The Causal Structure of the Vector Autoregression in Economics:

A Case Study of U.S. M2

Kevin D. Hoover
Department of Economics
Department of Philosophy
Duke University

Workshop: Case Studies of Causal Discovery with Model Search
Source


Coauthors:
- Selva Demiralp, *Koç University*, Istanbul
- Stephen J. Perez, *California State University, Sacramento*
The Real World Problem

\[ M2 = \]
\[ \text{liquid deposits} \quad 65\% \]
\[ = \text{demand deposits} \quad 5\% \]
\[ + \text{other checkable deposits} \quad 5\% \]
\[ + \text{savings deposits} \quad 55\% \]
\[ + \text{small time deposits} \quad 16\% \]
\[ + \text{retail money funds} \quad 11\% \]
\[ + \text{currency in circulation} \quad 11\% \]

**M2 and the Fed:** Monetary and Reserve Analysis Section of the Division of Monetary Affairs of the Board of Governors of the Federal Reserve System – a minimally theoretical and informal analysis of M2 growth with a money-demand orientation.
Minimal Theory

The Quantity Theory of Money: the growth rate of money should equal the growth rate of nominal income, adjusting for the trend in velocity.

Special Factors:
  i) Interest rate effects
  ii) Equity market effects:
  iii) Other special factors including:
       activity in mortgage-backed securities;
       tax effects; and
       currency shipments abroad.

How far can we get with only such minimal prior theory?
An Illustration – 1

Object of Study: Structural Vector-Autoregression (SVAR)

$$
\begin{bmatrix}
1 & 0 & 0 & 0 \\
\alpha_{YM} & 1 & 0 & 0 \\
\alpha_{CM} & \alpha_{CY} & 1 & 0 \\
\alpha_{IM} & \alpha_{YI} & \alpha_{IC} & 1
\end{bmatrix}
\begin{bmatrix}
M_t \\
Y_t \\
C_t \\
I_t
\end{bmatrix}
= 
\begin{bmatrix}
\beta_{MM} & \beta_{MY} & \beta_{MC} & \beta_{MI} \\
\beta_{YM} & \beta_{YY} & \beta_{YC} & \beta_{YI} \\
\beta_{CM} & \beta_{CY} & \beta_{CC} & \beta_{CI} \\
\beta_{IM} & \beta_{YI} & \beta_{IC} & \beta_{II}
\end{bmatrix}
\begin{bmatrix}
M_{t-1} \\
Y_{t-1} \\
C_{t-1} \\
I_{t-1}
\end{bmatrix}
+ 
\begin{bmatrix}
\varepsilon_t^M \\
\varepsilon_t^Y \\
\varepsilon_t^C \\
\varepsilon_t^I
\end{bmatrix}
$$

- Data are time series
- Contemporaneous relations are meant to be structural; lagged relationships are meant to be reduced-form (i.e., summaries of autocorrelations)
- Contemporaneous matrix can be read as a directed graph
- Errors are mutually independent:
  - would not generally obtain if contemporaneous coefficient matrix = the identity matrix
  - implicitly requires causal sufficiency – though not well understood by current economists (better understood in the 1940s/50s by econometricians in the Cowles Commission tradition.
- Typical use: impulse-response functions and counterfactual analysis
Impulse Responses of Money to a Consumption Shock for Two Contemporaneous Causal Orderings of U.S. Money, GDP, Consumption, and Investment

Response of Y to a one-standard deviation shock to C (0.33)

Choleski
(M, Y, C, I)

Choleski
(M, C, I, Y)

