

Guns, Butter, and Growth: The Consequences of Military Spending Reconsidered Appendix

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This appendix is divided into four sections. The first includes information about the univariate series. The second section includes the parameter estimates of our primary vector autoregressive (VAR) model, granger causality tests, graphs of the impulse response functions (IRFs) for the effect of *Military Spending* on methods of government finance, and graphs of the forecast error variance decompositions (FEVDs) for the effect of *Military Spending* on methods of government finance. The third and fourth sections contain the same information for our robustness checks that account for U.S. involvement in an interstate war (based on data from Palmer et al. 2015) and security shocks (based on data from Ramey 2011).

1 Univariate Analysis: Descriptives and Diagnostics

Before engaging in multivariate analysis with the Vector Autoregression (VAR), we conducted basic analysis of the univariate series to understand their underlying dynamic processes. Figure 1 plots each of the univariate time series in their levels. Each series contains a strong trend, suggesting that the series are non-stationary. A stationary series is one in which stochastic shocks to the system decay over time, rather than being permanently integrated into the series. Importantly, stationary series have a constant mean and variance (Box-Steffensmeier et al. 2014, Enders 2004). The series in Figure 1 clearly do not have a constant mean and, therefore, are non-stationary.

The lack of stationarity in the level univariate series is confirmed by analyzing the autocorrelation functions, partial autocorrelation functions, and dickey fuller for unit roots tests. The

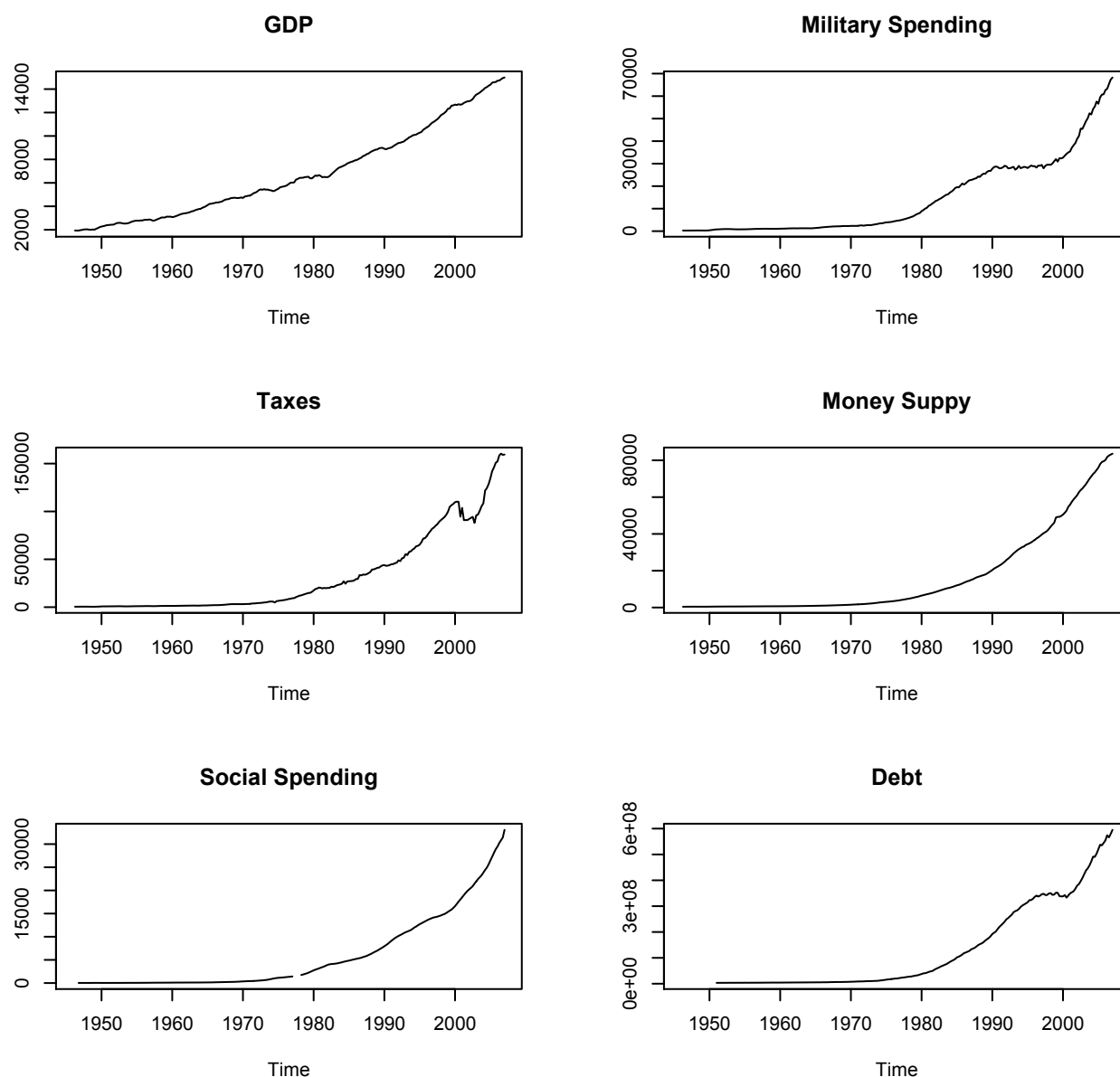


Figure 1: Univariate Times Series in Levels 1946-2007, Constant Dollars

auto-correlation functions for each series showed strong and highly persistent correlation across lags, the tell-tale sign of a non-stationary series. The first column in Table 1 reports the test statistic for each of the Dickey-Fuller tests. All the tests on the level series indicate that we cannot reject the null that the series contains an unit root.

Typically, but not always, researchers conducting time series analysis analyze stationary series

Table 1: Dickey-Fuller Tests for Unit Root on Univariate Series in Levels and Growth Rate

	Levels	Growth Rates
	Z(t)	Z(t)
Military Spending	9.66	-5.65* * *
Social Spending	3.81	-6.44* * *
Money Supply	6.37	-2.91**
Taxes	5.42	-7.40* * *
Debt	5.72	-6.35* * *
GDP	3.68	-8.19* * *

* ≤ 0.10 , ** ≤ 0.05 , *** ≤ 0.01

in order to limit spurious results and have their data adhere to underlying modeling assumptions. There is some debate about whether series need to be stationary to use a VAR model. The argument is that transforming non-stationary series into stationary series throws away information about the variables that could be modeled in the VAR (Enders 2004). We chose to take a more conservative route and model the series as growth rates instead of levels. Looking at growth rates provide us with a more equivalent data generating process across the different series. However, modeling all the series as growth rates makes it harder for us to find significant relationships because the process of transforming the series removes parts of the series' data generating processes that could be shared across the series in the VAR.

