Permanent and Temporary Oil Price shocks and Non-Oil Growth in Oil-Exporting Countries

Preliminary Draft

Amir Sadeghi*

George Washington University

November 15, 2017

* Thanks to …

1. Empirical Framework

In the essay, I estimated a recursive vector autoregression analysis where oil price was assumed to be strictly exogenous and government expenditure and non-oil GDP would respond contemporaneously and with a one-year lag to oil price shocks:

$$
\begin{aligned}
o_{i,t} &= \nu_{i,1} + \sum_{l=1}^{p} b_{11,l} o_{i,t-l} + \omega_{i,t}^{o} \\
g_{i,t} &= \nu_{i,2} + \sum_{l=0}^{p} b_{21,l} o_{i,t-l} + \sum_{l=1}^{p} b_{22,l} g_{i,t-l} + \sum_{l=1}^{p} b_{23,l} y_{i,t-l} + \omega_{i,t}^{g} \\
y_{i,t} &= \nu_{i,3} + \sum_{l=0}^{p} b_{31,l} o_{i,t-l} + \sum_{l=0}^{p} b_{32,l} g_{i,t-l} + \sum_{l=1}^{p} b_{33,l} y_{i,t-l} + \omega_{i,t}^{y}
\end{aligned}
\qquad (1)
$$

$i = 1 \dots N$ (countries), $t = 1 \dots T$ (years).

Results suggested that oil price shocks have significant impact on both government expenditure and non-oil GDP, with the impact being larger the larger is the size of government, measured as the ratio of government expenditure to non-oil GDP. The study, however, did not investigate the possibility that the endogenous variables in the model may respond only to permanent shocks as it did not distinguish between temporary and permanent shocks. Current report is trying to address that by analyzing the response of the endogenous variables of the model to shocks to oil price trend (trend shocks) versus changes in the cyclical component of the oil price (cyclical shocks). I use oil price data at annual basis starting from 1970 until 2016.[2]

1.1. State Space Model

To decompose the series into a permanent and cyclical component, I follow the literature (Clark, 1987; Schwartz and Smith, 2000) and develop a univariate Unobserved Components model,

$$y_t = n_t + x_t, \qquad (2)$$

where y_t is the real oil price level, n_t is the trend and x_t is the cyclical component. Trend is assumed to receive shocks to both its level and its slope,

[2] I use annual data because the main database is at annual frequency and to be able to feed the decomposed oil price series into the vector autoregression system, the obtained series should be annual.

$$n_t = \mu_t + n_{t-1} + v_t$$

$$\mu_t = \mu_{t-1} + w_t, \qquad (3)$$

and the cyclical component follows a stationary $AR(1)$ process,

$$x_t = \phi_1 x_{t-1} + e_t. \qquad (4)$$

The disturbances v_t, e_t, and w_t are mutually independent and normally and independently distributed with mean zero and variance σ. Imposing $\sigma_v^2 = 0$, generates a smoother trend – called integrated random walk trend. If both σ_v^2 and σ_w^2 are set to zero, the trend becomes deterministic. Finally, setting σ_w^2 to zero reduces the trend to a random walk with drift, μ.

1.2. Updating and Estimation

Based on the model explained by equations (2) to (4), I form a state-space model and use Kalman filter, in the manner of Hamilton (1994), to obtain estimators of the components of the model. The unknown parameter ϕ_1 is estimated by constructing a likelihood function from random innovations drawn from a uniform function and imposing positive variances and stationary equation (4), $|\phi_1| < 1$, and maximizing it by an iterative procedure.

$$Y_t = DX_t + \boldsymbol{V}_t, \qquad (5)$$

$$X_t = AX_{t-1} + C\boldsymbol{U}_t, \qquad (6)$$

$$D = \begin{bmatrix} 1 & 1 & 0 \end{bmatrix}, \qquad X_t = \begin{bmatrix} n_t \\ x_t \\ \mu_t \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & 0 & 1 \\ 0 & \phi_1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \qquad C = \begin{bmatrix} \sigma_v & 0 & 0 \\ 0 & \sigma_e & 0 \\ 0 & 0 & \sigma_w \end{bmatrix}, \qquad \boldsymbol{U} \sim N(0,1), \qquad \boldsymbol{V}_t = \boldsymbol{0}.$$

The unobserved state vector evolves according to the following equation:

$$X_{t|t} = X_{t|t-1} + K_t\left(Y_t - DX_{t|t-1}\right). \quad (7)$$

K_t is the Kalman gain,

$$K_t = P_{t|t-1}D'\left(DP_{t|t-1}D' + \Sigma_{vv}\right)^{-1}, \qquad (8)$$

where Σ_{vv} is the variance covariance matrix of the errors in the observation equation (5)[3] and

$$P_{t|t-1} = AP_{t-1|t-1}A' + CC', \qquad (9)$$

where $P_{t-1|t-1}$ is the covariance matrix,

$$P_{t-1|t-1} = E\left[\left(X_{t-1} - X_{t-1|t-1}\right)\left(X_{t-1} - X_{t-1|t-1}\right)'\right], \qquad (10)$$

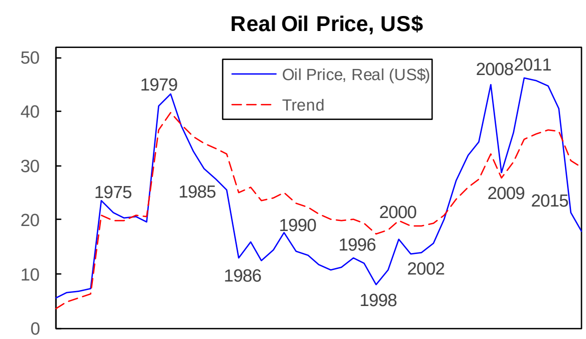
and $X_{t-1|t-1}$ is the estimated value of the previous period.

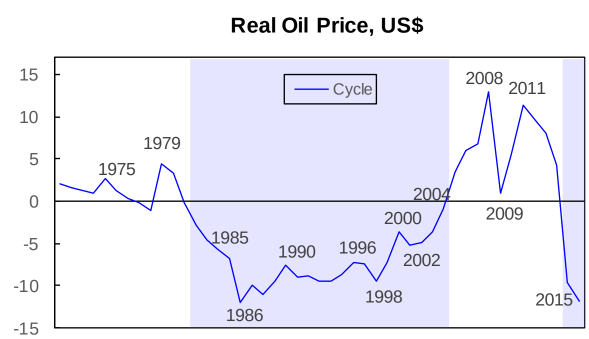
Following Hamilton (1994), the log likelihood function is defined as,

$$l(\theta) = -\frac{Tn}{2}\ln(2\pi) - \frac{T}{2}\ln\left(\det\left(DP_{t|t-1}D' + \Sigma_{vv}\right)\right) + \sum_{t=1}^{T}\left(Y_t - DX_{t|t-1}\right)'\left(DP_{t|t-1}D' + \Sigma_{vv}\right)^{-1}\left(Y_t - DX_{t|t-1}\right). (11)$$

2. Stylized Facts

Below I report the new series for the trend and the cyclical component of the real oil price series:

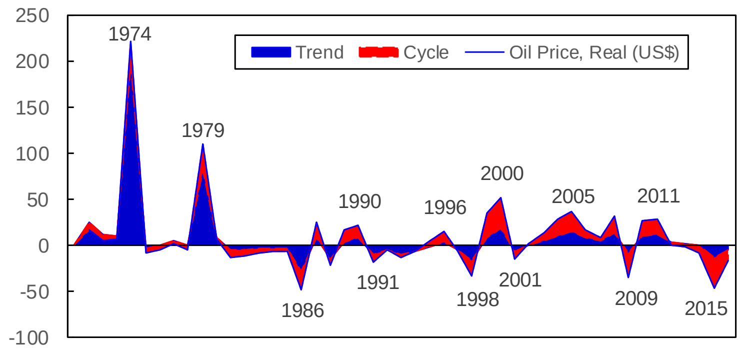




[3] Since no error term enters equation (2), $\Sigma_{vv} = 0$.

According to above charts, the model identifies the large changes in oil prices in 1974 and 1979 as break in the trend, while 2009 decline is attributed mostly to changes in the temporary component – a trend outlier. To see these stylized facts better, the following chart illustrates the contribution of each component to changes in the real price of oil since 1970s:

Real Oil Price Growth Contributors, %



It is clear that the model attributes most of the changes in the oil price during 1970s to changes in the trend. In the recent period, while results show a mixed contribution by both long-term and short-term factors, short-term factors seem to have become the dominant driver of changes in the oil price.

3. The Impact of Oil Price Shocks Revisited

Figures 1 and 2 show the (cumulative) response of government expenditure (i.e. total, current, and capital expenditure) and non-oil growth to shocks to both trend and cyclical component of the oil price as well as shocks to oil price level for the period of 1990 to 2016.

Both IRFs and cumulative IRFs support the hypothesis that *shocks to oil price trend cause much stronger reaction in the endogenous variables of the model (government expenditure and non-oil growth) than shocks to the irregular par to of the oil price series.* Trend shocks create stronger impact than shocks to the level of the price, which was studied in the previous section. Panel A, B, and C in the appendix show the same IRFs and cumulative IRFs for the full spectrum of the government spending to non-oil output ratio along with their confidence intervals.