Quarters
An Illustration – 2

Problem of Causal Inference in the SVAR:

\[
\begin{bmatrix}
1 & 0 & 0 & 0 & \alpha_{YM} & 1 & 0 & 0 & \alpha_{CM} & \alpha_{CY} & \alpha_{IC} & 1 \\
0 & 0 & \beta_{MM} & \beta_{MY} & \beta_{MC} & \beta_{MI} & M_{t-1} & I_{t-1} & \varepsilon^M_t \\
0 & 0 & \beta_{YM} & \beta_{YY} & \beta_{YC} & \beta_{YI} & Y_{t-1} & I_{t-1} & \varepsilon^Y_t \\
0 & 0 & \beta_{CM} & \beta_{CY} & \beta_{CC} & \beta_{CI} & C_{t-1} & I_{t-1} & \varepsilon^C_t \\
0 & 0 & \beta_{IM} & \beta_{MY} & \beta_{MC} & \beta_{MI} & I_{t-1} & I_{t-1} & \varepsilon^I_t
\end{bmatrix}
\]

- Algorithms normally work directly on variables without time series structure:
  - must account for it in all cases
  - particularly difficult in nonstationary cases: admissible probability distributions are nonstandard (e.g., distributions appropriate to Brownian motion) in which ordinary statistics do not apply
Dynamic Processes

- Independent Stationary
- Stationary Autoregressive
- Random Walk
Solution to time-series structure:

- Condition variables on past history:
  - regression problem involving only observables

\[
\begin{bmatrix}
M_t \\
Y_t \\
C_t \\
I_t
\end{bmatrix} = \begin{bmatrix}
\gamma_{MM} & \gamma_{MY} & \gamma_{MC} & \gamma_{MI} \\
\gamma_{YM} & \gamma_{YY} & \gamma_{YC} & \gamma_{YI} \\
\gamma_{CM} & \gamma_{CY} & \gamma_{CC} & \gamma_{CI} \\
\gamma_{IM} & \gamma_{IY} & \gamma_{IC} & \gamma_{II}
\end{bmatrix} \begin{bmatrix}
M_{t-1} \\
Y_{t-1} \\
C_{t-1} \\
I_{t-1}
\end{bmatrix} + \begin{bmatrix}
\omega^M_t \\
\omega^Y_t \\
\omega^C_t \\
\omega^I_t
\end{bmatrix}
\]

- estimated error terms (\(\tilde{\omega}^j_t\)) = original variables purged of time-series structure:
  - stationary
  - preserves contemporaneous causal order (i.e., unlike the \(\varepsilon^j_t\), the \(\tilde{\omega}^j_t\) not independent, but preserve the causally induced covariances that serve as inputs to search algorithms.
The new object of analysis:

\[ \begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha_{YM} & 1 & 0 & 0 \\ \alpha_{CM} & \alpha_{CY} & 1 & 0 \\ \alpha_{IM} & \alpha_{IY} & \alpha_{IC} & 1 \end{bmatrix} \begin{bmatrix} \tilde{M}_t \\ \tilde{Y}_t \\ \tilde{C}_t \\ \tilde{I}_t \end{bmatrix} = \begin{bmatrix} \tilde{\varepsilon}^M_t \\ \tilde{\varepsilon}^Y_t \\ \tilde{\varepsilon}^C_t \\ \tilde{\varepsilon}^I_t \end{bmatrix} \]

Further Problems of Causal Inference in the SVAR:

- How to specify contemporaneous causal structure?
  - usually (not necessarily) lower triangular
    - identification restriction: matrix must be full rank – i.e., \( \geq n(n - 1)/2 \) restrictions
    - typically just identified (no overidentifying restrictions) – i.e., \( = n(n - 1)/2 \) restrictions
    - typical appeal to “economic theory” (= just so stories) to determine order of variables
Further Problems of Causal Inference in the SVAR:

- Observational equivalence
  - all just-identified models have the same likelihood: no statistical basis for model choice
  - same point in causal graphs:
    - no unshielded colliders
    - any reordering of arrowheads (= reordering vector of variables) produces same skeleton
    - Pearl’s observational equivalence theorem
Further Problems of Causal Inference in the SVAR:

- Nonequivalent impulse-response functions:

![Graph showing impulse responses of money to a consumption shock for two contemporaneous causal orderings of U.S. money, GDP, consumption, and investment.](image-url)
An Illustration – 7