Figure 2 illustrates each of the univariate series model as growth rates. The growth rate specification of the series all have a fairly constant mean. This suggests the series are mean stationary. The variance is larger at the start of both the military spending and social spending series and the variance slightly fluctuates in the taxes series. Overall, though, the series are fairly constant, indicating that the series are variance stationary as well. The stationary nature of the series is confirmed with auto-correlation functions, partial auto-correlation functions, and dickey fuller tests. The dickey fuller tests for the growth rates of the series are reported in the second column of Table 1. Importantly, we are able to reject the null that the series contain a unit root for each of the series specified when they are specified as growth rates .

Fundamental changes in the data generating process, or a structural break, could be a source of non-stationarity in the levels specification of the series. Our decision to model the series in growth rates versus the levels removes this concern. The stationary nature of the growth rate series suggests that they do not contain structural breaks. We additionally tested for structural breaks in the growth-rate specification of each series using two different approaches. First, we tested for the possibility of structural breaks in each series around specific events: (1) the move away from the gold standard in the first quarter of 1971, (2) the end of the Cold War in the fourth quarter of 1991, and (3) September 11th in the third quarter of 2001. Second, we looked for unknown structural breaks in the data. Searching for unknown structural breaks should be done with caution due to the likelihood of committing Type I errors due to the weak power of the structural break tests. Using these two approaches, we did not find consistent evidence of structural breaks in the data.

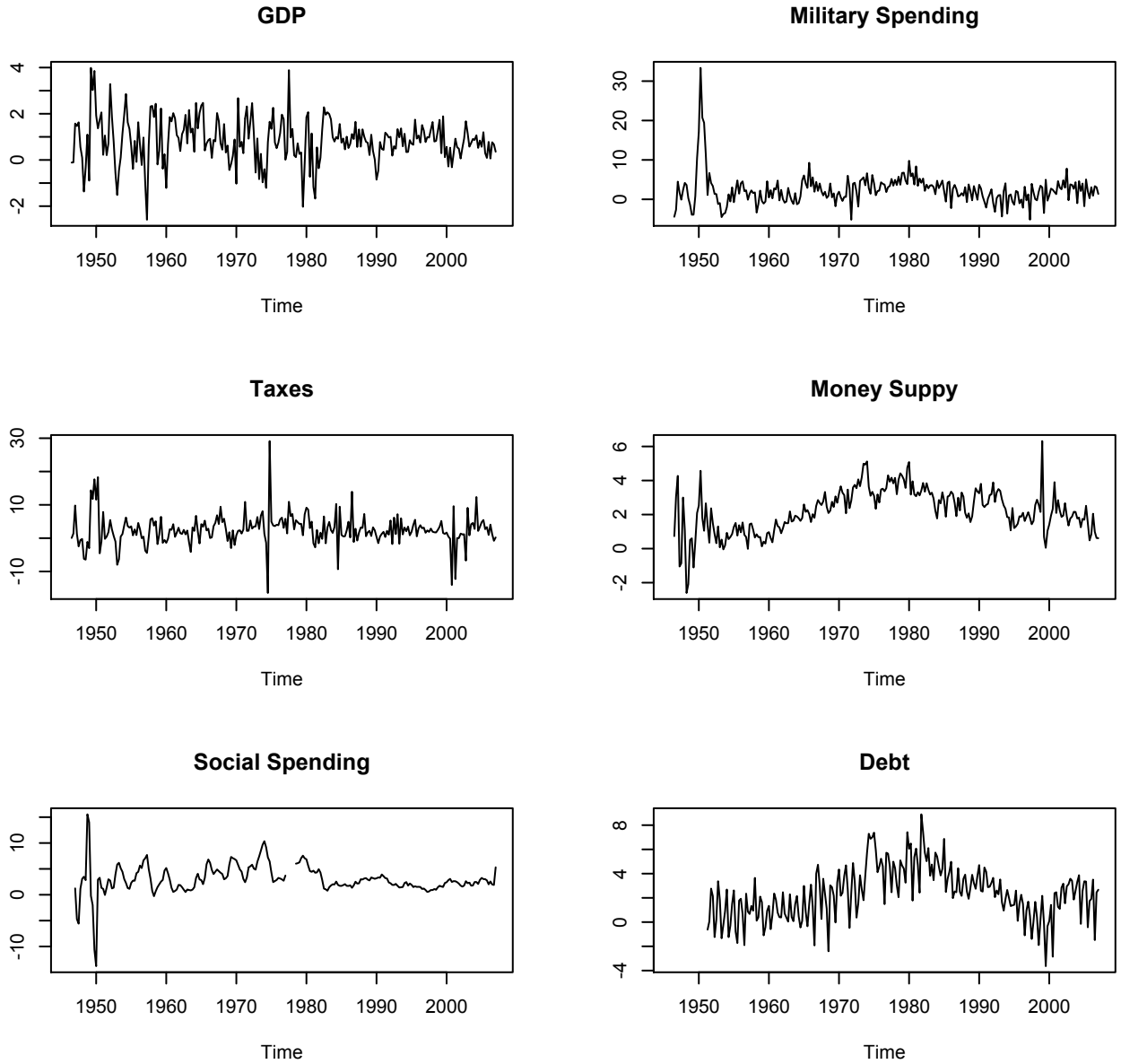


Figure 2: Univariate Time Series in Growth Rates 1946-2007, Constant Dollars

2 Primary Model

The large number of lags associated with each variable in our system of equations renders meaningless the individual coefficients, and associated statistical significance, among any of the potentially endogenous relationships in the model (Enders 2004). Instead, we assess the relation-

ships among our variables using Granger causality tests that jointly determine whether the lags for the endogenous variables are equal to zero using Wald tests.¹ Table 3 reports the results of our Granger causality tests.

Starting with the first block of variables, there is not a direct relationship between military spending and the other variables. However, this does not mean that military spending does not have an indirect influence on the other variables in the equation. The second block of variable indicate that the growth rate in social spending Granger causes changes in the growth rates of the other variables included in the VAR. We find evidence that the growth rate in social spending Granger causes changes in the growth rates of taxes, debt, and GDP. Looking at the third block of variables, there is not evidence of a direct effect of the growth rate in money supply on any of the other variables in the VAR. The fourth block of variables indicate changes in the growth rate Granger cause changes in the growth rates of all the variables jointly, and specifically the growth rates of social spending and GDP. The fifth block of variables indicate that the growth rate in debt Granger causes changes in the growth rate of all the variables jointly. The growth rate of debt Granger causes changes in the growth rates of military spending, social spending, and taxes. The sixth block of variables shows the growth rate in GDP Granger causes changes in the growth rates of all the variables, jointly. Additionally, we see that the growth rate of GDP Granger causes changes in the growth rate of social spending.

Granger causality tests are limited in what they can tell us about the relationship among the variables in the VAR. As a result, we utilize impulse response functions (IRF) and forecast error variance decompositions (FEVD) to assess how changers in military spending influence the other variables in the VAR. These tools are much more effective at analyzing the results of a VAR than the Granger causality tests (Box-Steffensmeier et al. 2014, Enders 2004).

¹An alternative to the Granger causality test is to perform block F-tests to jointly test if the lags are different from zero. The Granger causality and block-F tests yield similar results.

