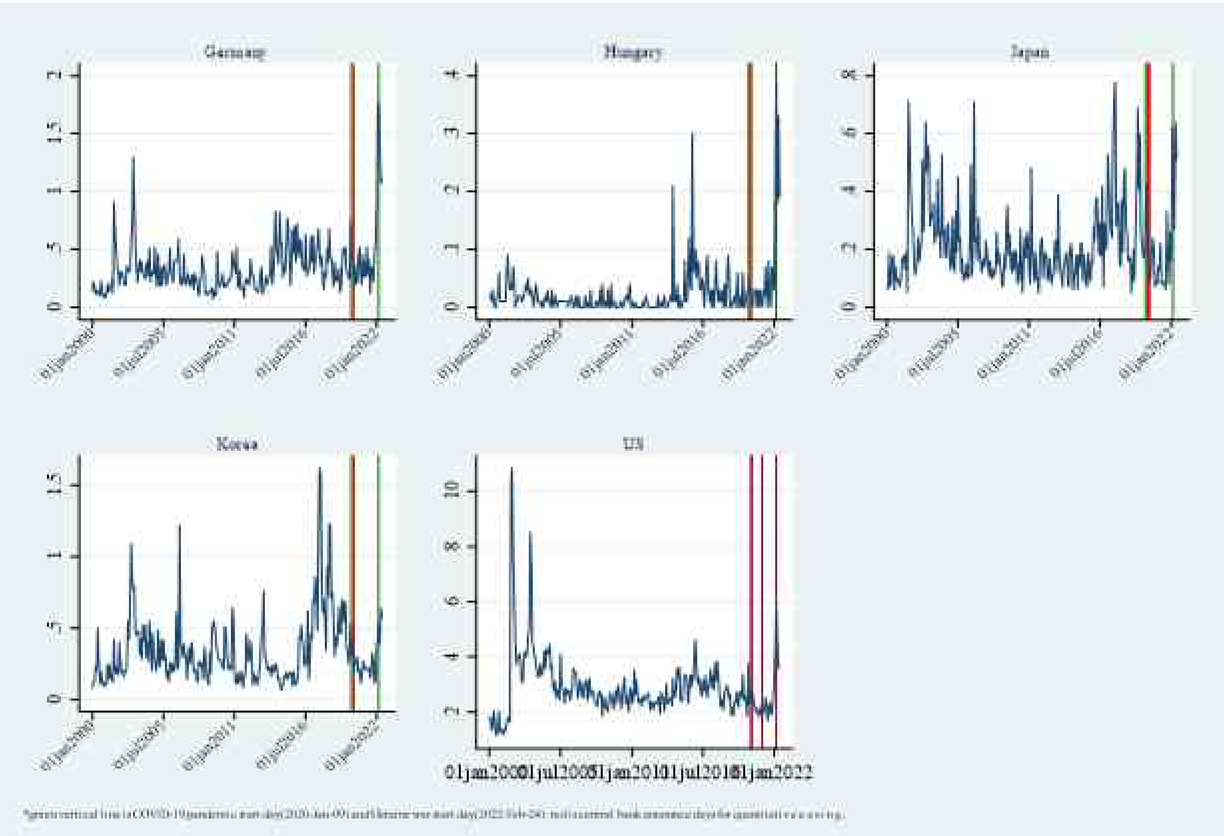

Figure 5-2. *Economic Instability (Developed Countries)*

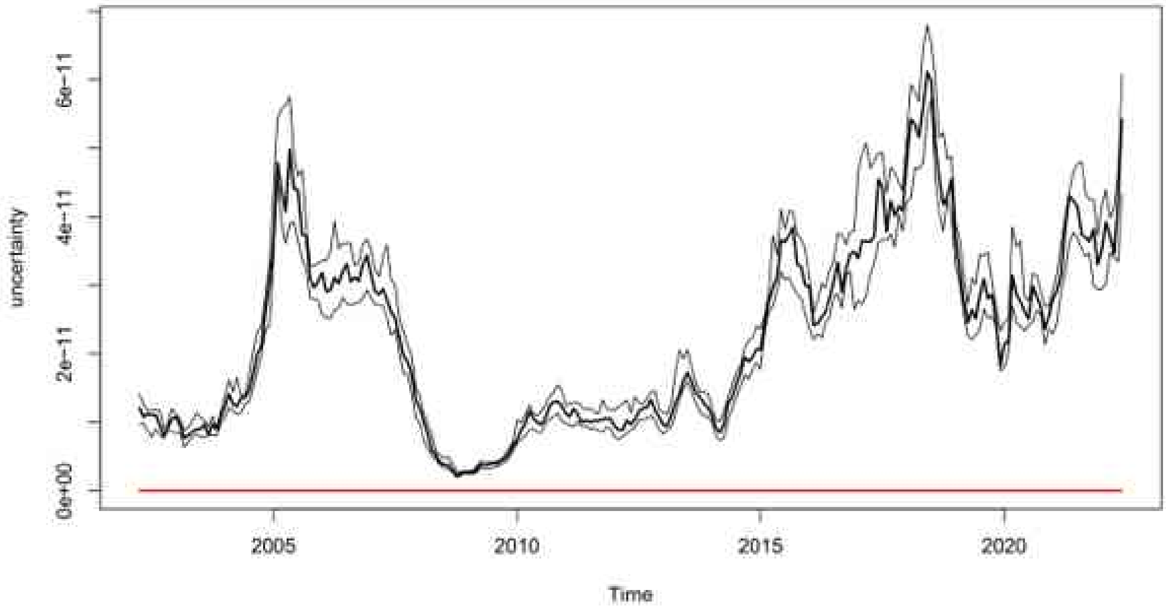

Figure 6. *Global Uncertainty*

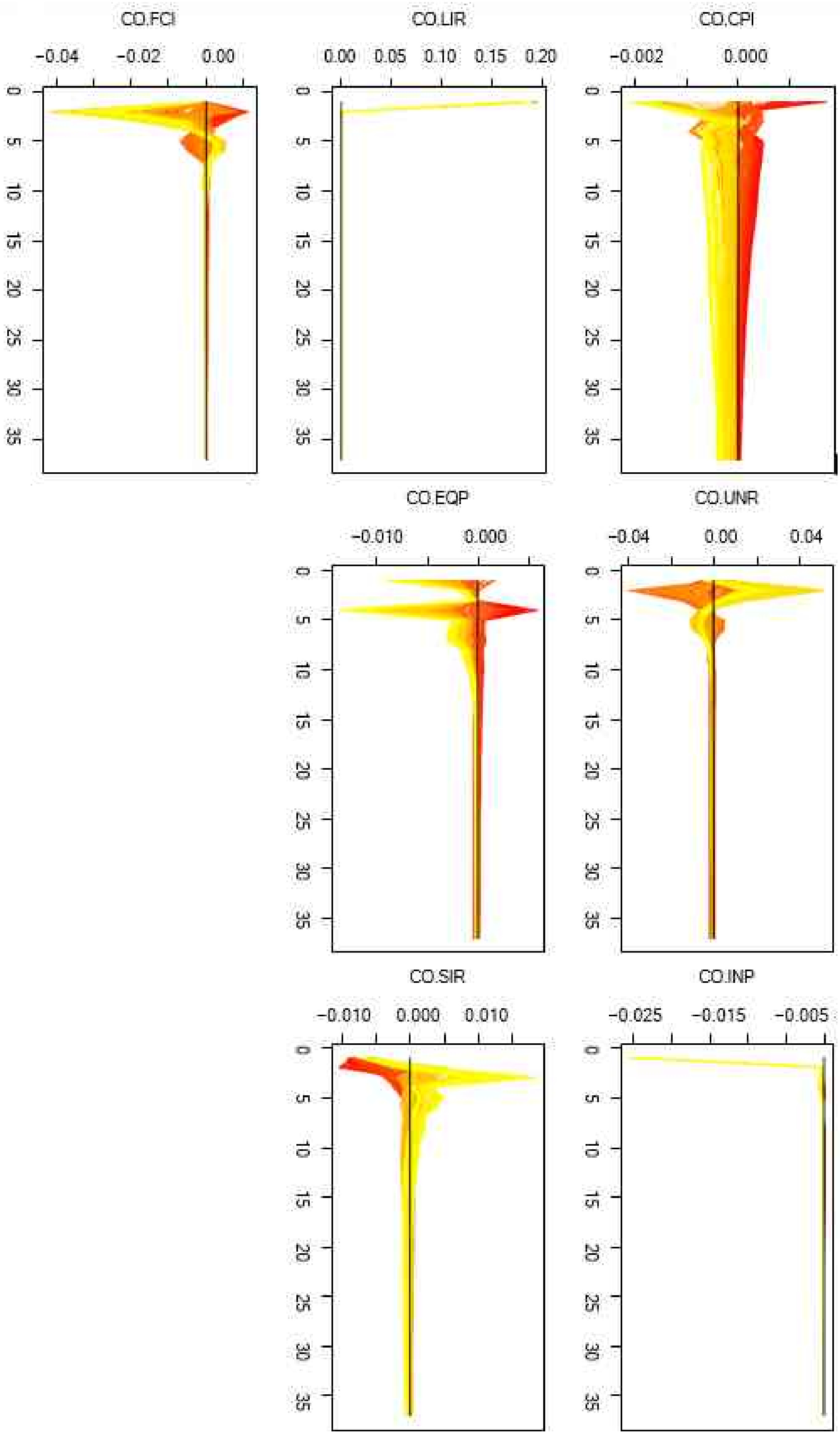

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Columbia*

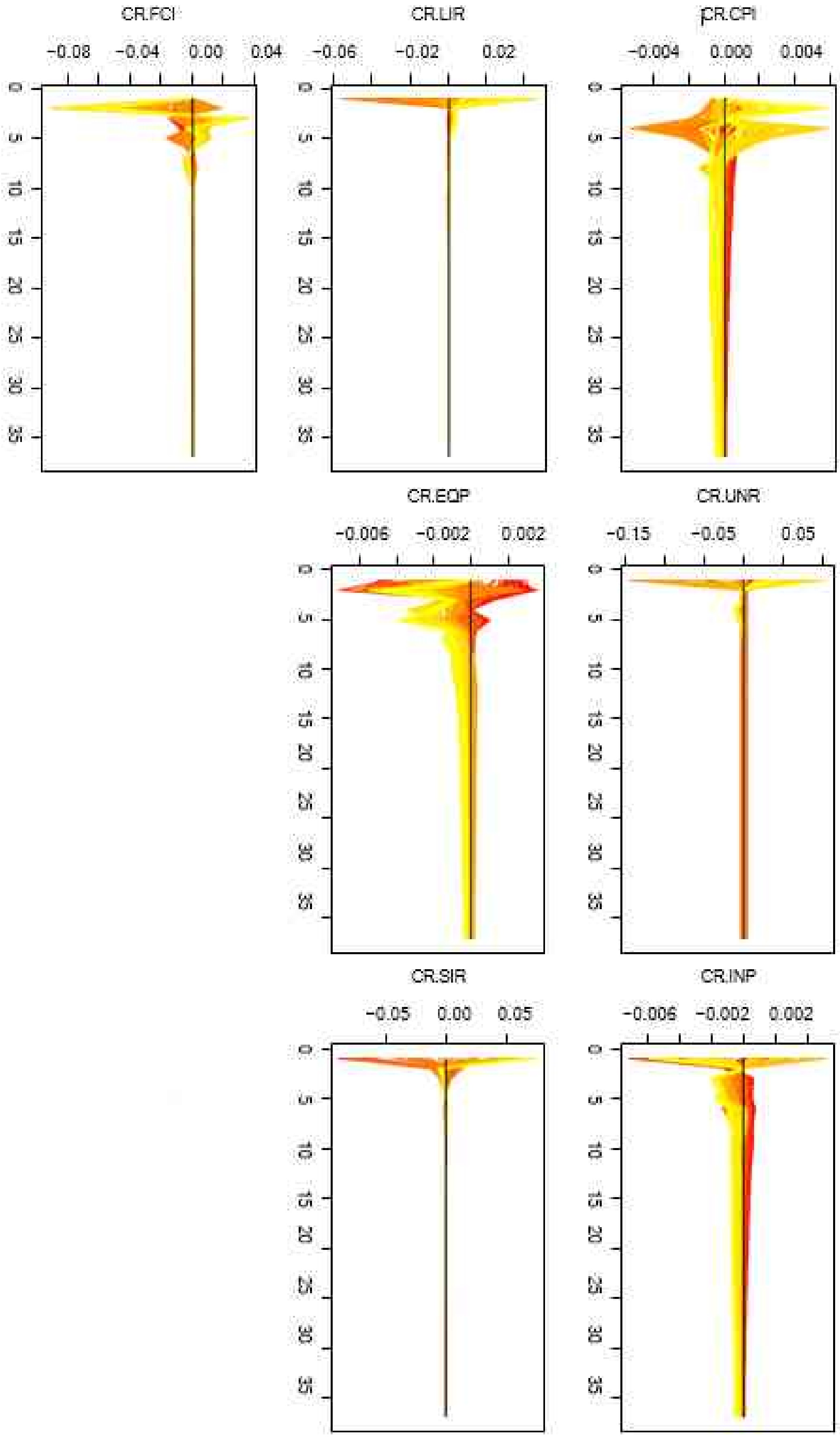

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Croatia*

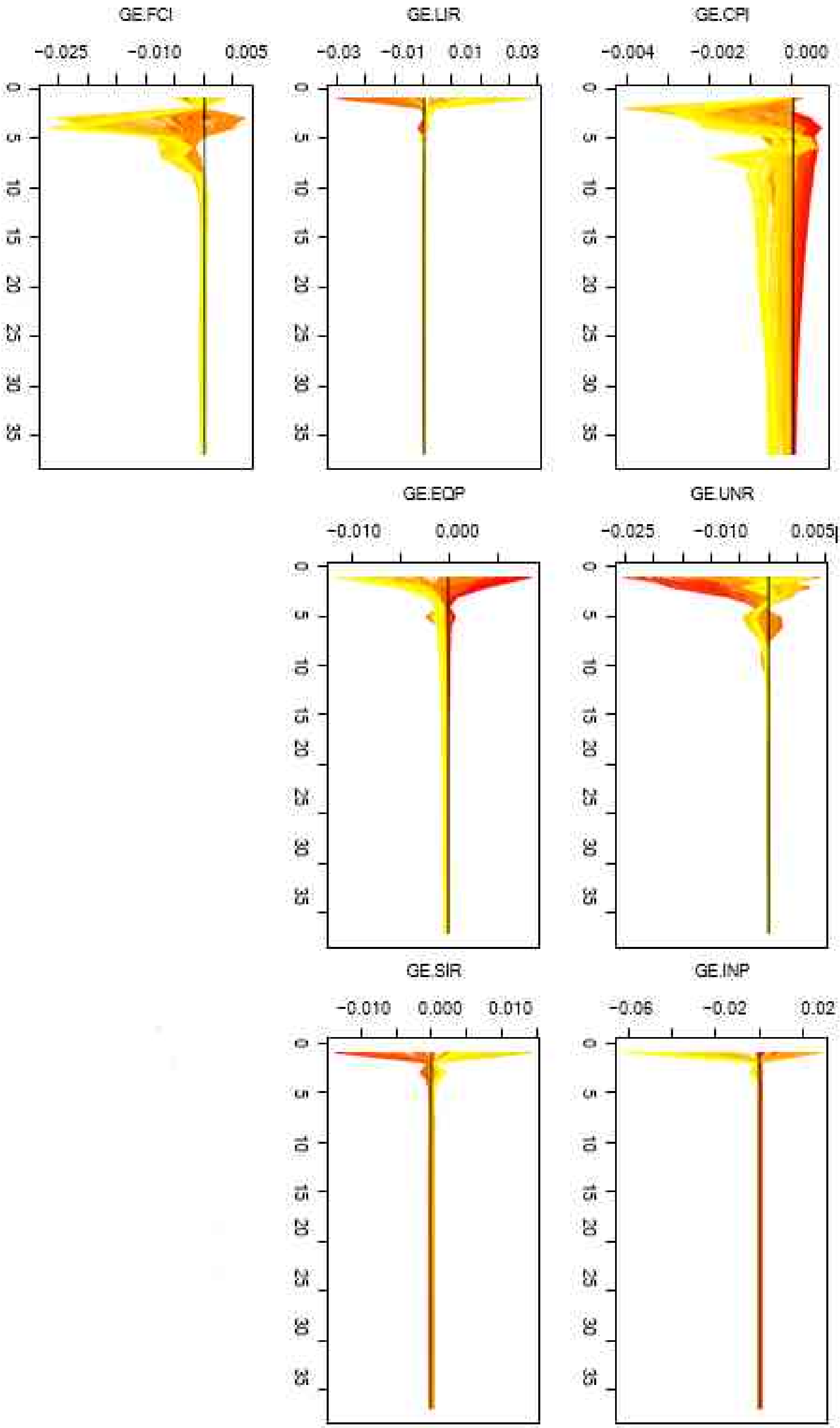

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Hungary*

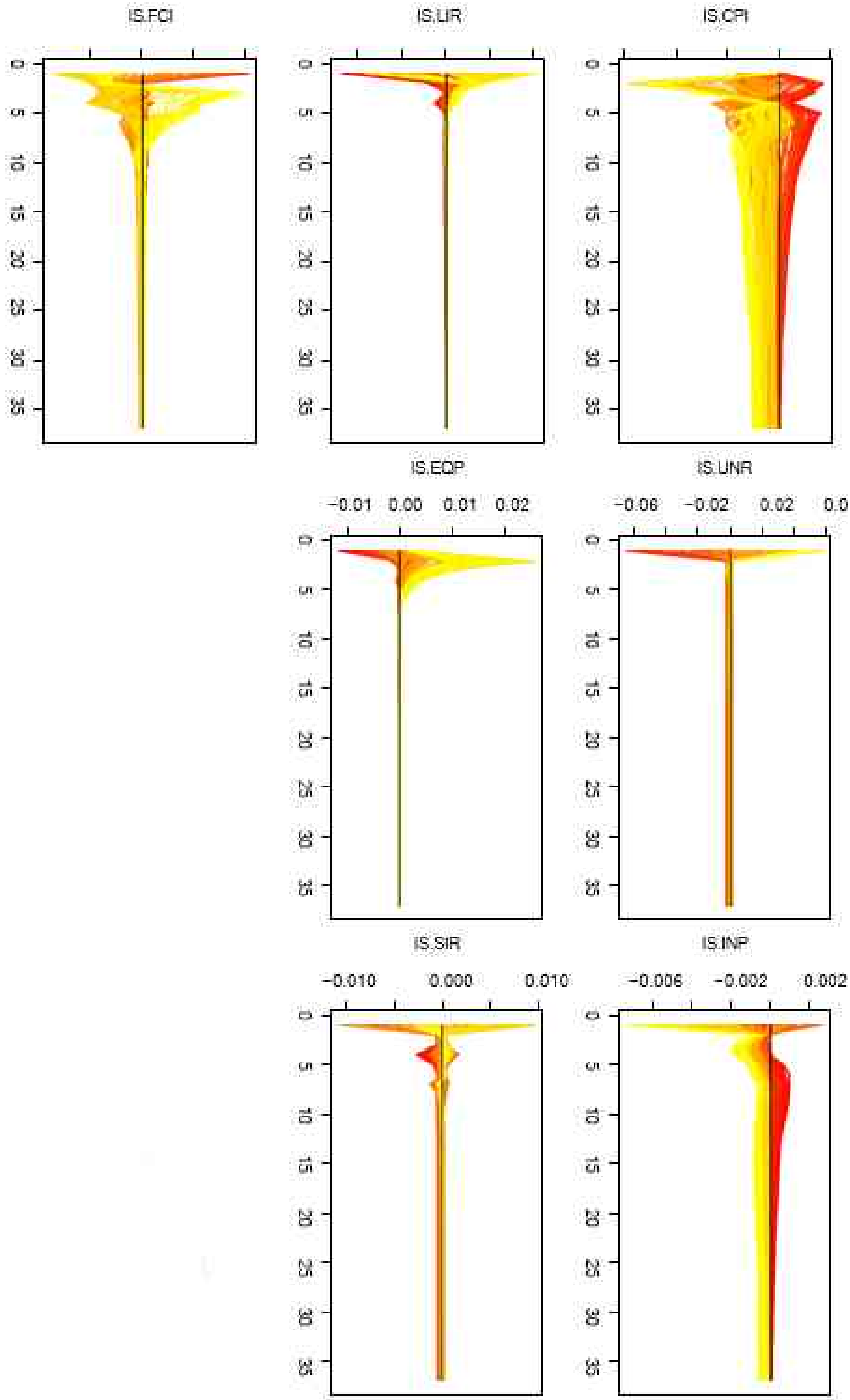

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Israel*

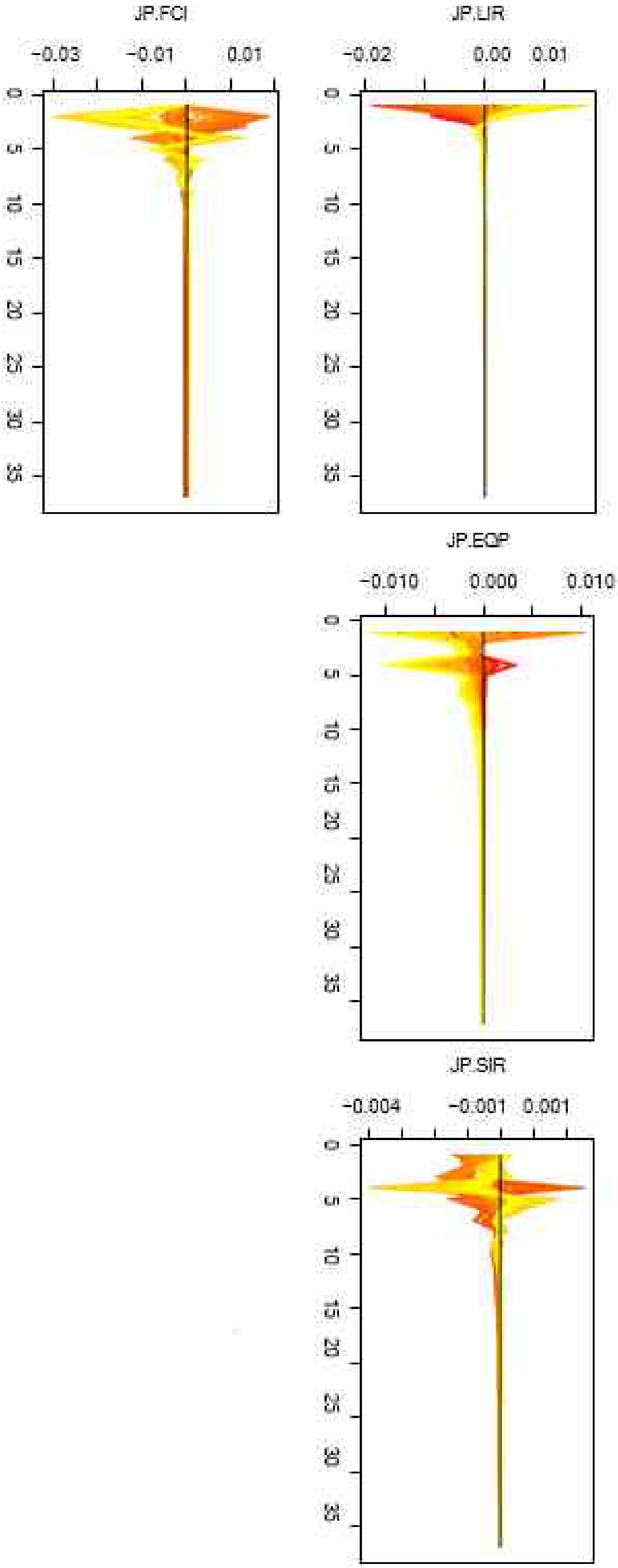

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Japan*

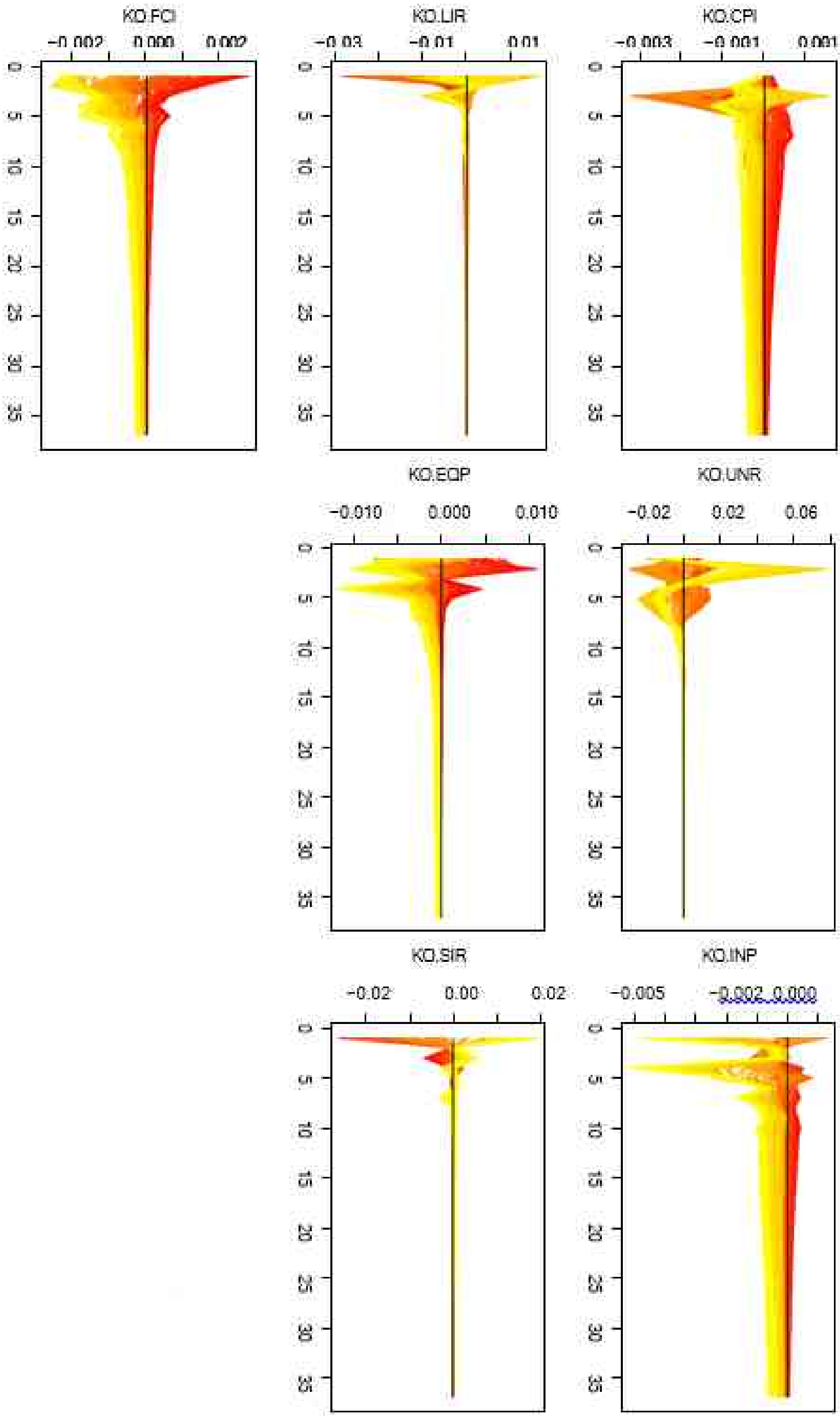

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Korea*

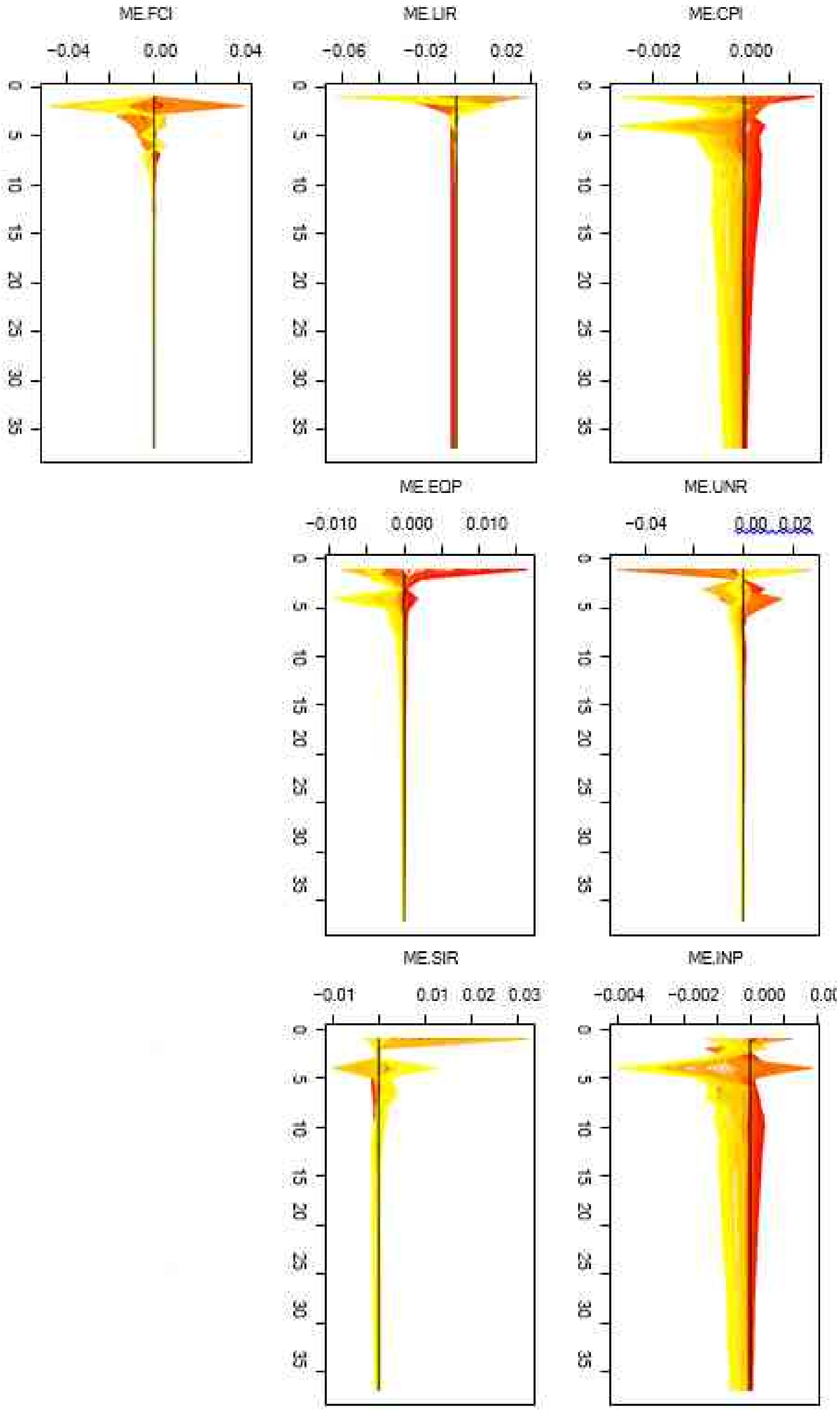

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Mexico*