• If data are actually overidentified, apply causal search algorithm to filtered data:

\[
\begin{bmatrix}
1 & \alpha_{MY} & \alpha_{MC} & \alpha_{MI} \\
\alpha_{YM} & 1 & \alpha_{YC} & \alpha_{YI} \\
\alpha_{CM} & \alpha_{CY} & 1 & \alpha_{CI} \\
\alpha_{IM} & \alpha_{IY} & \alpha_{IC} & 1
\end{bmatrix}
\begin{bmatrix}
\tilde{M}_t \\
\tilde{Y}_t \\
\tilde{C}_t \\
\tilde{I}_t
\end{bmatrix}
= 
\begin{bmatrix}
\tilde{\epsilon}_t^M \\
\tilde{\epsilon}_t^Y \\
\tilde{\epsilon}_t^C \\
\tilde{\epsilon}_t^I
\end{bmatrix}
\]

• Impose structure of contemporaneous matrix on original SVAR and estimate:

\[
\begin{bmatrix}
1 & \alpha_{MY} & \alpha_{MC} & \alpha_{MI} \\
\alpha_{YM} & 1 & \alpha_{YC} & \alpha_{YI} \\
\alpha_{CM} & \alpha_{CY} & 1 & \alpha_{CI} \\
\alpha_{IM} & \alpha_{IY} & \alpha_{IC} & 1
\end{bmatrix}
\begin{bmatrix}
M_t \\
Y_t \\
C_t \\
I_t
\end{bmatrix}
= 
\begin{bmatrix}
\beta_{MM} & \beta_{MY} & \beta_{MC} & \beta_{MI} \\
\beta_{YM} & \beta_{YY} & \beta_{YC} & \beta_{YI} \\
\beta_{CM} & \beta_{CY} & \beta_{CC} & \beta_{CI} \\
\beta_{IM} & \beta_{IY} & \beta_{IC} & \beta_{II}
\end{bmatrix}
\begin{bmatrix}
M_{t-1} \\
Y_{t-1} \\
C_{t-1} \\
I_{t-1}
\end{bmatrix}
+ 
\begin{bmatrix}
\epsilon_t^M \\
\epsilon_t^Y \\
\epsilon_t^C \\
\epsilon_t^I
\end{bmatrix}
\]

Back to the Actual Case

The Data
11 monthly series that run from 1990:02 to 2005:03;

- liquid deposits \((LIQDEP)\);
- core CPI inflation \((COREINF)\);
- industrial production \((IP)\);
- S&P 500 stock market index \((SP500)\)
- price-earnings ratio \((SPPE)\);
- stock market volatility \((VOL)\);
- index of mortgage refinancing \((REFI)\);
- interest rate on 30-year fixed-rate mortgages \((MORG30)\);
- the Federal funds rate \((FF)\);
- the opportunity cost of M2 \((M2OC)\) \(= M2OWN – TBILL3\);
- the own rate of interest on M2 \((M2OWN)\);
- the 3-month T-bill rate \((TBILL3)\).
How reliable is this graph?


\[
\begin{bmatrix}
M_t \\
Y_t \\
C_t \\
I_t
\end{bmatrix} =
\begin{bmatrix}
\gamma_{MM} & \gamma_{MY} & \gamma_{MC} & \gamma_{MI} \\
\gamma_{YM} & \gamma_{YY} & \gamma_{YC} & \gamma_{YI} \\
\gamma_{CM} & \gamma_{CY} & \gamma_{CC} & \gamma_{CI} \\
\gamma_{IM} & \gamma_{IY} & \gamma_{IC} & \gamma_{II}
\end{bmatrix}
\begin{bmatrix}
M_{t-1} \\
Y_{t-1} \\
C_{t-1} \\
I_{t-1}
\end{bmatrix} +
\begin{bmatrix}
\omega_t^M \\
\omega_t^Y \\
\omega_t^C \\
\omega_t^I
\end{bmatrix}
\]

- Draw columns with replacement from estimated error matrix
- Use equation system to generate simulated variables
- Apply PC algorithm to simulated data and record graph
- Repeat 10,000 times
### Table 3
Bootstrap Evaluation of the Causal Graph