Table 2: Primary Vector Autoregressive Model

	Military Spending	Social Spending	Money Supply	Taxes	Debt	GDP
L.Military Spending	0.048 (0.069)	0.025 (0.020)	0.017 (0.021)	-0.107 (0.121)	0.044 (0.033)	-0.022 (0.024)
L2.Military Spending	0.096 (0.068)	0.018 (0.020)	-0.006 (0.021)	-0.078 (0.121)	0.047 (0.033)	0.002 (0.023)
L3.Military Spending	0.171* (0.067)	0.020 (0.020)	-0.028 (0.021)	0.016 (0.119)	0.058 (0.033)	-0.042 (0.023)
L4.Military Spending	0.274*** (0.070)	0.011 (0.021)	-0.011 (0.022)	-0.064 (0.122)	0.035 (0.034)	-0.022 (0.024)
L.Social Spending	-0.160 (0.251)	1.277*** (0.075)	-0.012 (0.078)	-0.974* (0.442)	0.237 (0.121)	-0.411*** (0.086)
L2.Social Spending	0.121 (0.407)	-0.447*** (0.121)	0.096 (0.126)	0.983 (0.716)	-0.216 (0.196)	0.363** (0.139)
L3.Social Spending	0.073 (0.408)	-0.010 (0.121)	-0.046 (0.126)	0.337 (0.718)	0.055 (0.197)	0.073 (0.139)
L4.Social Spending	0.044 (0.239)	0.090 (0.071)	0.015 (0.074)	-0.121 (0.421)	0.122 (0.115)	-0.104 (0.082)
L.Money Supply	0.037 (0.236)	-0.077 (0.070)	0.458*** (0.073)	0.606 (0.416)	0.179 (0.114)	0.060 (0.081)
L2.Money Supply	0.310 (0.256)	0.104 (0.076)	0.185* (0.079)	-0.557 (0.452)	0.006 (0.124)	-0.045 (0.088)
L3.Money Supply	0.010 (0.256)	0.076 (0.076)	0.133 (0.079)	0.107 (0.450)	0.125 (0.123)	-0.053 (0.087)
L4.Money Supply	-0.055 (0.236)	0.003 (0.070)	0.060 (0.073)	0.322 (0.416)	-0.062 (0.114)	0.036 (0.081)
L.Taxes	0.063 (0.042)	-0.006 (0.012)	-0.010 (0.013)	-0.221** (0.074)	-0.064** (0.020)	0.011 (0.014)
L2.Taxes	0.001 (0.043)	0.012 (0.013)	-0.008 (0.013)	0.114 (0.076)	-0.063** (0.021)	0.001 (0.015)
L3.Taxes	0.018 (0.043)	0.014 (0.013)	0.006 (0.013)	0.019 (0.075)	-0.031 (0.021)	-0.027 (0.015)
L4.Taxes	0.004 (0.042)	-0.008 (0.012)	-0.008 (0.013)	0.048 (0.074)	-0.010 (0.020)	-0.011 (0.014)
L.Debt	0.041 (0.104)	-0.063* (0.031)	0.009 (0.032)	0.174 (0.184)	0.032 (0.050)	0.037 (0.036)
L2.Debt	-0.082 (0.102)	-0.098** (0.030)	-0.019 (0.032)	0.027 (0.179)	-0.074 (0.049)	0.066 (0.035)
L3.Debt	0.073 (0.105)	0.003 (0.031)	-0.008 (0.033)	-0.011 (0.185)	0.045 (0.051)	-0.042 (0.036)
L4.Debt	-0.154 (0.102)	0.033 (0.030)	0.064* (0.032)	0.135 (0.180)	0.695*** (0.049)	0.011 (0.035)
L.GDP	-0.263 (0.214)	-0.061 (0.064)	-0.017 (0.066)	0.996** (0.377)	0.131 (0.103)	0.169* (0.073)
L2.GDP	0.030 (0.216)	-0.058 (0.064)	-0.001 (0.067)	-0.001 (0.381)	-0.155 (0.104)	0.089 (0.074)
L3.GDP	0.042 (0.214)	0.163* (0.063)	0.047 (0.066)	0.204 (0.376)	-0.022 (0.103)	-0.013 (0.073)
L4.GDP	0.273 (0.215)	0.099 (0.064)	0.038 (0.067)	0.201 (0.378)	-0.114 (0.104)	0.028 (0.073)
Constant	-0.181 (0.599)	0.048 (0.178)	0.133 (0.186)	-0.844 (1.056)	-0.309 (0.289)	0.893*** (0.205)
Observations	211					
Log-Likelihood	-1951.669					

Table 3: Granger Causality Test: Primary Vector Autoregressive Model

Military Spending	<i>Granger Cause</i>	Social Spending	0.787
Military Spending	<i>Granger Cause</i>	Money Supply	0.557
Military Spending	<i>Granger Cause</i>	Taxes	0.583
Military Spending	<i>Granger Cause</i>	Debt	0.600
Military Spending	<i>Granger Cause</i>	GPD	0.527
Military Spending	<i>Granger Cause</i>	ALL	0.891
Social Spending	<i>Granger Cause</i>	Military Spending	0.212
Social Spending	<i>Granger Cause</i>	Money Supply	0.226
Social Spending	<i>Granger Cause</i>	Taxes	0.605
Social Spending	<i>Granger Cause</i>	Debt	0.000
Social Spending	<i>Granger Cause</i>	GPD	0.024
Social Spending	<i>Granger Cause</i>	ALL	0.000
Money Supply	<i>Granger Cause</i>	Military Spending	0.619
Money Supply	<i>Granger Cause</i>	Social Spending	0.584
Money Supply	<i>Granger Cause</i>	Taxes	0.769
Money Supply	<i>Granger Cause</i>	Debt	0.242
Money Supply	<i>Granger Cause</i>	GPD	0.908
Money Supply	<i>Granger Cause</i>	ALL	0.913
Taxes	<i>Granger Cause</i>	Military Spending	0.703
Taxes	<i>Granger Cause</i>	Social Spending	0.039
Taxes	<i>Granger Cause</i>	Money Supply	0.412
Taxes	<i>Granger Cause</i>	Debt	0.662
Taxes	<i>Granger Cause</i>	GPD	0.088
Taxes	<i>Granger Cause</i>	ALL	0.006
Debt	<i>Granger Cause</i>	Military Spending	0.009
Debt	<i>Granger Cause</i>	Social Spending	0.005
Debt	<i>Granger Cause</i>	Money Supply	0.114
Debt	<i>Granger Cause</i>	Taxes	0.001
Debt	<i>Granger Cause</i>	GPD	0.306
Debt	<i>Granger Cause</i>	ALL	0.000
GPD	<i>Granger Cause</i>	Military Spending	0.124
GPD	<i>Granger Cause</i>	Social Spending	0.000
GPD	<i>Granger Cause</i>	Money Supply	0.898
GPD	<i>Granger Cause</i>	Taxes	0.421
GPD	<i>Granger Cause</i>	Debt	0.135
GPD	<i>Granger Cause</i>	ALL	0.000