Figure 1. Impulse Response of Government Expenditure and Non-Oil Growth to Oil Price Shocks

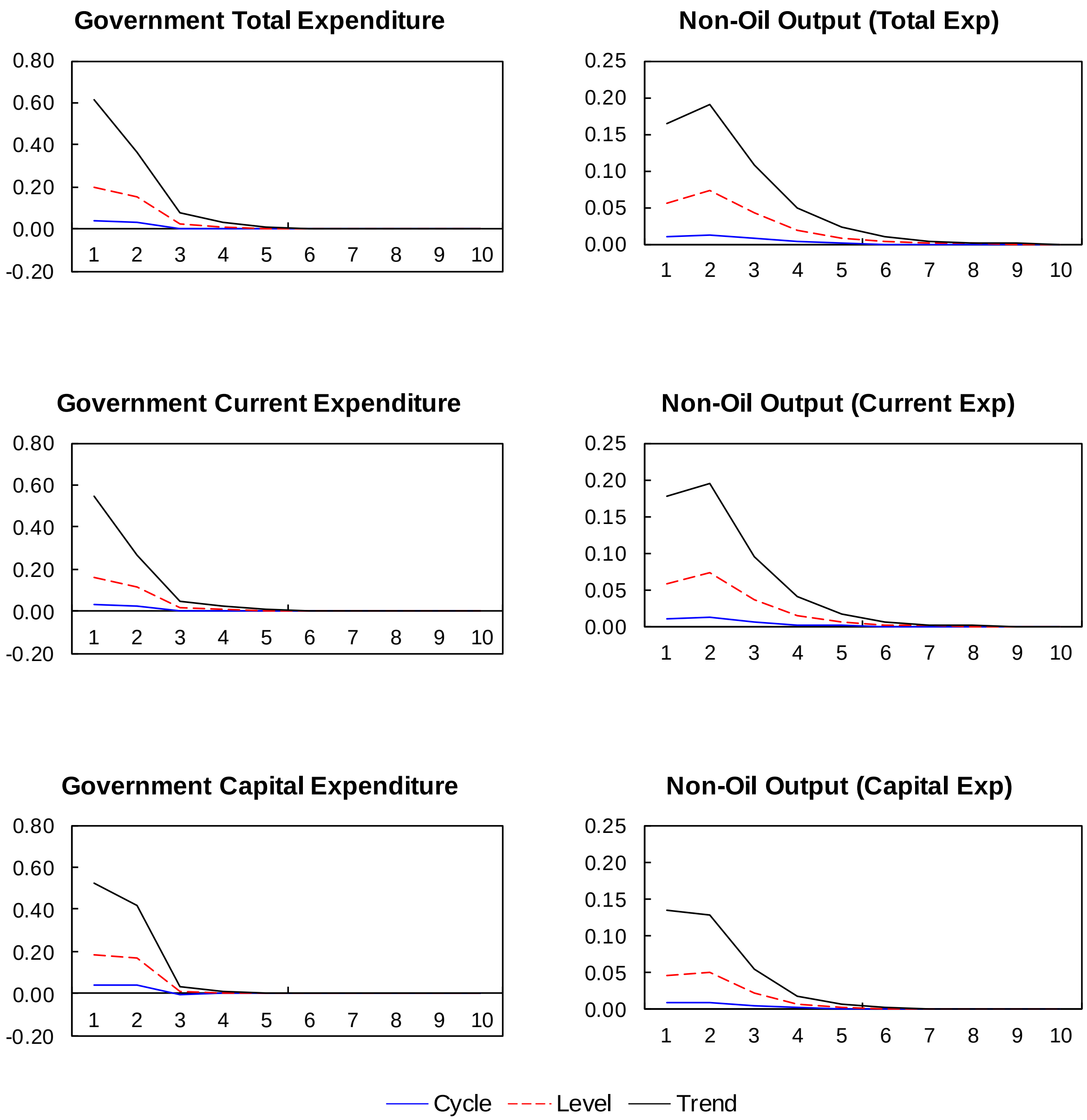
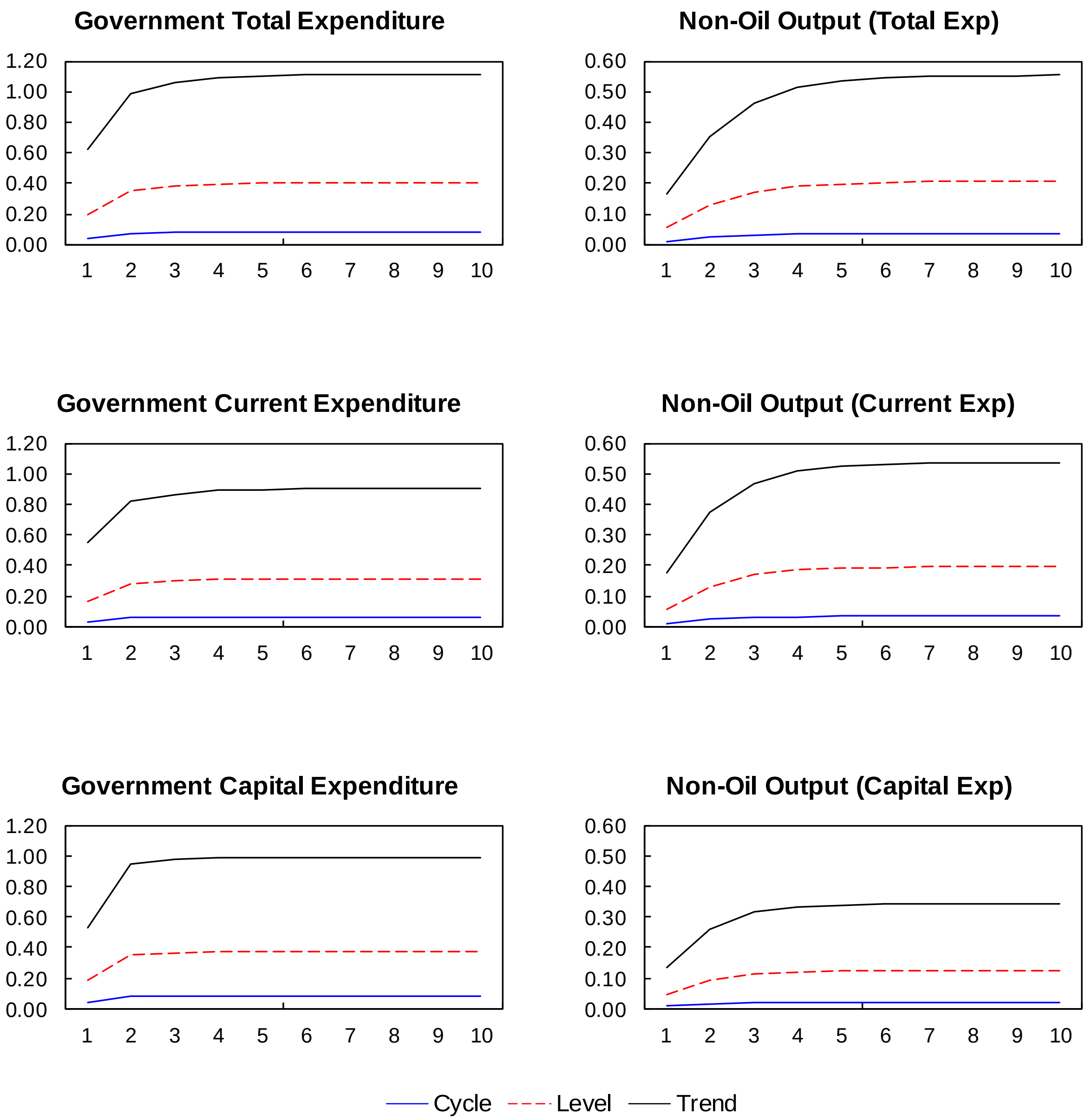


Figure 2. Cumulative Impulse Response of Government Expenditure and Non-Oil Growth to Oil Price Shocks



4. Bibliography

Carvalho, M. Vasco, and Andrew C. Harvey, 2005. “Growth, Cycles and Convergence in US Regional Time Series,” International Journal of Forecasting 21, pp. 667-686.

Clark, Peter K., 1987. "The Cyclical Component of U. S. Economic Activity," The Quarterly Journal of Economics, Oxford University Press, vol. 102(4), pages 797-814.

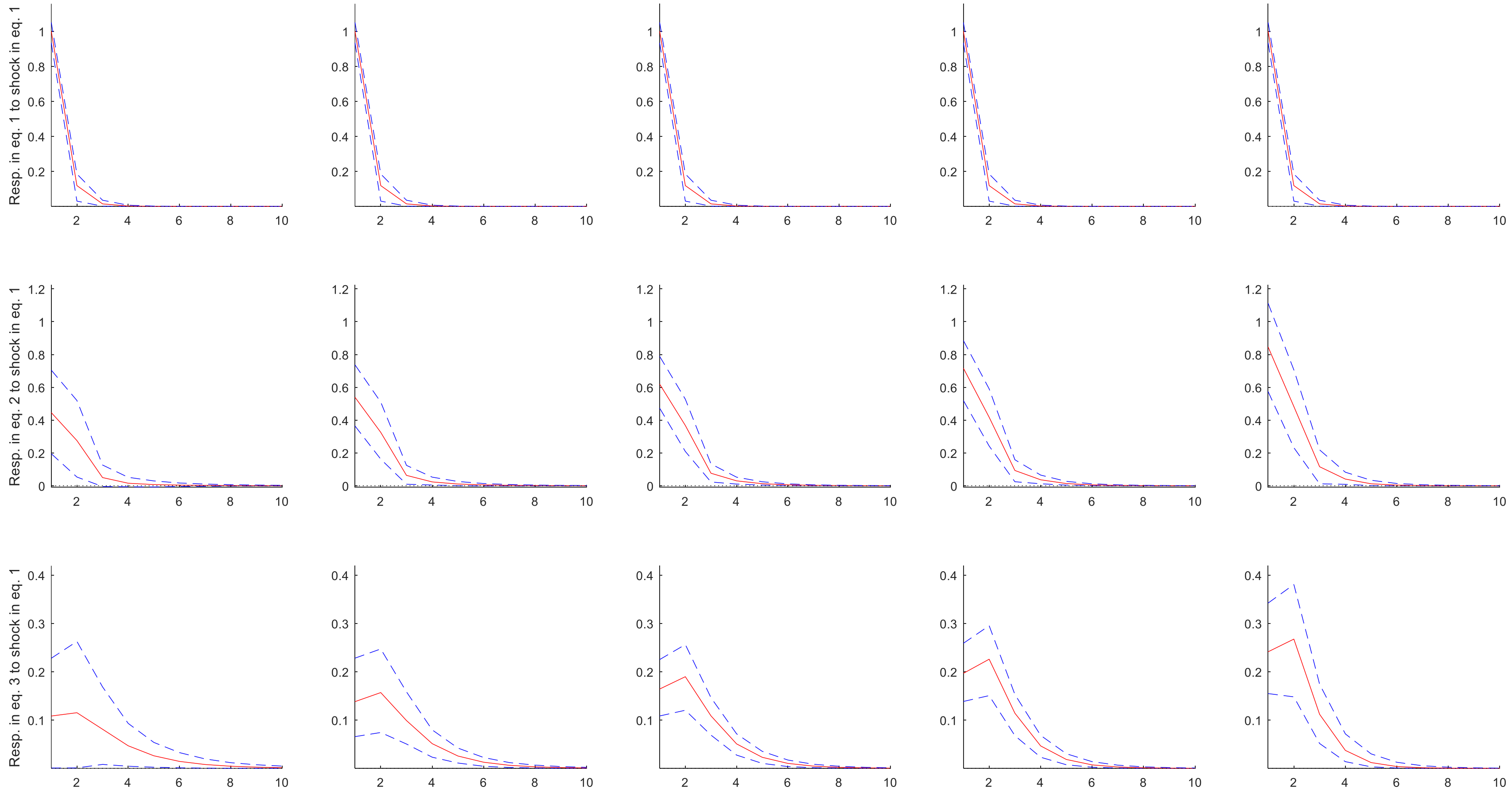
Hamilton, James D., 1994. Time Series Analysis. Princeton University Press, Princeton.

