# Estimating the effects of fiscal policy in Structural VAR models

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# SVARs

Structural vector autoregression (SVARs) can be used to address the following type of questions:

- How does the economy respond to different economic shocks?
  - Monetary policy shocks: Sims (1980), Bernanke (1986), Christiano, Eichenbaum, and Evans (1999), Uhlig (2005), etc. etc...
  - Oil price shocks: Hamilton (1983, 1996, 2003, 2009), Kilian (2009) ...
  - **Fiscal policy shocks**: Blanchard and Perotti (2002), Mountford and Uhlig (2009), Romer and Romer (2010), Mertens and Ravn (2011)...
- What is the contribution of the different shocks to the business cycle?
  - Blanchard and Watson (1986), King et al. (1991), Blanchard and Quah (1999), Gali (1999), Chari, Kehoe and McGrattan (2005),...

# VAR-VMA

Structural VAR analysis starts off by estimating a *reduced* form VAR model of order $p$

$$y_t = \mu + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + e_t \tag{1}$$

where $y_t$ is a $(K \times 1)$ vector of variables, $A$ is a $(K \times K)$ coefficient matrix, $\mu$ denotes a $(K \times 1)$ vector of intercept terms and $e_t$ is a $(K \times 1)$ dimension vector of white noise that are serially uncorrelated but may be mutually correlated.

Taking the $y$'s to the left hand side and using the lag operators, we can write:

$$(I - A_1 L - A_2 L^2 - \cdots - A_p L^p) y_t = \mu + e_t$$

or

$$A(L) y_t = \mu + e_t$$

Assuming $A(L)$ to be invertible, we can multiply with $A(L)^{-1}$ to get:

# VAR-VMA cont.

$$\begin{aligned} y_t = A(L)^{-1}\mu + A(L)^{-1}e_t &= B(L)\mu + B(L)e_t \\ &= v + e_t + B_1 e_{t-1} + B_2 e_{t-2} + \cdots \end{aligned} \tag{2}$$

where $B(L) = A(L)^{-1}$ (such that $B(L)A(L) = I$) and $v = B(L)\mu$.

- The error terms can be interpreted as the one-step ahead forecast errors.
- Note, however, that the error can be correlated and can not be interpreted as structural shocks.

# Choleski decomposition

Assume the reduced form MA representation in (2), $y_t = v + B(L)e_t$ where $e_t$ is a white noise process with covariance matrix $\Sigma$.

Assume the positive definite symmetric matrix can be written as the product $\Sigma = PP'$, where $P$ is a lower triangular matrix with positive diagonal elements (and zero above the diagonal). This decomposition is called the **Choleski decomposition**. Using this, (2) can be rewritten as:

$$y_t = v + B(L)PP^{-1}e_t = v + \Theta(L)\epsilon_t \tag{3}$$

where $\Theta_i = B_i P$ and $\epsilon_t = P^{-1}e_t$ so that:

$E(\epsilon_t \epsilon_t') = P^{-1}E(e_t e_t')(P^{-1})' = P^{-1}(PP')(P^{-1})' = I$ (unit variance).

Given that $P$ is a lower triangular matrix, the components of $\epsilon_t$ will be uncorrelated (although the components of $e_t$ may not).

# Fiscal policy in SVAR

- Blanchard and Perotti (2002)
  - Assume a three variable system with quarterly data of log GDP $(X_t)$, Government spending $(G_t)$ and tax revenue $(T_t)$.
  - Assume a recursive structural relationship (Choleski) between the variables and some shocks which can be written as:

$$\begin{bmatrix} T_t \\ G_t \\ X_t \end{bmatrix} = \begin{bmatrix} \theta_{11,0} & 0 & 0 \\ \theta_{21,0} & \theta_{22,0} & 0 \\ \theta_{31,0} & \theta_{32,0} & \theta_{33,0} \end{bmatrix} \begin{bmatrix} \varepsilon_{T,t} \\ \varepsilon_{G,t} \\ \varepsilon_{X,t} \end{bmatrix} + \Theta_1 \varepsilon_{t-1} + \cdots$$ where $\varepsilon_{T,t}$ is a shock to tax revenues, $\varepsilon_{G,t}$ is a government spending shock and $\varepsilon_{X,t}$ is a shock to output.