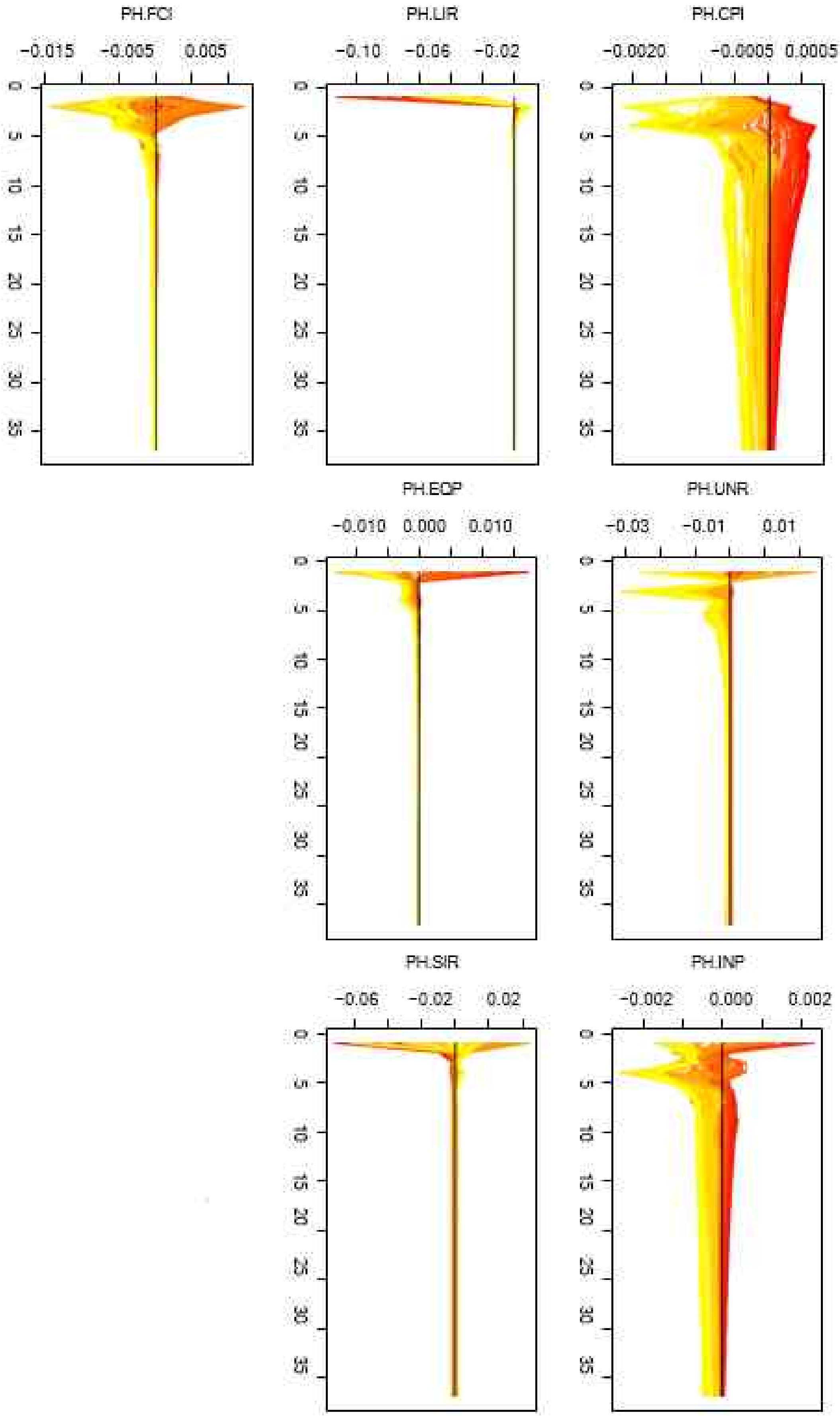

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Philippines*

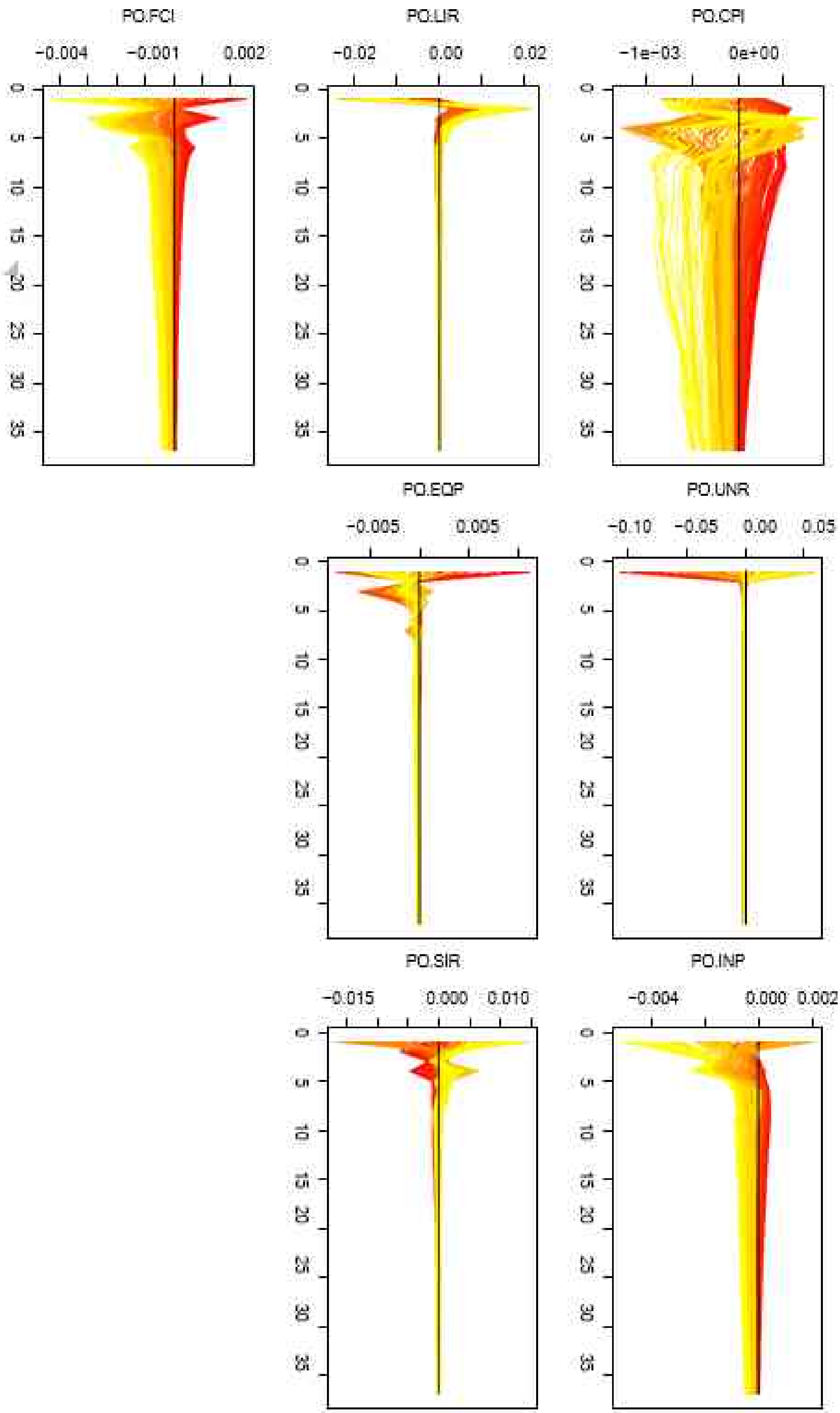

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Poland*

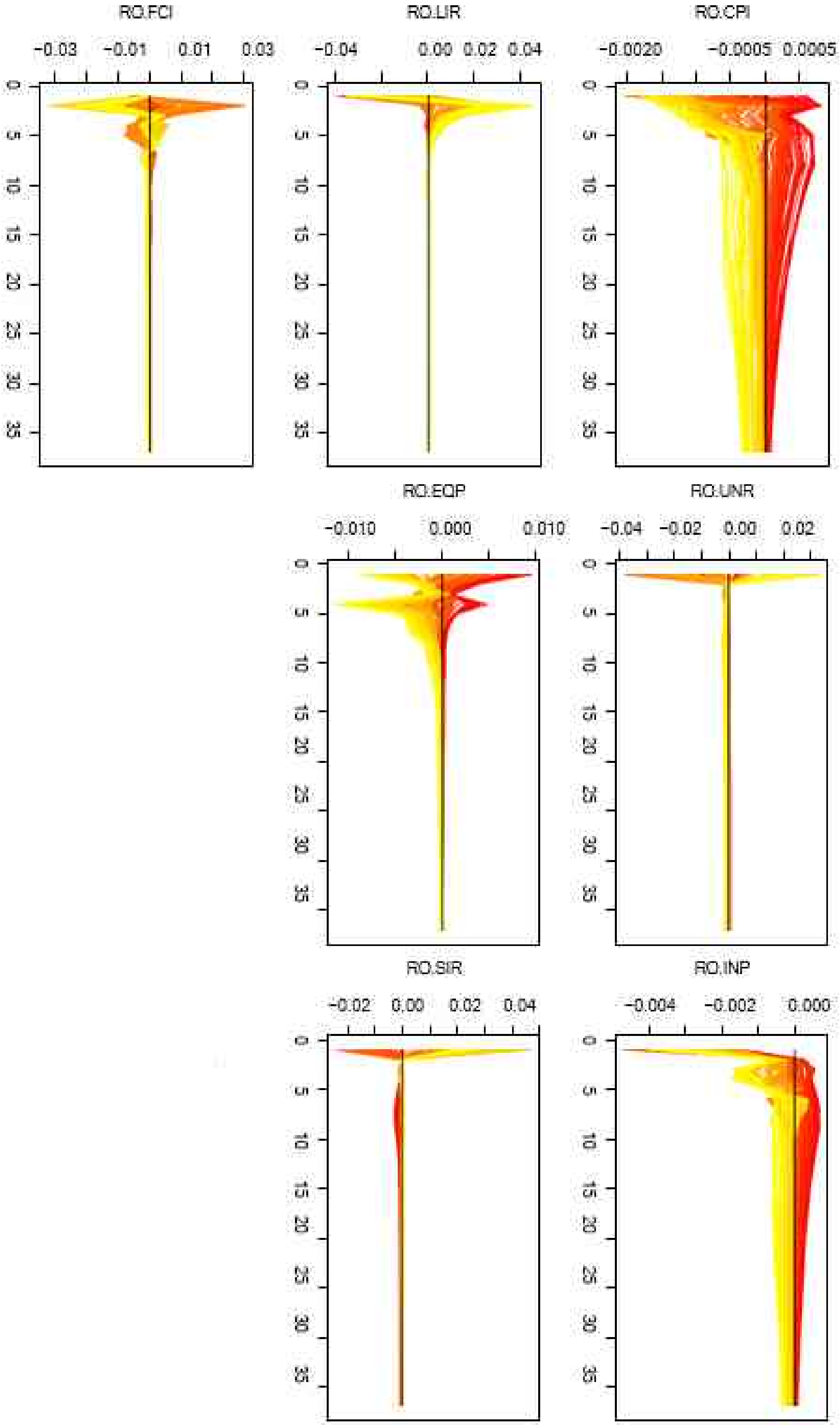

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Romania*

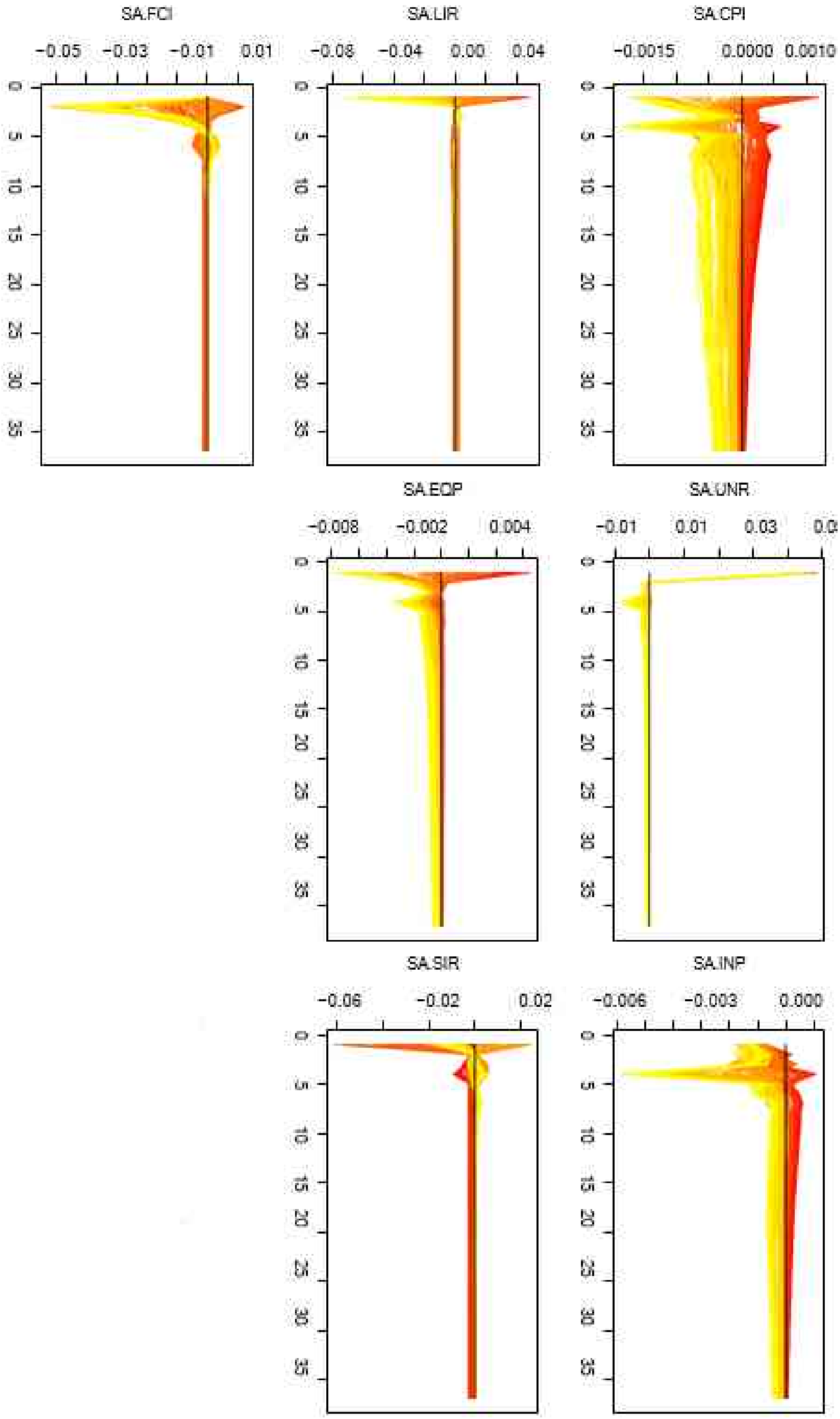

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). SouthAfrica*

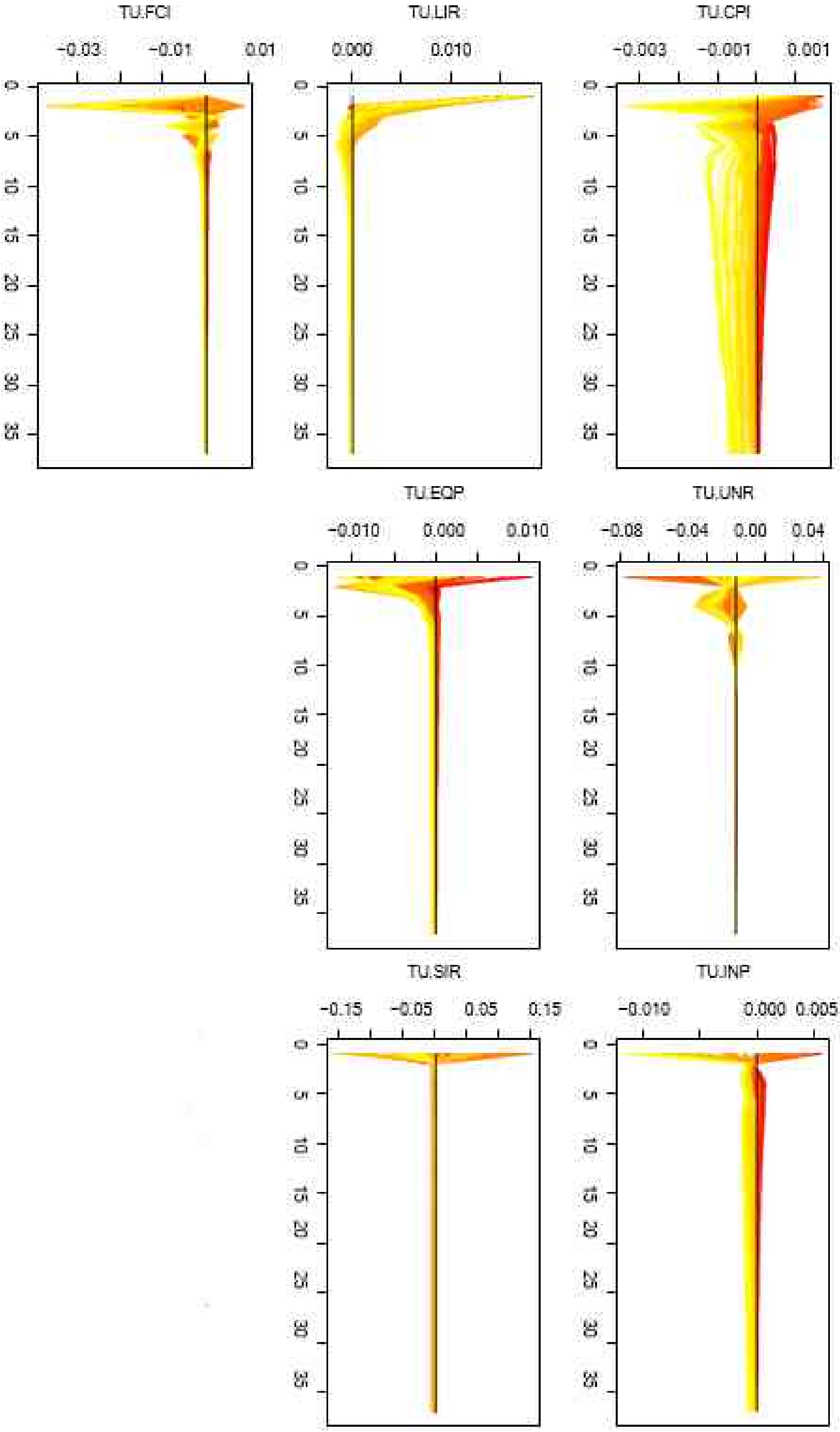

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). Turkey*

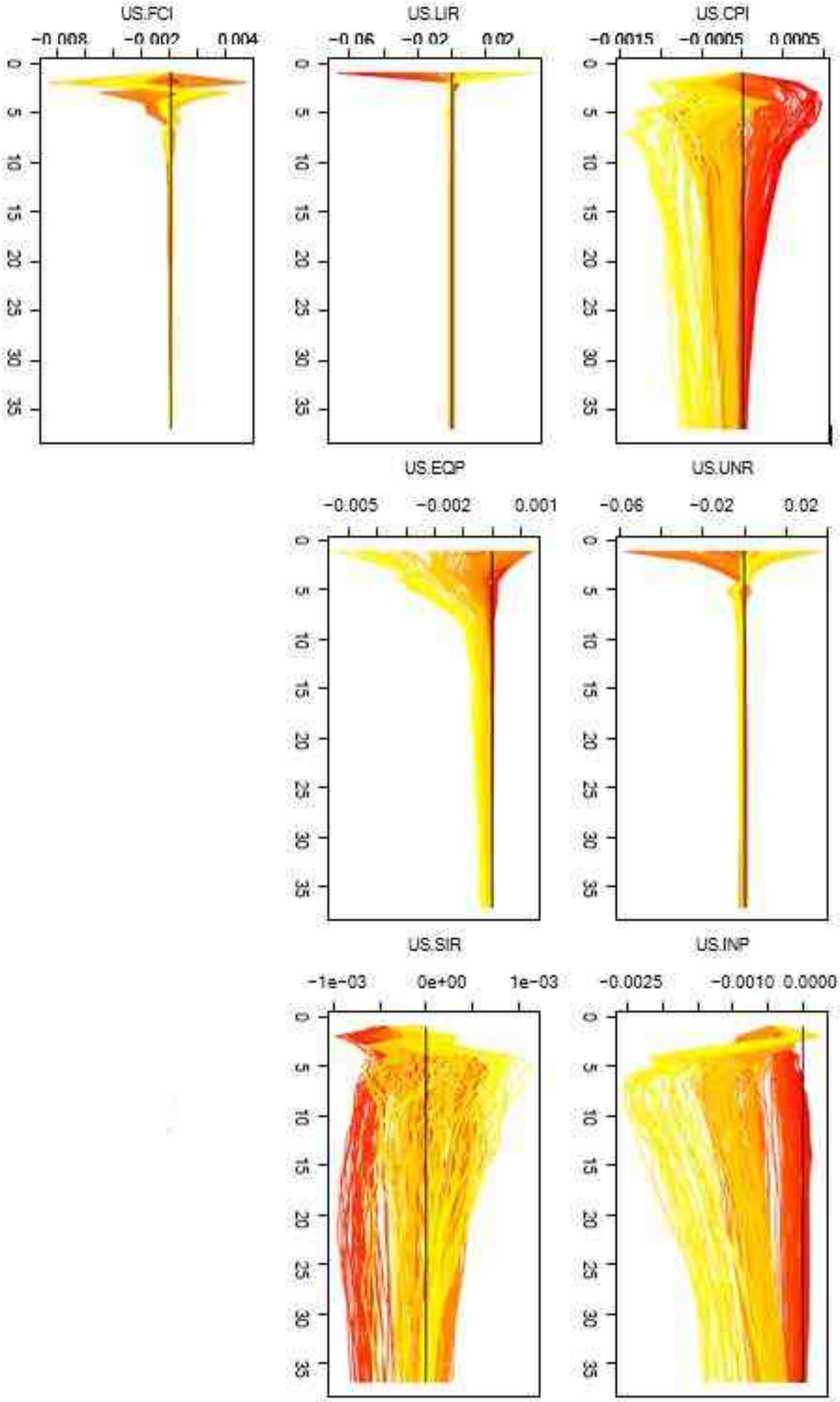

Figure 7. *Impulse responses to an international uncertainty shock (Not Include Nelson-Siegel variables). United States*

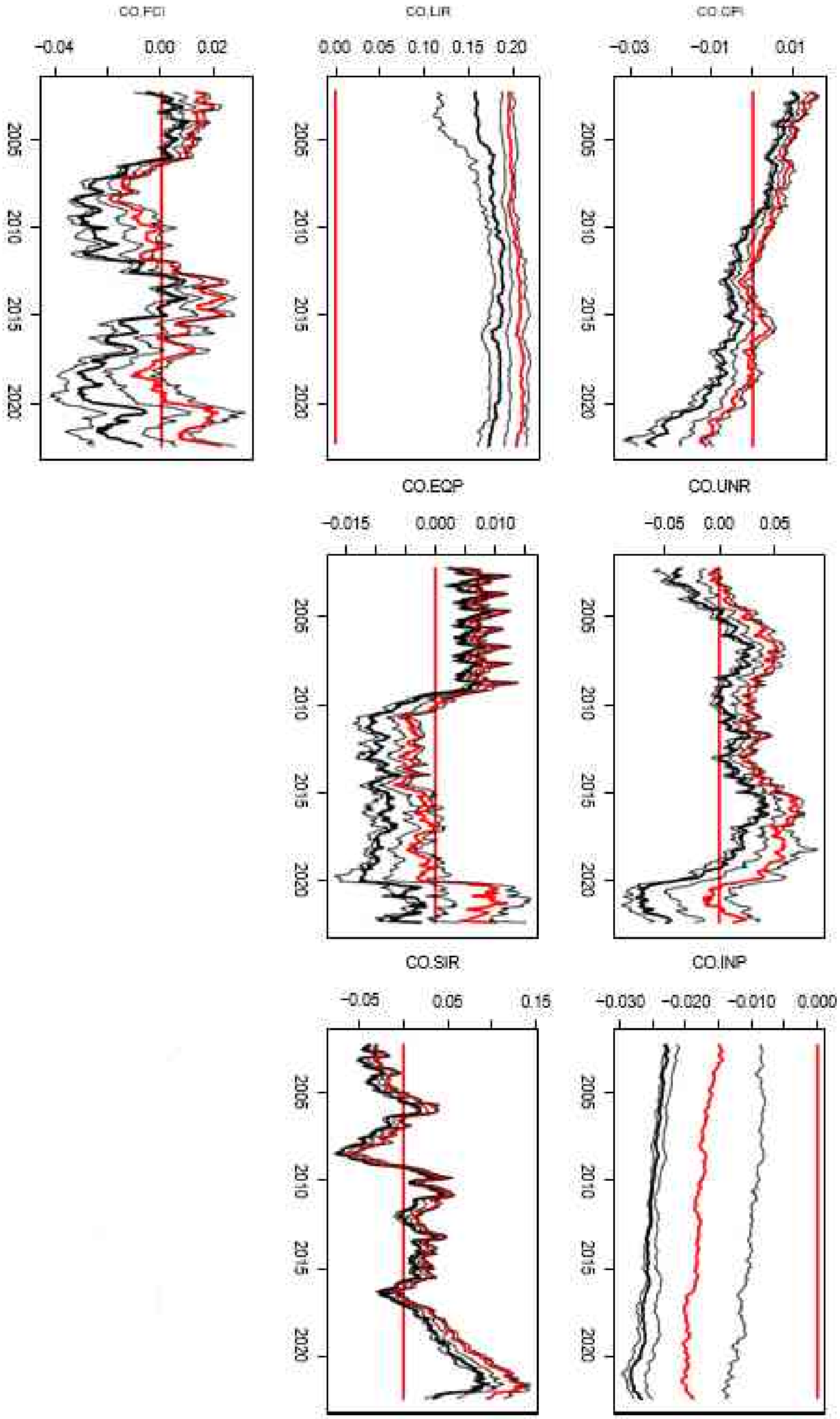

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Columbia*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