Schwartz, Eduardo, and James E. Smith, 2000. “Short-Term Variations and Long-Term Dynamics in Commodity Prices," Management Science 46(7), pp. 893-911.

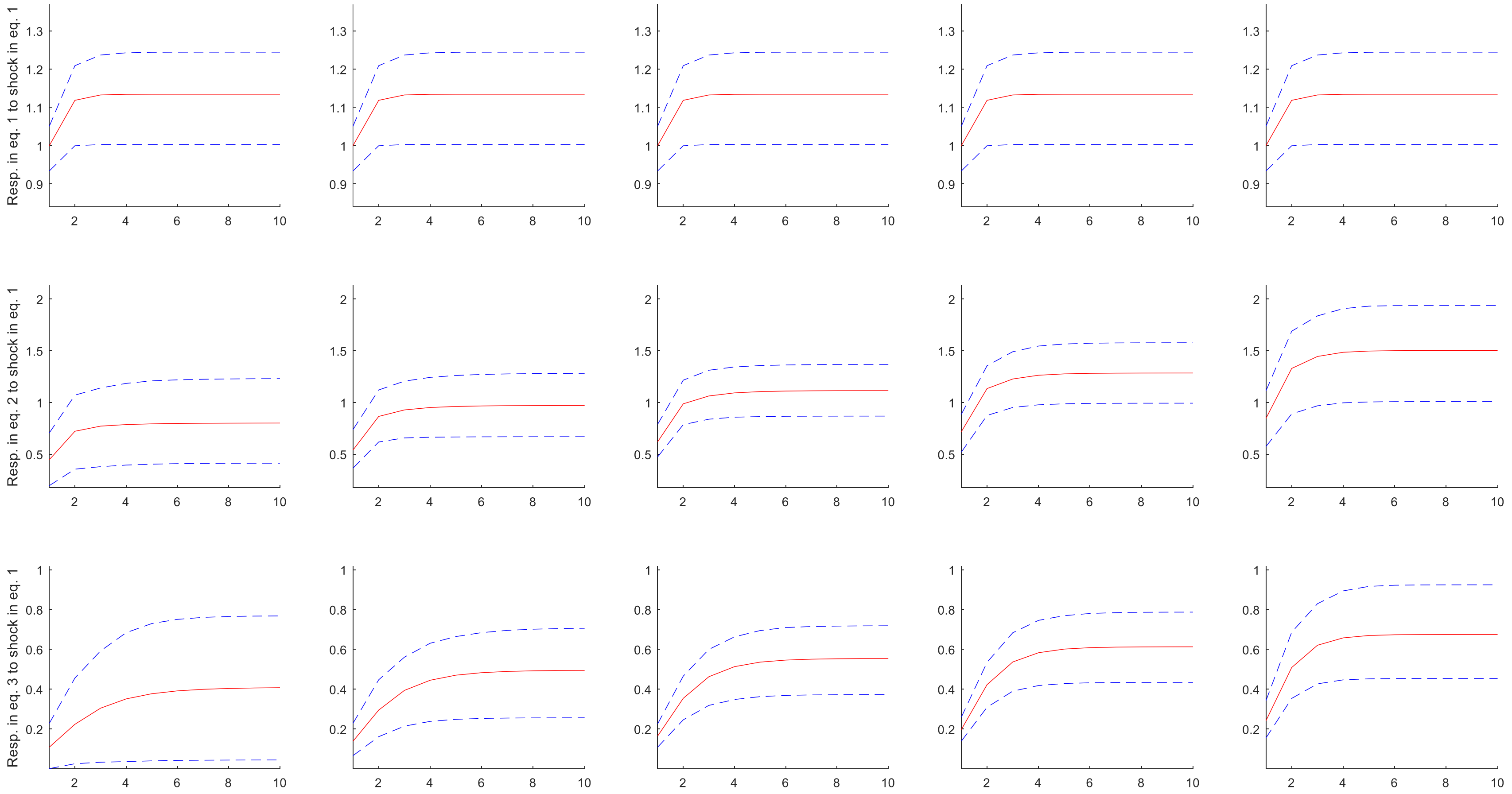
5. Appendix

Panel A

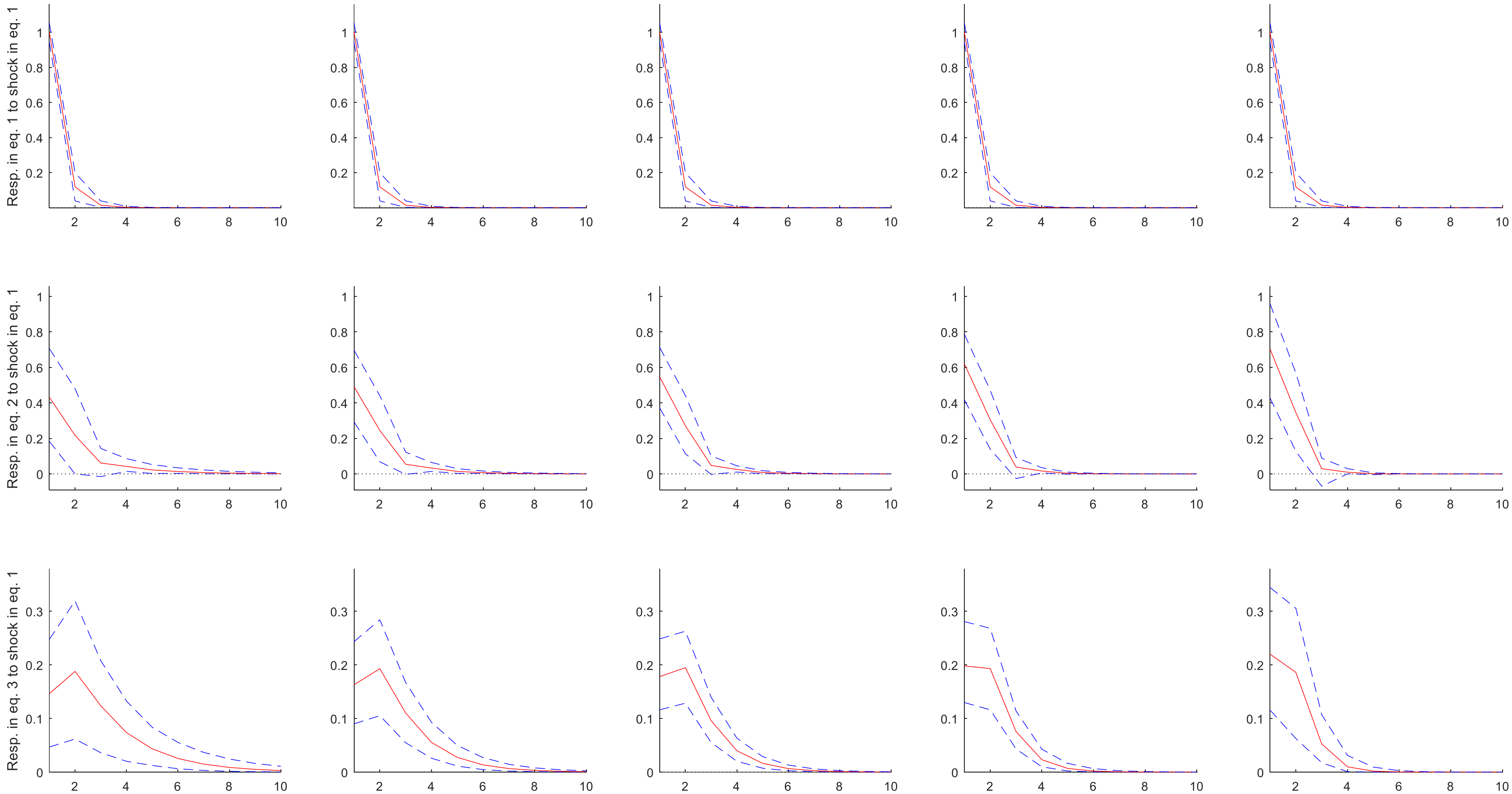
A.1. Total Expenditure - IMUPULSE RESPONSE FUNCTION



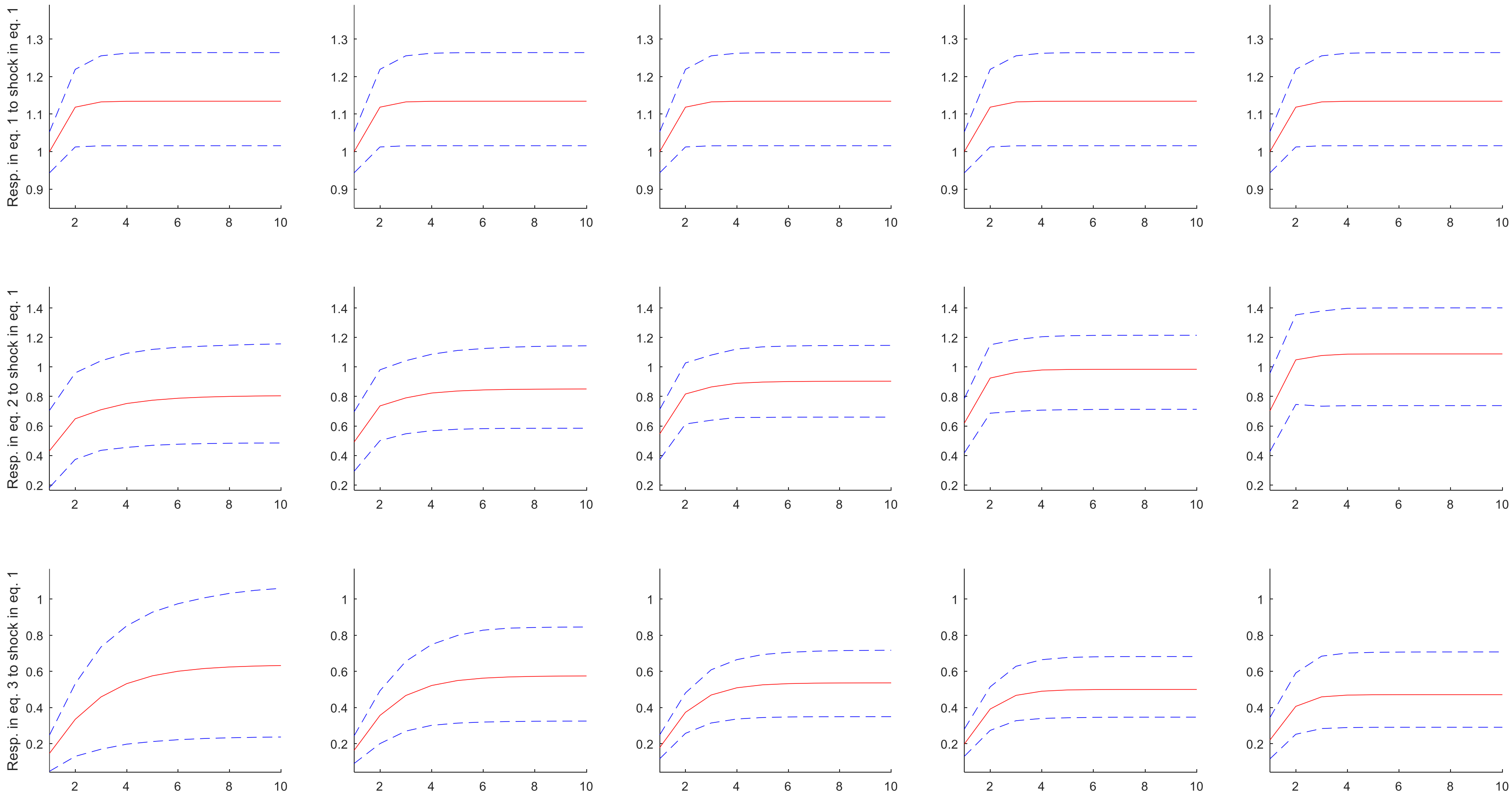
A.1. Total Expenditure - CUMULATIVE IMUPULSE RESPONSE FUNCTION