# Fiscal policy in SVAR cont.

We can write out the system as follows:

$$
\begin{aligned}
T_t &= \theta_{11,0}\varepsilon_{T,t} + \cdots \text{lags} \\
G_t &= \theta_{21,0}\varepsilon_{T,t} + \theta_{22,0}\varepsilon_{G,t} + \cdots \text{lags} \\
X_t &= \theta_{31,0}\varepsilon_{T,t} + \theta_{32,0}\varepsilon_{G,t} + \theta_{33,0}\varepsilon_{X,t} + \cdots \text{lags}
\end{aligned}
$$

- When the variables are ordered recursively $(T, G, X)$, as above we see that:
    - **It takes more than a quarter for policymakers to implement discretionary fiscal responses to unexpected shocks in GDP**
    - Eliminates systematic discret. responses in fiscal variables to unexpected output shocks.
    - All shocks can affect output contemporaneously.
- Opposite to MP shocks... it takes a period (quarter) before (unsystematic) monetary policy affect GDP. Interest rate, (systematic monetary policy) is affected by all shocks immediately

# Some SVAR studies

In the literature, three main types of identification strategies have been employed: The Blanchard and Perotti (2002) (recursive) approach (BP), sign restrictions (S), and narrative identification (N).

- Blanchard and Perotti (2002) and Perotti (2005)
  - $G \uparrow \Rightarrow X \uparrow > 1$ only for the US in the pre-1980 period, no evidence that tax cuts work faster or more effectively than spending increases.
  - Effects of government spending shocks and tax cuts on GDP and its components have become substantially weaker over time.
- Ilzetzkia, Mendozab, Veghc (2013)
  - Show that the impact of government expenditure shocks depends crucially on key country characteristics, such as the level of development, exchange rate regime, openness to trade, and public indebtedness.
  - Based on a dataset of government expenditure in 44 countries, find (i) the output effect of an increase in government consumption is larger in industrial than in developing countries; (ii) the fiscal multiplier is relatively large in economies operating under predetermined exchange rates but is zero in economies operating under flexible exchange rates; (iii) fiscal multipliers in open economies are smaller than in closed economies.

# Effect of fiscal policy

## Ilzetzki et al (2013)

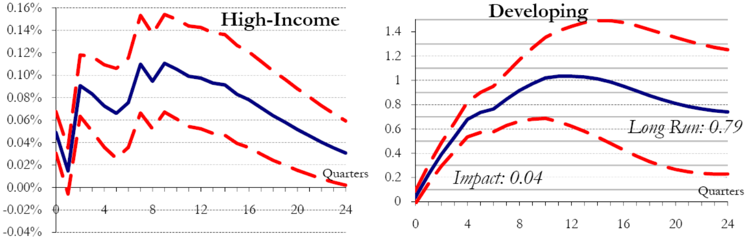
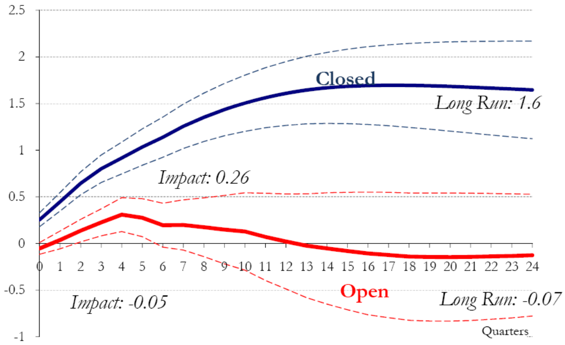



Figure 1: Output Response to a 1% shock to government consumption

# Effect of fiscal policy

Cumulative multipliers: Open and closed economies




Source: Ilzetzki et al (2013)

# Some SVAR studies cont.

- Mertens and Ravn (2012)
  - Policy may affect the economy prior to their actual implementation.
  - Distinguish between surprise and anticipated tax changes using a timing-convention.
  - Pre-announced but not yet implemented tax cuts give rise to contractions in output, investment and hours worked while real wages increase. In contrast, there are no significant anticipation effects on aggregate consumption.
  - Implemented tax cuts, regardless of their timing, have expansionary and persistent effects on output, consumption, investment, hours worked and real wages. Results are shown to be very robust.
  - Argue that tax shocks are empirically important impulses to the U.S. business cycle and that anticipation effects have been important during several business cycle episodes.

