「これからの社会資本整備のありかた」

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多変量自己回帰モデルを用いた公共資本（公共投資）の効果にかかる研究

多変量自己回帰モデル
vector autoregressive model

- VAR(p)モデル

$$\boldsymbol{y}_t = \mathbf{c} + \boldsymbol{\Phi}_1 \boldsymbol{y}_{t-1} + \boldsymbol{\Phi}_2 \boldsymbol{y}_{t-2} + \cdots + \boldsymbol{\Phi}_p \boldsymbol{y}_{t-p} + \boldsymbol{\varepsilon}_t$$

$\boldsymbol{y}_t$: $K \times 1$ vector of time series
$\boldsymbol{c}$: $K \times 1$ vector of constants
$\boldsymbol{\Phi}_j$: $K \times K$ matrix of coefficients
$\boldsymbol{\varepsilon}_t$: $K \times 1$ vector of errors, $E(\boldsymbol{\varepsilon}_t) = \mathbf{0}$, $E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t') = \boldsymbol{\Omega}$, $E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_s') = \mathbf{0}$ for $t \neq s$.

- MA(∞) form

$$\boldsymbol{y}_t = \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t + \boldsymbol{\Psi}_1 \boldsymbol{\varepsilon}_{t-1} + \boldsymbol{\Psi}_2 \boldsymbol{\varepsilon}_{t-2} + \cdots$$

$\boldsymbol{\Psi}_j$: $K \times K$ matrix of coefficients; $\boldsymbol{\Psi}_1 = \boldsymbol{\Phi}_1$, $\boldsymbol{\Psi}_2 = \boldsymbol{\Phi}_1 \boldsymbol{\Psi}_1 + \boldsymbol{\Phi}_2$, ..., $\boldsymbol{\Psi}_s = \boldsymbol{\Phi}_1 \boldsymbol{\Psi}_{s-1} + \boldsymbol{\Phi}_2 \boldsymbol{\Psi}_{s-2} + \boldsymbol{\Phi}_3 \boldsymbol{\Psi}_{s-3} + \cdots + \boldsymbol{\Phi}_p \boldsymbol{\Psi}_{s-p}$ with $\boldsymbol{\Psi}_0 = \mathbf{I}_K$ and $\boldsymbol{\Psi}_s = \mathbf{0}$ for s<0.
$\mu = E(\boldsymbol{y}_t)$.

- VAR(p)モデル

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \\ \vdots \\ y_{K,t} \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} + \begin{bmatrix} \phi_{11}^1 \, \phi_{12}^1 \dots \phi_{1K}^1 \\ \phi_{12}^1 \, \phi_{22}^1 \cdots \phi_{2K}^1 \\ \vdots \quad \vdots \quad \ddots \quad \vdots \\ \phi_{K1}^1 \phi_{K2}^1 \cdots \phi_{KK}^1 \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \\ \vdots \\ y_{K,t-1} \end{bmatrix} + \begin{bmatrix} \phi_{11}^2 \, \phi_{12}^2 \dots \phi_{1K}^2 \\ \phi_{12}^2 \, \phi_{22}^2 \cdots \phi_{2K}^2 \\ \vdots \quad \vdots \quad \ddots \quad \vdots \\ \phi_{K1}^2 \phi_{K2}^2 \cdots \phi_{KK}^2 \end{bmatrix} \begin{bmatrix} y_{1,t-2} \\ y_{2,t-2} \\ \vdots \\ y_{K,t-2} \end{bmatrix}$$

$$+ \cdots + \begin{bmatrix} \phi_{11}^p \, \phi_{12}^p \dots \phi_{1K}^p \\ \phi_{12}^p \, \phi_{22}^p \cdots \phi_{2K}^p \\ \vdots \quad \vdots \quad \ddots \quad \vdots \\ \phi_{K1}^p \phi_{K2}^p \cdots \phi_{KK}^p \end{bmatrix} \begin{bmatrix} y_{1,t-p} \\ y_{2,t-p} \\ \vdots \\ y_{K,t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \vdots \\ \varepsilon_{K,t} \end{bmatrix}$$