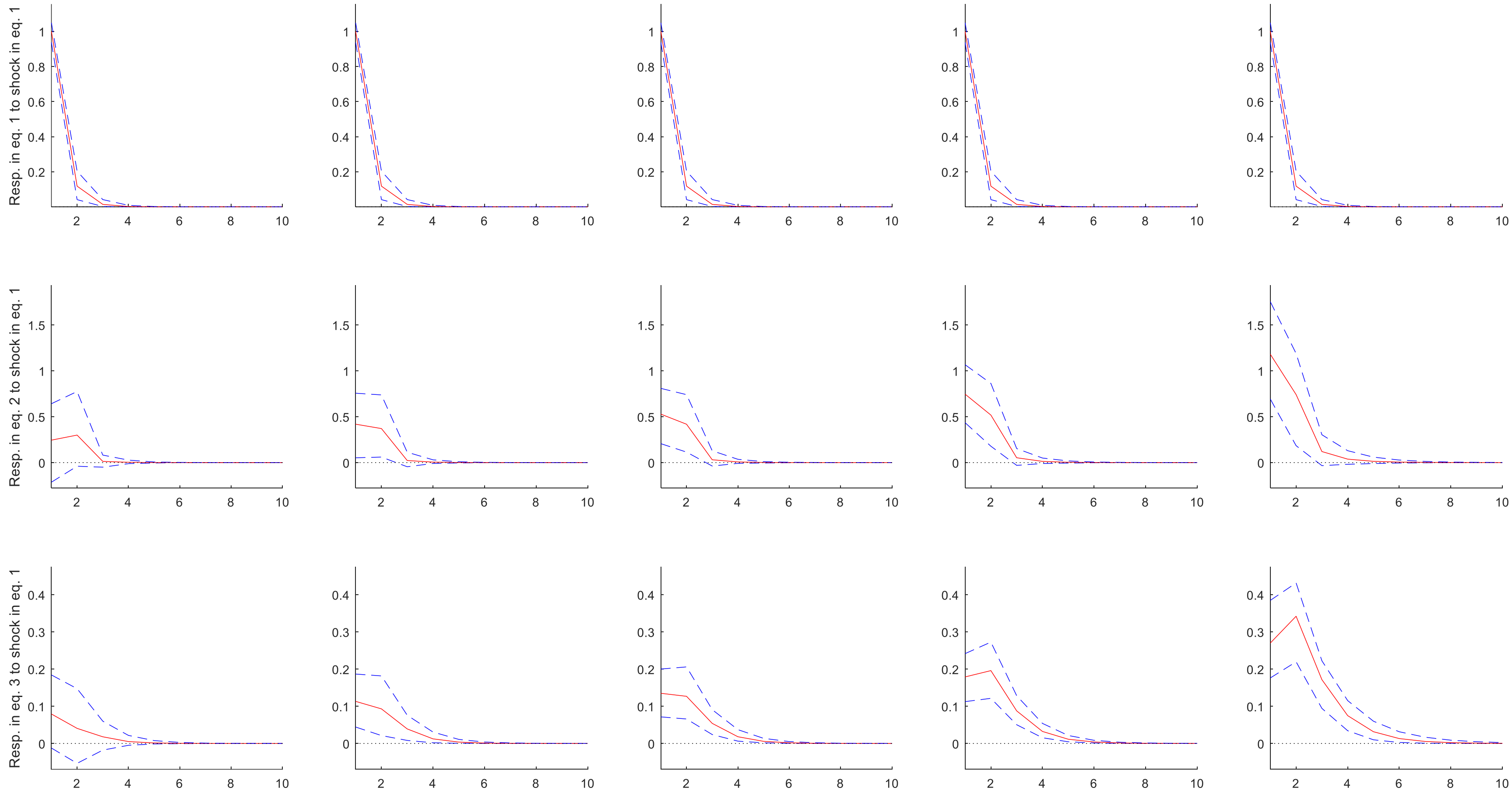
A.2. Current Expenditure - IMUPULSE RESPONSE FUNCTION



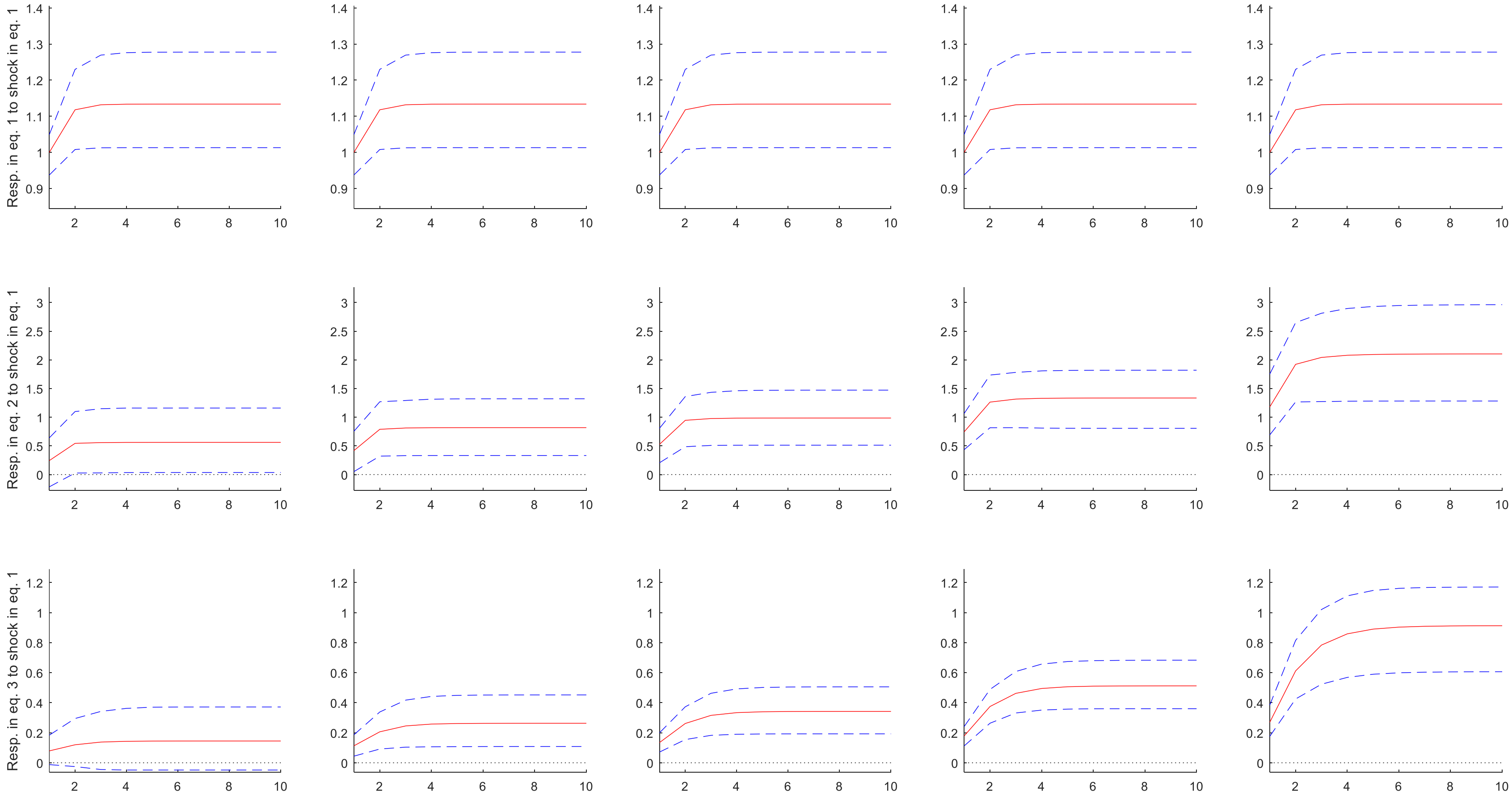
A.2. Current Expenditure - CUMULATIVE IMUPULSE RESPONSE FUNCTION