2.1 Impulse Response Functions

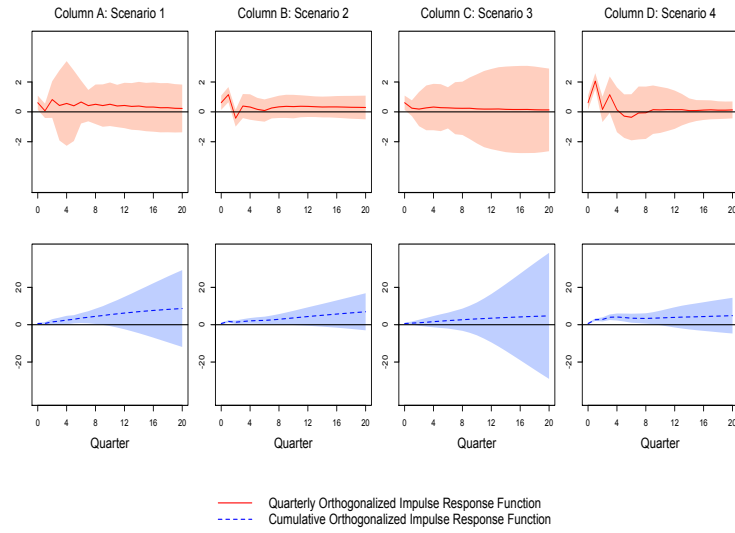


Figure 3: Effect of Increasing Military Spending on Tax Revenue

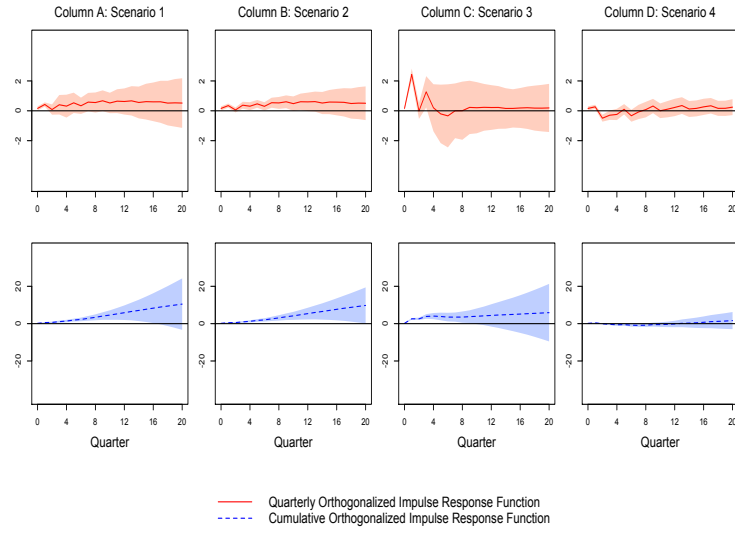


Figure 4: Effect of Increasing Military Spending on Debt

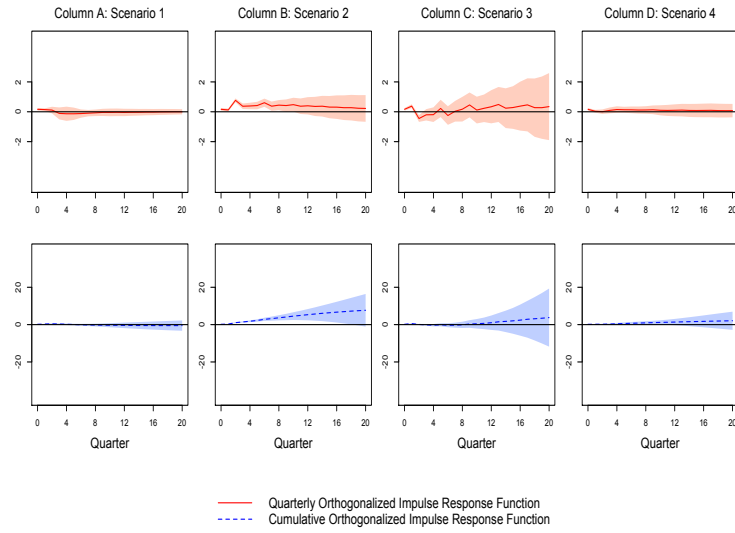


Figure 5: Effect of Increasing Military Spending on Money Supply

2.2 Forecast Error Variance Decompositions

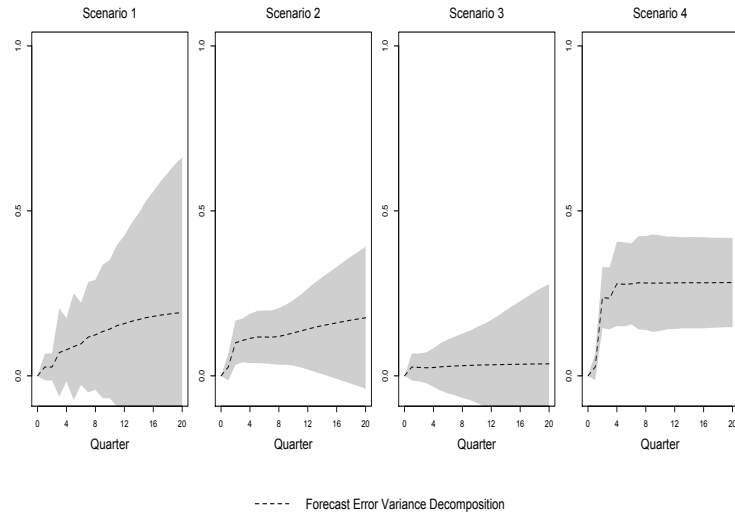


Figure 6: Variance in Tax Revenue Explained by an Increase in Military Spending

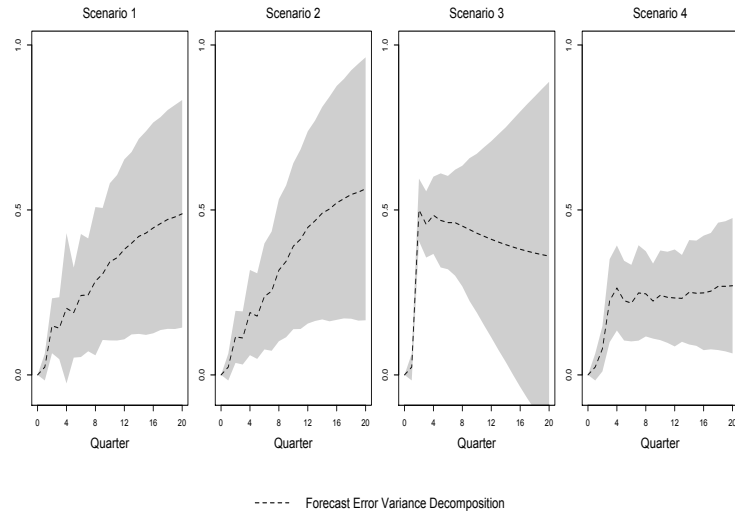


Figure 7: Variance in Debt Explained by an Increase in Military Spending

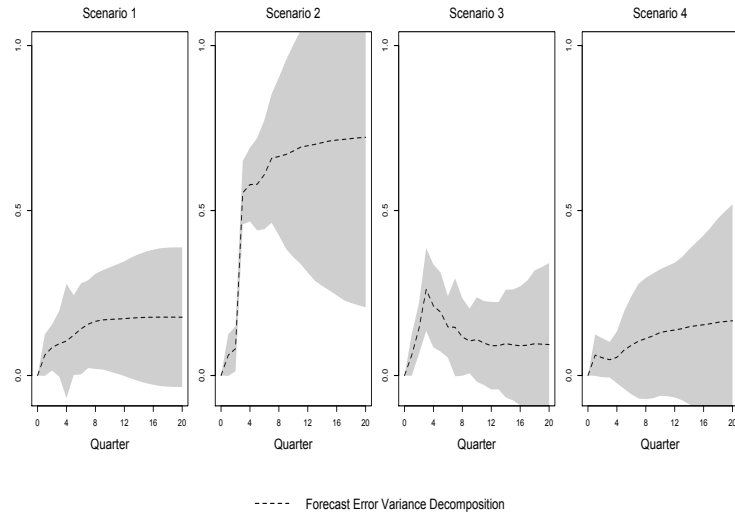


Figure 8: Variance in Money Supply Explained by an Increase in Military Spending

3 Interstate War Model

3.1 Model

Table 4: Vector Autoregressive Model Accounting for Interstate War Involvement

	Military Spending	Social Spending	Money Supply	Taxes	Debt	GDP
L.Military Spending	0.048 (0.069)	0.025 (0.020)	0.018 (0.021)	-0.107 (0.121)	0.043 (0.033)	-0.022 (0.023)
L2.Military Spending	0.095 (0.069)	0.018 (0.020)	-0.007 (0.021)	-0.073 (0.120)	0.049 (0.033)	0.001 (0.023)
L3.Military Spending	0.168* (0.068)	0.021 (0.020)	-0.034 (0.021)	0.032 (0.119)	0.063 (0.033)	-0.046* (0.023)
L4.Military Spending	0.271*** (0.070)	0.013 (0.021)	-0.017 (0.022)	-0.048 (0.123)	0.041 (0.034)	-0.027 (0.024)
L.Social Spending	-0.155 (0.252)	1.274*** (0.075)	-0.000 (0.077)	-1.007* (0.443)	0.225 (0.121)	-0.402*** (0.086)
L2.Social Spending	0.112 (0.408)	-0.442*** (0.121)	0.075 (0.125)	1.041 (0.717)	-0.195 (0.196)	0.348* (0.139)
L3.Social Spending	0.076 (0.408)	-0.012 (0.121)	-0.038 (0.125)	0.315 (0.717)	0.047 (0.196)	0.079 (0.139)
L4.Social Spending	0.041 (0.239)	0.092 (0.071)	0.009 (0.073)	-0.103 (0.420)	0.128 (0.115)	-0.108 (0.081)