- 第j番目の変数に関する回帰式

$$y_{j,t} = c_j + \sum_{l=1}^{K} \phi_{j,l}^1 \cdot y_{l,t-1} + \sum_{l=1}^{K} \phi_{j,l}^2 \cdot y_{l,t-2} + \cdots + \sum_{l=1}^{K} \phi_{j,l}^p \cdot y_{l,t-p} + \varepsilon_{j,t}$$

$$= c_j + \sum_{s=1}^{p} \phi_{j,1}^s \cdot y_{1,t-s} + \sum_{s=1}^{p} \phi_{j,2}^s \cdot y_{2,t-2} + \cdots + \sum_{s=1}^{p} \phi_{j,K}^s \cdot y_{K,t-p} + \varepsilon_{j,t}$$

多変量誤差修正モデル Vector Error Correction Model

- VAR(p)⇒VECM

$$\boldsymbol{y}_t = \mathbf{c} + \boldsymbol{\Phi}_1 \boldsymbol{y}_{t-1} + \boldsymbol{\Phi}_2 \boldsymbol{y}_{t-2} + \cdots + \boldsymbol{\Phi}_p \boldsymbol{y}_{t-p} + \boldsymbol{\varepsilon}_t$$

$$\boldsymbol{y}_t - \boldsymbol{\Phi}_1 \boldsymbol{y}_{t-1} - \boldsymbol{\Phi}_2 \boldsymbol{y}_{t-2} - \cdots - \boldsymbol{\Phi}_p \boldsymbol{y}_{t-p} = \mathbf{c} + \boldsymbol{\varepsilon}_t$$

$$(\mathrm{I}_K - \boldsymbol{\Phi}_1 L - \boldsymbol{\Phi}_2 L^2 - \cdots - \boldsymbol{\Phi}_p L^p)\boldsymbol{y}_t = \mathbf{c} + \boldsymbol{\varepsilon}_t$$

$$[(\mathrm{I}_K - \Theta L) - (\Gamma_1 L + \Gamma_2 L^2 + \cdots + \Gamma_p L^{p-1})(1-L)]\boldsymbol{y}_t = \mathbf{c} + \boldsymbol{\varepsilon}_t$$

$$(\mathrm{I}_K - \Theta L)\boldsymbol{y}_t - (\Gamma_1 L + \Gamma_2 L^2 + \cdots + \Gamma_p L^{p-1})(1-L)\boldsymbol{y}_t = \mathbf{c} + \boldsymbol{\varepsilon}_t$$

$$\boldsymbol{y}_t - \Theta \boldsymbol{y}_{t-1} - (\Gamma_1 L + \Gamma_2 L^2 + \cdots + \Gamma_p L^{p-1})(\boldsymbol{y}_t - \boldsymbol{y}_{t-1}) = \mathbf{c} + \boldsymbol{\varepsilon}_t$$

$$\boldsymbol{y}_t = (\Gamma_1 L + \Gamma_2 L^2 + \cdots + \Gamma_p L^{p-1})\Delta \boldsymbol{y}_t + \Theta \boldsymbol{y}_{t-1} + \mathbf{c} + \boldsymbol{\varepsilon}_t$$

$$\Delta \boldsymbol{y}_t = \Gamma_1 \Delta \boldsymbol{y}_{t-1} + \Gamma_2 \Delta \boldsymbol{y}_{t-2} + \cdots + \Gamma_p \Delta \boldsymbol{y}_{t-p+1} + \mathrm{B}\boldsymbol{y}_{t-1} + \mathbf{c} + \boldsymbol{\varepsilon}_t$$

where

$$\mathrm{B} \equiv \Theta - \mathrm{I}_K = -(\mathrm{I}_K - \boldsymbol{\Phi}_1 - \boldsymbol{\Phi}_2 - \boldsymbol{\Phi}_3 - \cdots - \boldsymbol{\Phi}_{p-1} - \boldsymbol{\Phi}_p)$$