A.3. Capital Expenditure - IMUPULSE RESPONSE FUNCTION

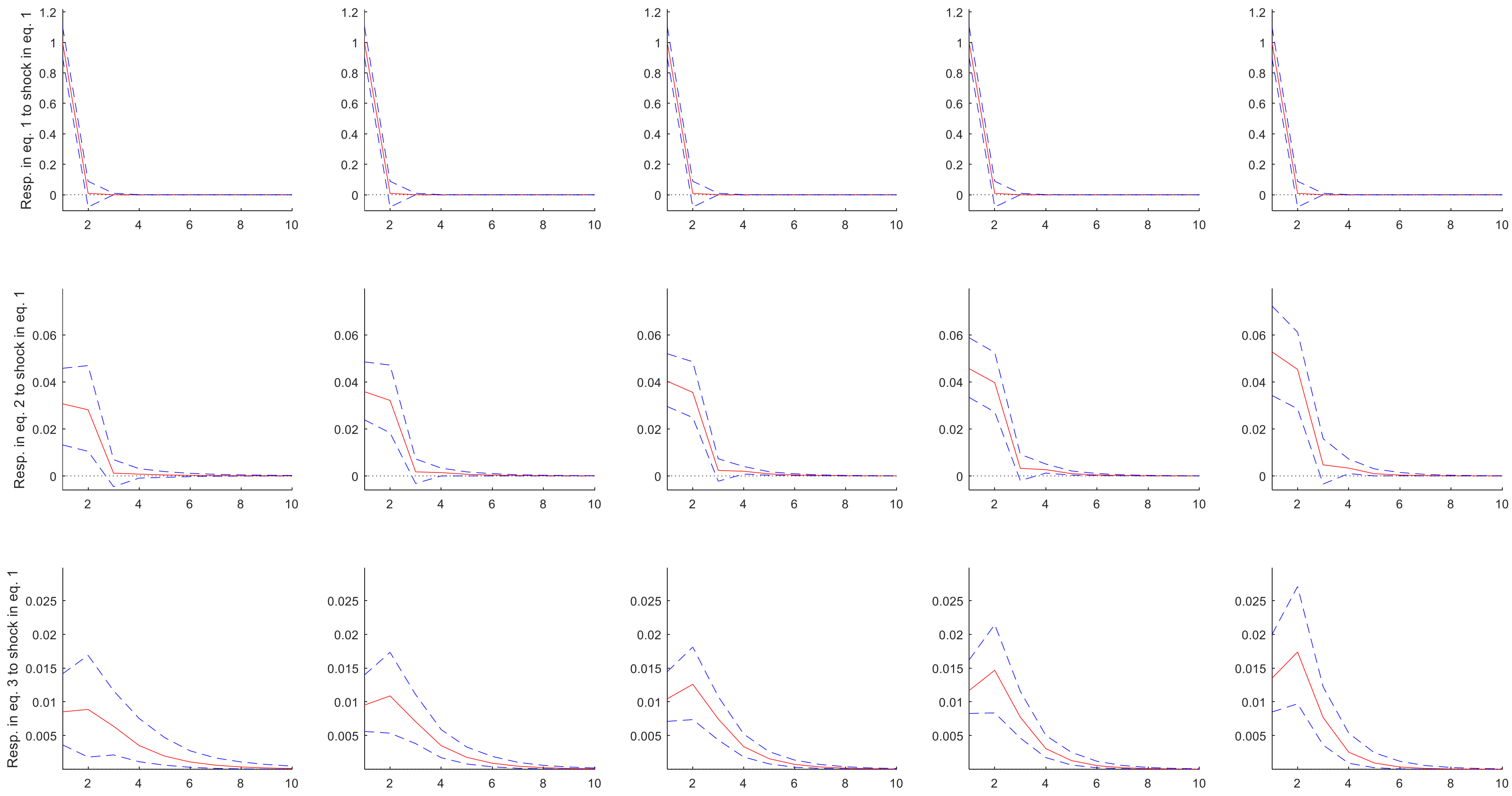


A.3. Capital Expenditure - CUMULATIVE IMUPULSE RESPONSE FUNCTION

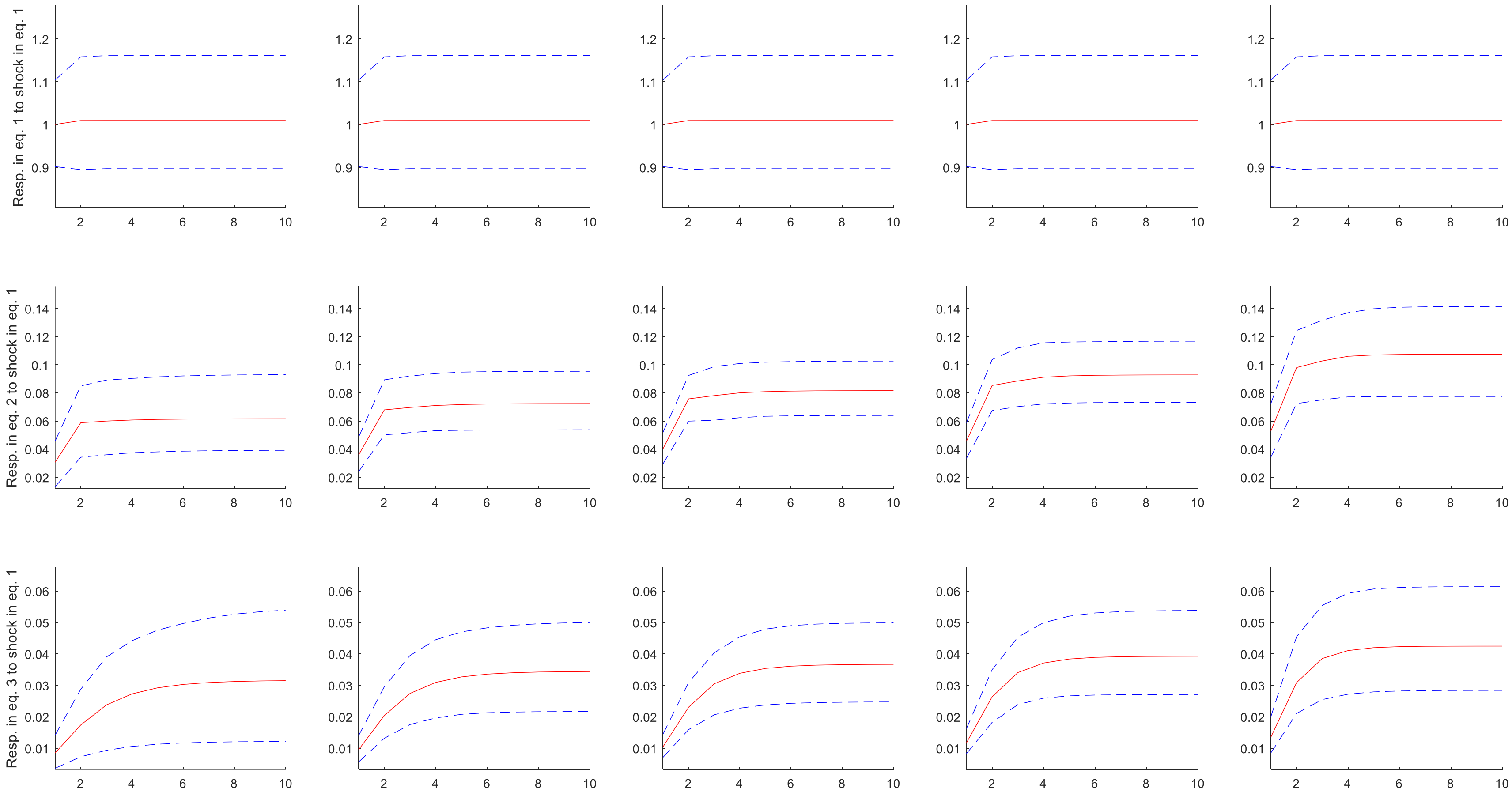


Panel B

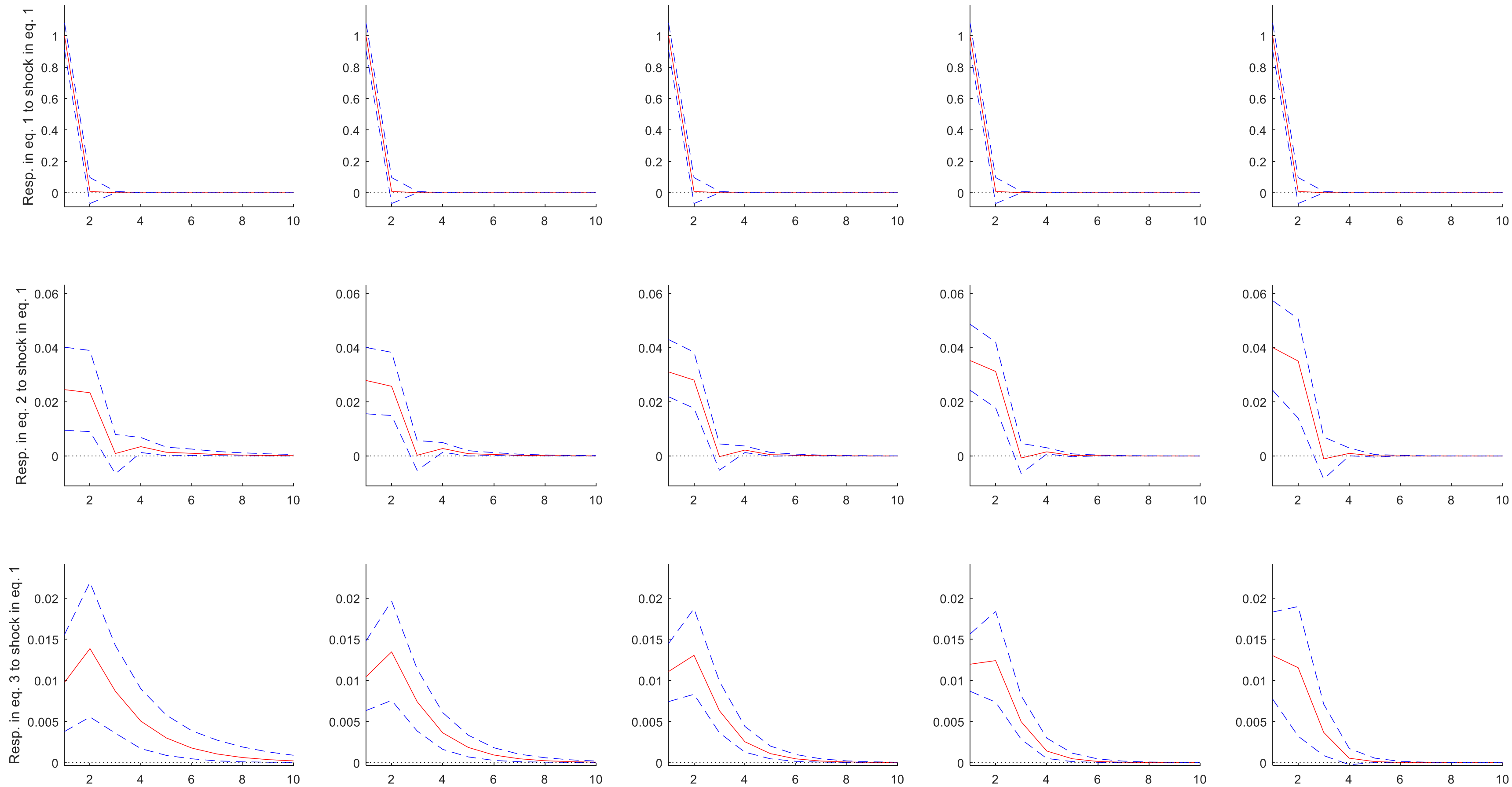
B.1. Total Expenditure - IMUPULSE RESPONSE FUNCTION