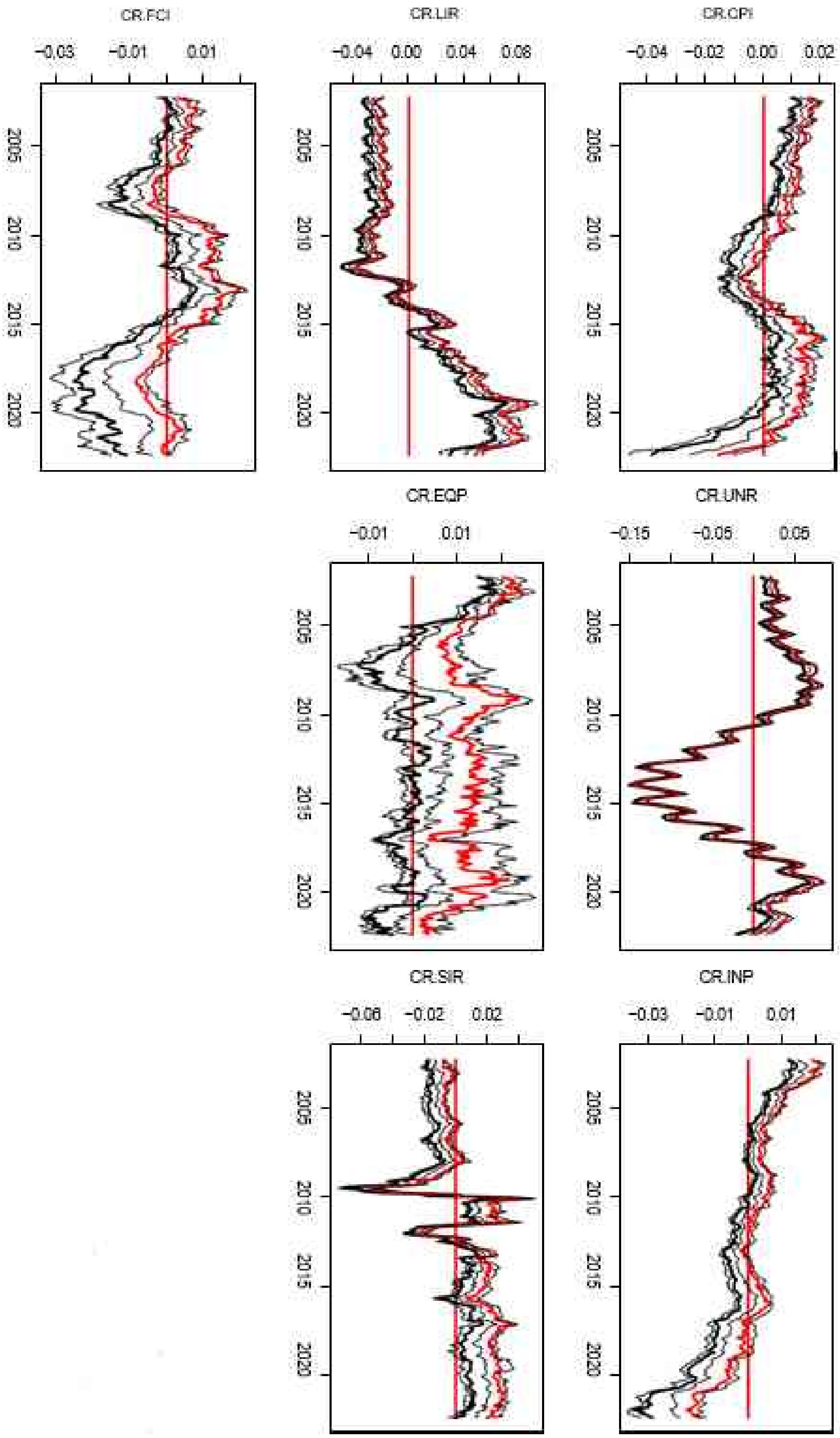

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Croatia*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

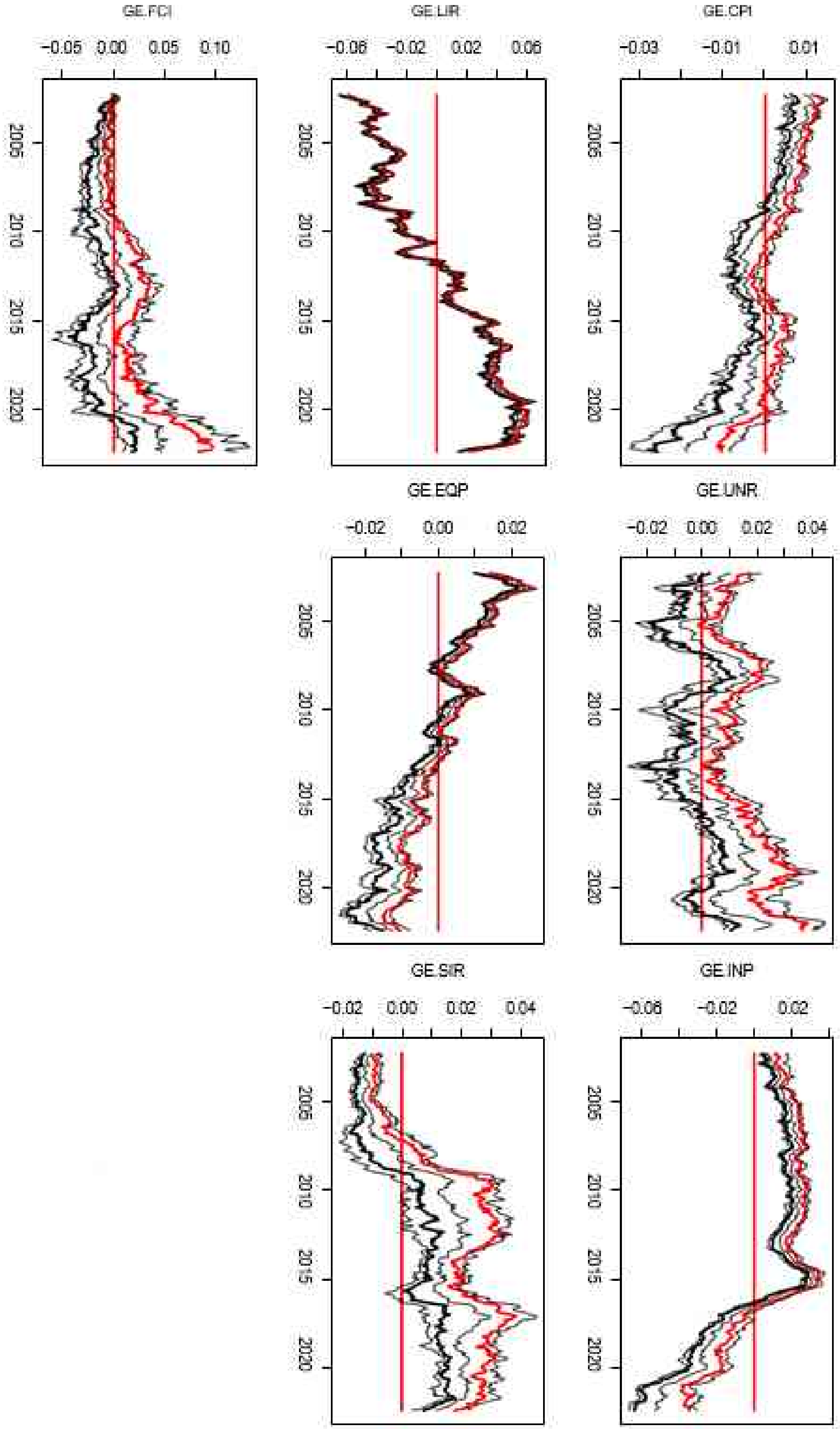

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). German*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

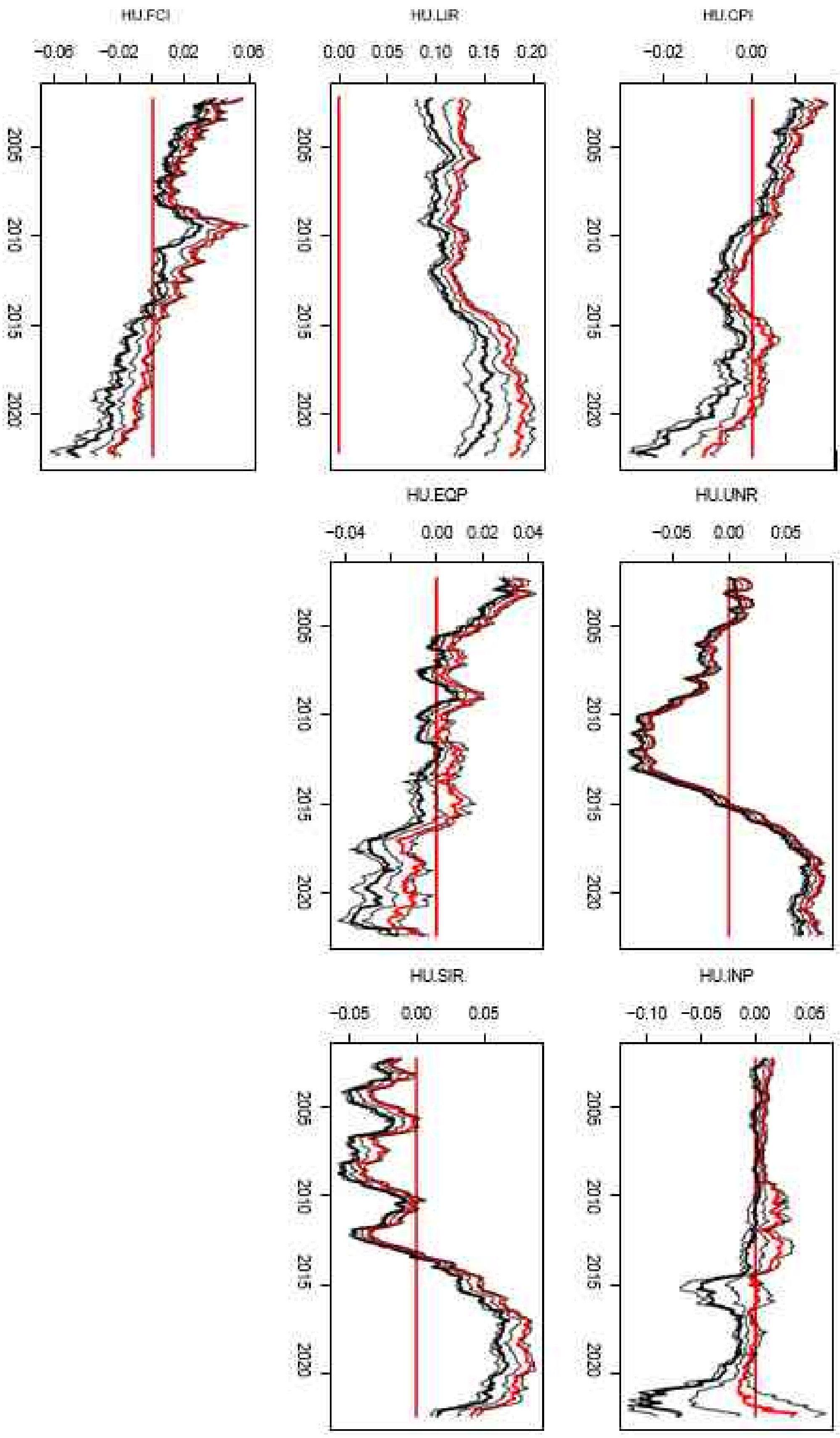

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Hungary*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

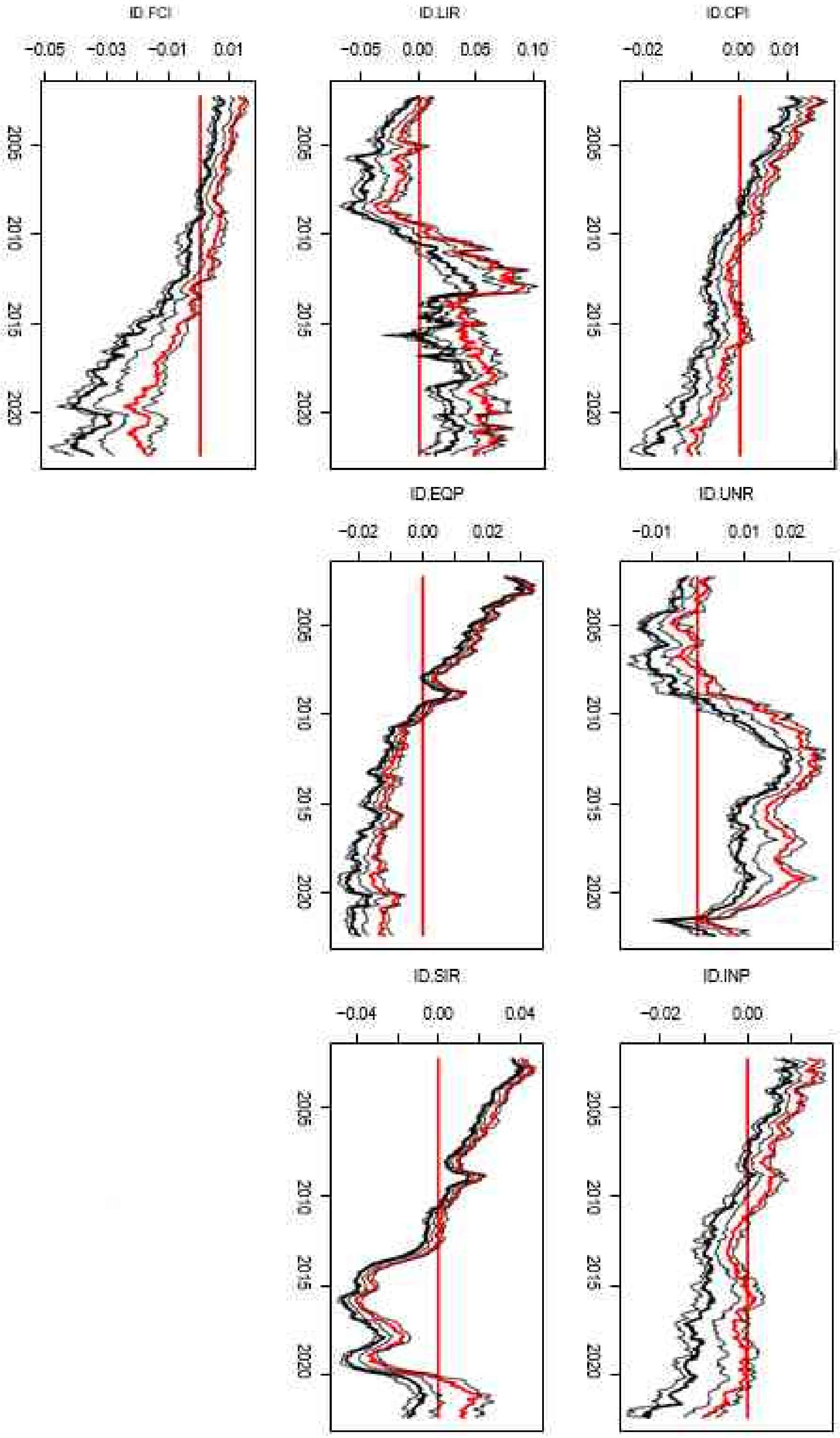

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Indonesia*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

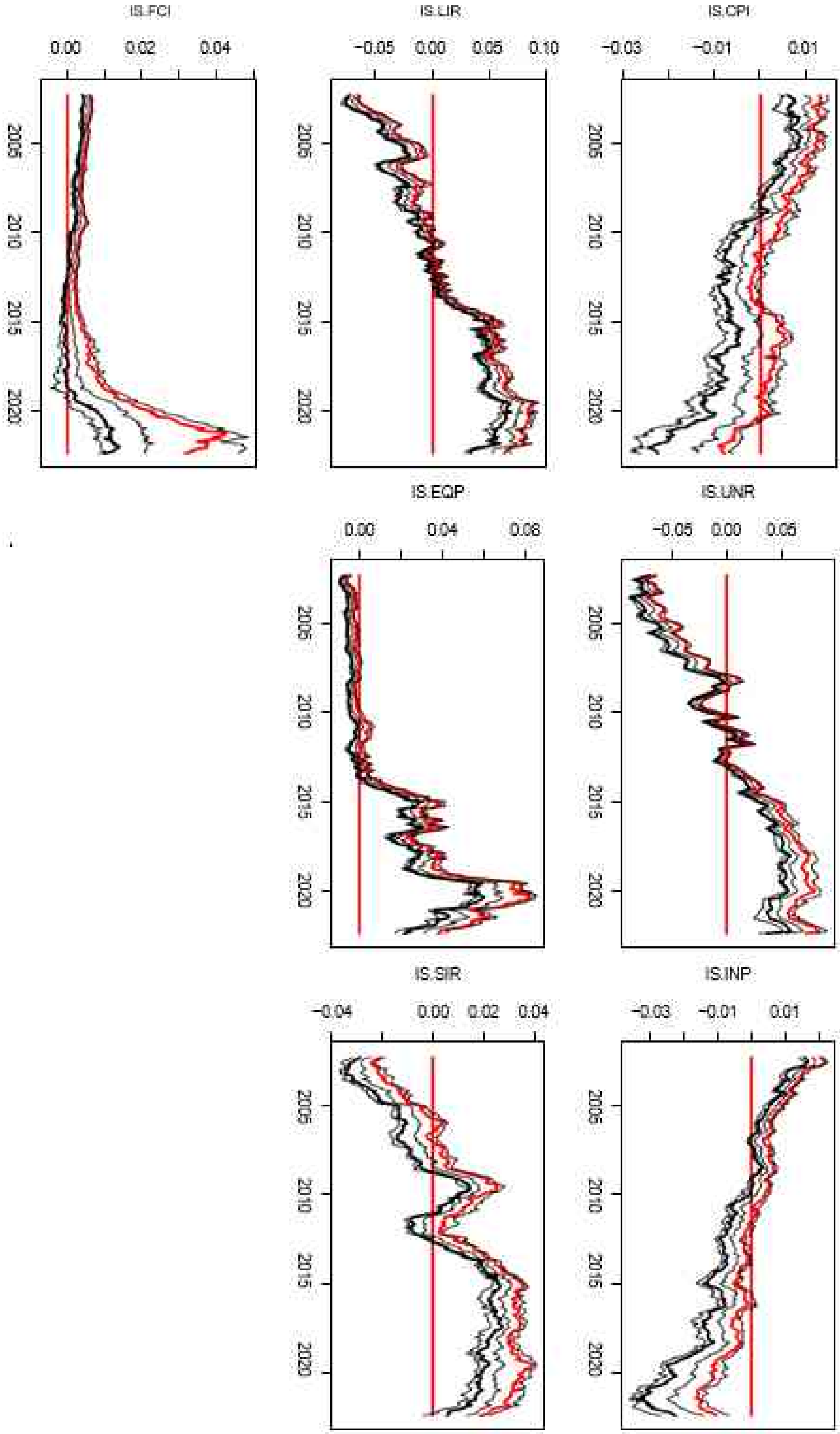

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Israel*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

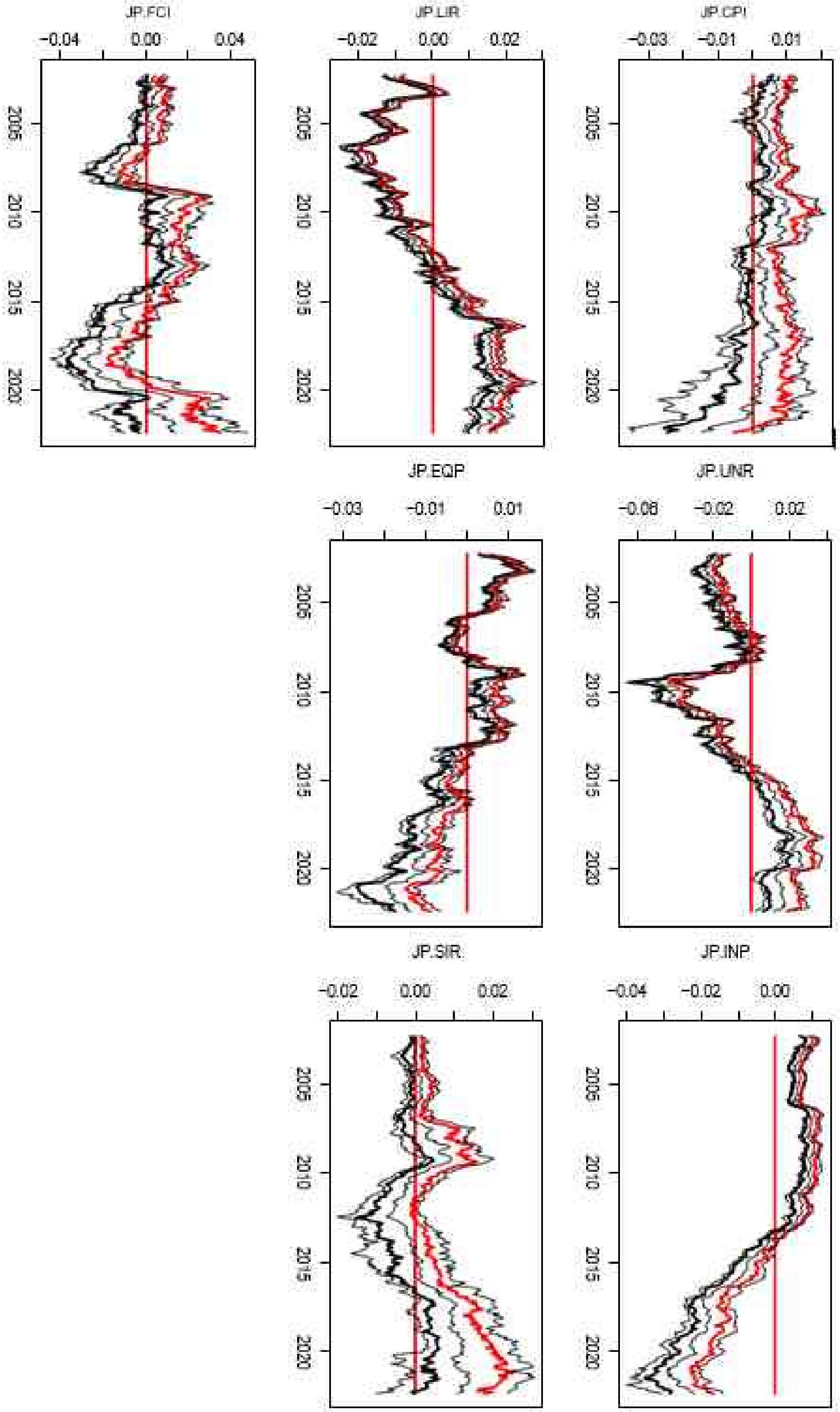

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Japan*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

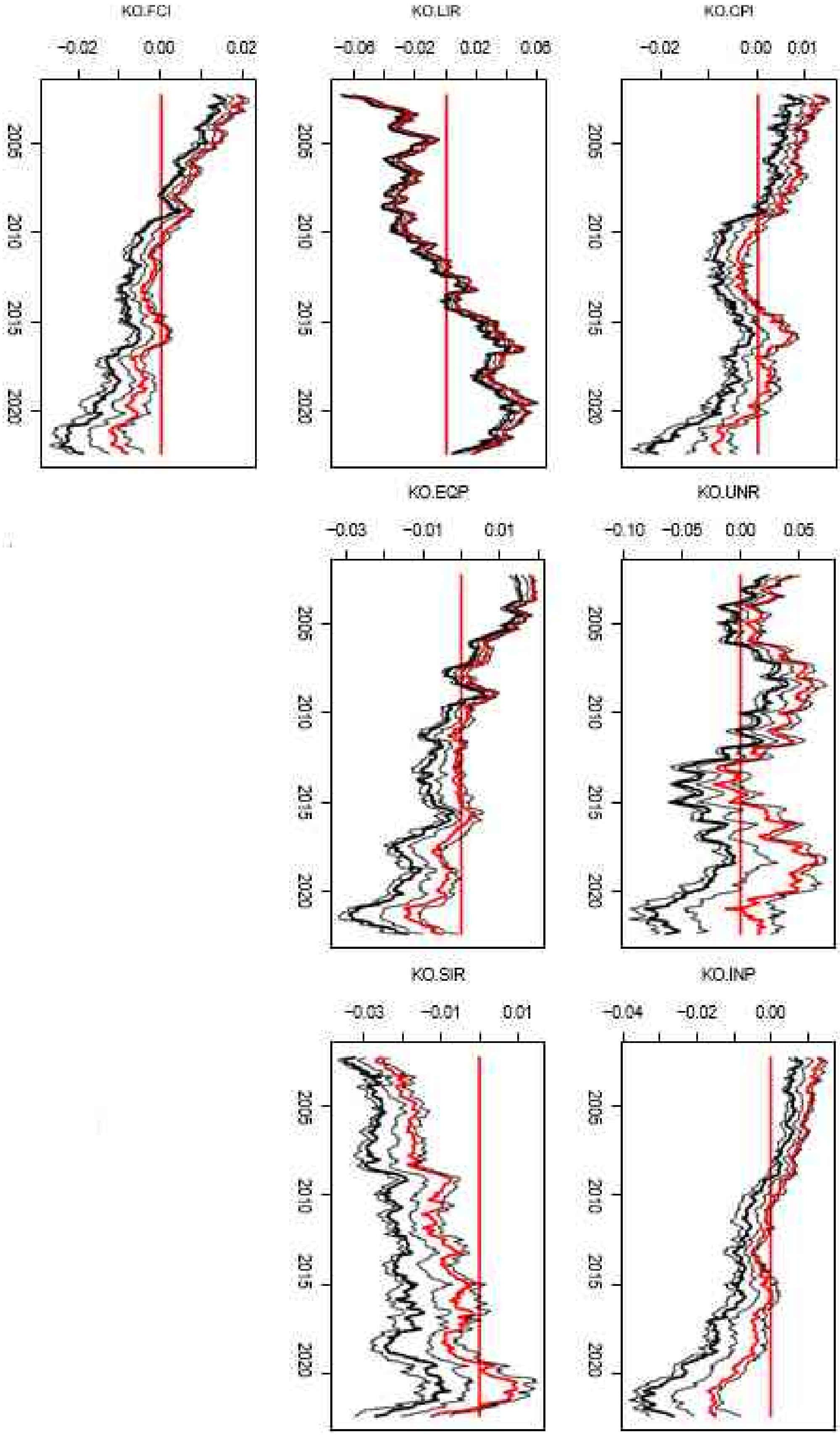

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Korea*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