<table>
<thead>
<tr>
<th>Causal Order Selected by the PC Algorithm</th>
<th>Edge Identification (percent of bootstrap realizations)</th>
<th>Summary Statistics for Bootstrap Distribution&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no edge → ← exists directed net direction</td>
<td></td>
</tr>
<tr>
<td><strong>REFI</strong> → ← <strong>MORG30</strong></td>
<td>65 22 0 11 3 100 35 -11</td>
<td></td>
</tr>
<tr>
<td><strong>SP500</strong> ← → <strong>SPPE</strong></td>
<td>17 52 0 11 20 100 83 -41</td>
<td></td>
</tr>
<tr>
<td><strong>FF</strong> ← → <strong>M2OWN</strong></td>
<td>47 14 0 38 1 100 53 25</td>
<td></td>
</tr>
<tr>
<td><strong>VOL</strong> ← → <strong>SP500</strong></td>
<td>8 20 5 28 39 95 92 8</td>
<td></td>
</tr>
<tr>
<td><strong>MORG30</strong> ← → <strong>TBILL3</strong></td>
<td>7 3 5 75 10 95 93 72</td>
<td></td>
</tr>
<tr>
<td><strong>LIQDEP</strong> ← → <strong>SP500</strong></td>
<td>0 0 45 30 24 55 100 30</td>
<td></td>
</tr>
<tr>
<td><strong>IP</strong> ← → <strong>VOL</strong></td>
<td>2 1 47 37 14 53 97 37</td>
<td></td>
</tr>
<tr>
<td><strong>M2OWN</strong> ← → <strong>TBILL3</strong></td>
<td>0 10 64 16 10 36 99 6</td>
<td></td>
</tr>
<tr>
<td><strong>LIQDEP</strong> ← → <strong>M2OWN</strong></td>
<td>2 8 72 7 12 28 94 -1</td>
<td></td>
</tr>
<tr>
<td><strong>REFI</strong> no edge ← → <strong>TBILL3</strong></td>
<td>0 0 82 15 3 18 98 14</td>
<td></td>
</tr>
<tr>
<td><strong>REFI</strong> no edge ← → <strong>M2OWN</strong></td>
<td>3 6 83 3 4 17 80 -3</td>
<td></td>
</tr>
<tr>
<td><strong>IP</strong> no edge ← → <strong>SPPE</strong></td>
<td>1 0 85 7 7 15 94 7</td>
<td></td>
</tr>
<tr>
<td><strong>SP500</strong> no edge ← → <strong>M2OWN</strong></td>
<td>1 4 86 1 9 14 95 -3</td>
<td></td>
</tr>
<tr>
<td><strong>COREINF</strong> no edge ← → <strong>SP500</strong></td>
<td>1 0 87 10 2 13 95 10</td>
<td></td>
</tr>
<tr>
<td><strong>IP</strong> no edge ← → <strong>M2OWN</strong></td>
<td>0 0 88 5 7 12 99 5</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> 16 of 55 candidate edges; only edges that are identified as existing in 12 percent or more of the bootstrap replications are shown.

<sup>2</sup> Values indicate percentage of 10,000 bootstrap replications in which each type of edge is found. Based on the procedure in Demiralp, Hoover, and Perez (2008) with critical value of 2.5 percent for tests of conditional correlation (corresponding to the 10 percent critical value used in the PC algorithm).

<sup>3</sup> *exists* = the percentage of bootstrap replications in which an edge is selected (= 100 – no edge); *directed* = edges directed as a percentage of edges selected; *net direction* = difference between edges directed right (→) and left (←).
## Bootstrap Evaluation of the Causal Graph