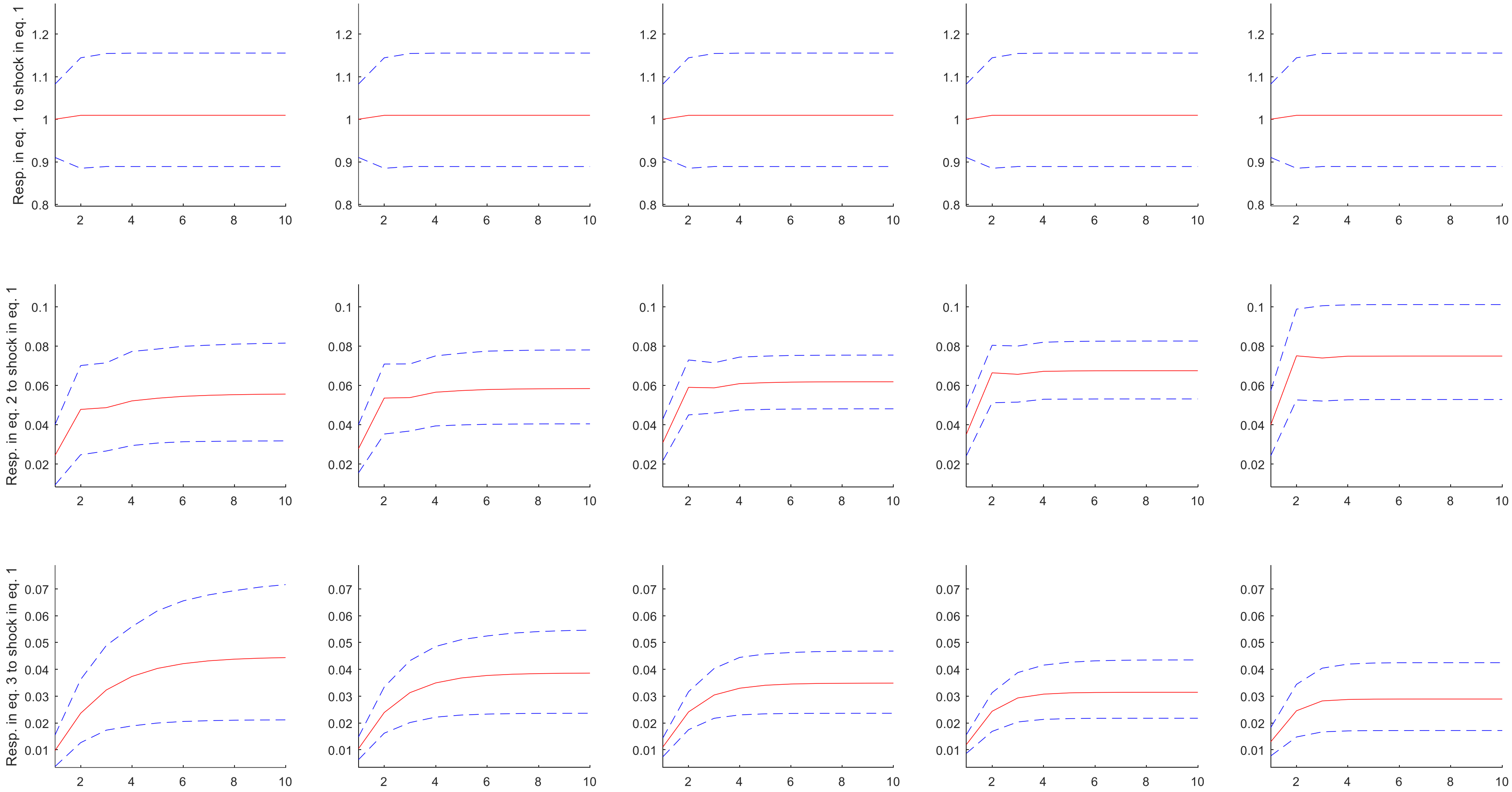
B.1. Total Expenditure - CUMULATIVE IMUPULSE RESPONSE FUNCTION



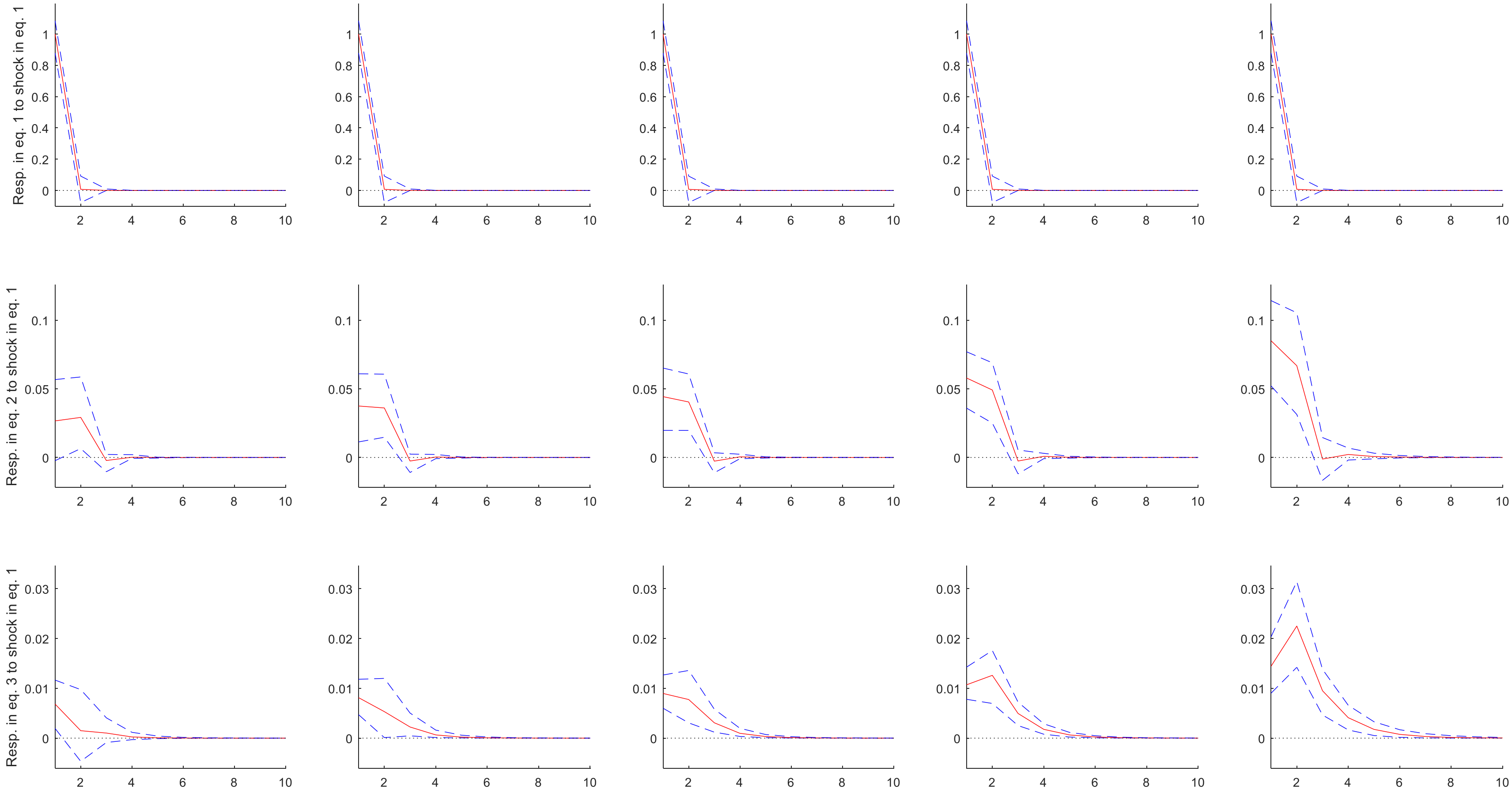
B.2. Current Expenditure - IMUPULSE RESPONSE FUNCTION



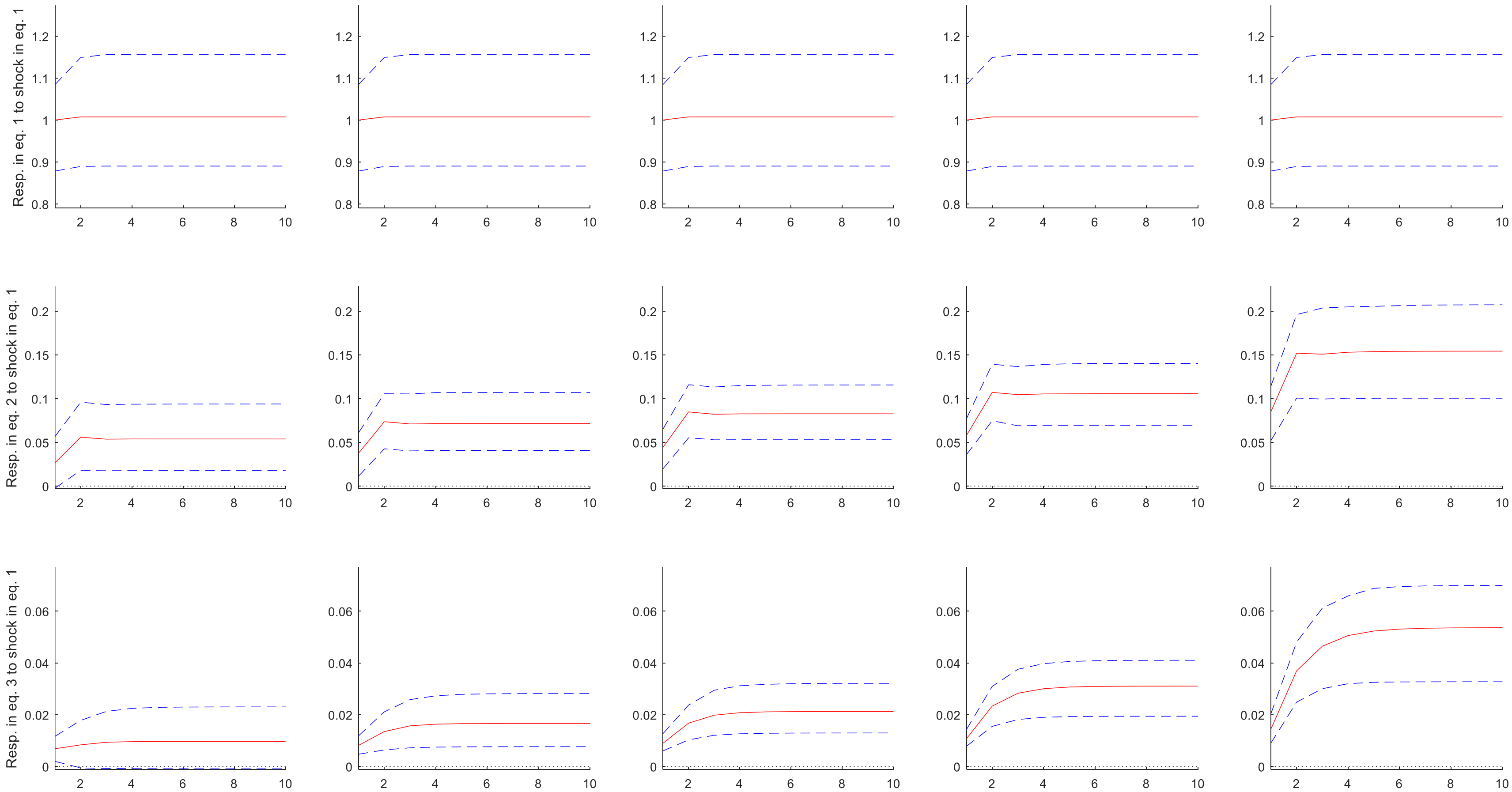
B.2. Current Expenditure - CUMULATIVE IMUPULSE RESPONSE FUNCTION