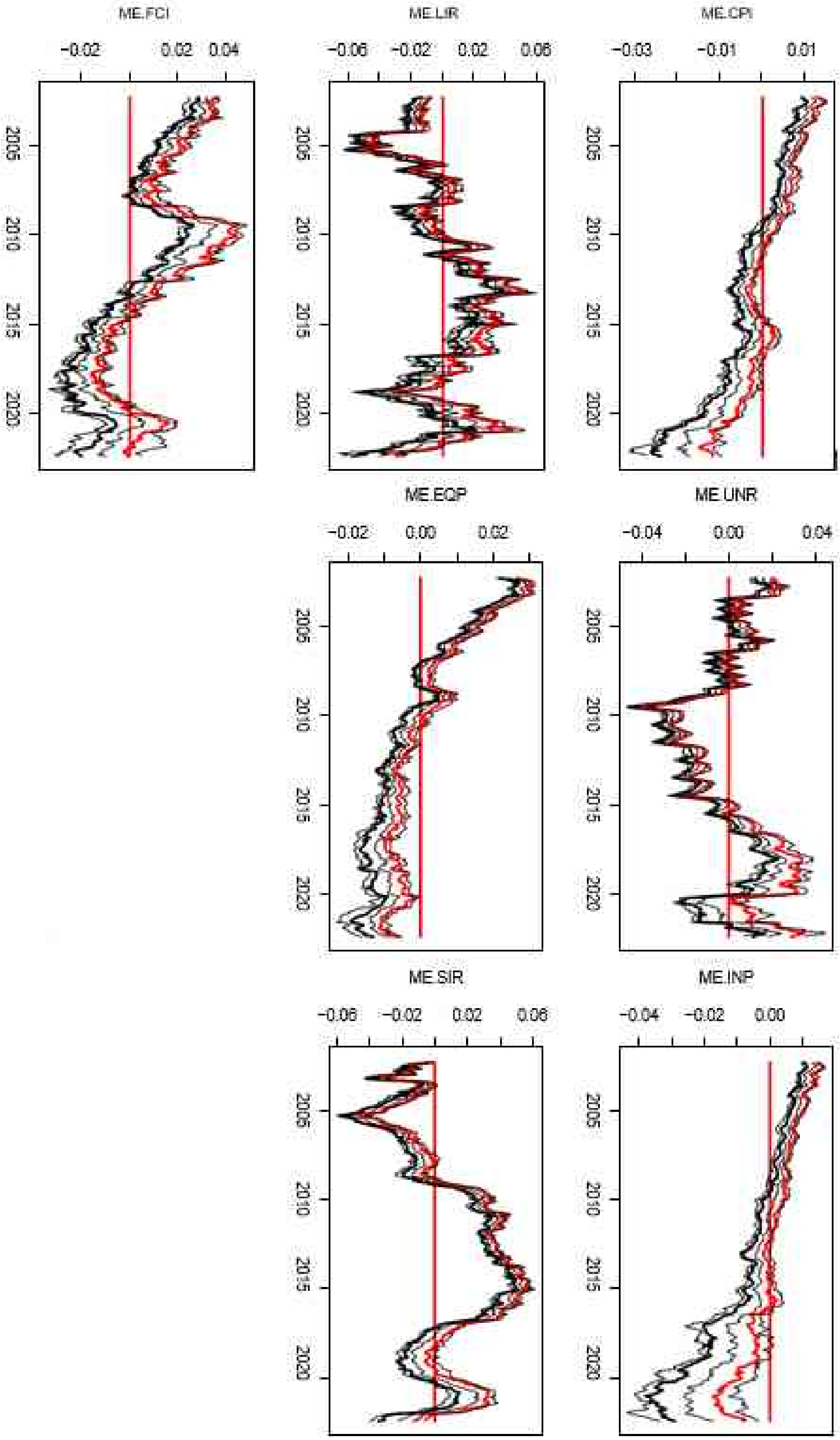

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Mexico*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

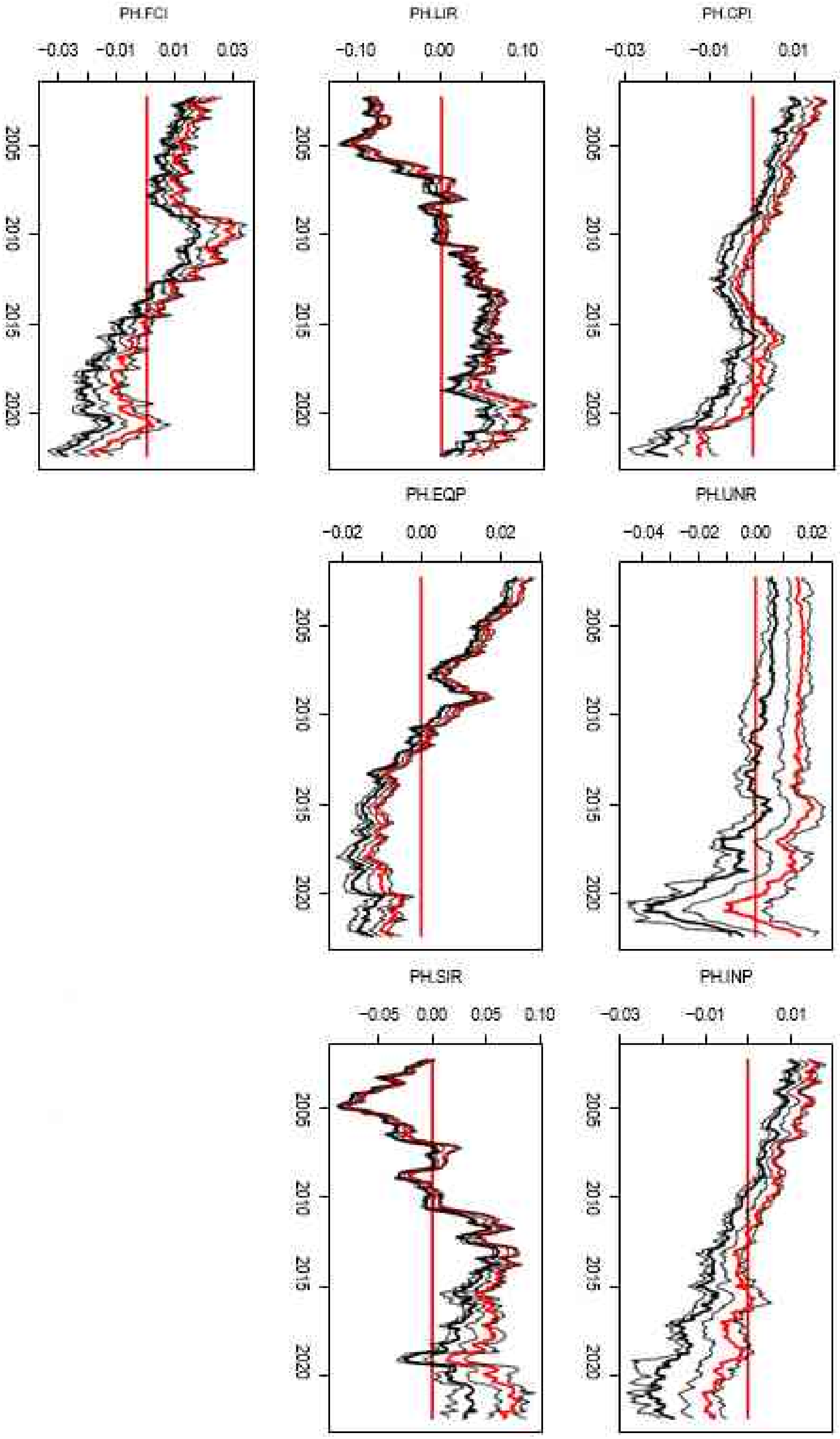

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Philippines*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

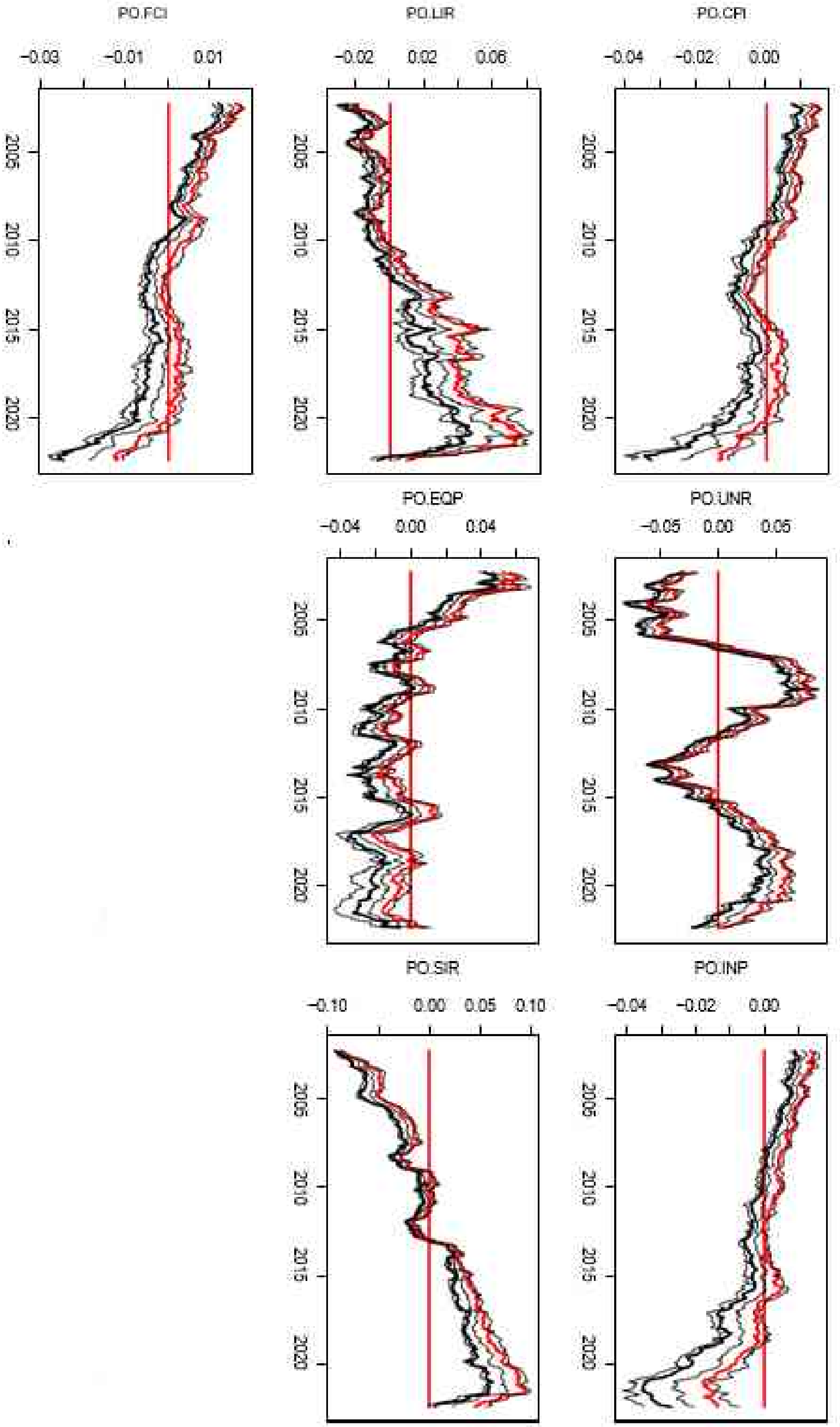

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Poland*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

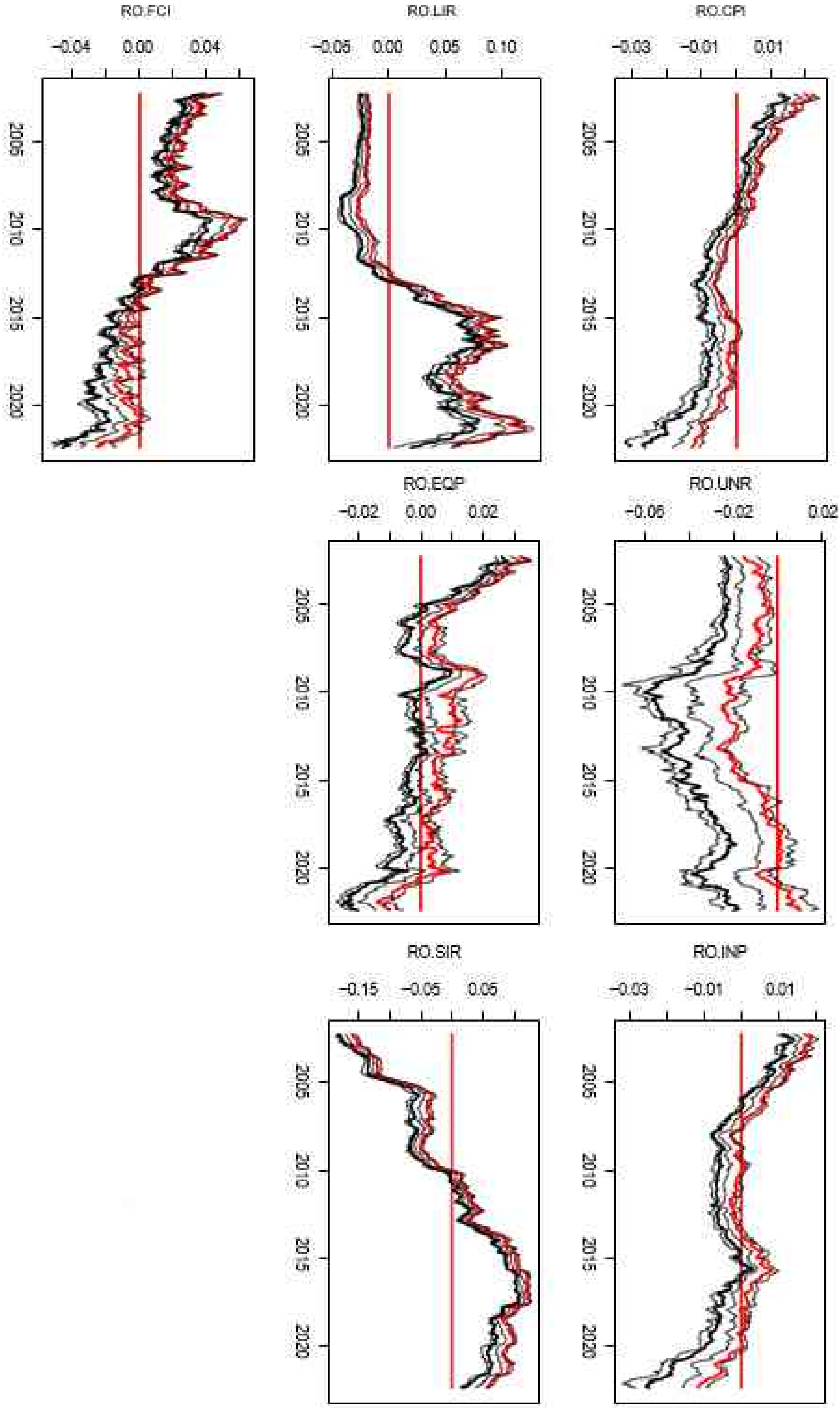

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). Romania*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

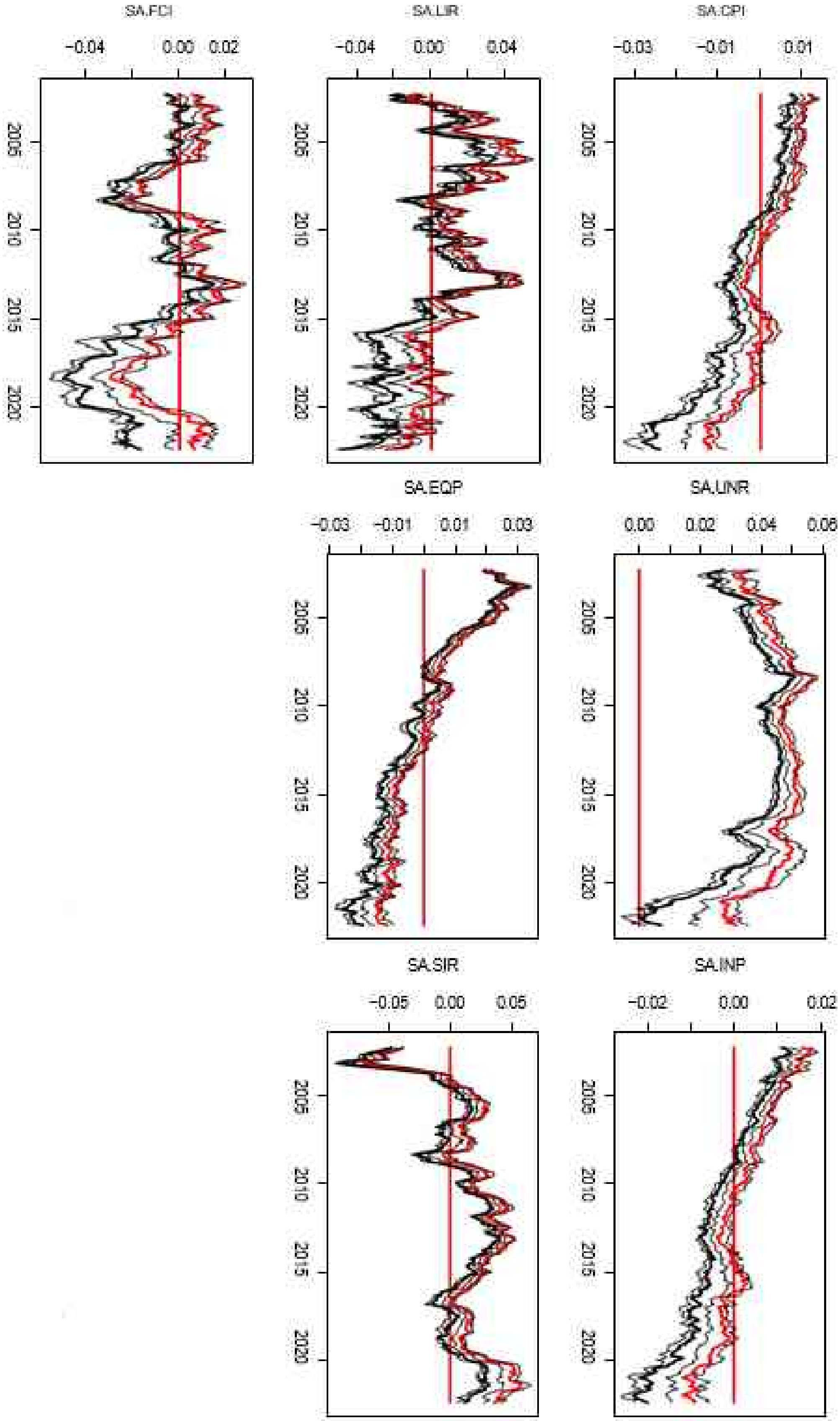

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables). South Africa*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

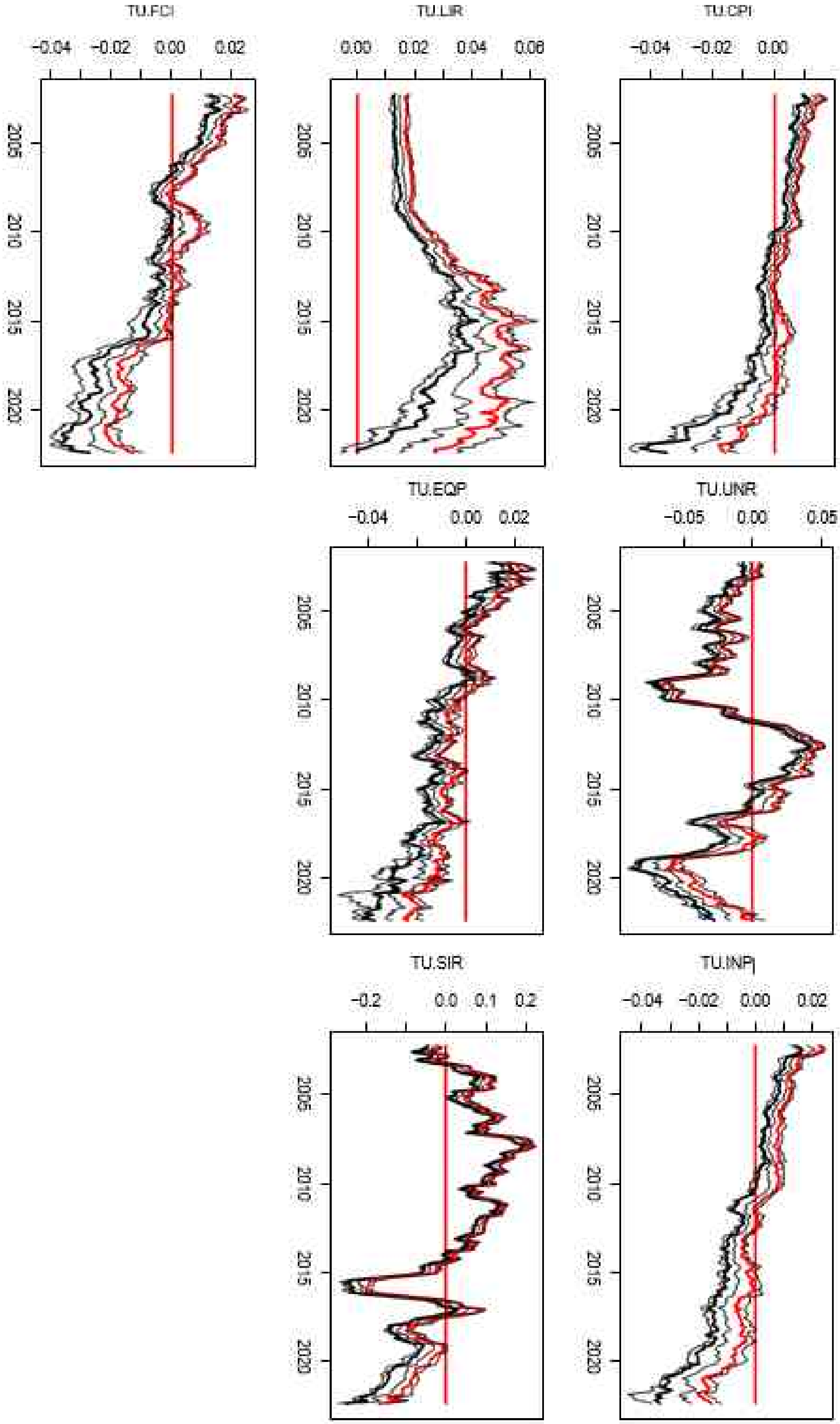

Figure 8. Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables).Turkey

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

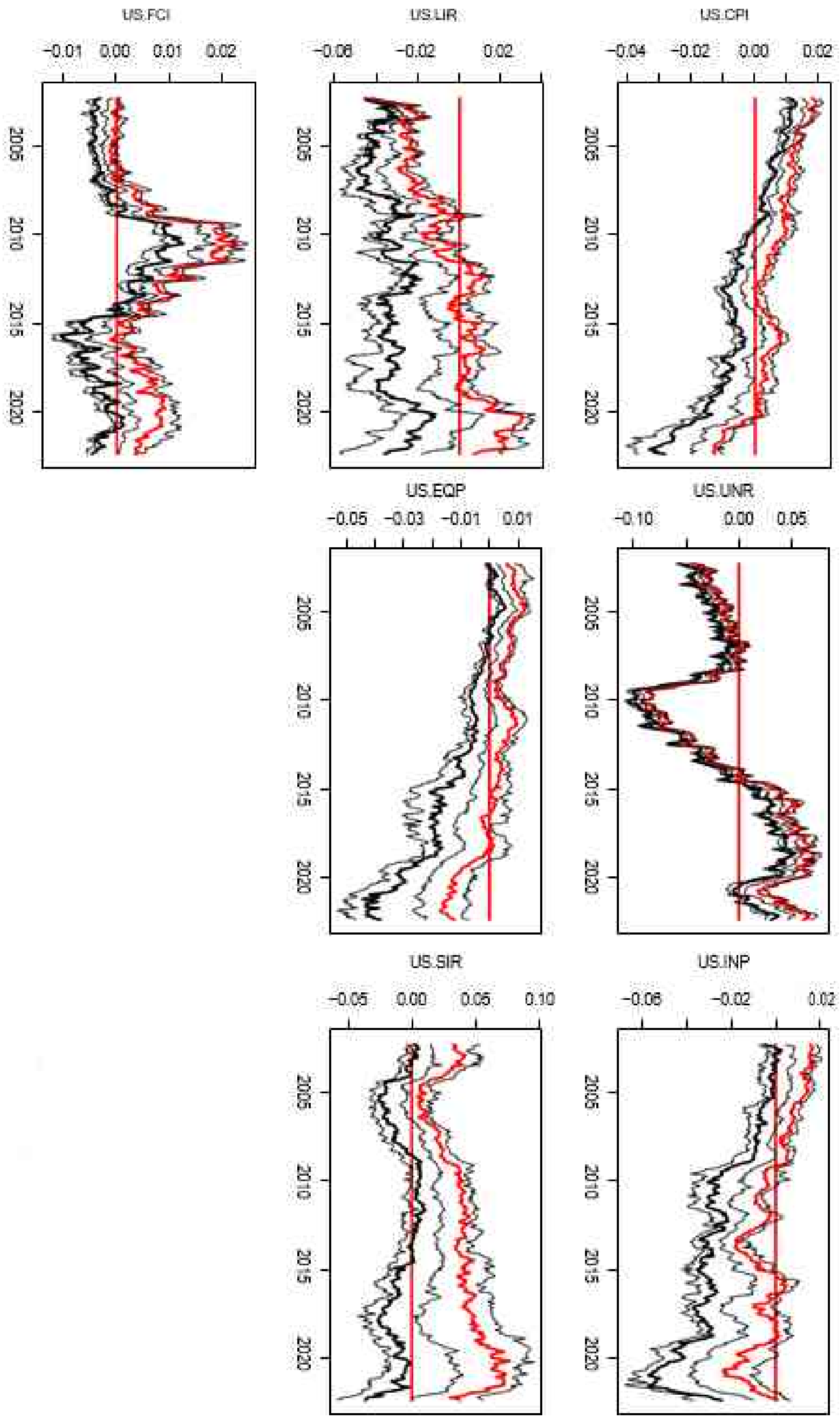

Figure 8. *Cumulative impulse response functions to an international uncertainty shock (Not Include Nelson-Siegel variables).United States*

Note: The thick black line depicts the posterior median, alongside the 16th and 84th posterior percentiles (thin lines). The red line marks zero.