Lag operator

- Lag operator

$$\mathbf{I}_K - \Phi_1 L - \Phi_2 L^2 - \Phi_2 L^3 - \cdots - \Phi_{p-1} L^{p-1} - \Phi_p L^p$$

$$=$$

$$\mathbf{I}_K - \Phi_1 L - \Phi_2 L - \Phi_3 L - \cdots - \Phi_{p-1} L - \Phi_p L + \left(\Phi_2 L + \Phi_3 L + \cdots + \Phi_{p-1} L + \Phi_p L\right)$$

$$-\Phi_2 L^2 - \Phi_2 L^2 - \cdots - \Phi_{p-1} L^2 - \Phi_p L^2 + \left(\Phi_3 L^2 + \cdots + \Phi_{p-1} L^2 + \Phi_p L^2\right)$$

$$-\Phi_2 L^3 - \cdots - \Phi_{p-1} L^3 - \Phi_p L^3 + \cdots + \left(\Phi_{p-1} L^{p-2} - \Phi_p L^{p-2}\right)$$

$$-\Phi_{p-1} L^{p-1} - \Phi_p L^{p-1} + \left(\Phi_p L^{p-1}\right)$$

$$-\Phi_p L^p$$

$$=$$

$$\mathbf{I}_K - \left(\Phi_1 + \Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L$$

$$+\left(\Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L - \left(\Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L^2$$

$$+\left(\Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L^2 - \left(\Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L^3$$

$$+ \cdots +$$

$$+\left(\Phi_{p-1} + \Phi_p\right) L^{p-2} - \left(\Phi_{p-1} + \Phi_p\right) L^{p-1}$$

$$+\left(\Phi_p L^{p-1}\right) - \Phi_p L^p$$

Lag operator

- Lag operator

$$\mathbf{I}_K - \Phi_1 L - \Phi_2 L^2 - \Phi_2 L^3 - \cdots - \Phi_{p-1} L^{p-1} - \Phi_p L^p$$

$$=$$

$$\mathbf{I}_K - \left(\Phi_1 + \Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L + \left(\Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right)(1-L)L$$
$$+ \left(\Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right)(1-L)L^2 + \cdots + \left(\Phi_{p-1} + \Phi_p\right)(1-L)L^{p-2} + \Phi_p (1-L) L^{p-1}$$

$$=$$

$$\mathbf{I}_K - \left(\Phi_1 + \Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L$$
$$+ \left[\left(\Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L + \left(\Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right) L^2 + \cdots + \left(\Phi_{p-1} + \Phi_p\right) L^{p-2} + \Phi_p L^{p-1}\right](1-L)$$

$$=$$

$$\mathbf{I}_K - \Theta L - (1-L)\left(\Gamma_1 L + \Gamma_2 L^2 + \cdots + \Gamma_{p-2} L^{p-2} + \Gamma_p L^{p-1}\right)$$

where

$$\Theta \equiv \Phi_1 + \Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p$$

$$\Gamma_1 \equiv -\left(\Phi_2 + \Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right), \Gamma_2 \equiv -\left(\Phi_3 + \cdots + \Phi_{p-1} + \Phi_p\right)$$

$$\Gamma_3 \equiv -\left(\Phi_4 + \cdots + \Phi_{p-1} + \Phi_p\right), \cdots, \Gamma_{p-2} \equiv -\left(\Phi_{p-1} + \Phi_p\right), \Gamma_{p-1} \equiv -\Phi_p$$

インパルス応答関数
impulse response function

- 第t_0期における$\boldsymbol{y}_{t_0}$における第k番目の変数y_{kt_0}の予期できない変化＝イノベーション ε_{k,t_0}が引き起こす将来の$y_{j,t+s}$の一連の値

$$\left\{\frac{\Delta y_{j,t_0+1}}{\Delta\varepsilon_{k,t_0}}, \frac{\Delta y_{j,t_0+2}}{\Delta\varepsilon_{k,t_0}}, \frac{\Delta y_{j,t_0+3}}{\Delta\varepsilon_{k,t_0}}, \frac{\Delta y_{j,t_0+4}}{\Delta\varepsilon_{k,t_0}}, \cdots\right\}$$