**Causal Order Selected by the PC Algorithm**

<table>
<thead>
<tr>
<th>Relation</th>
<th>Summary Statistics for Bootstrap Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>exists</td>
</tr>
<tr>
<td><strong>REFI</strong></td>
<td>——</td>
</tr>
<tr>
<td>SP500</td>
<td>←</td>
</tr>
<tr>
<td>FF</td>
<td>→</td>
</tr>
<tr>
<td>FF</td>
<td>→</td>
</tr>
<tr>
<td>VOL</td>
<td>↔</td>
</tr>
<tr>
<td>MORG30</td>
<td>→</td>
</tr>
<tr>
<td>LIQDEP</td>
<td>↔</td>
</tr>
<tr>
<td>IP</td>
<td>→</td>
</tr>
<tr>
<td>M2OWN</td>
<td>←</td>
</tr>
<tr>
<td>LIQDEP</td>
<td>←</td>
</tr>
<tr>
<td>REFI</td>
<td>no edge</td>
</tr>
<tr>
<td>REFI</td>
<td>no edge</td>
</tr>
<tr>
<td>IP</td>
<td>no edge</td>
</tr>
<tr>
<td>SP500</td>
<td>no edge</td>
</tr>
<tr>
<td>COREINF</td>
<td>no edge</td>
</tr>
<tr>
<td>IP</td>
<td>no edge</td>
</tr>
</tbody>
</table>
Notes on Initial Causal Order

- Unoriented edge from $REFI \rightarrow MORG30$ based on dominant order in Table 3.
- Bidirectional edges: $VOL \leftrightarrow SP500$ and $SP500 \leftrightarrow LIQDEP$ despite acyclicity assumption:
  - possible reasons
    - i) small sample problem
    - ii) omitted latent variable
- Initial graph strongly rejected against a just-identified model: $p = 0.002$ with $VOL \leftrightarrow SP500$ and $SP500 \leftrightarrow LIQDEP$ left bidirectional and either $REFI \rightarrow MORG30$ or $REFI \leftarrow MORG30$
- Fear of omission greater than fear of commission.
  - Supplement the graph with all the *borderline* edges that appear in
    - $> 10\%$
    - $> 2.5\%$ of bootstrap replications for $REFI \leftarrow MORG30$
Table 4
Contemporaneous Causal Structure: Specification Search

<table>
<thead>
<tr>
<th>Specification</th>
<th>Likelihood Ratio Test against the Just-Identified Model (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Search I</strong></td>
<td></td>
</tr>
<tr>
<td>Initial Model</td>
<td>Graph in Figure 1 modified with</td>
</tr>
<tr>
<td></td>
<td>( \text{REFI} \rightarrow \text{MORG30} )</td>
</tr>
<tr>
<td></td>
<td>( \text{REFI} \rightarrow \text{MORG30} ) 0.002</td>
</tr>
<tr>
<td>General Model I</td>
<td>As above, plus:</td>
</tr>
<tr>
<td></td>
<td>( \text{REFI} \rightarrow \text{TBILL3} )</td>
</tr>
<tr>
<td></td>
<td>( \text{REFI} \leftarrow \text{M2OWN} )</td>
</tr>
<tr>
<td></td>
<td>( \text{IP} \rightarrow \text{SPPE} )</td>
</tr>
<tr>
<td></td>
<td>( \text{M2OWN} \rightarrow \text{SP500} )</td>
</tr>
<tr>
<td></td>
<td>( \text{IP} \rightarrow \text{M2OWN} )</td>
</tr>
<tr>
<td></td>
<td>( \text{COREINF} \rightarrow \text{REFI} )</td>
</tr>
<tr>
<td>Tests of Restrictions</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>omit ( \text{LIQDEP} \leftarrow \text{SP500} )</td>
</tr>
<tr>
<td></td>
<td>no convergence</td>
</tr>
<tr>
<td>2</td>
<td>restore ( \text{LIQDEP} \leftarrow \text{SP500} );</td>
</tr>
<tr>
<td></td>
<td>omit ( \text{VOL} \rightarrow \text{SP500} )</td>
</tr>
<tr>
<td>3</td>
<td>omit ( \text{LIQDEP} \leftarrow \text{SP500} )</td>
</tr>
<tr>
<td>4</td>
<td>omit ( \text{IP} \rightarrow \text{SPPE} )</td>
</tr>
<tr>
<td>5</td>
<td>omit ( \text{M2OWN} \leftarrow \text{TBILL3} )</td>
</tr>
<tr>
<td>6</td>
<td>omit ( \text{COREINF} \rightarrow \text{SP500} )</td>
</tr>
<tr>
<td>7</td>
<td>omit ( \text{IP} \rightarrow \text{M2OWN} )</td>
</tr>
<tr>
<td>8</td>
<td>omit ( \text{REFI} \rightarrow \text{TBILL3} )</td>
</tr>
<tr>
<td></td>
<td>( \text{REFI} \rightarrow \text{TBILL3} ) 0.068</td>
</tr>
<tr>
<td><strong>Search II</strong></td>
<td></td>
</tr>
<tr>
<td>Initial Model</td>
<td>Graph in Figure 1 modified with</td>
</tr>
<tr>
<td></td>
<td>( \text{REFI} \leftarrow \text{MORG30} )</td>
</tr>
<tr>
<td></td>
<td>( \text{REFI} \leftarrow \text{MORG30} ) 0.002</td>
</tr>
<tr>
<td>General Model II</td>
<td>As above, plus:</td>
</tr>
<tr>
<td></td>
<td>all edges that appeared in more</td>
</tr>
<tr>
<td></td>
<td>than 2.5 percent of bootstrap replications</td>
</tr>
<tr>
<td></td>
<td>0.069</td>
</tr>
</tbody>
</table>
Figure 2
Final Contemporaneous Causal Graph