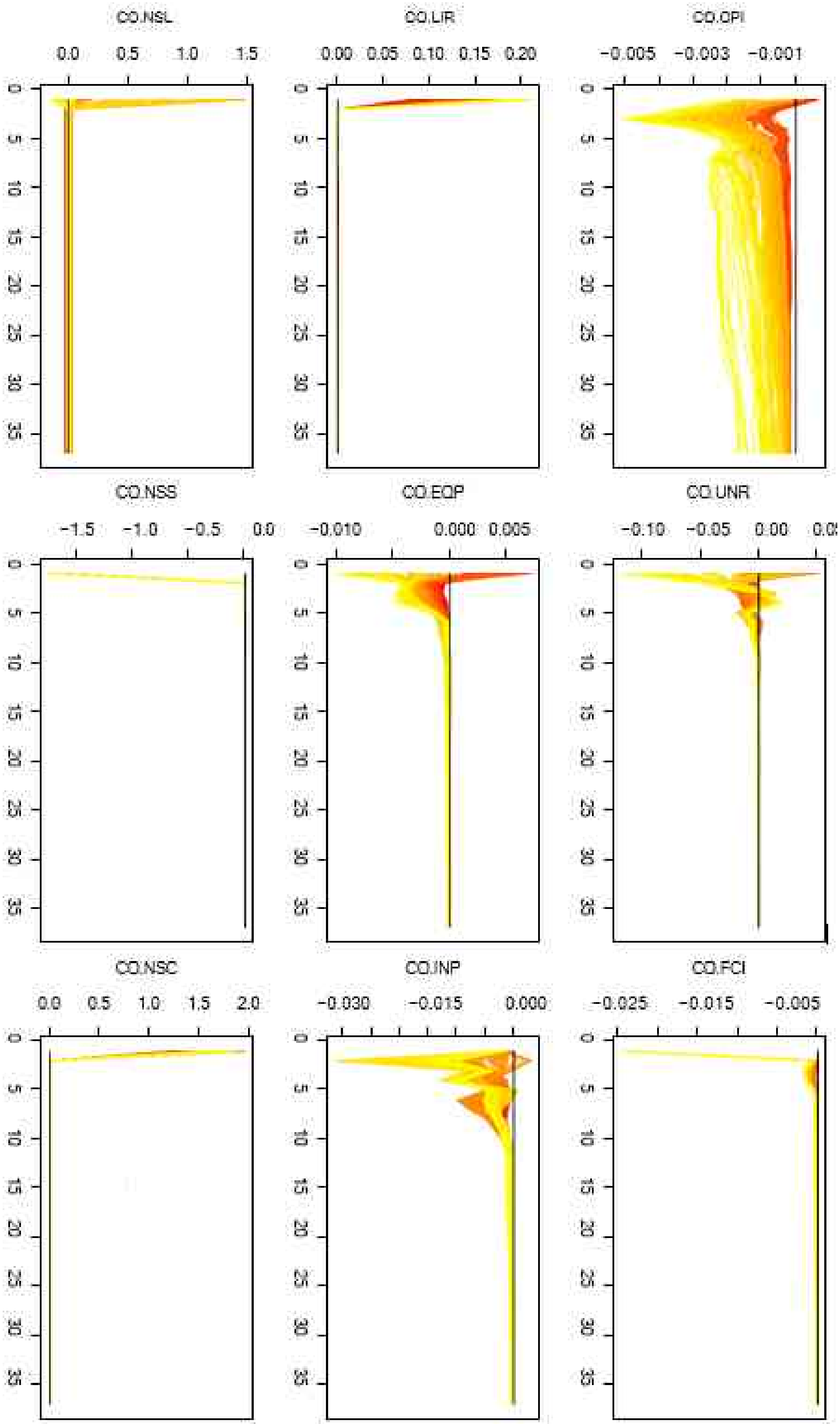

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Columbia*

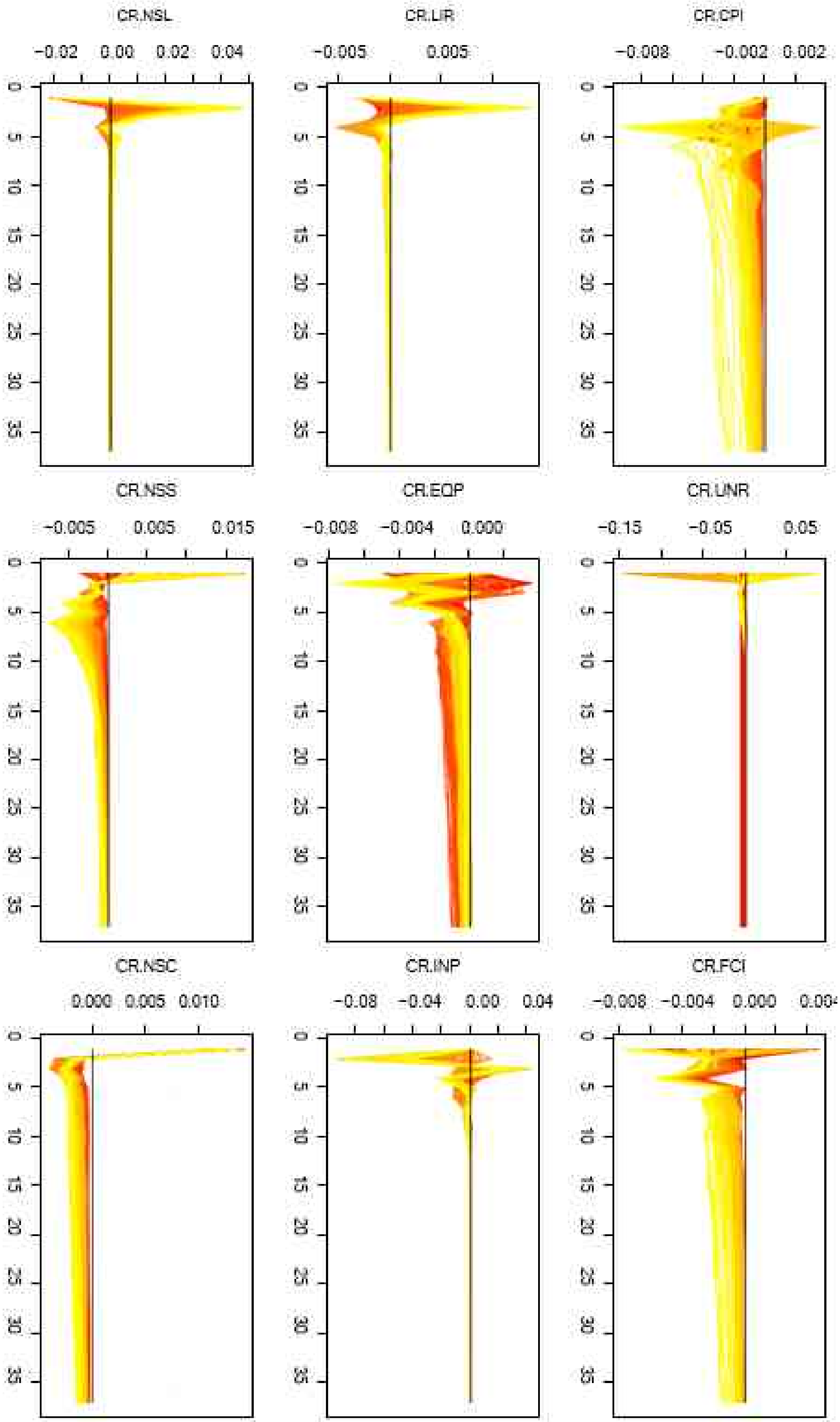

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Croatia*

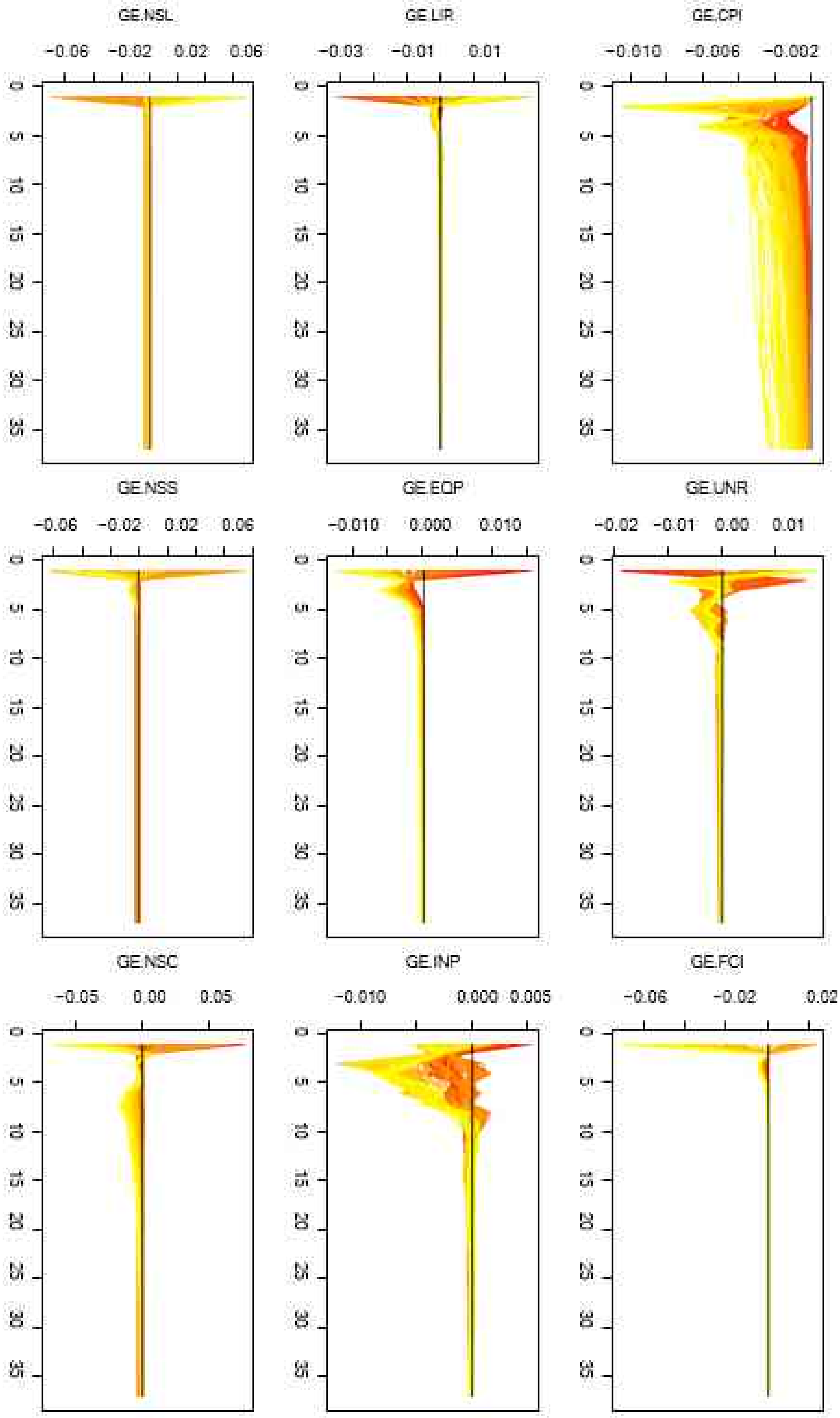

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). German*

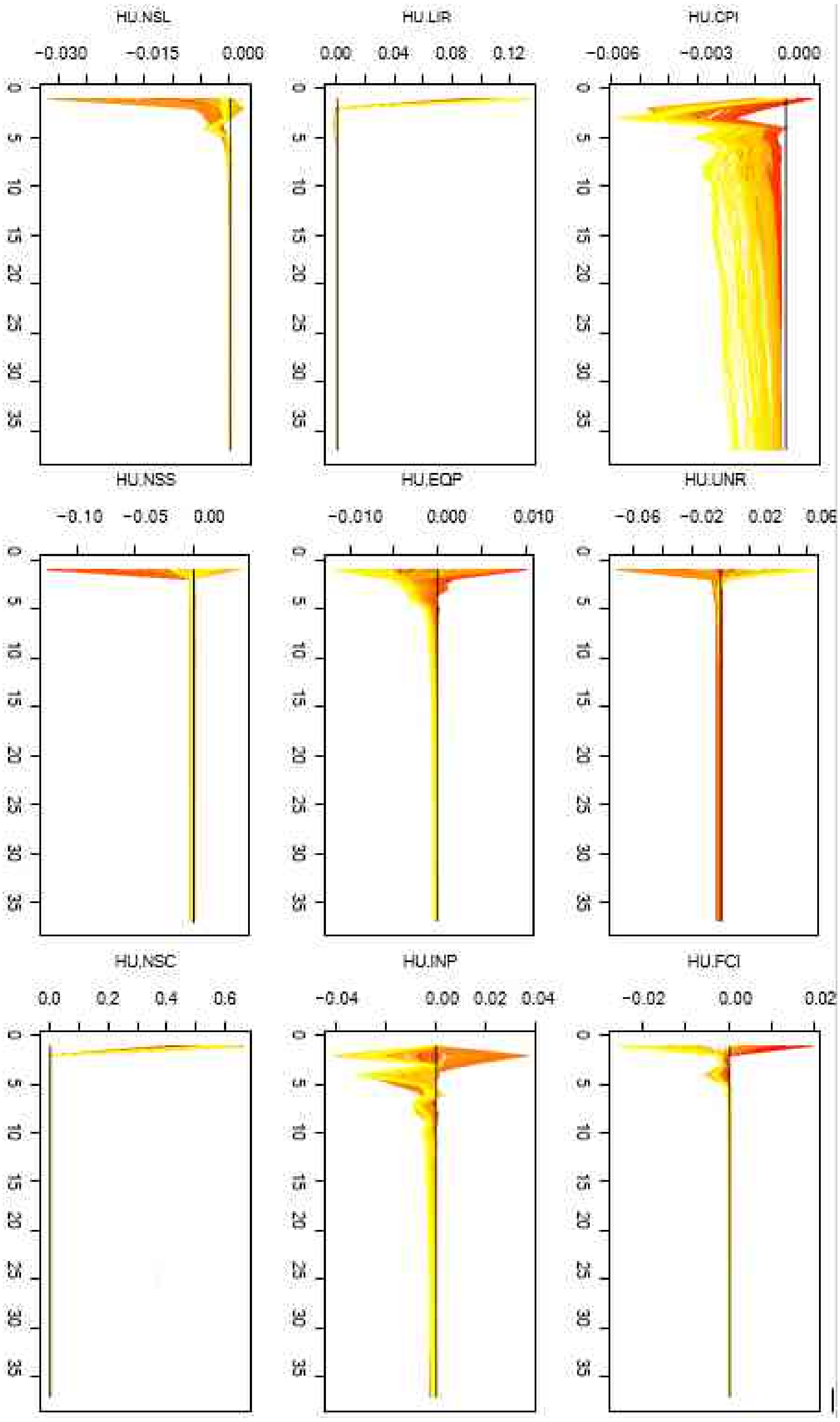

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Hungary*

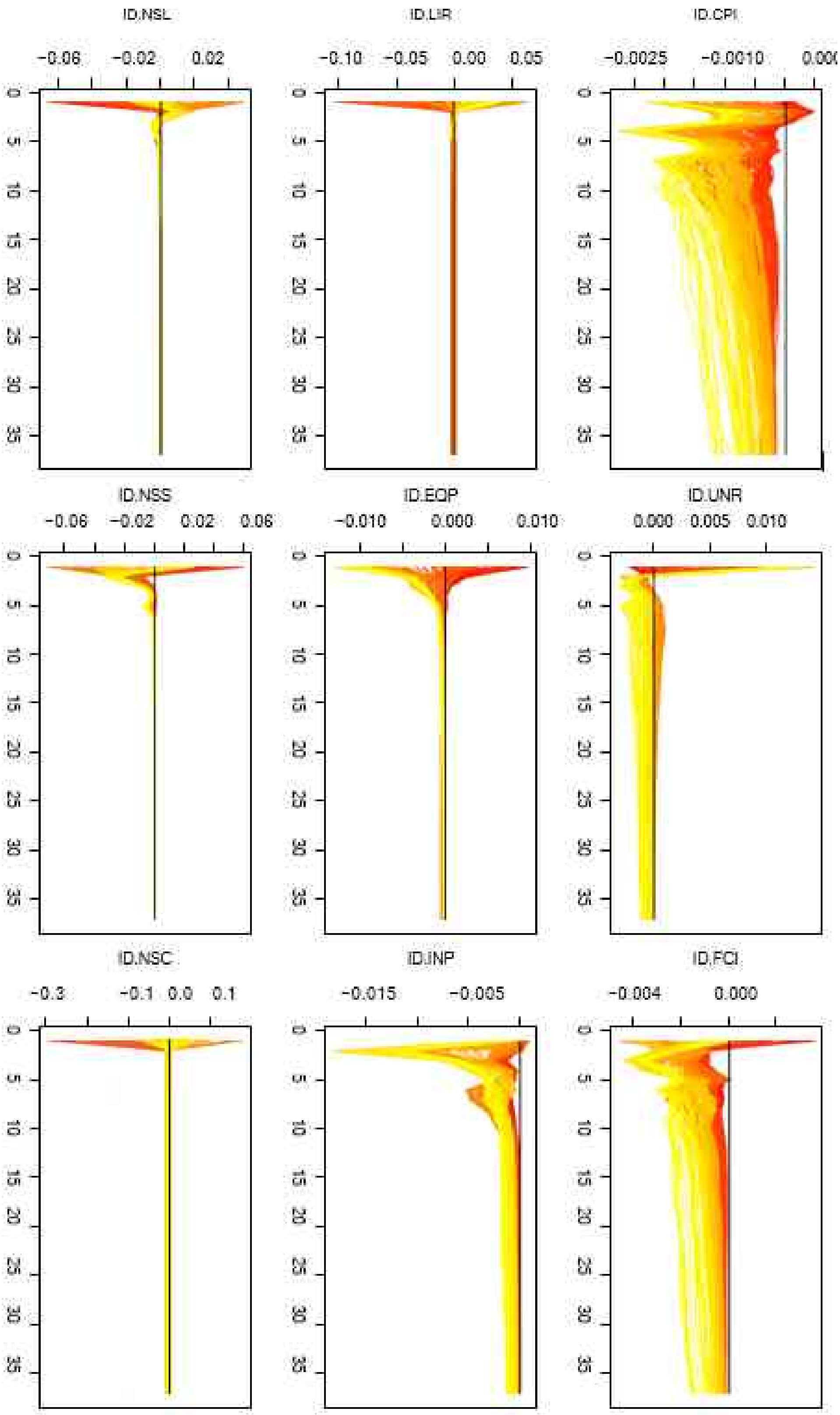

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Indonesia*

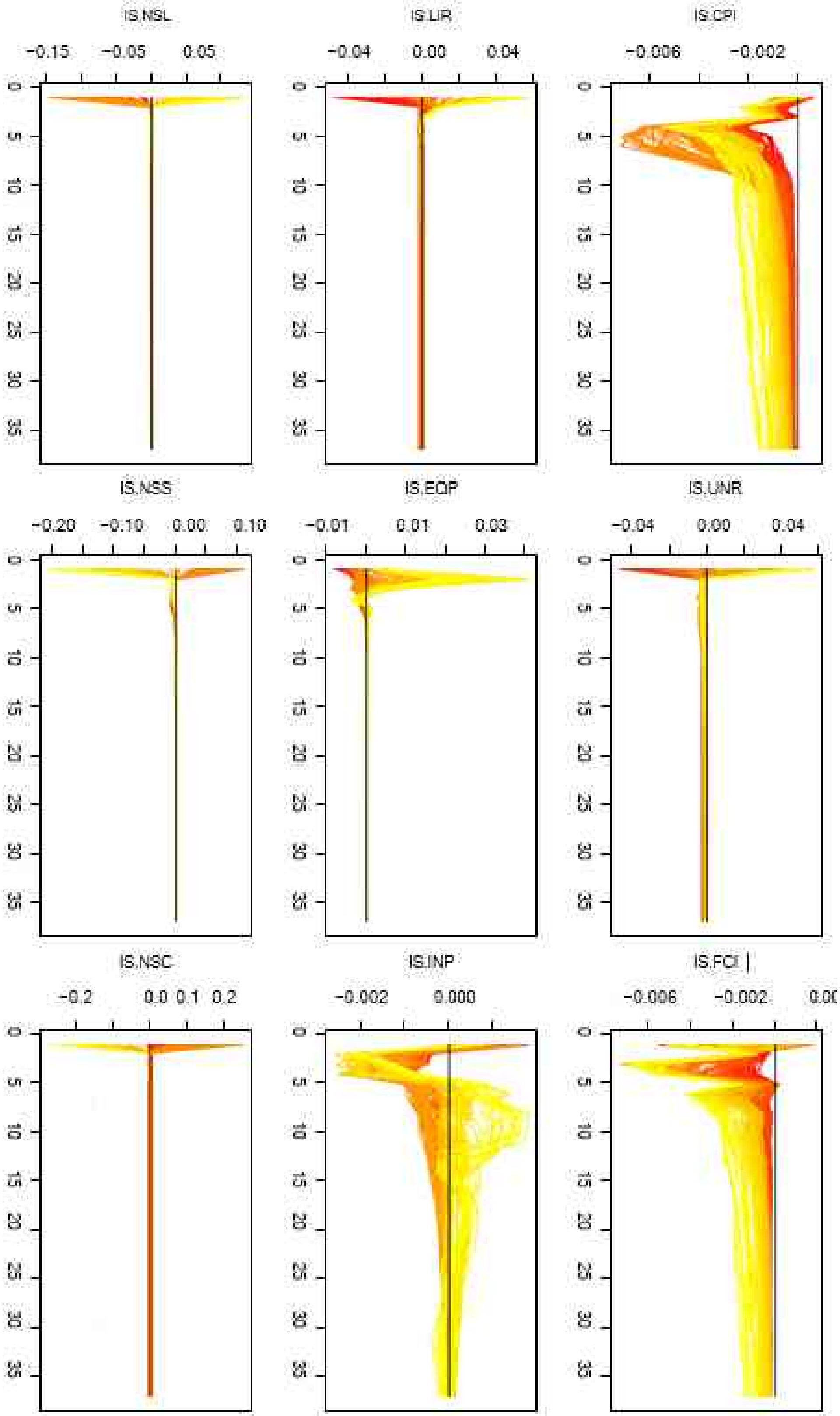

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Israel*

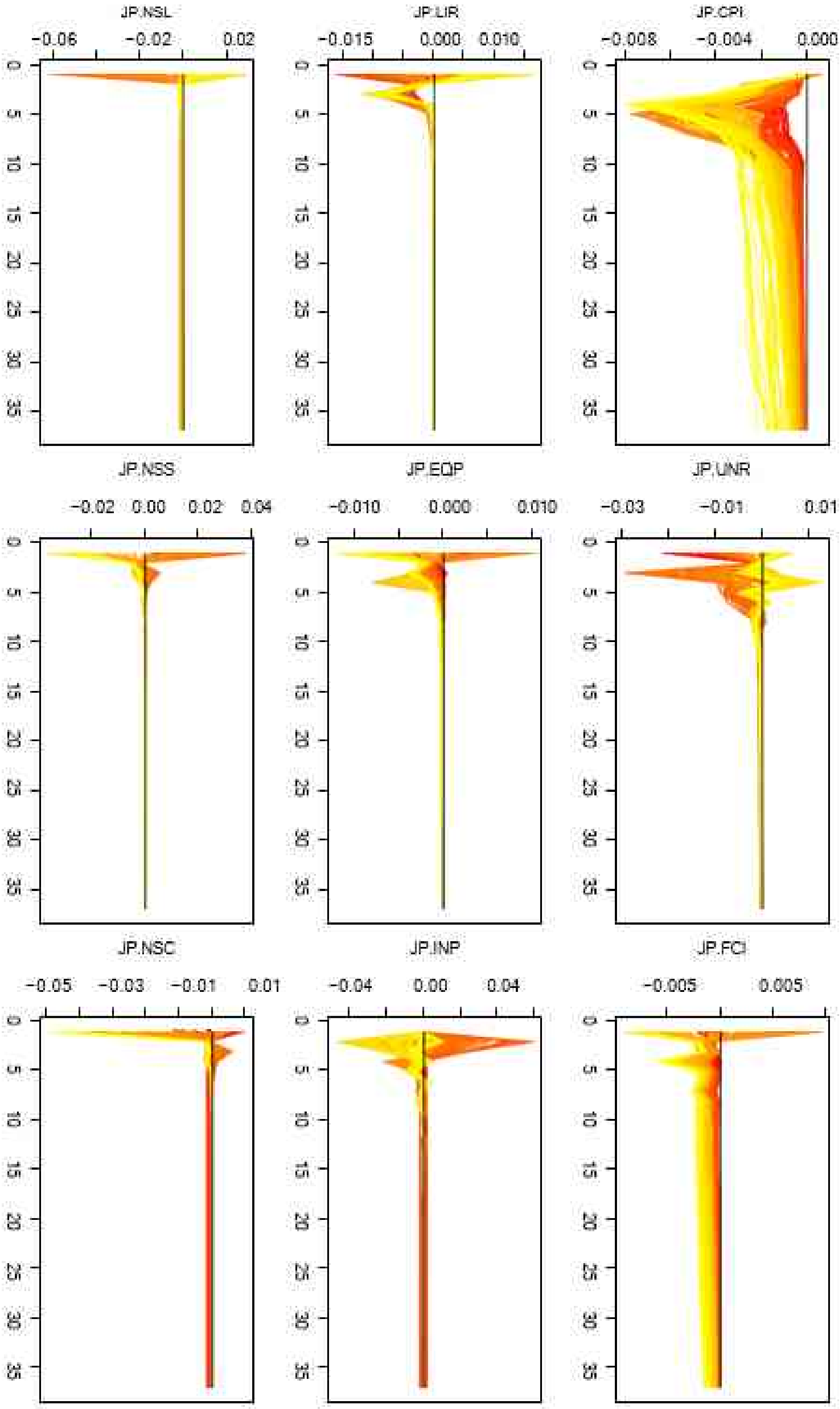

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Japan*

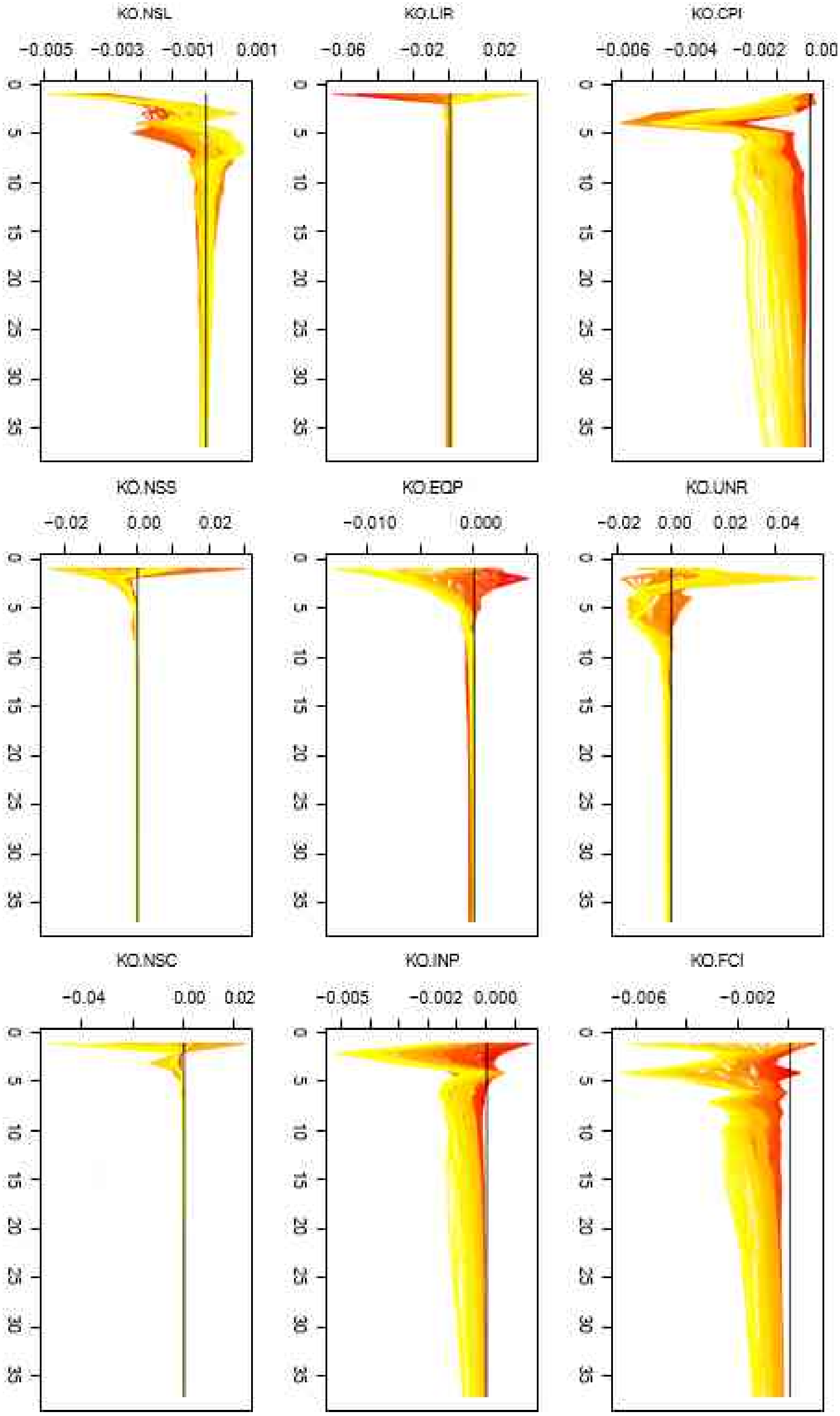

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Korea*