- MA(∞) form

$$\boldsymbol{y}_t = \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t + \boldsymbol{\Psi}_1\boldsymbol{\varepsilon}_{t-1} + \boldsymbol{\Psi}_2\boldsymbol{\varepsilon}_{t-2} + \cdots; \rightarrow \frac{\Delta \boldsymbol{y}_{t+s}}{\Delta \boldsymbol{\varepsilon}_t'} = \boldsymbol{\Psi}_s$$

$$y_{j,t} = \mu_j + \varepsilon_{j,t} + \sum_{l=1}^{K}\psi_{j,l}^1 \cdot \varepsilon_{l,t-1} + \sum_{l=1}^{K}\psi_{j,l}^2 \cdot \varepsilon_{l,t-2} + \cdots;\ \rightarrow \frac{\Delta y_{j,t_0+s}}{\Delta\varepsilon_{k,t_0}} = \psi_{jk}^s$$

- 実際は推定されたVAR(p)もしくはVECMを利用してシミュレーション
  - VAR: y_tが定常の場合　(非定常の場合はインパルス応答は一致推定量にはならない←Phillips 1998)
  - VECM: y_tが非定常で共和分関係にあるとき

先行研究: 公共資本

Authors	Variables y	Notes
McMillin and Smyth (1994)	Y/K, L/K, G/K, π, Pe,	VAR, LL & DLL, annual 1952-90, US.
Otto and Voss (1996)	Y, L, K, G	VAR, LL, Quarterly 1959-92, Australia
Crowder and Himarios (1997)	Y, L, K, G, Pe	VECM, annual 1947-89, US.
Batina (1998)	Y, L, K, G (or highway & street + water & sewer systems)	Standardized log, Y = index 1985=100, VAR & VECM annual 1948-93, US.
Flores de Frutos, Gracia-Diez, & Perez-Amaral (1998).	Y, L, K, G	VARMA, LL, annual 1964-1992, Spain
Nourzad (1998)	Y, L, K, G	VECM, annual 1948-87, US.
Mamatzakis (1999)	Y, L, K, G	VECM, annual 1959-93, Greece.

Y=output; G =public capital; K =private capital; L =labor; Ig =public investment, Ip =private investment, Cp=private consumption, Cg=government consumption, π =inflation rate; P=price level; Pe =energy price; w =wage rate; r=interest rate; VAR=vector auto-regressions; VECM=vector error correction model; VARMA=vector autoregressive moving average model; LL=log levels; DLL = Differenced log levels;

先行研究: 公共資本

Authors	Variables y	Notes
Pereria and Flores de Frutos (1999)	Y, L, K, G	VAR, DLL, annual 1956-89, US.
Pereria and Roca-Sagalés (1999)	Y, L, K, G	VAR, DLL, annual 1970-89, Spain.
畑農 (2000)	Y, L (employment & hours), K, G, w	VAR, LL, annual & quarterly 1957-98, Japan
Pereria and Roca-Sagalés (2001)	Y, L, K, G	VAR, DLL, annual 1970-93, Spain
Ligthart (2002)	Y, L, K, G	VAR, LL, annual 1965-1995, Portugal
Everaert (2003)	Y, K, G, Ip, Ig	VECM, annual 1953-1996, Belgium
Pereria and Roca-Sagalés (2003)	Y, L, K, G (also allows for G in other regions)	VAR, DLL, annual 1970-95,whole country & 17 communities in Spain.

Y=output; G =public capital; K =private capital; L =labor; Ig =public investment, Ip =private investment, Cp=private consumption, Cg=government consumption, π =inflation rate; P=price level; Pe =energy price; w =wage rate; r=interest rate; VAR=vector auto-regressions; VECM=vector error correction model; VARMA=vector autoregressive moving average model; LL=log levels; DLL = Differenced log levels;

先行研究: 公共資本

Authors	Variables y	Notes
Kawakami and Doi (2004)	Y, K, G (port), P	VAR, LL, annual 1966-97, Japan
林 (2004)	Y, L, K, G	VAR, DLL, annual 1960-97, Japan
Kamps (2005)	Y, L, K, G	VAR with DLL & VECM, annual 1960-2001, 22 OECD countries
Annala, Batina and Feehan (2008)	Y (aggregate and subsectors), L, K, G	VECM, annual 1970-98, Japan
Creel and Poilon (2008)	Y, L, K, G, Ip, Ig	VAR, LL, annual 1960-2004, 5 OECD countries
Dekujtas, Önder, and Karadag (2009)	Y, L, K, G (also allows for G in other regions)	VECM, annual 1980-2000, 7 regions in Turkey