L.Money Supply	0.024 (0.241)	-0.070 (0.071)	0.429*** (0.074)	0.687 (0.423)	0.208 (0.116)	0.039 (0.082)
L2.Money Supply	0.302 (0.258)	0.108 (0.077)	0.168* (0.079)	-0.508 (0.453)	0.024 (0.124)	-0.057 (0.088)
L3.Money Supply	0.003 (0.257)	0.080 (0.076)	0.119 (0.079)	0.147 (0.451)	0.139 (0.123)	-0.064 (0.087)
L4.Money Supply	-0.064 (0.238)	0.008 (0.071)	0.041 (0.073)	0.376 (0.419)	-0.042 (0.115)	0.022 (0.081)
L.Taxes	0.064 (0.042)	-0.006 (0.012)	-0.007 (0.013)	-0.227** (0.074)	-0.066** (0.020)	0.013 (0.014)
L2.Taxes	0.003 (0.044)	0.011 (0.013)	-0.004 (0.013)	0.103 (0.077)	-0.067** (0.021)	0.004 (0.015)
L3.Taxes	0.020 (0.044)	0.013 (0.013)	0.011 (0.013)	0.005 (0.076)	-0.036 (0.021)	-0.023 (0.015)
L4.Taxes	0.006 (0.042)	-0.009 (0.013)	-0.004 (0.013)	0.037 (0.074)	-0.014 (0.020)	-0.008 (0.014)
L.Debt	0.049 (0.108)	-0.067* (0.032)	0.027 (0.033)	0.126 (0.190)	0.015 (0.052)	0.049 (0.037)
L2.Debt	-0.075 (0.105)	-0.102** (0.031)	-0.003 (0.032)	-0.019 (0.185)	-0.090 (0.051)	0.077* (0.036)
L3.Debt	0.080 (0.109)	-0.001 (0.032)	0.009 (0.033)	-0.060 (0.191)	0.027 (0.052)	-0.030 (0.037)
L4.Debt	-0.148 (0.105)	0.030 (0.031)	0.078* (0.032)	0.096 (0.184)	0.682*** (0.050)	0.021 (0.036)
L.GDP	-0.271 (0.216)	-0.056 (0.064)	-0.035 (0.066)	1.047** (0.380)	0.149 (0.104)	0.156* (0.074)
L2.GDP	0.021 (0.219)	-0.053 (0.065)	-0.022 (0.067)	0.059 (0.384)	-0.133 (0.105)	0.074 (0.074)
L3.GDP	0.034 (0.216)	0.167** (0.064)	0.029 (0.066)	0.256 (0.379)	-0.004 (0.104)	-0.027 (0.073)
L4.GDP	0.267 (0.216)	0.103 (0.064)	0.023 (0.066)	0.243 (0.380)	-0.099 (0.104)	0.017 (0.074)
Interstate War	0.116 (0.421)	-0.063 (0.125)	0.263* (0.129)	-0.738 (0.740)	-0.263 (0.202)	0.189 (0.143)
Constant	-0.171 (0.600)	0.042 (0.178)	0.156 (0.184)	-0.908 (1.055)	-0.332 (0.289)	0.909*** (0.204)
Observations	211					
Log-Likelihood	-1945.345					