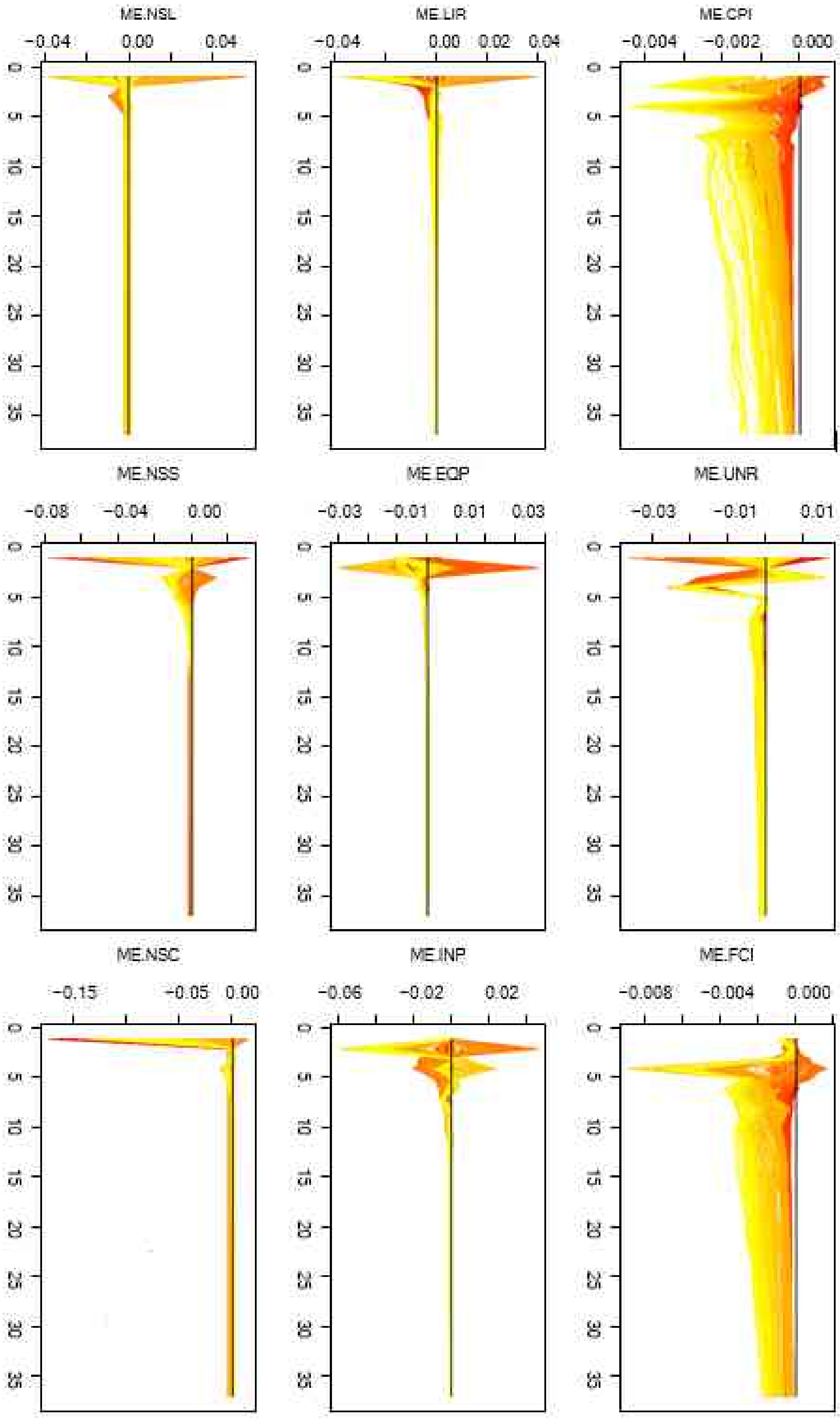

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Mexico*

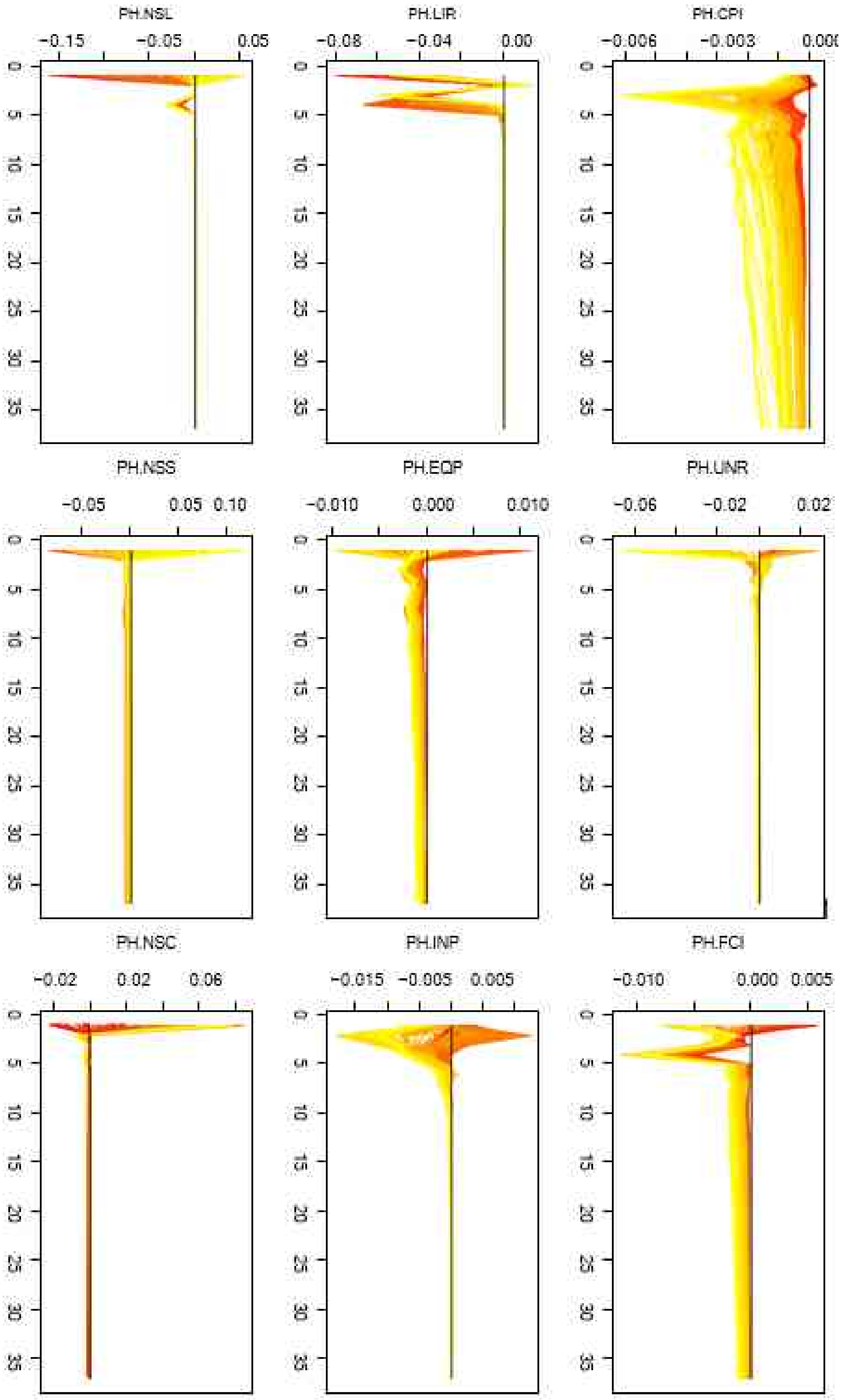

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Philippines*

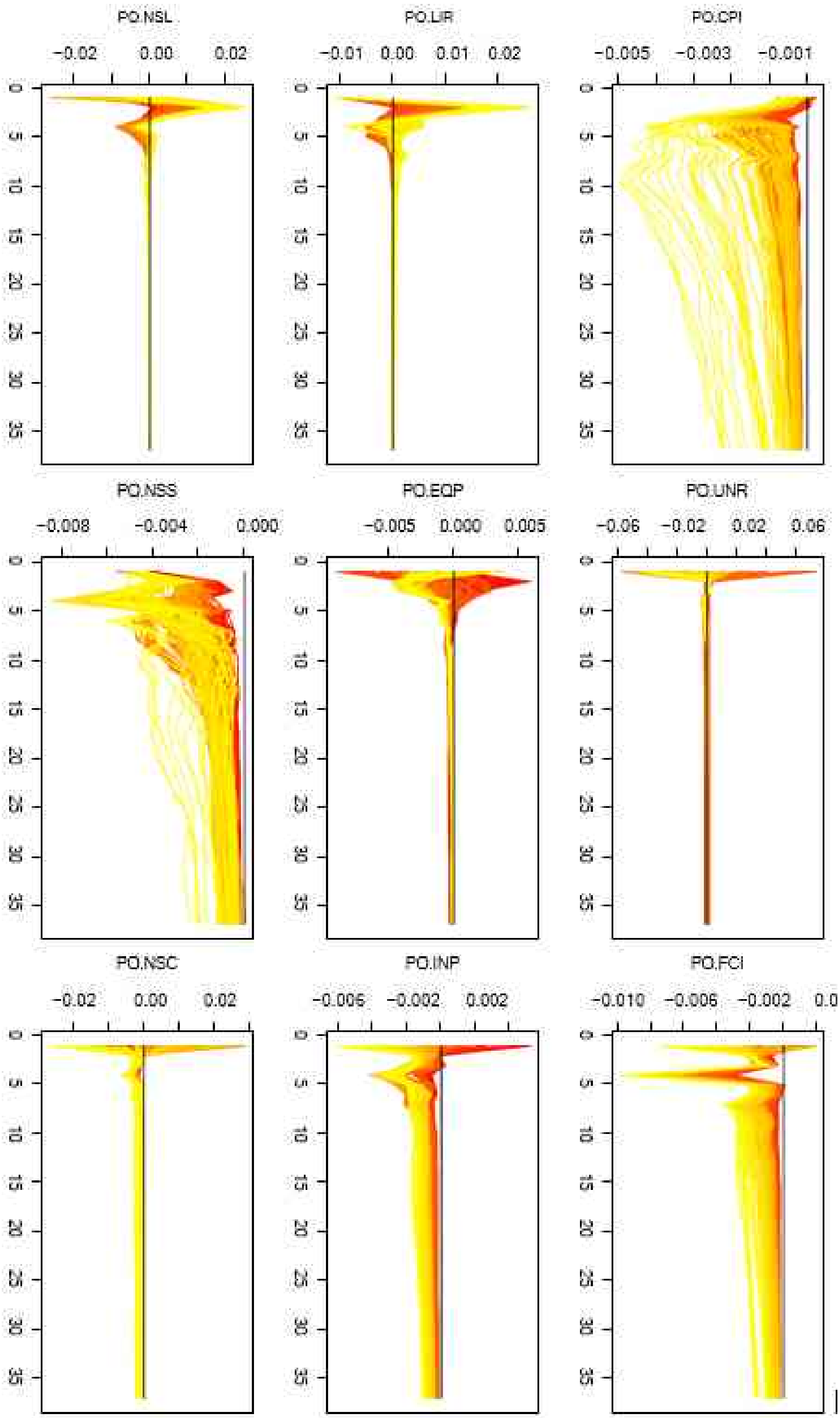

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Poland*

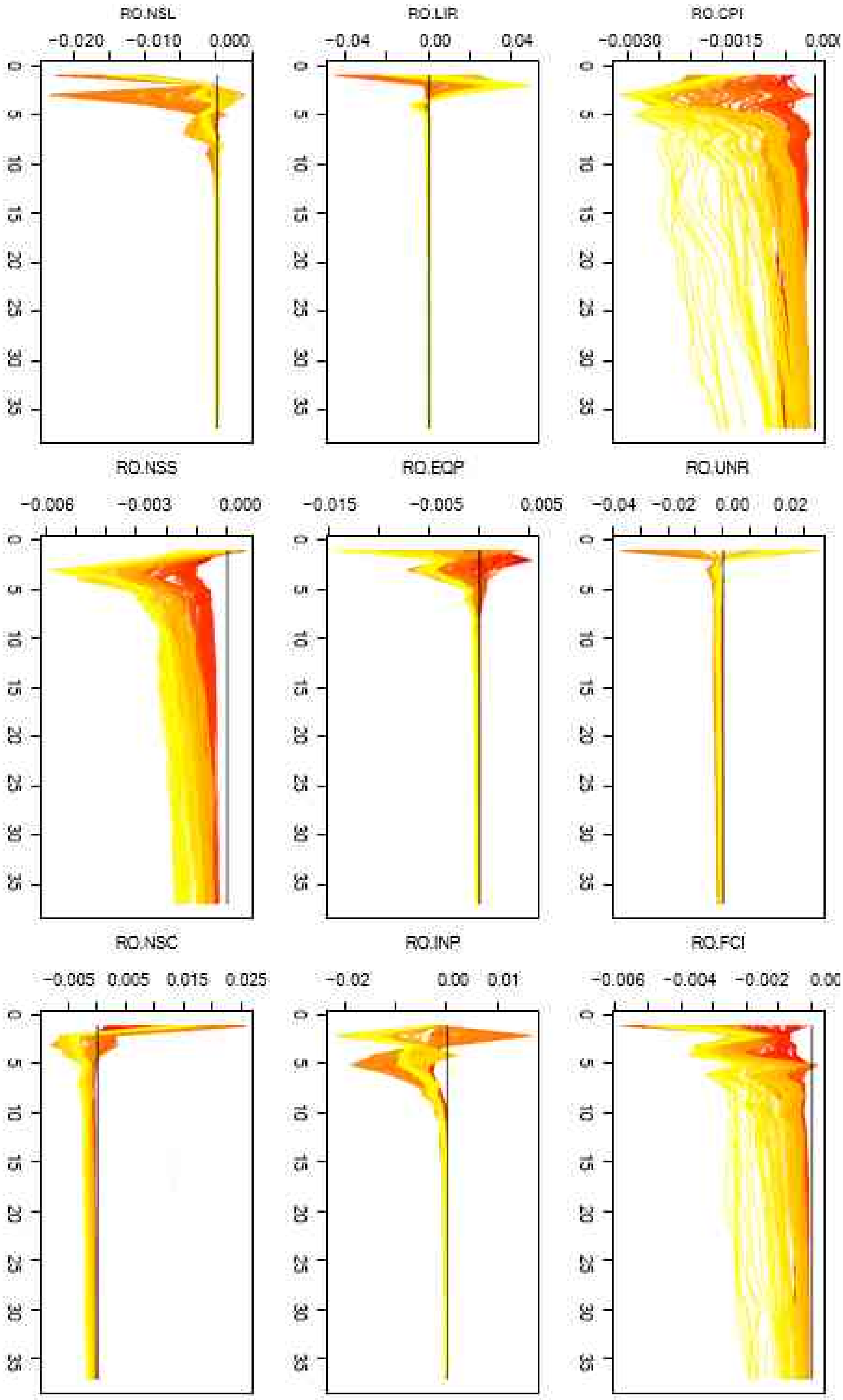

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Romania*

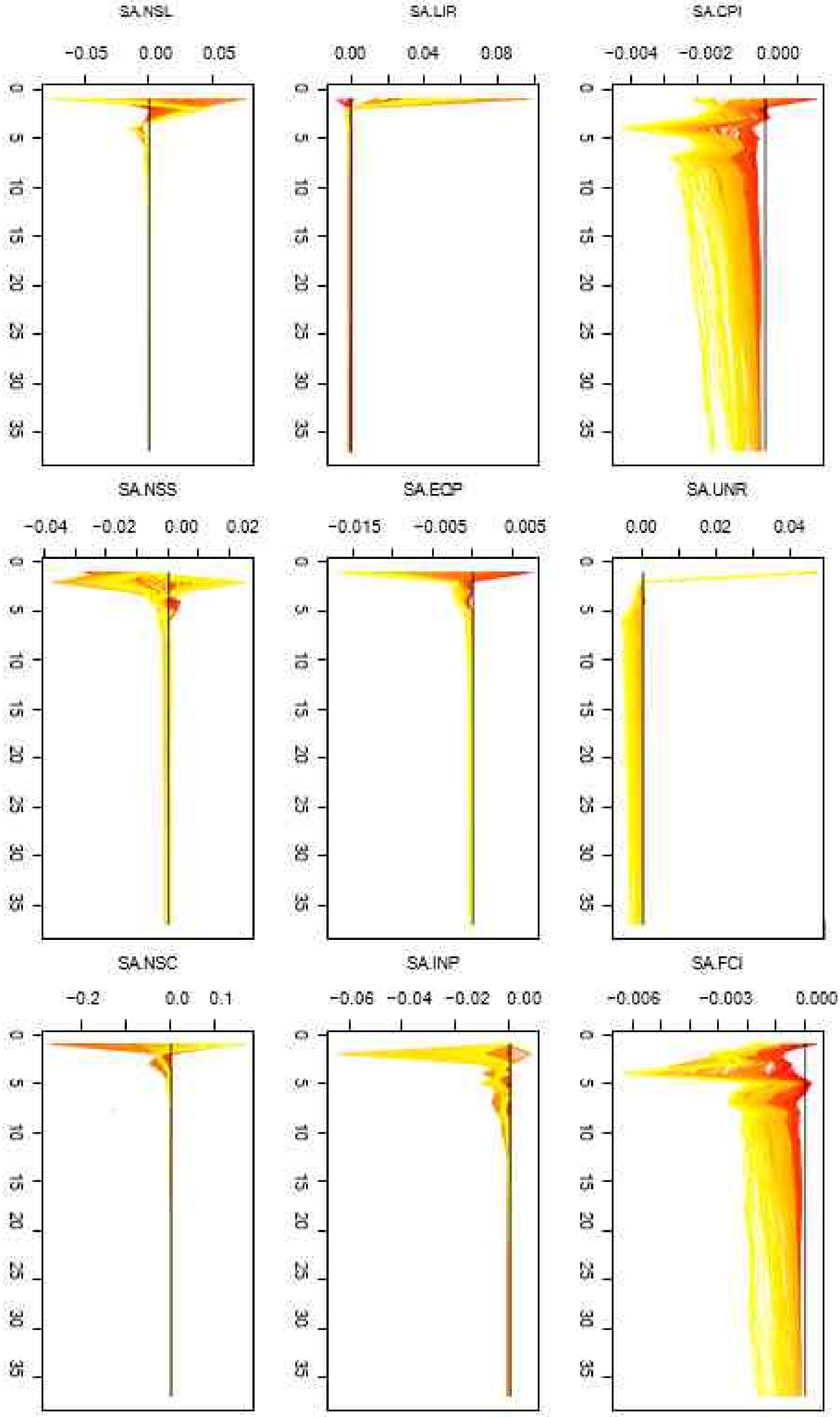

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). South Africa*

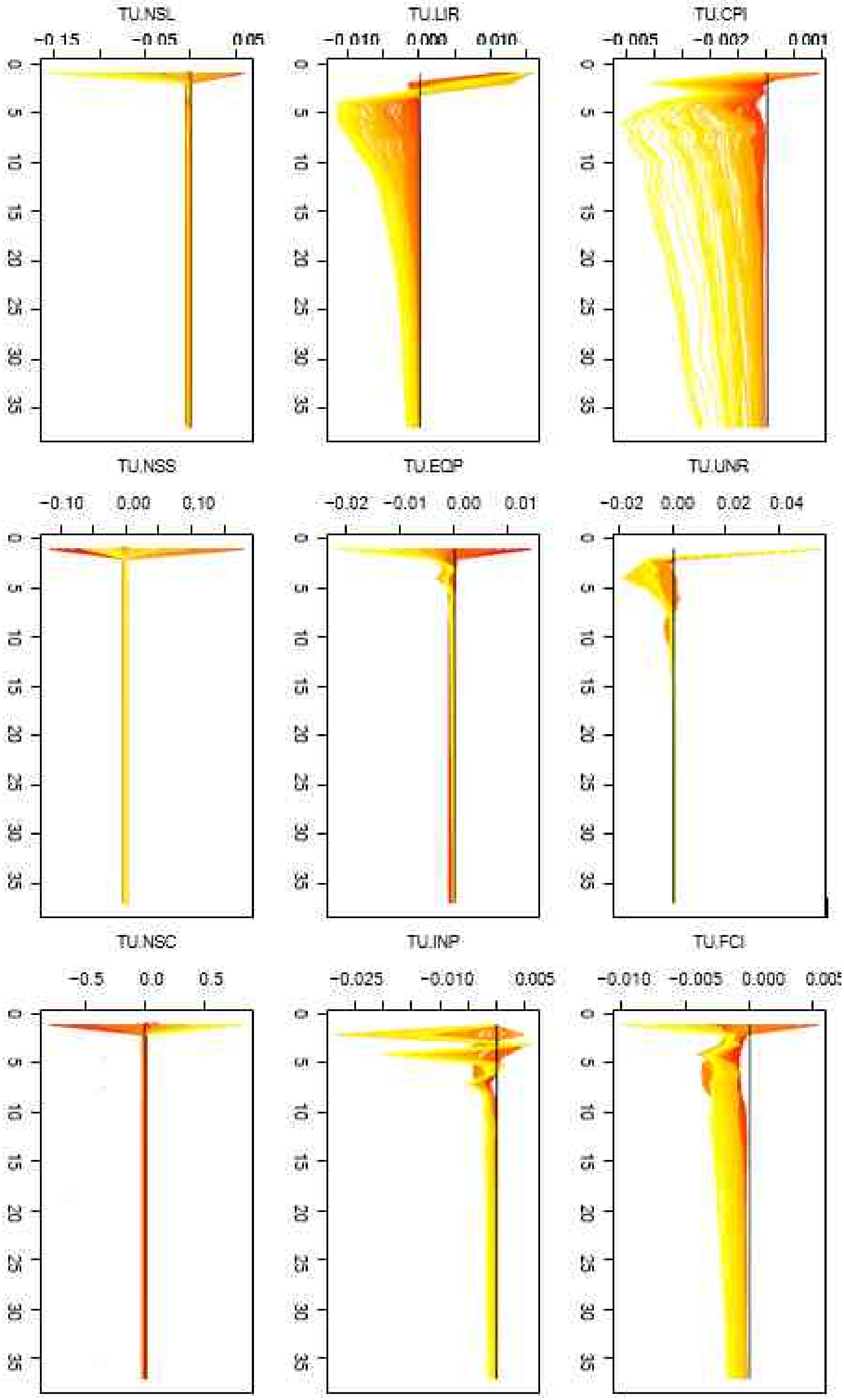

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). Turkey*

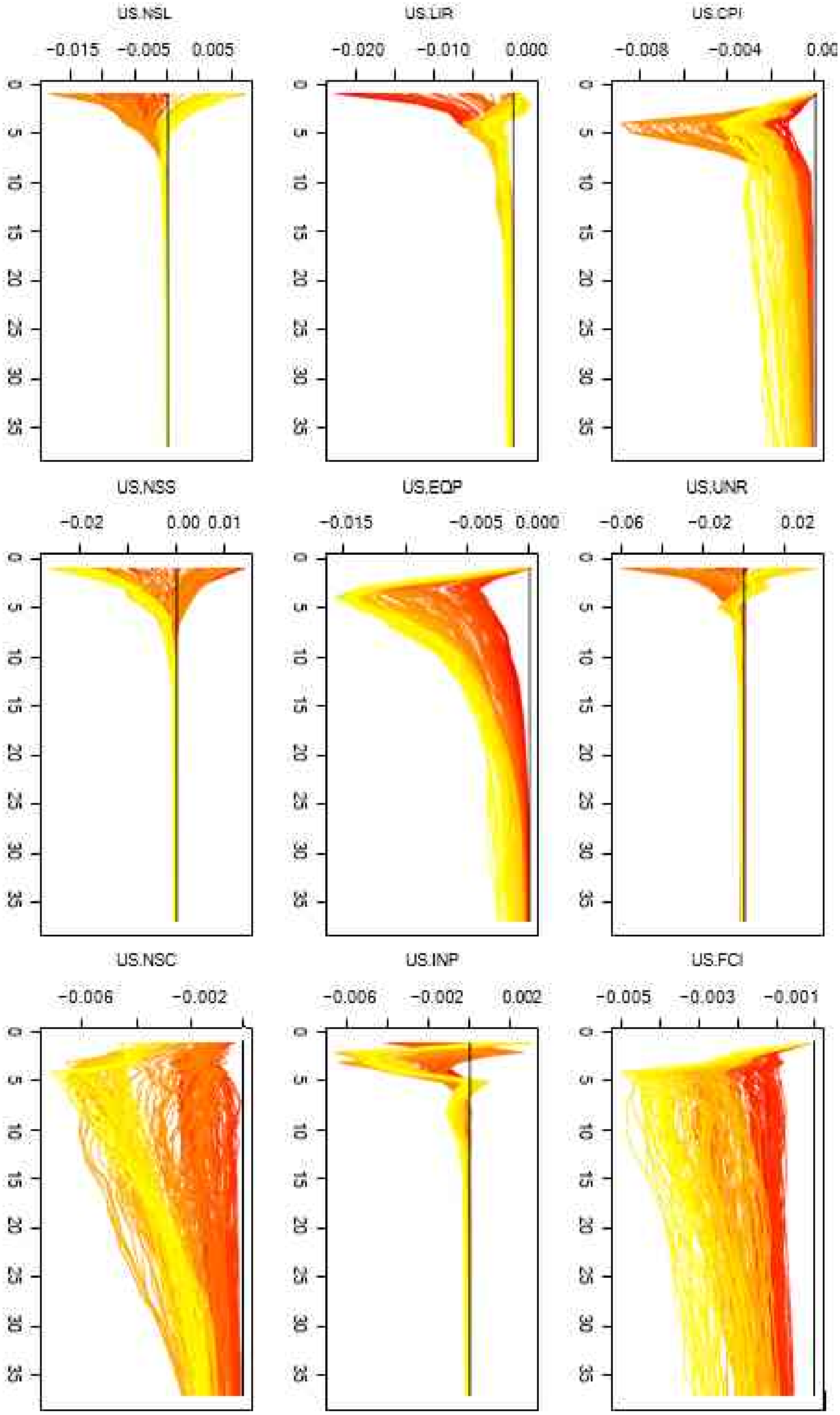

Figure 9. *Impulse responses to an international uncertainty shock (Include Nelson-Siegel variables). United States*