# Some SVAR studies cont.

- Canova and Pappa (2011)
  - Results generally stress that fiscal policy could be an effective countercyclical tool and that the output multipliers it generates may be significantly larger than 1.
  - For this to happen, monetary policy should facilitate fiscal expansion; expectations about future output growth and inflation should not be affected; and structural relationships, such as the sensitivity of consumption to output or the real interest rate, should be invariant to the policy change.

# Some SVAR studies cont.

- Mountford and Uhlig (2009)
  - Use sign restrictions to identify a government revenue shock as well as a government spending shock, while controlling for a generic business cycle shock and a monetary policy shock.
  - Allow for the possibility of announcement effects, i.e., that a current fiscal policy shock changes fiscal policy variables in the future, but not at present.
  - Construct the impulse responses to three linear combinations of these fiscal shocks, corresponding to the three scenarios of deficit-spending, deficit-financed tax cuts and a balanced budget spending expansion. Apply the method to US quarterly data from 1955-2000.
  - Deficit-financed tax cuts work best among these three scenarios to improve GDP.

# Some SVAR studies cont.

- Auerbach and Gorodnichenko (2012)
  - Using regime-switching models
  - Find large differences in the size of spending multipliers in recessions and expansions with fiscal policy being considerably more effective in recessions than in expansions.
  - Estimate multipliers for more disaggregate spending variables which behave differently relative to aggregate fiscal policy shocks, with military spending having the largest multiplier.
  - Controlling for predictable components of fiscal shocks tends to increase the size of the multipliers in recessions.

# Some event studies

- Romer and Romer (2010) Single equation estimation and VAR estimation. Event study. US data, narrative record. The baseline specification implies that an exogenous tax increase of one percent of GDP lowers real GDP by almost three percent.
- Ramey (2011) VAR estimation, US data - narrative record. The implied government spending multipliers range from 0.6 to 1.2.
- Alesina and Ardagna (2009). Event study and single equation estimation. Examine the evidence on episodes of large stances in fiscal policy, both in cases of fiscal stimuli and in that of fiscal adjustments in OECD countries. Fiscal stimuli based upon tax cuts are more likely to increase growth than those based upon spending increases. As for fiscal adjustments, those based upon spending cuts and no tax increases are more likely to reduce deficits and debt over GDP ratios than those based upon tax increases. In addition, adjustments on the spending side rather than on the tax side are less likely to create recessions.
- Fund (2010) Event study and simple regressions, 15 countries, 30 years. Fiscal consolidations based on either tax increases or spending cuts have on average been contractionary over the near term, though those based on tax increases are more so.

# VAR specific studies: Some highlights

| Study | Country | Sample | Variables | Id. | Finding |
|---|---|---|---|---|---|
| Blanchard and Perotti (2002) | US | 1960:Q1-1997:Q4 | $[T_b, G_b, X_b]'$ | BP | $G \uparrow \Rightarrow X \uparrow \approx 0.5,\ T \uparrow \Rightarrow X \downarrow \approx 1$ |
| Perotti (2005) | Germany, Canada, Australia, UK, US | 1961:Q1-2001:Q4 | $[T_b, G_b, X_b \pi_p i_p]'$ | BP | $G \uparrow \Rightarrow X \uparrow < 1.$ |
| Mountford and Uhlig (2009) | US | 1955:Q1-2000:Q4 | $Y_m'$ | S | $G \uparrow \mid T \downarrow \Rightarrow X \uparrow, I \downarrow, C \approx 0.$ |
| Burriel et al. (2010) | US and Euro Area | 1981:Q1-2007:Q4 | $[G_{bb} T_{bb} X_{bb} \pi_{bb} i_{bb}]'$ | BP | $G \uparrow \Rightarrow X \uparrow, C \uparrow, I \uparrow < 1$ |
| Fatás and Mihov (2001) | US | 1960:Q1-1996:Q4 | $[G_b X_b \pi_p T_p i_p]'$ | BP | $G \uparrow \Rightarrow X \uparrow, C \uparrow > 1, I \approx 0$ |
| Galí et al. (2007) | US | 1954:Q1-1998:Q4 | $[G_b X_b H_g i_p y_g]'$ | BP | Similar to Blanchard and Perotti (2002). |
| Canova and Pappa (2011) | US, Euro Area, UK | 1993:Q1-2009:Q4 | $y_c'$ | S | $G \uparrow \Rightarrow X > 1.$ |
| Ramey (2011) | US | 1939-2008 | $y_r'$ | N | $G \uparrow \Rightarrow X \uparrow \approx (0.6 - 1.2)$ |