3.2 Impulse Response Functions

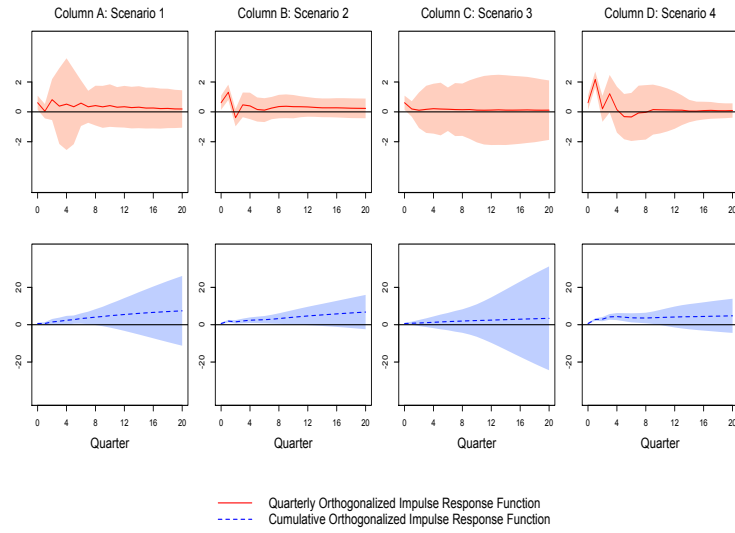


Figure 9: Effect of Increasing Military Spending on Tax Revenue

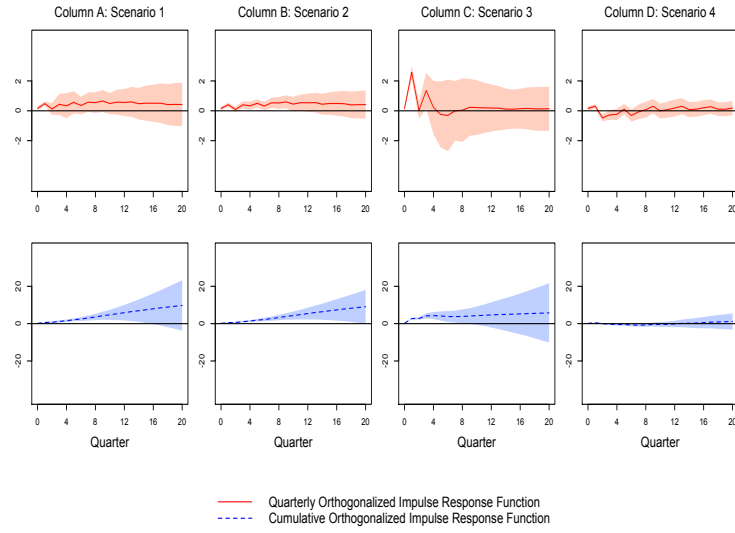


Figure 10: Effect of Increasing Military Spending on Debt

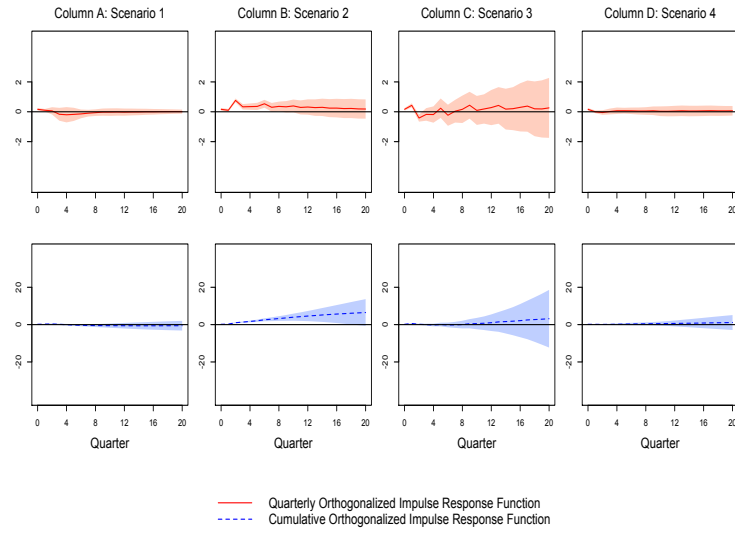


Figure 11: Effect of Increasing Military Spending on Money Supply

3.3 Forecast Error Variance Decompositions

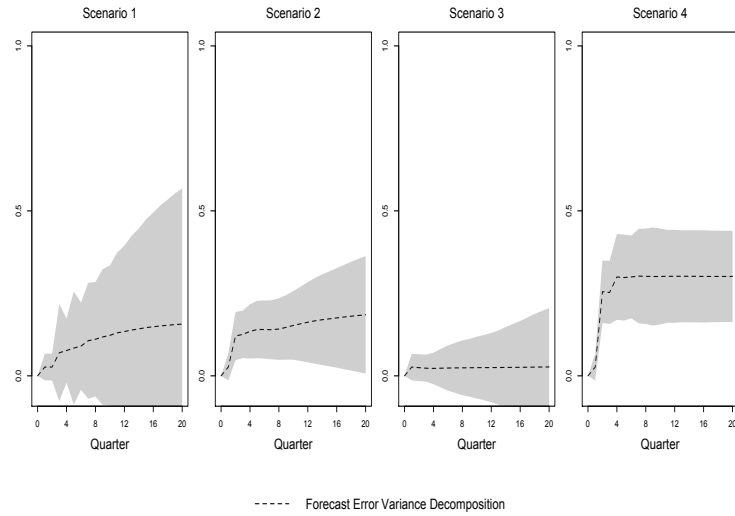


Figure 12: Variance in Tax Revenue Explained by an Increase in Military Spending

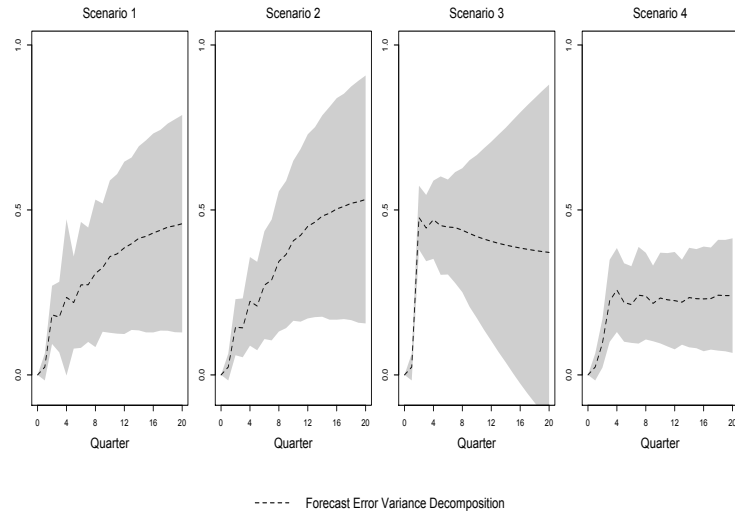


Figure 13: Variance in Debt Explained by an Increase in Military Spending

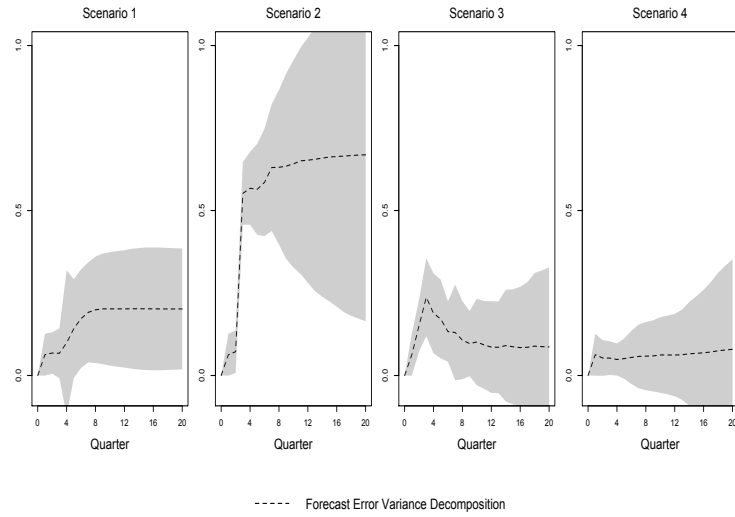


Figure 14: Variance in Money Supply Explained by an Increase in Military Spending