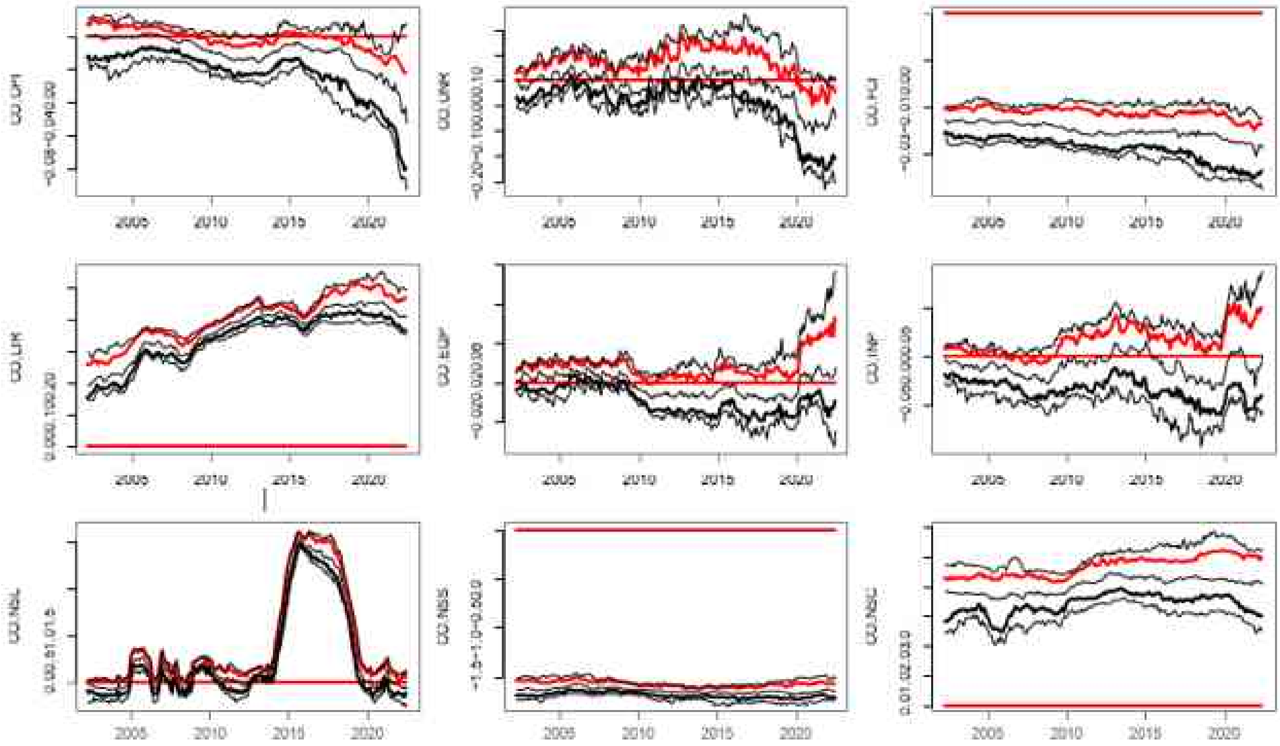

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Columbia*

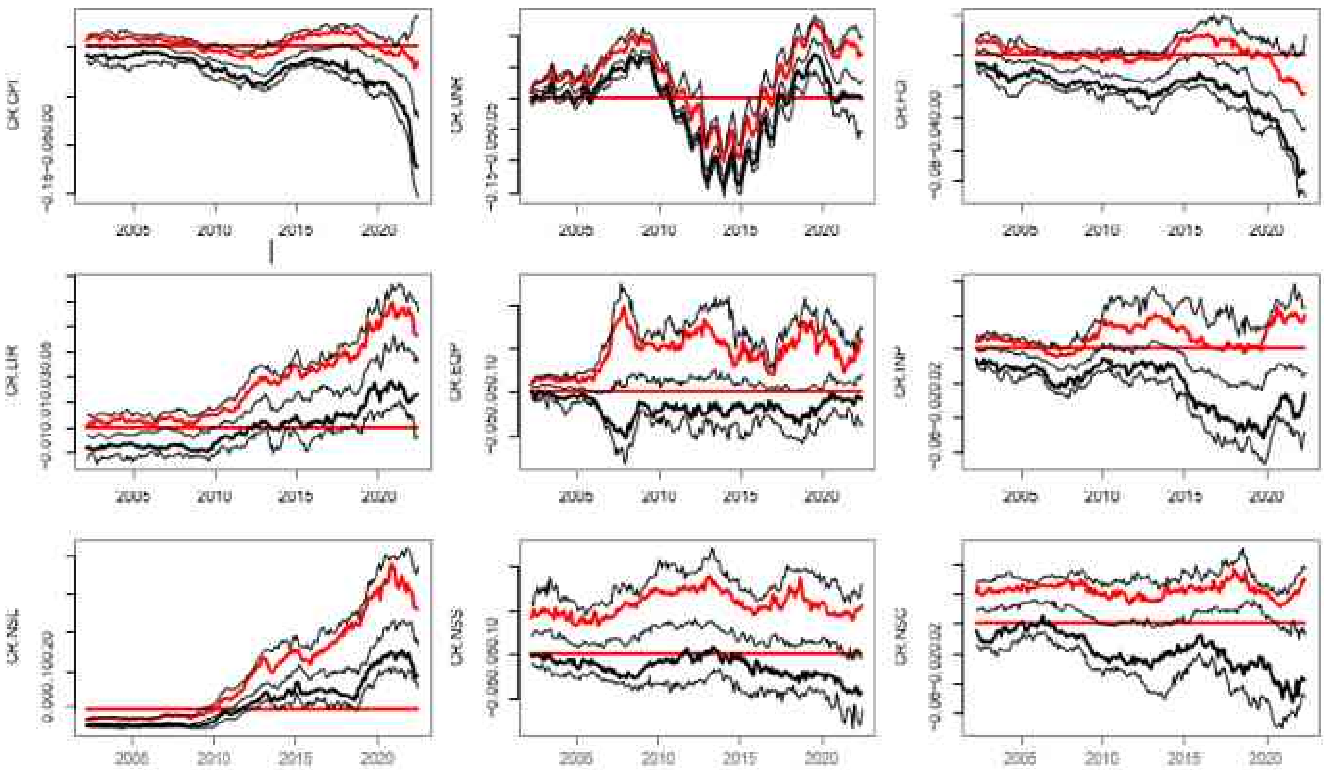

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Croatia*

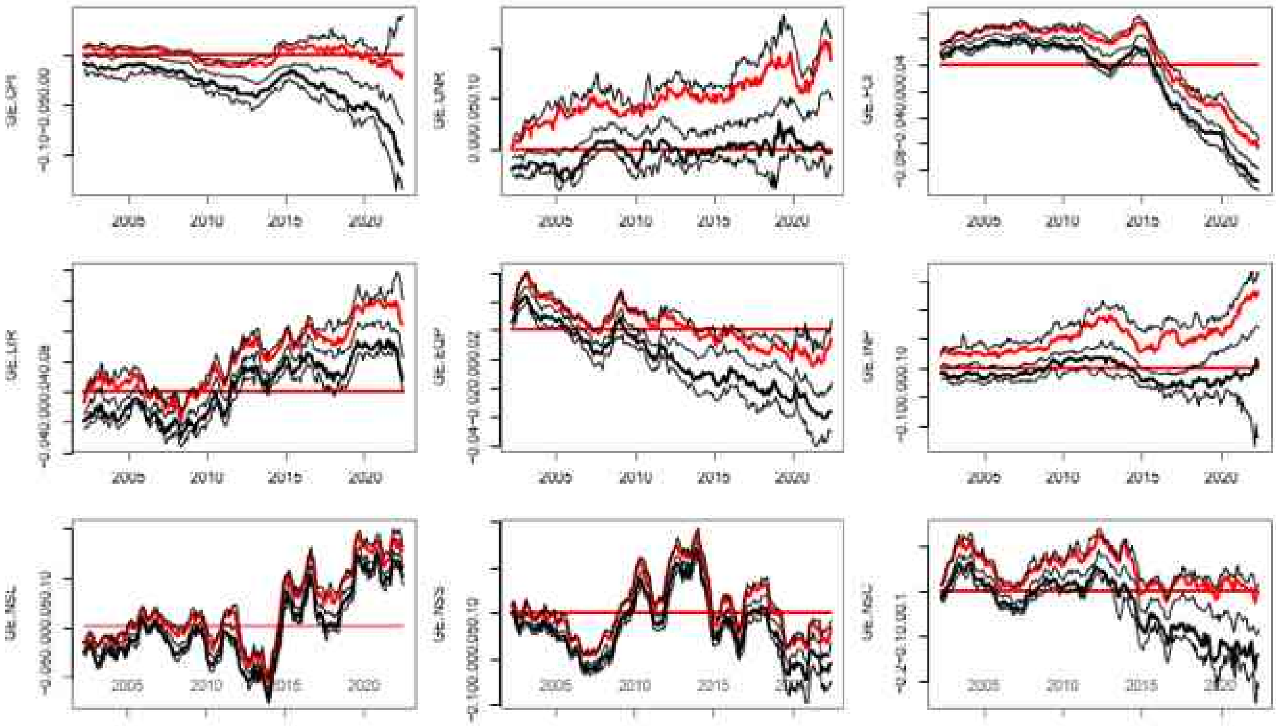

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). German*

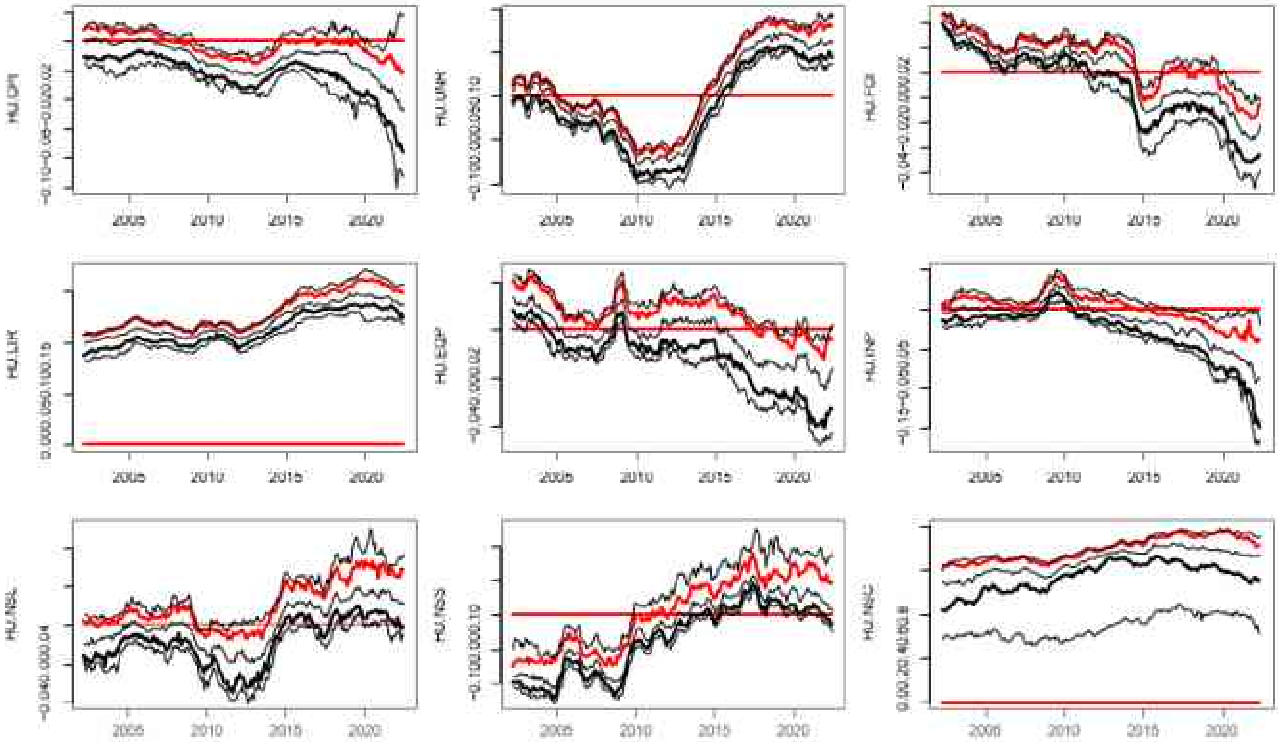

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Hungary*

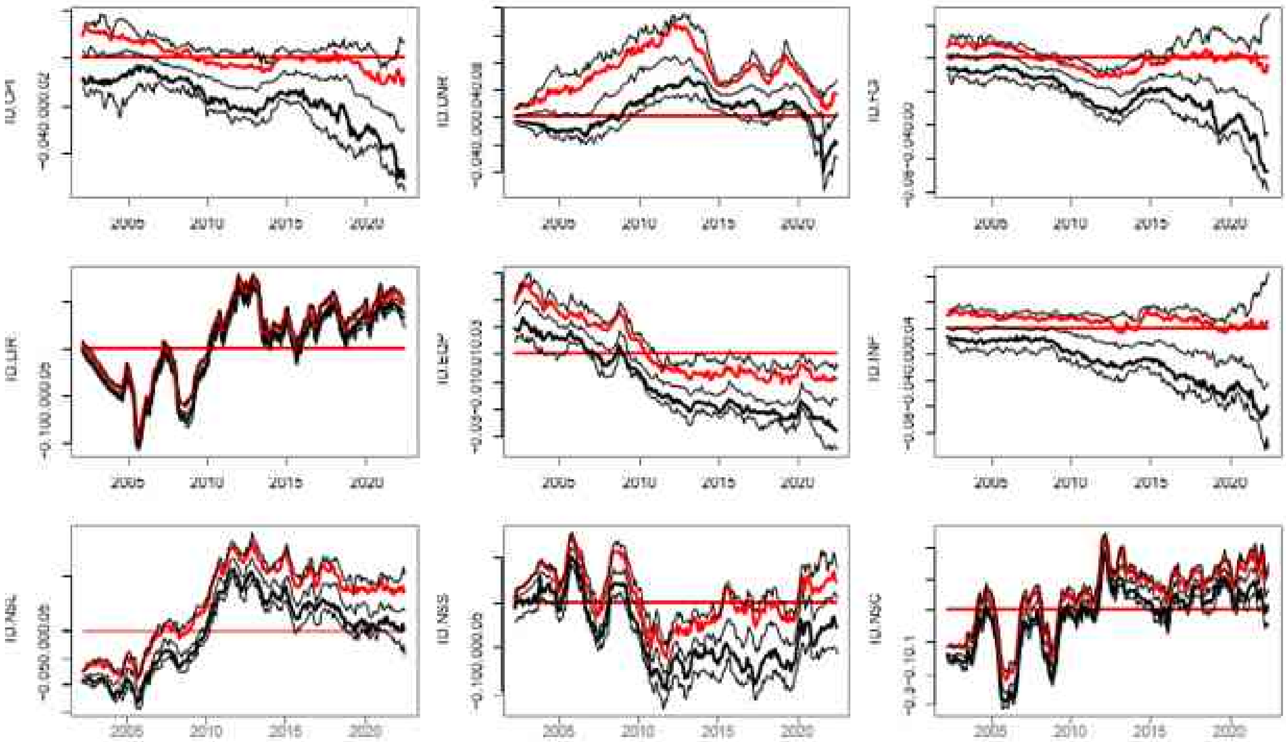

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Indonesia*

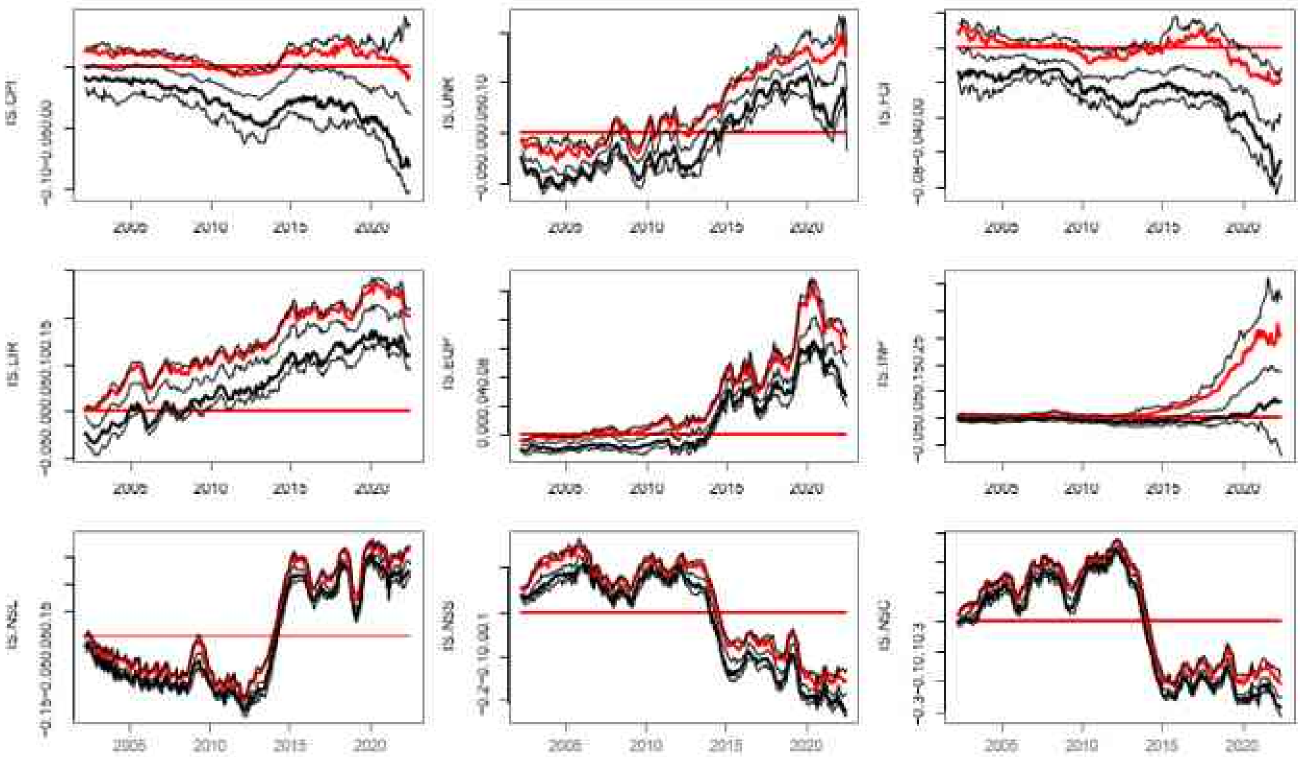

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables).Israel*

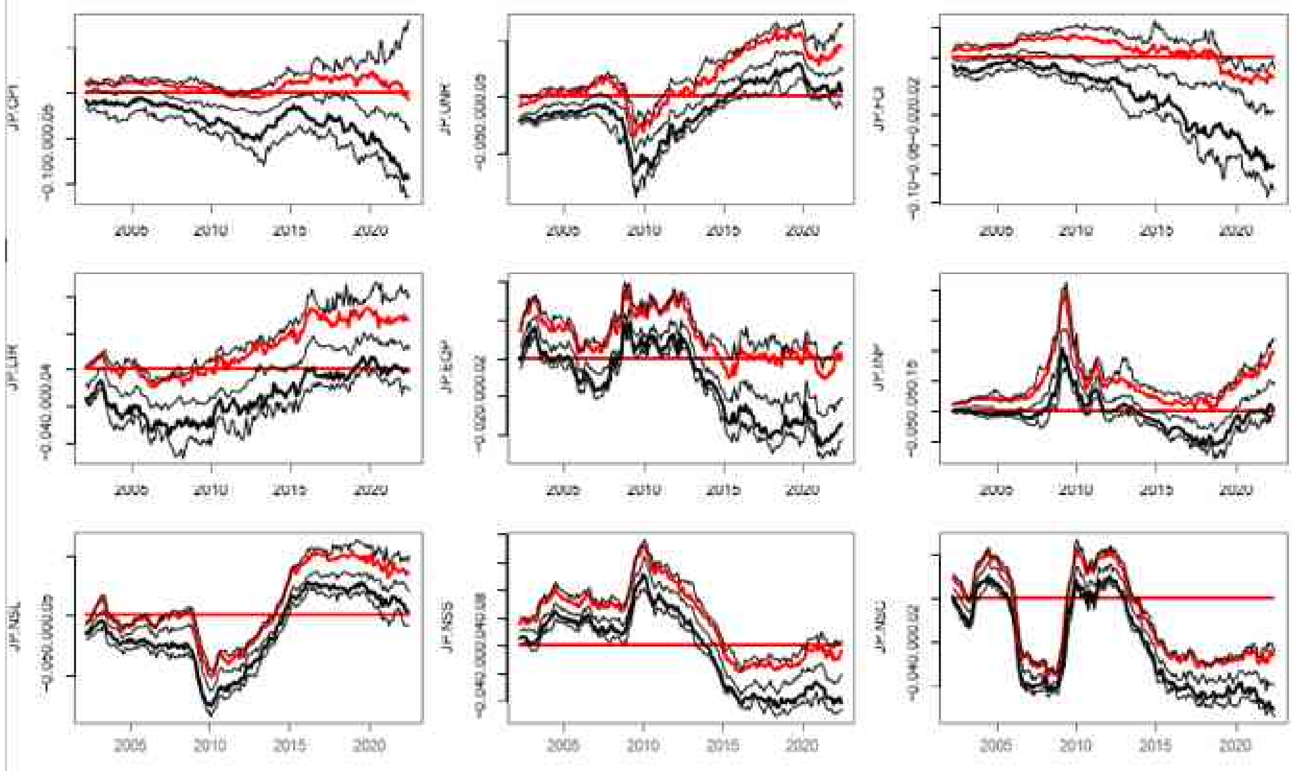

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Japan*

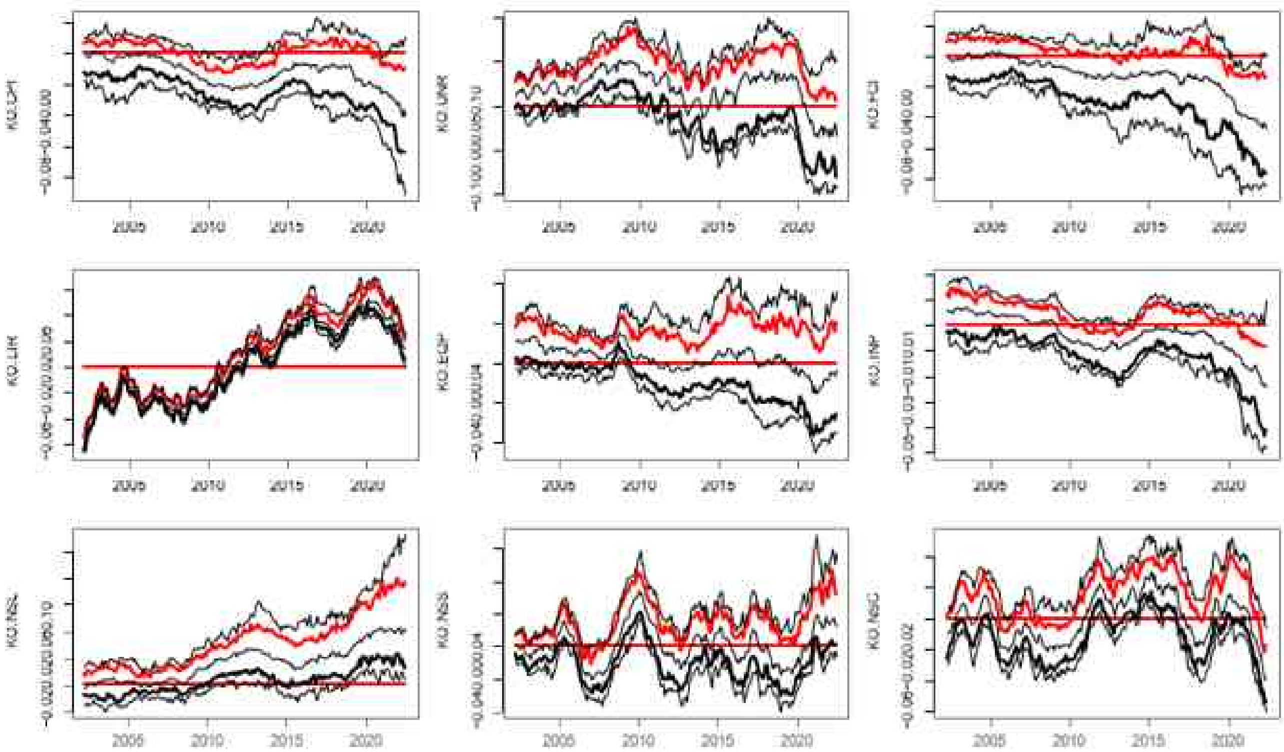

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Korea*

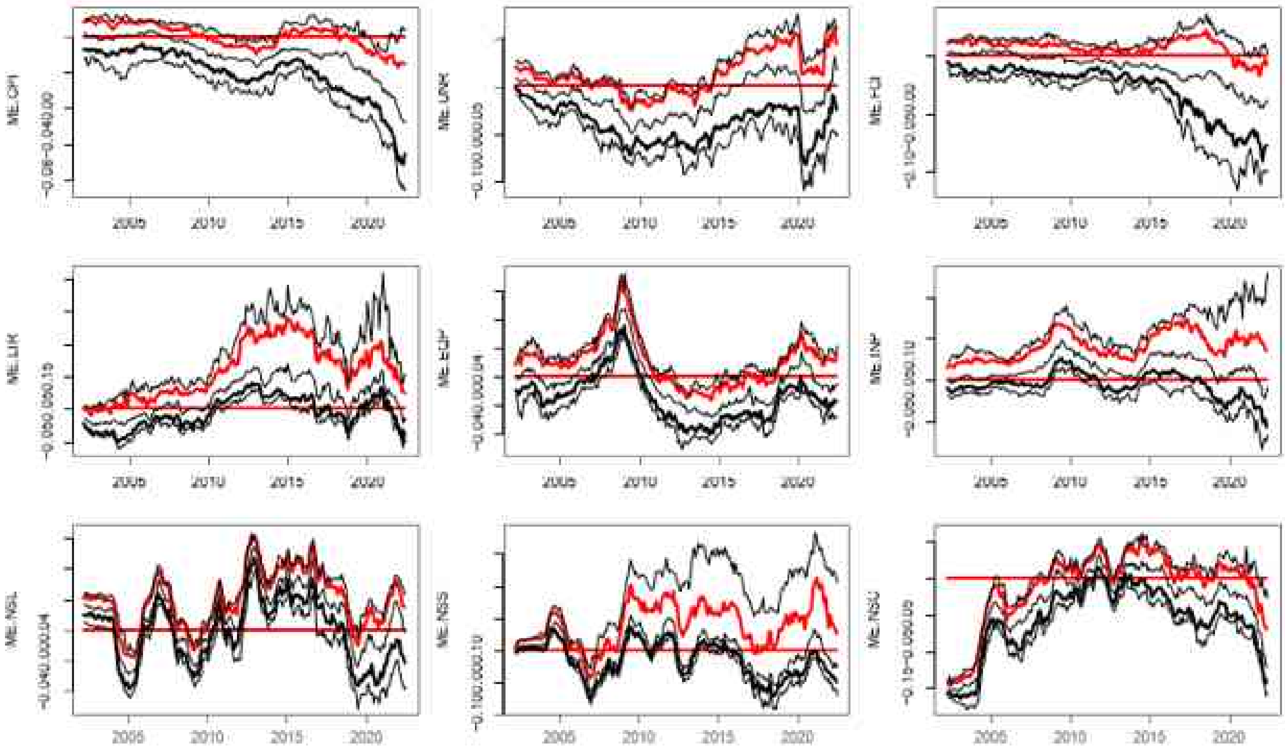

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Mexico*

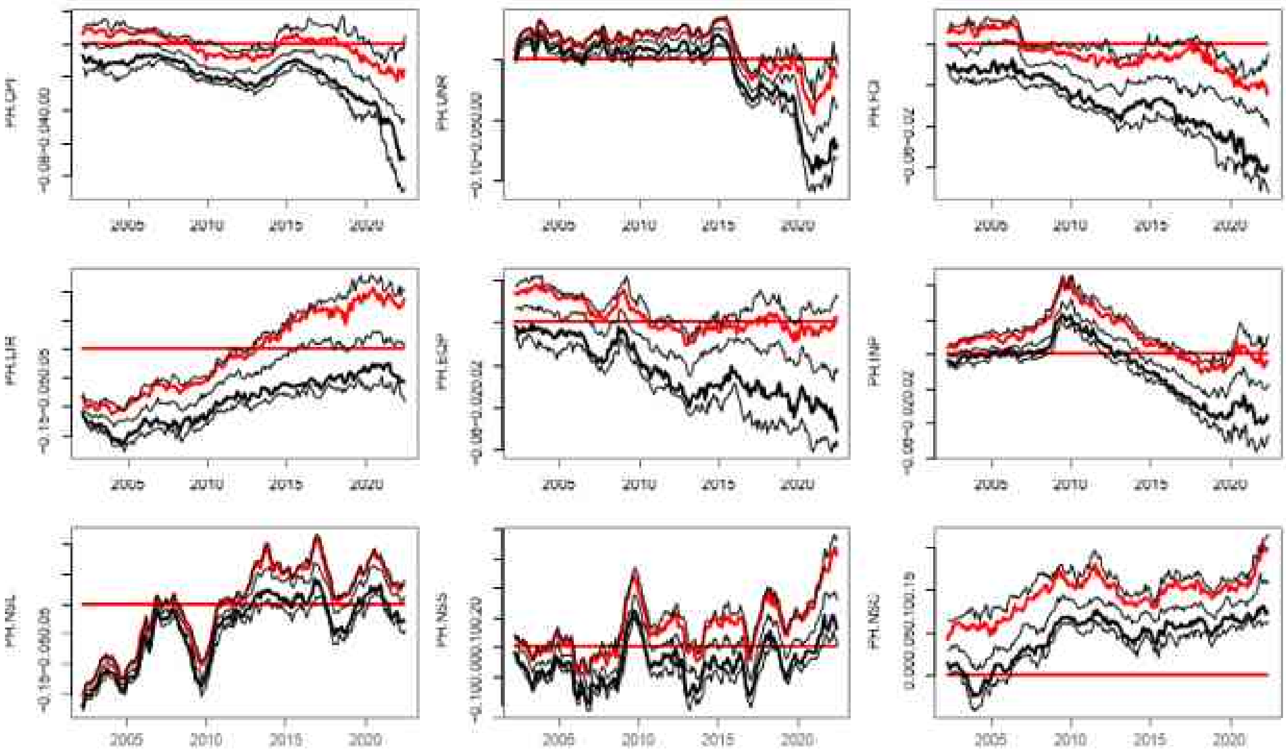

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Philippines*

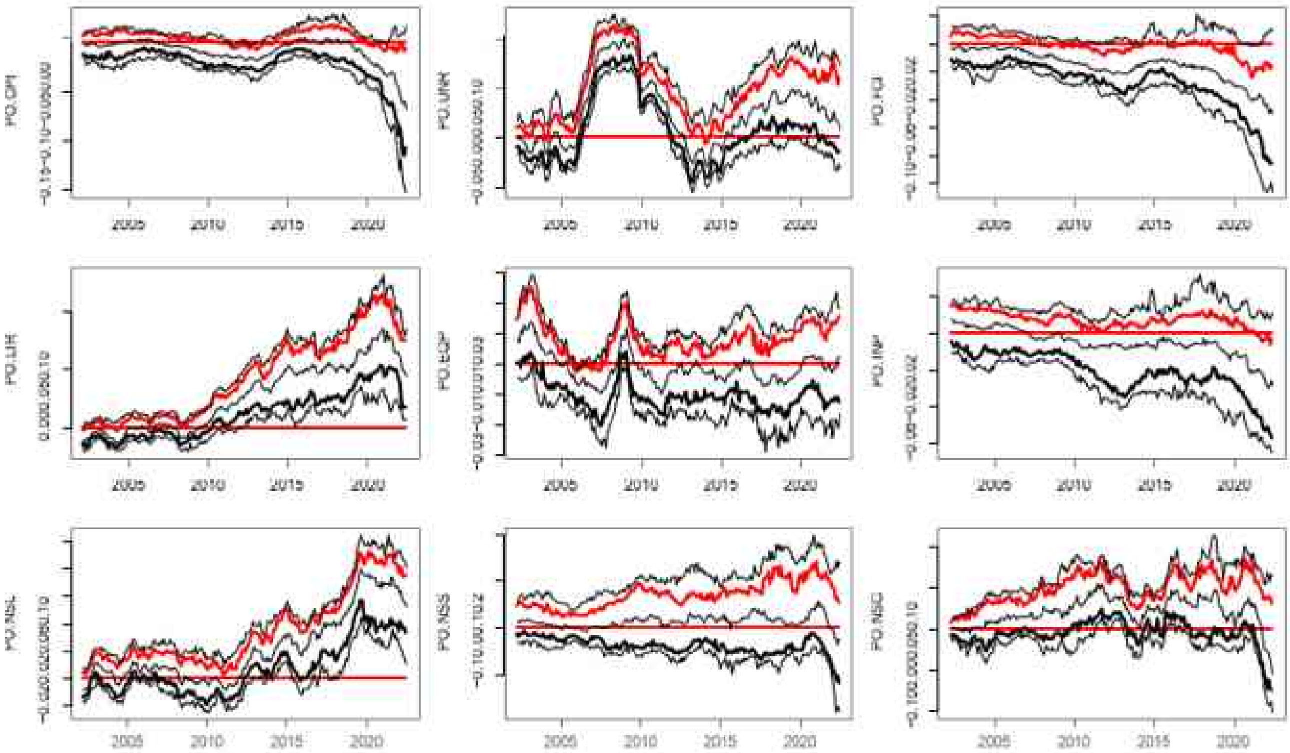

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Poland*

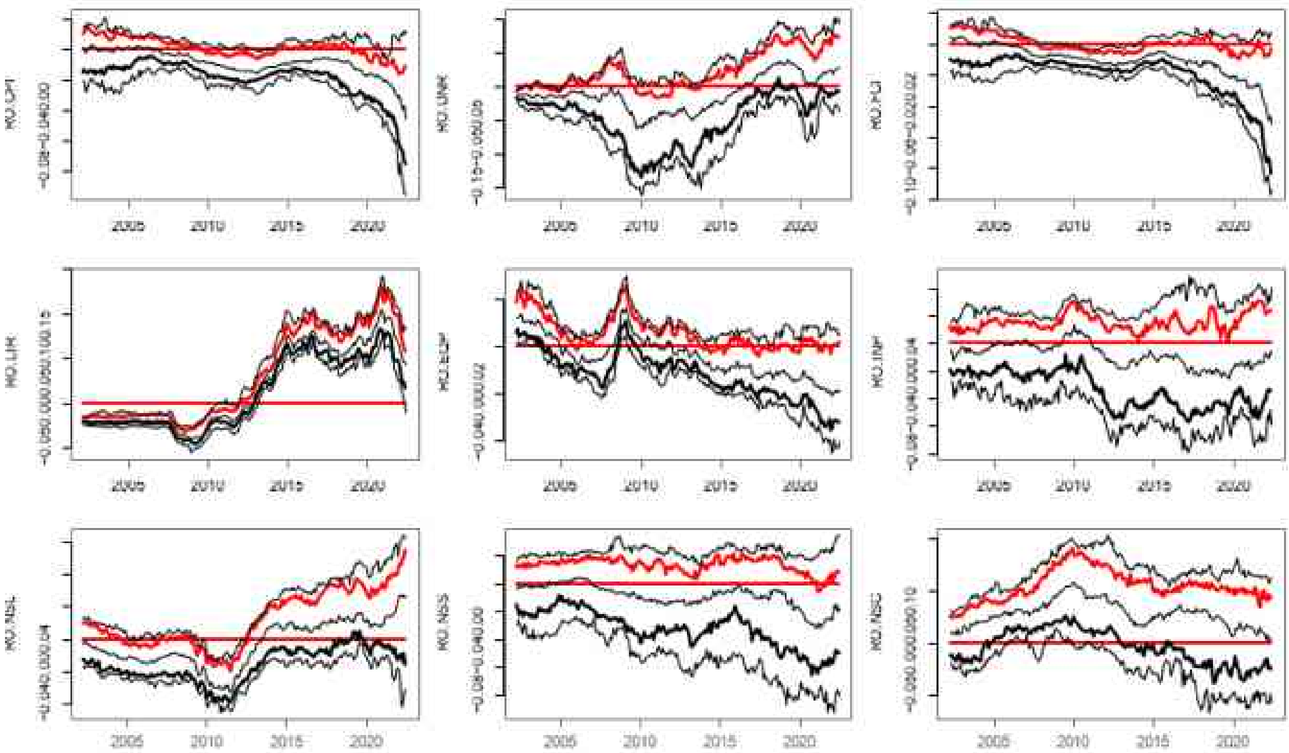

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Romania*

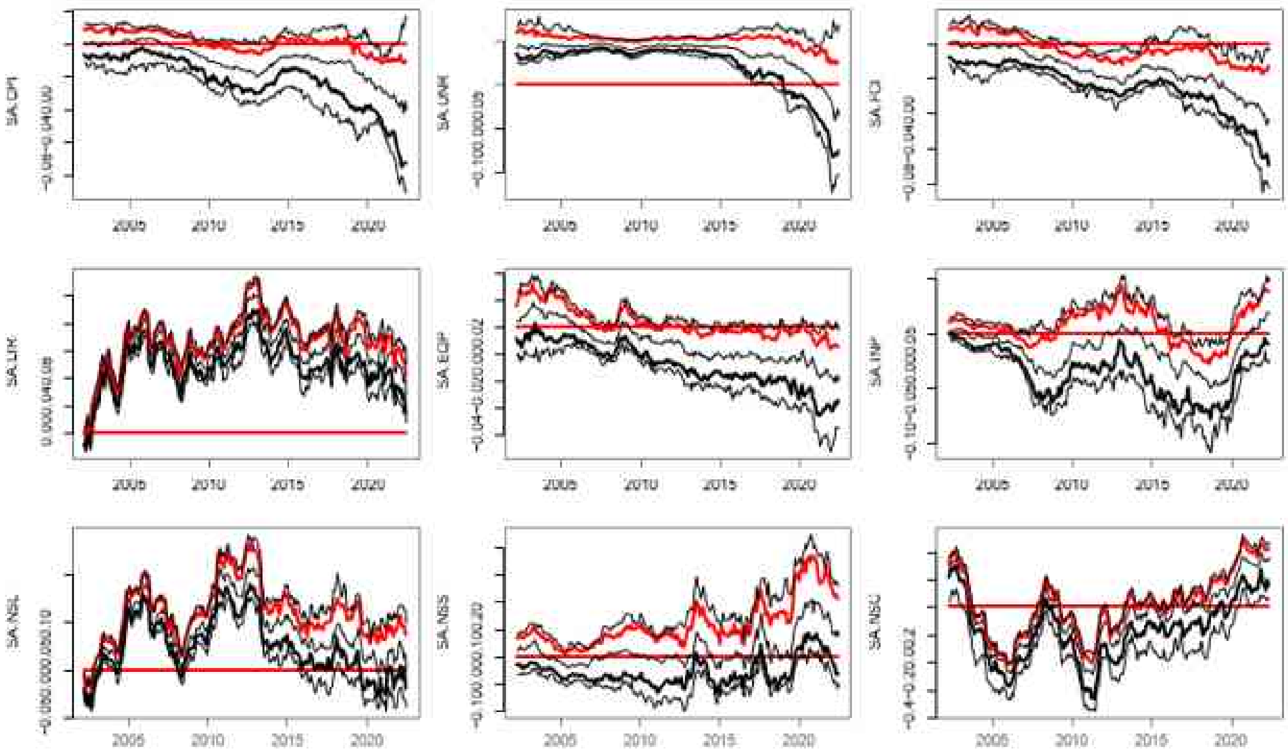

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables).South Africa*

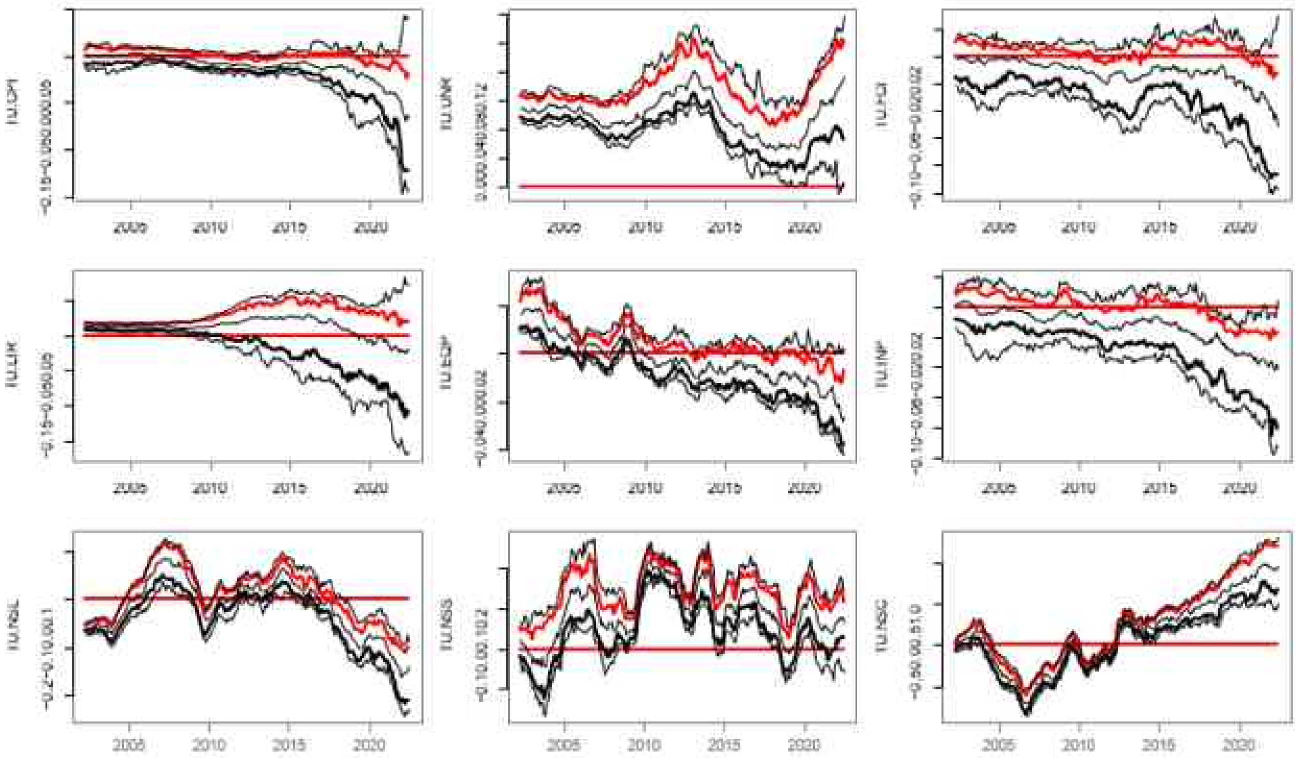

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). Turkey*

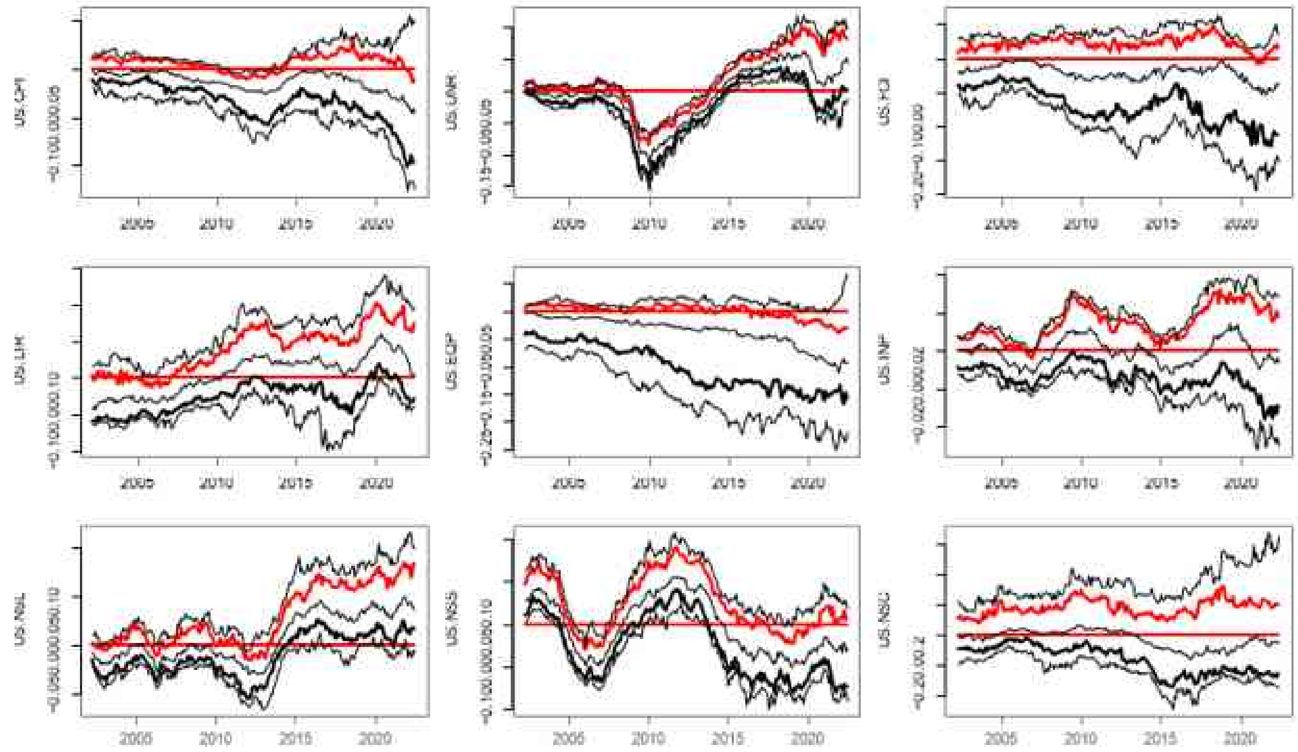

Figure 10. *Cumulative impulse response functions to an international uncertainty shock (Include Nelson-Siegel variables). United States*

Appendix

A Central Bank Announcements

(Refer to Hartley, J and A Rebucci (2020))

U.S Federal Reserve

On 03/15/2020, the Fed announced 700 billion USD of new Treasury and MBS QE in addition to cutting the federal funds rate range from 1.00%-1.25% to 0.00%-0.25% [Retrieved from]. We select the first subsequent trading date, 03/16/2020, as the event date. On 03/23/2020, the Fed announced potentially "unlimited" MBS and Treasury QE (meeting our criteria for an event date) as well as a host of new facilities including the Primary Market Corporate Credit Facility (PMCCF) and Secondary Market Corporate Credit Facility (SMCCF) [Retrieved from]. On 04/09/2020, the Fed announced it would include high yield bonds in the PMCCF and the SMCCF that had at least one investment grade rating prior to 03/23/2020 and at least two current BB ratings. We do not include this as an event date since the announcement does not involve the direct purchase of government bonds. During this period, the Fed also made several announcements related to the establishment of international swap lines. On 03/15/2020 [Retrieved from], the Fed announced it was reactivating its Great Recession era permanent U.S. dollar liquidity swap line arrangements with the Bank of Canada, the Bank of England, the Bank of Japan, the European Central Bank, and the Swiss National Bank. On 03/19/2020, the Fed announced new central bank swap lines with 8 additional central banks (in Australia, Brazil, South Korea, Mexico, Singapore, Sweden, Denmark, Norway and NewZealand), with a commitment to provide $60 billion in U.S. dollar liquidity for each central bank over a period of 6 months [Retrieved from]. On 03/20/2020, Bank of Canada, the Bank of England, the Bank of Japan, the European Central Bank, and the Swiss National Bank announced coordinated action to further enhance the provision of global liquidity [Retrieved from]. Note that while the G7 on a conference call on 03/03/2020 agreed to taking coordinated stimulus measures, they postponed any action. We also note that there were no instances of coordinated QE.

Bank of England

On the evening of 03/18/2020, the Bank of England (BoE) announced it would purchase 200 billion GBP worth of U.K. gilts: [Retrieved from]. We select the first subsequent trading date, 03/19/2020, as the event date.

European Central Bank

On the evening of 03/18/2020, the European Central Bank (ECB) announced it would purchase 750 billion EUR worth of various European sovereign bonds [Retrieved from]. Since the first trading day after the announcement was 03/19/2020, we use 03/19/2020 as the first event date.

Bank of Japan

On 03/16/2020, the Bank of Japan pledged to buy risky assets such as exchange-traded funds at an annual pace of around ¥12 trillion JPY (approximately $112.55 billion USD), double its previous pace [Retrieved from]. It also created a new loan program to extend one-year, zero-rate loans to financial institutions to provide lending to firms hit by the virus outbreak. We do not include this event as it only pertains to risky assets and not sovereign bonds. On 04/27/2020, the Bank of Japan also committed to buy unlimited amounts of government bonds (JGBs) by discarding previous guidance to buy them at an annual pace of 80 trillion yen and said it would boost three-fold the maximum amount of corporate bonds and commercial paper it buys to 20 trillion yen (approximately $186 billion USD) [Retrieved from]. Hence, we include both 03/16/2020 and 04/27/2020 as event dates since they both involve the direct purchase of sovereign bonds.

Bank of Canada

On 03/27/2020, the Bank of Canada (BoC) announced it would purchase $5 billion CAD per week of Canadian sovereign bonds in addition to commercial paper in a newly created Commercial Paper Purchase Program, marking the first foray into large scale asset purchases by the BoC [Retrieved from]. Meanwhile, the Canada Mortgage Housing Corporate (CMHC) previously announced it would be buying Canadian mortgage bonds. We do not include the latter in our event study since it is not a direct purchase of sovereign bonds. The central bank also cut its benchmark interest rate on 3/27/2020 from 0.75% to 0.25%.

Reserve Bank of Australia

On 03/19/2020, the Reserve Bank of Australia announced it would purchase an unlimited amount of Australian sovereign bonds [Retrieved from], hence we include it as an event date. The central bank also cut its benchmark interest rate on 3/19/2020 from 0.50% to 0.25%.

Reserve Bank of New Zealand

On 03/23/2020, the Reserve Bank of New Zealand announced it would purchase 30 billion NZD of New Zealand sovereign bonds [Retrieved from], hence we include it as an event date. The central bank previously cut its benchmark interest rate from 1.00% to 0.25% on 03/16/2020.

Riksbank

On 03/16/2020, the Riksbank announced it was buying an additional 300 billion SEK of government bonds in 2020 [Retrieved from]. Hence, we include it as an event date. In addition, the Riksbank said on the prior Friday, 03/13/2020, it would lend up to 500 billion SEK to Swedish companies via banks. We do not include this as a separate event.