Y=output; G =public capital; K =private capital; L =labor; Ig =public investment, Ip =private investment, Cp=private consumption, Cg=government consumption, π =inflation rate; P=price level; Pe =energy price; w =wage rate; r=interest rate; VAR=vector auto-regressions; VECM=vector error correction model; VARMA=vector autoregressive moving average model; LL=log levels; DLL = Differenced log levels;

先行研究: 公共投資

Authors	Variables y	Notes
Cullison (1993)	Y, Ig, defense spending, public debt, money supply	VAR, DLL, annual 1955-92, US.
Ghali (1998)	Y, Ip, Ig	VAR, LL, annual 1963-93, Tunisia
Sturm, Jacobs and Groote (1999)	Y, Ig, Ip	VAR, LL, annual 1853-1913, Netherlands.
Pereria (2000)	Y, L, Ip, Ig (or disaggregated into 5 categories)	VAR, DLL, annual 1956-1997, US.
Mittnick and Neuman (2001)	Y, Ip, Ig, Cg	VAR with DLL & VECM, quarterly 1955-1994, 6 OECD countries
Pereria (2001a)	Y, Ip (aggregate or 7 types), Ig (aggregate or 5 types)	VAR, DLL, annual 1956-97, US.
Pereria (2001b)	Y, L, Ip, Ig	VAR with DLL & VECM, annual 1960-1990, 12 OECD countries

Y=output; G =public capital; K =private capital; L =labor; Ig =public investment, Ip =private investment, Cp=private consumption, Cg=government consumption, π =inflation rate; P=price level; Pe =energy price; w =wage rate; r=interest rate; VAR=vector auto-regressions; VECM=vector error correction model; VARMA=vector autoregressive moving average model; LL=log levels; DLL = Differenced log levels;

先行研究: 公共投資

Authors	Variables y	Notes
鴨井・橘木 (2001)	Y, Cp, Ip, Ig, taxes, M2+CD	VAR, LL, quarterly 1975-1990, Japan
Voss (2002)	Y, Ip/Y, Ig/Y, prices of Ip and Ig, r	VAR, DLL, quarterly 1947-1996, US and Canada
中澤・大西・原田 (2002)	Y, Ig, M2+CD, r, P, 為替, 輸出	VAR, LL, quarterly 1980-01, Japan
Pereria and Andraz (2003)	Y, L, Ip, Ig	VAR, DLL, annual 1956-1997, US
中里・小西 (2004)	Ip, Ig, private consumption, deflator, M2+CD	VAR, Quarterly 1981-2001, Japan
Afonso and Aubyn (2009)	Y, Ip, Ig, tax receipts, interest rate	DLL, annual 1960-2005, 17 OECD countries.
Miyazaki (2009)	Y, Ig (central and local), tax receipts	Structural VAR, LL, monthly 1986:01-2007:12, Japan.

Y=output; G =public capital; K =private capital; L =labor; Ig =public investment, Ip =private investment, Cp=private consumption, Cg=government consumption, π =inflation rate; P=price level; Pe =energy price; w =wage rate; r=interest rate; VAR=vector auto-regressions; VECM=vector error correction model; VARMA=vector autoregressive moving average model; LL=log levels; DLL = Differenced log levels;

先行研究: 公共投資

Authors	Variables y	Notes
江口·平賀 (2009)	Ip, Ig, Cp, Cg, 公務労働者数	VAR, LL, quarterly 1969-08, Japan
Miyazaki (2010)	Cp/Y*, Ip/Y*, stock price (log), unemployment rate (log), dummies for fiscal shocks	Quarterly, 1980:1-2003:1, Japan.
亀田 (2010)	Ig, 平均労働時間, 有効求人数, 鉱工業出荷指数(資本財)	Panel VAR, annual-31 pref., Japan
近藤 (2010)	Y, Y, Cp, Ip, Cg, Ig	Panel VAR, annual 1960-07, pref. Japan
Fujii, Hiraga, and Kozuka (2011)	Ig, principal components Y(120), Ip (135), interest rate (114), taxes (130).	Factor augmented VAR, Log levels (ex. rates), Quarterly, 1983:2-2008:1, Japan.

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