4 Security Shocks Model

4.1 Model

Table 5: Vector Autoregressive Model Accounting for Security Shock

	Military Spending	Social Spending	Money Supply	Taxes	Debt	GDP
L.Military Spending	0.048 (0.069)	0.025 (0.020)	0.018 (0.021)	-0.110 (0.121)	0.045 (0.033)	-0.022 (0.024)
L2.Military Spending	0.097 (0.069)	0.016 (0.020)	-0.009 (0.021)	-0.062 (0.120)	0.043 (0.033)	0.002 (0.023)
L3.Military Spending	0.170* (0.067)	0.020 (0.020)	-0.027 (0.021)	0.012 (0.118)	0.059 (0.032)	-0.042 (0.023)
L4.Military Spending	0.273*** (0.070)	0.012 (0.021)	-0.009 (0.021)	-0.071 (0.122)	0.037 (0.033)	-0.022 (0.024)
L.Social Spending	-0.160 (0.251)	1.276*** (0.074)	-0.013 (0.077)	-0.971* (0.439)	0.236* (0.120)	-0.411*** (0.086)
L2.Social Spending	0.119 (0.407)	-0.445*** (0.121)	0.100 (0.125)	0.963 (0.712)	-0.210 (0.195)	0.364** (0.139)
L3.Social Spending	0.071 (0.408)	-0.009 (0.121)	-0.042 (0.125)	0.319 (0.714)	0.060 (0.196)	0.074 (0.139)
L4.Social Spending	0.046 (0.239)	0.088 (0.071)	0.010 (0.073)	-0.099 (0.418)	0.116 (0.115)	-0.105 (0.082)
L.Money Supply	0.040 (0.237)	-0.081 (0.070)	0.446*** (0.073)	0.655 (0.414)	0.166 (0.114)	0.058 (0.081)
L2.Money Supply	0.311 (0.256)	0.103 (0.076)	0.184* (0.079)	-0.551 (0.449)	0.005 (0.123)	-0.045 (0.088)
L3.Money Supply	0.011 (0.256)	0.076 (0.076)	0.131 (0.078)	0.116 (0.447)	0.122 (0.123)	-0.054 (0.087)
L4.Money Supply	-0.057 (0.236)	0.005 (0.070)	0.066 (0.072)	0.298 (0.414)	-0.055 (0.113)	0.037 (0.081)
L.Taxes	0.063 (0.042)	-0.006 (0.012)	-0.010 (0.013)	-0.218** (0.073)	-0.065** (0.020)	0.011 (0.014)
L2.Taxes	0.001 (0.043)	0.012 (0.013)	-0.008 (0.013)	0.113 (0.076)	-0.063** (0.021)	0.001 (0.015)
L3.Taxes	0.017 (0.043)	0.015 (0.013)	0.009 (0.013)	0.007 (0.075)	-0.028 (0.021)	-0.026 (0.015)
L4.Taxes	0.003 (0.042)	-0.007 (0.012)	-0.006 (0.013)	0.040 (0.073)	-0.008 (0.020)	-0.010 (0.014)
L.Debt	0.038 (0.105)	-0.060 (0.031)	0.018 (0.032)	0.137 (0.184)	0.042 (0.050)	0.039 (0.036)
L2.Debt	-0.081 (0.102)	-0.099** (0.030)	-0.022 (0.031)	0.041 (0.178)	-0.078 (0.049)	0.065 (0.035)
L3.Debt	0.072 (0.105)	0.004 (0.031)	-0.005 (0.032)	-0.027 (0.184)	0.049 (0.051)	-0.042 (0.036)
L4.Debt	-0.154 (0.102)	0.033 (0.030)	0.064* (0.031)	0.135 (0.179)	0.695*** (0.049)	0.011 (0.035)
L.GDP	-0.266 (0.215)	-0.057 (0.064)	-0.008 (0.066)	0.960* (0.375)	0.141 (0.103)	0.171* (0.073)
L2.GDP	0.028 (0.216)	-0.056 (0.064)	0.006 (0.066)	-0.032 (0.379)	-0.146 (0.104)	0.091 (0.074)
L3.GDP	0.044 (0.214)	0.161* (0.063)	0.043 (0.066)	0.221 (0.374)	-0.027 (0.103)	-0.014 (0.073)
L4.GDP	0.275 (0.215)	0.097 (0.064)	0.034 (0.066)	0.219 (0.376)	-0.119 (0.103)	0.027 (0.073)
Security Shock	-0.351 (1.565)	0.394 (0.464)	1.049* (0.479)	-4.551 (2.738)	1.217 (0.751)	0.199 (0.534)
Constant	-0.170 (0.602)	0.034 (0.178)	0.098 (0.184)	-0.693 (1.053)	-0.349 (0.289)	0.886*** (0.206)
Observations	211					
Log-Likelihood	-1945.922					