Bank of Israel

On 03/15/2020, the Bank of Israel announced that it "will carry out open market operations and will purchase in the secondary market government bonds of various types and maturities in the necessary quantities needed to ensure the smooth functioning of the government bond market" [Retrieved from]. On 03/23/2020, the Bank of Israel committed to buying 50 billion ILS of Israeli government bonds [Retrieved from]. Hence, we include both 03/15/2020 and 03/23/2020 as event dates. Later, on 04/10/2020, it reduced its benchmark interest rate from 0.25% to 0.10%.

Bank of Korea

On 03/26/2020, the Bank of Korea announced plans to offer "unlimited" repos for three months [Retrieved from]. Hence, we include it as an event date. It previously cut its benchmark interest rate from 1.25% to 0.75% on 03/17/2020.

Banco de la República

Colombia's central bank announced QE measures during an emergency session on 03/23/2020 [Retrieved from], the first time any South American central bank announced QE, where it would buy government bonds. Since 3/23/2020 was St. Joseph's day, a public holiday in Colombia where markets were closed, we choose 3/24/2020 as the first event date. The same measure authorized the central bank to buy up to 2 trillion COP worth of Colombia Treasury bonds (TES) before the end of March as well as 10 trillion COP worth of private bonds. It subsequently cut its benchmark interest rate from 4.25% to 3.75% on 03/27/2020 and again to 3.25% on 04/30/2020.

South Africa Reserve Bank

On 3/25/2020, the South African Reserve Bank (SARB) announced it would begin an unspecified amount of South African government bond asset purchases [Retrieved from]. Hence, we include it as an event date. It previously cut its benchmark interest rate from 6.25% to 5.25% on 03/20/2020 and again to 4.25% on 4/15/2020.

National Bank of Romania

On 03/20/2020, the Romanian central bank had a surprise meeting, announcing it would provide liquidity to banks via repo transactions and purchase local leu-denominated debt on the secondary market to consolidate structural liquidity [Retrieved from]. Hence, we include it as an event date. Romania's central bank also cut its benchmark interest rate by from 2.5% to 2.0% on this date.

National Bank of Poland

On 03/17/2020, the National Bank of Poland received approval to buy an unspecified amount of Polish government bonds from commercial banks. Hence, we include it as an event date. On the same date, it also announced an extension of repo operations increasing banks' liquidity [Retrieved from]. The National Bank of Poland announced it was cutting its benchmark interest rate from 1.0% to 0.5% on 03/17/2020; on 04/08/2020, it announced a ramping up its QE not only buying government bonds but also other bonds with state guarantees, including those issued by the Polish Development Fund [Retrieved from]. Hence, we include this second event date. The National Bank of Poland announced it was cutting its benchmark interest rate again from 0.5% to 0% on 04/08/2020.

Croatia National Bank

On 03/13/2020, the Croatian National Bank (CNB) announced it had started to purchase Republic of Croatia government bonds with the aim of maintaining stability in the market of government securities [Retrieved from]. Hence, we include 3/13/2020 as an event date.

Bangko Sentral ng Pilipinas

On 03/23/2020, the Philippine Monetary Board authorized the Bangko Sentral ng Pilipinas to purchase securities from the Bureau of Treasury (BTr) under a repurchase agreement in the amount of 300 billion PHP with a maximum repayment period of 6 months [Retrieved from]. We include this event, but we date it 03/23/2020 to evaluate its the financial market impact. On 04/09/2020, the Philippine Monetary Board announced it was conducting further asset purchases and expanding the range of eligible securities to cover all peso-denominated Government Securities (GS) issuances [Retrieved from]. Since 04/09/2020 was Thursday and 04/10/2020 was Good Friday, both bank holidays in the Philippines, we include the following Monday 04/13/2020 as the first event date for this particular intervention. The central bank previously cut its benchmark interest rate from 3.75% to 3.25% on 03/19/2020 and again to 2.75% later on 04/17/2020.

Banco de México

On 04/21/2020, the Banco de Mexico announced 750 billion MXN of economic support, including 100 billion MXN of Mexican government long-term bond asset purchases in addition to a 100 billion MXN corporate securities repurchase facility for securities issued by private nonfinancial institutions [Retrieved from]. Hence, we include 04/21/2020 as an event date. On the same day, the central bank also cut its benchmark interest rate from 6.5% to 6.0%.

Central Bank of the Republic of Turkey

On 03/31/2020, the Central Bank of Turkey announced it was commencing the purchase of several billion TRY of Turkish government bonds [Retrieved from]. Hence, we include 03/31/2020 as an event date. Previously, on 03/17/2020, the central bank cut its benchmark interest rate from 10.75% to 9.75%. On 4/17/2020, the central bank announced it was lifting the limit on government bond asset purchases from 5% to 10% of Central Bank of Turkey assets [Retrieved from]. Hence, we include 4/17/2020 as an event date as well. Later, on 04/22/2020, the central bank cut its benchmark interest rate from 9.75% to 8.75% and again to 8.25% on 05/21/2020.

Reserve Bank of India

On 03/18/2020 and 03/20/2020, the Reserve Bank of India announced asset purchases of government bonds. While the announcement on 03/18/2020 only included government bonds up to five years in maturity for a total amount of 100 billion INR [Retrieved from], the second announcement on 03/20/2020 for a total amount of 300 billion INR [Retrieved from] included government bonds up to 9 years in maturity. To avoid potential double counting given the event window overlap (two event dates are only 2 days apart), we include 03/20/2020 and 3/22 as event dates but only include a two day impact for 3/20 to avoid double counting the impact on 3/22. The central bank also later cut its key benchmark interest rate on 03/27/2020. On April 27, 2020 the Reserve Bank of India decided to conduct simultaneous purchase and sale of government securities under Open Market Operations (OMO) for 10,000 crores.

Bank Indonesia

On 04/01/2020, Bank Indonesia announced the expansion of its authority to purchase long-term government securities (SBN) and government Islamic securities (SBSN) in the primary market [Retrieved from]. Hence, we include 04/01/2020 as an event date. The central bank had previously cut its benchmark interest rate on 03/19/2020.

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