B.3. Capital Expenditure – IMUPULSE RESPONSE FUNCTION

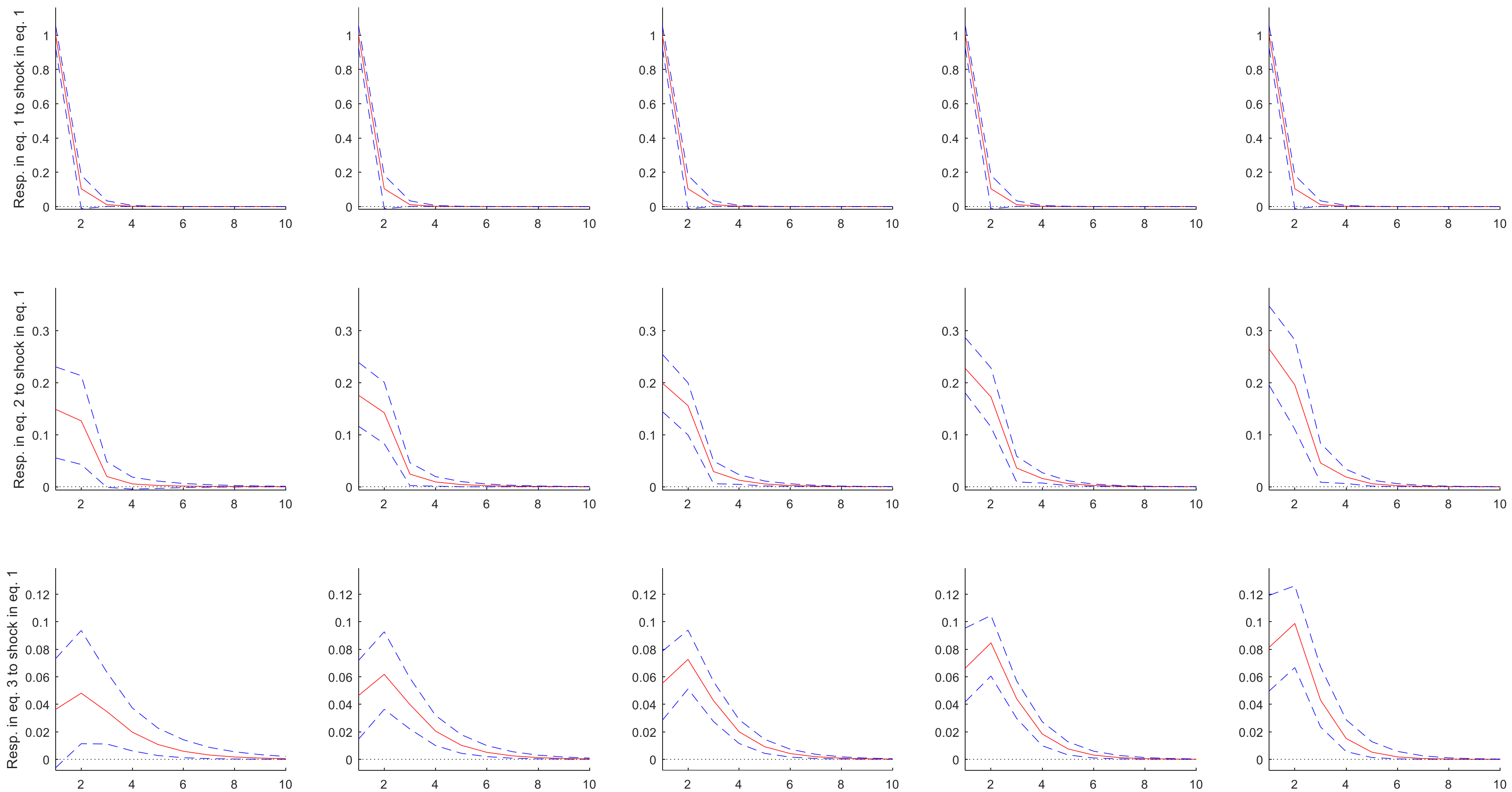


B.3. Capital Expenditure – CUMULATIVE IMUPULSE RESPONSE FUNCTION

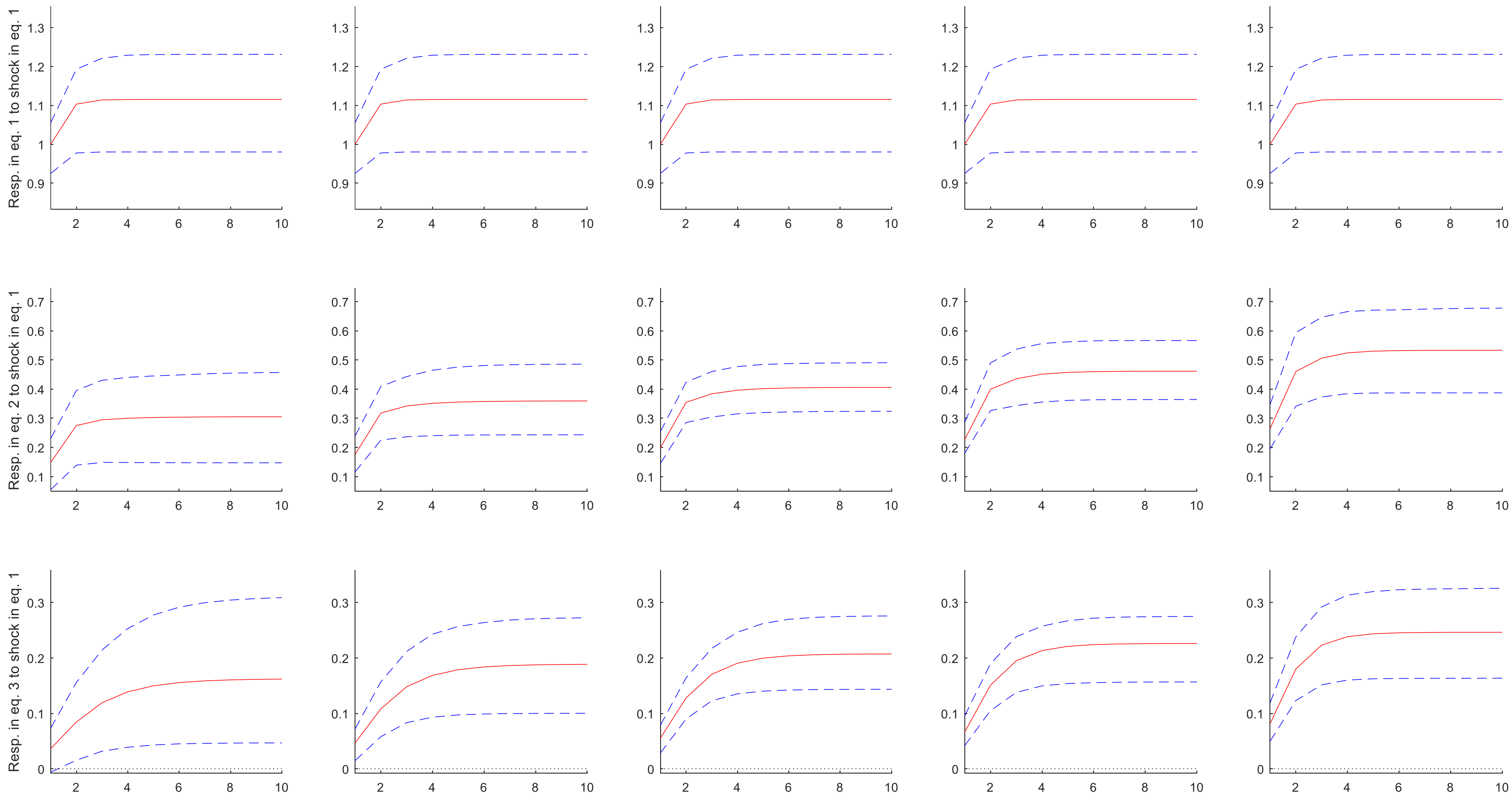


Panel C

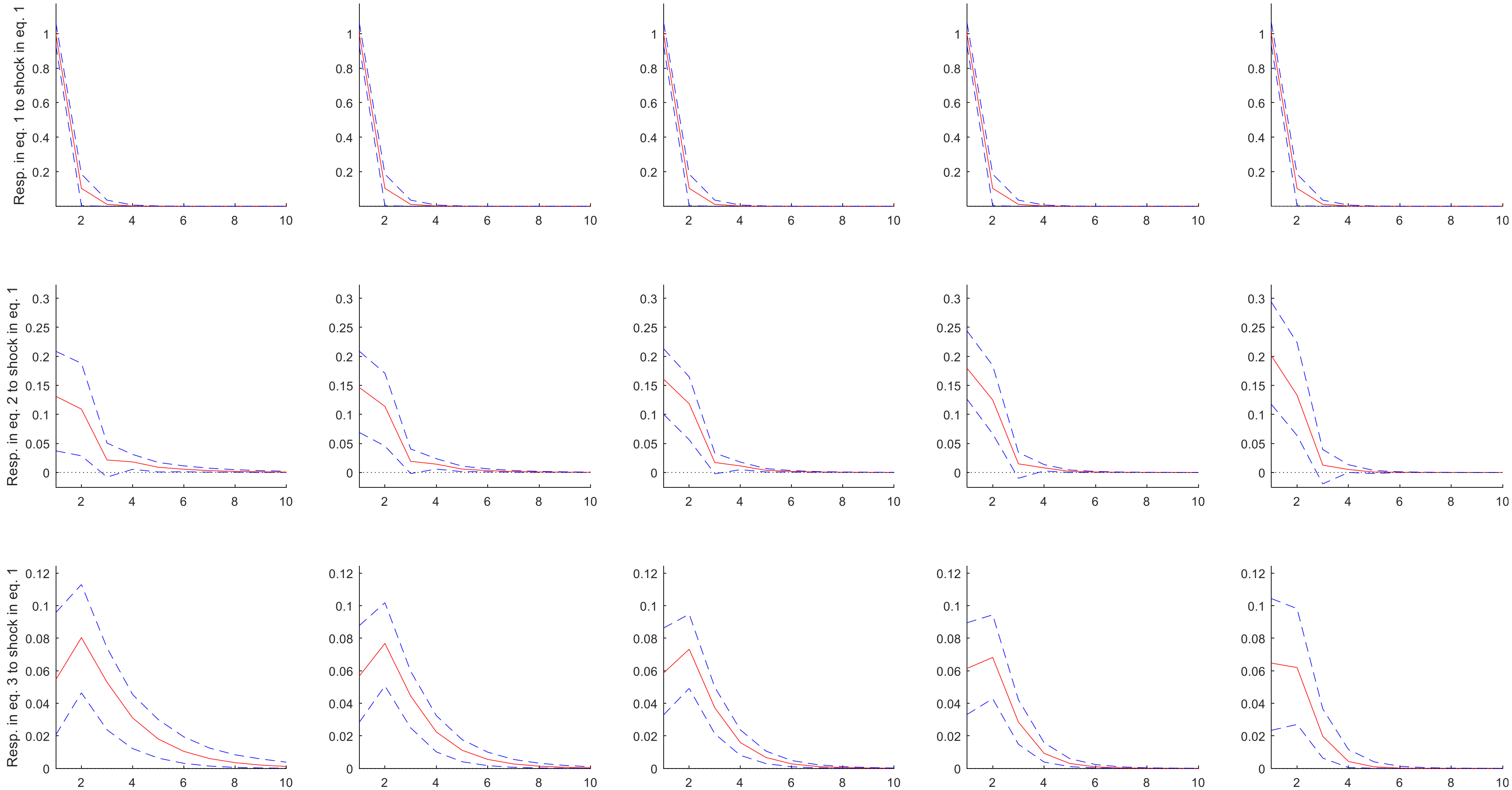
C.1. Total Expenditure - IMUPULSE RESPONSE FUNCTION



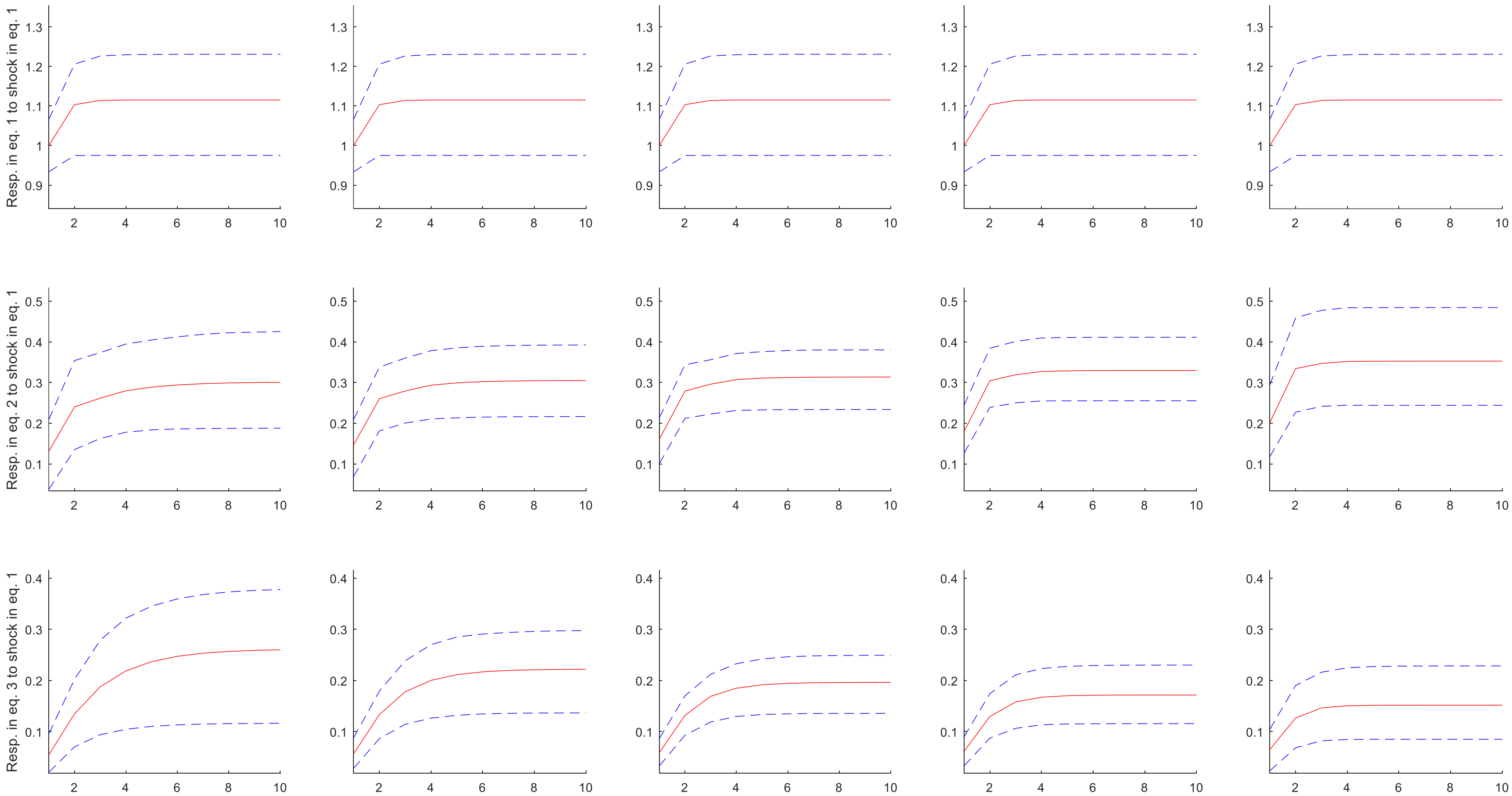