4.2 Impulse Response Functions

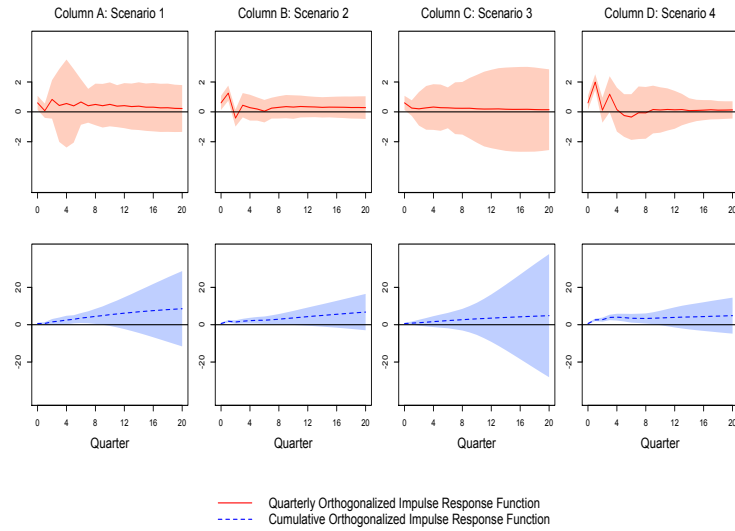


Figure 15: Effect of Increasing Military Spending on Tax Revenue

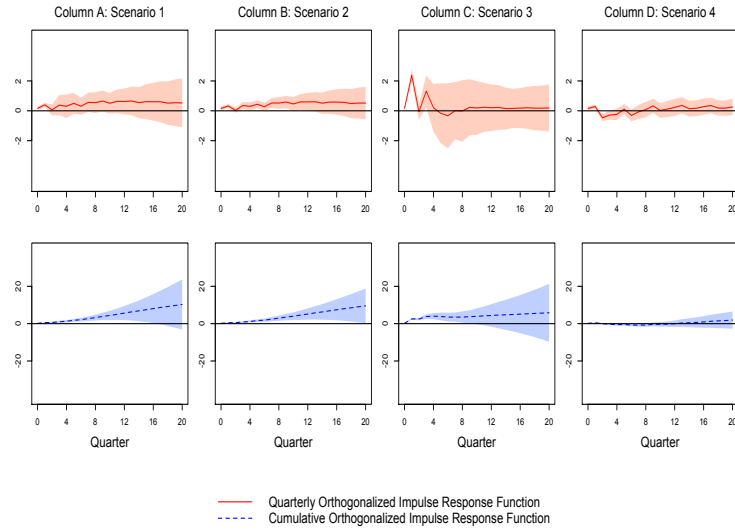


Figure 16: Effect of Increasing Military Spending on Debt

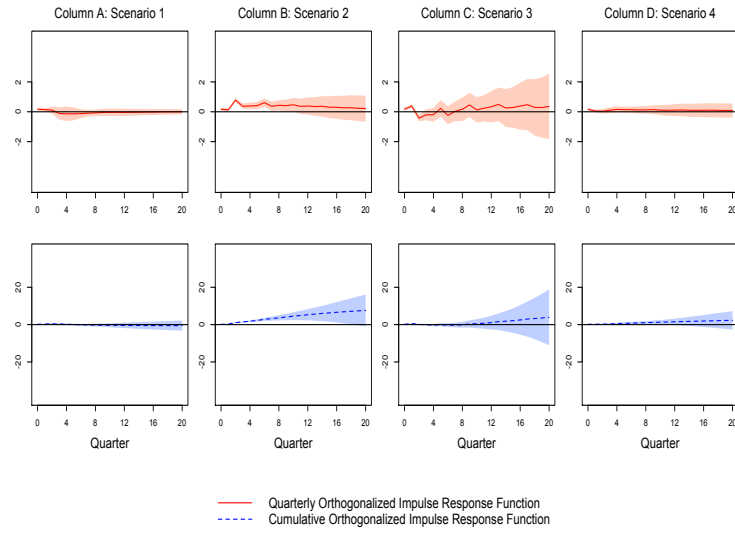


Figure 17: Effect of Increasing Military Spending on Money Supply

4.3 Forecast Error Variance Decompositions

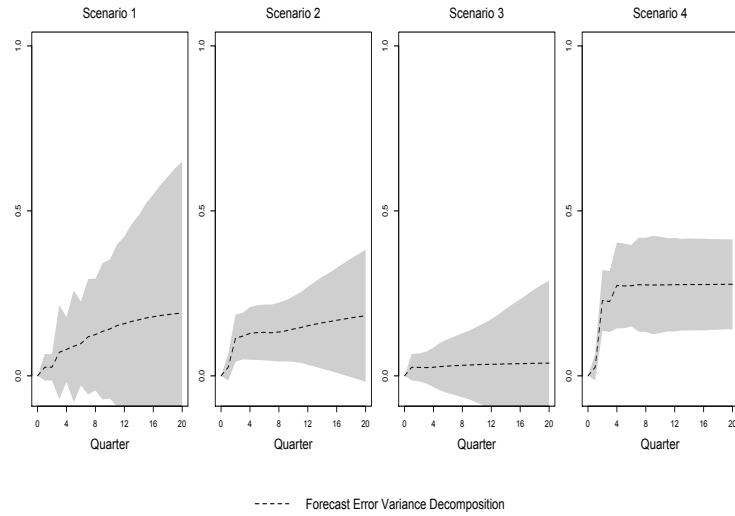


Figure 18: Variance in Tax Revenue Explained by an Increase in Military Spending

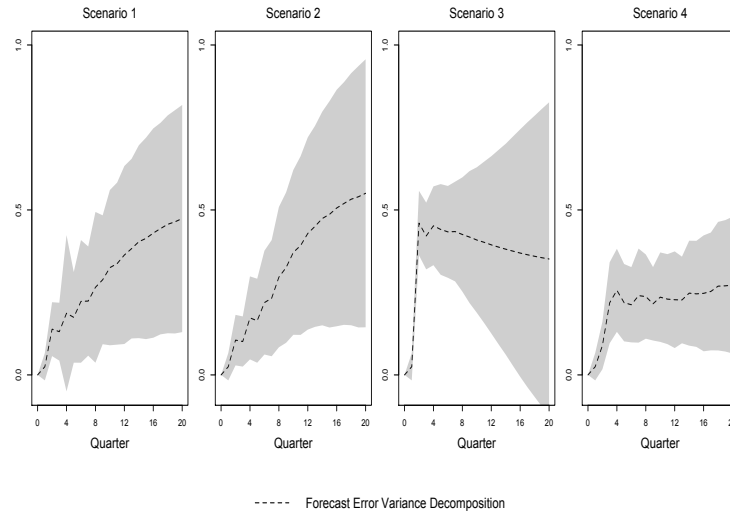


Figure 19: Variance in Debt Explained by an Increase in Military Spending

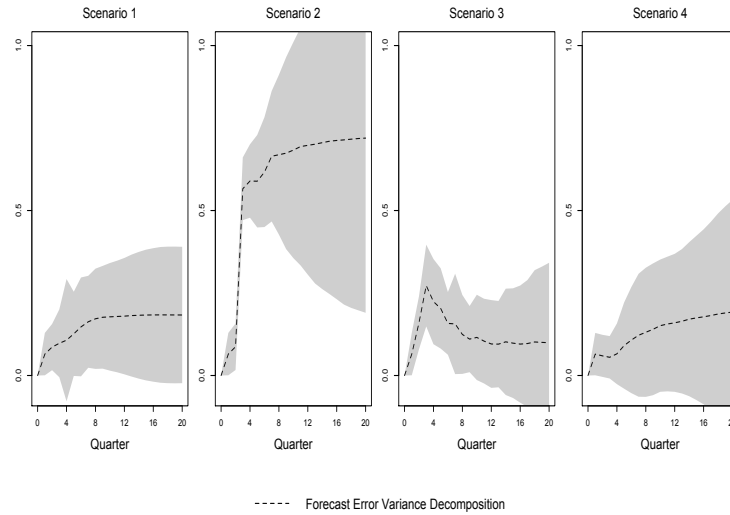


Figure 20: Variance in Money Supply Explained by an Increase in Military Spending

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