MORG30

FF → TBILL3 ← REFI

M2OWN

VOL ← SP500 ← LIQDEP

IP SPPE

COREINF
### The $A_0$ Matrix

#### Causes

<table>
<thead>
<tr>
<th>Effects</th>
<th>C</th>
<th>O</th>
<th>R</th>
<th>E</th>
<th>I</th>
<th>N</th>
<th>F</th>
<th>F</th>
<th>F</th>
<th>F</th>
<th>F</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>COREINF</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>FF</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>IP</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>SPPE</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>M2OWN</td>
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<td>$a_{52}$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>LIQDEP</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>$a_{65}$</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SP500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>$a_{74}$</td>
<td>$a_{75}$</td>
<td>$a_{76}$</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>REFI</td>
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<td>0</td>
<td>0</td>
<td>$a_{85}$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<td></td>
</tr>
<tr>
<td>MORG30</td>
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<td>$a_{98}$</td>
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<td>0</td>
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</tr>
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</tr>
<tr>
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Specification of Lagged Dynamics

- Apply LSE (David Hendry)-style general-to-specific specification search techniques.
  - Automated search algorithms first developed and demonstrated to be effective in:
  - Developed into commercially available software:
    - Hendry and Krolzig, *PcGets*
    - Doornik and Hendry, *Autometrics* package in *PcGive* version 12 and above.
# Summary of Results

## The Causal Structure of the SVAR

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Key:
- = lagged causes only
- = contemporaneous causes only
= = lagged and contemporaneous causes

Notes: Based on the detailed SVAR specification in Appendix B.
Compare to a Choleski (Lower-Triangular) Ordering:

The Causal Structure of the SVAR

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- **LIQDEP** depends on almost everything but what the quantity theory suggests: on **M2OWN**, but not **TBILL3**, **COREINF**, or **IP**;
- Nevertheless, **LIQDEP** causes everything but **SPPE**, **M2OWN**, and **MORG30**.
Counterfactual Experiment

Impulse Response of COREINF to permanent 25-basis-point shock to FF

Dashed lines are + and -2 standard-error bands for impulse-response functions including LIQDEP

Impulse Response of IP to permanent 25-basis-point shock to FF

Dashed lines are + and -2 standard-error bands for impulse-response functions including LIQDEP
Open Issues

• Causal search with simultaneous and cyclical cause
  o Piyachart Phiromswad and Kevin D. Hoover, "Selecting Instrumental Variables: A Graph-Theoretic Approach"

• Nonstationary variables frequently cointegrated:
  o implies latent common stochastic trends: number of trends + number of cointegrating relations = number of trending varaibles
  o opens possibility of causal relationships among the latent stochastic trends
  o work in progress
Thanks

The End