C.1. Total Expenditure - CUMULATIVE IMUPULSE RESPONSE FUNCTION



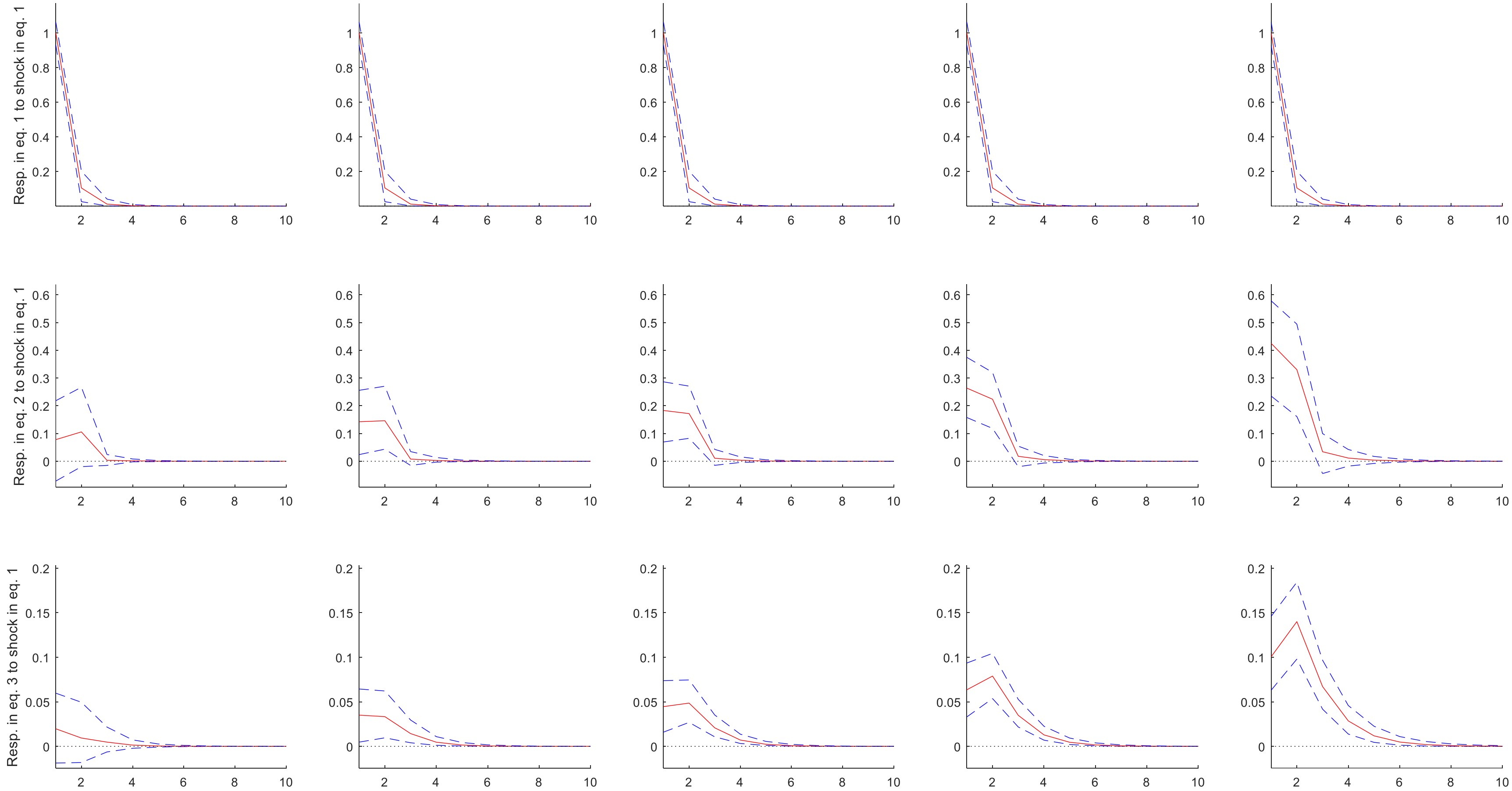
C.2. Current Expenditure - IMUPULSE RESPONSE FUNCTION



C.2. Current Expenditure - CUMULATIVE IMUPULSE RESPONSE FUNCTION



C.3. Capital Expenditure - IMUPULSE RESPONSE FUNCTION



C.3. Capital Expenditure - CUMULATIVE IMUPULSE RESPONSE FUNCTION