# VAR specific studies: Some highlights cont.

| Study | Country | Sample | Variables | Id. | Finding |
|---|---|---|---|---|---|
| Romer and Romer (2010) | US | 1947:Q1-2007:Q4 | $[TX]$ | N | $T \uparrow \Rightarrow X \downarrow \approx 3$ |
| Auerbach and Gorodnichenko (2012) | US | 1947:Q1-2008:Q4 | $[T_b, G_b, X_b]'$ | BP | $G \uparrow \Rightarrow X \uparrow \approx (0-0.5)$ normal, $G \uparrow \Rightarrow X \uparrow\approx$ |
| Mertens and Ravn (2012) | US | 1947:Q1-2006:Q4 | $[X_{me}\, C_{me}\, I_{me}\, T_{me}]'$ | N | Unant.: $T \downarrow \Rightarrow X \uparrow, C \uparrow, I \uparrow$ Antic.: $T \downarrow \Rightarrow$ |

*Note: $T_b$ = tax revenues minus transfers, $G_b$ = government consumption plus government investment, $X_b$ = GDP, quarterly, real, and in per capita terms. $\pi_p$ = inflation or deflator, $i_p$ = 10-year nominal interest rate. $X_e$ = real GDP, $i_e$ =3-month Treasury bill rate, $\pi_e$ =PPI, $y_e$ =Ramey-Shapiro defense purchases, $G_e$ =government purchases. $y_m$ = [$X_m$ =GDp, $C_m$ =private consumption, $Ge_m$ =total government expenditure, $Gr_m$ =total government revenue, $W_m$ =real wages, $Inr_m$ =private non-residential investment, $i_m$ =interest rate, $res_m$ =adjusted reserves, $pi_m$ =producer price index for crude materials, $\pi_m$ =GDP deflator ]$'$ $G_{bb}$ =public expenditure, $T_{bb}$ =net taxes, $X_{bb}$ =real GDP, $\pi_{bb}$ =GDp deflator, $i_{bb}$ =10-year interest rate of government bonds. $H_g$ =hours worked, $y_g$ = [$C$ = consumption$|W$ = realwage$|I$ = investment]$'$. $y_c$ = [$G_c$ =log ratio of government consumption expenditure to output, $T_c$ =log ratio of total tax receipts to output, $X_c$ =log of 1 plus the annualized quarter-on-quarter growth rate of real per-capita output, $W_c$ =log of 1 plus the annualized quarter-on-quarter growth rate of real wages, $i_c$ =log of 1 plus the ex-post annualized real interest rate, $We_c$ =log of the efficiency wedge, $\pi_c$ =log of 1 plus the annualized inflation rate, $yi_c$ =log of 1 plus the yield on long-term government bonds, $C_c$ =log of personal consumption expenditure to output ratio ]$'$ $y_r$ = [$G_r$ =government spending, $X_r$ =output, $H_r$ =hours worked, $C_r$ =nondurable plus service consumption, $I_r$ =private fixed investment, $T_r$ =tax rate, $W_r$ =deflated nominal compensation in private business ]$'$ $X_{me}$ =logarithm of U.S. GDP per adult in constant (chained) prices, $C_{me}$ =logarithm of the real per capita private sector consumption expenditure , $I_{me}$ =logarithm of real aggregate per capita gross private sector investment, $T_{me}$ =narrative tax data.*

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