Modeling the Global Wheat Market Using a GVAR Model

Elselien Breman and Cornelis Gardebroek

Selected Paper prepared for presentation at the International Agricultural Trade Research Consortium’s (IATRC’s) 2014 Annual Meeting: Food, Resources and Conflict, December 7-9, 2014, San Diego, CA.

Copyright 2014 by Elselien Breman and Cornelis Gardebroek. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.
Modelling the global wheat market using a GVAR model

Study presented at IATRC meeting Dec. 7-9, 2014, San Diego

Elselien Breman & Cornelis Gardebroek, Wageningen Univ., Netherlands
Background

- Global agricultural markets rather volatile in last decade

- Foreign shocks and international spill-overs play an important role
  - Australian drought 2007
  - Russian wheat export bans 2010
  - USA drought 2012

→ Analyse commodity markets from global perspective
### Common modelling approaches

<table>
<thead>
<tr>
<th><strong>Time-series econometric models</strong></th>
<th><strong>Simulation models</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on time-series observations</td>
<td>Based on economic theory</td>
</tr>
<tr>
<td>Parameters are estimated</td>
<td>Parameters are calibrated</td>
</tr>
<tr>
<td>Higher frequency data</td>
<td>Yearly data</td>
</tr>
<tr>
<td>Theoretical basis often weak</td>
<td>Complex; often considered as black box</td>
</tr>
<tr>
<td>Curse of dimensionality</td>
<td></td>
</tr>
</tbody>
</table>

**The GVAR model**

- Long-run relationships can be included
- As many countries and variables as desired
- Results relatively easy to interpret
Global Vector Autoregression (GVAR)

- Macroeconometric model
- Estimated subject to long-run relationships
- Able to take into account international linkages among a large number of countries
- Analysing shocks with impulse response functions
- Mostly used in financial markets, rather new for analysing agricultural markets
  - Gutierrez et al. (forthcoming)
GVAR: Two steps involved

1. Estimating country-specific VAR models
   - Domestic variables
   - Foreign variables; constructed using weights and assumed to be weakly exogenous
     → Co-integrating relationships

2. Country-specific models stacked together and solved for GVAR
Objective of the study

- Investigate the advantages and disadvantages of the GVAR modelling approach in analysing global agricultural markets

- To this purpose we developed a small GVAR model
Application: GVAR model for wheat market

- Wheat one of the most traded agricultural commodities
- Analyse interdependencies in wheat price movements
- Relatively small model
  - Countries: Argentina, Australia, Canada, Europe, US
  - Variables:
    - Domestic export prices ➔ Endogenous
    - Country-specific foreign prices ➔ Weakly endogenous
    - Exchange rates and oil price ➔ Exogenous
Country-specific ADL equations

\[ P_{i,t} = \beta_{i1} + \beta_{i2}t + \sum_{k=1}^{p_i} a_{ik} P_{i,t-k} + \sum_{l=0}^{q_i} \gamma_{il} P_{i,t-l} + \sum_{l=0}^{q_1} \delta_{il} E\!R_{i,t-l} + \sum_{l=0}^{q_i} \theta_{il} P\!O_{t-l} + \epsilon_{i,t} \]

\[ P_{i,t} = \text{Wheat export price} \]

\[ P_{i,t}^* = \sum_{j=0}^{N} w_{ij} P_{j,t} \]

\[ E\!R_{i,t} = \text{Nominal exchange rate} \]

\[ P\!O_t = \text{Nominal crude oil price} \]
# Data

- **Monthly data, covering July 2001 until April 2012**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{i,t}$</td>
<td>Wheat export price in US dollars per ton</td>
<td>International Grains Council (2012)</td>
</tr>
<tr>
<td>$PO_{t}$</td>
<td>Nominal crude oil price in US dollars per barrel obtained as an equally weighted average of the spot price of Brent, Dubai and West Texas Intermediate</td>
<td>World Bank Commodity Price Data (Pink Sheet) (2014)</td>
</tr>
<tr>
<td>$ER_{i,t}$</td>
<td>National currency per SDR, end of period</td>
<td>International Financial Statistics (2014)</td>
</tr>
</tbody>
</table>
Data: missing observations

- Single missing observations
  - Solved by interpolation

- Longer periods of missing observations
  - Australia: 14 months of missing observations
  - Combination of forecasting and backcasting
  - Using Australian barley prices
Construction of the weights

\[ P_{i,t}^* = \sum_{j=0}^{N} w_{ij} P_{j,t} \]

- Weights (\( w_{ij} \)) are constructed by export shares
- \( w_{ij} \) is the average share of the export volume of country \( j \) over 2009-2011 in total exports of all the countries in the model (excluding country \( i \))
### Weights

<table>
<thead>
<tr>
<th>Variables</th>
<th>Argentina</th>
<th>Australia</th>
<th>Canada</th>
<th>EU</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>0.000</td>
<td>0.198</td>
<td>0.220</td>
<td>0.246</td>
<td>0.336</td>
</tr>
<tr>
<td>Australia</td>
<td>0.082</td>
<td>0.00</td>
<td>0.252</td>
<td>0.281</td>
<td>0.384</td>
</tr>
<tr>
<td>Canada</td>
<td>0.084</td>
<td>0.233</td>
<td>0.000</td>
<td>0.289</td>
<td>0.394</td>
</tr>
<tr>
<td>EU</td>
<td>0.087</td>
<td>0.240</td>
<td>0.267</td>
<td>0.000</td>
<td>0.407</td>
</tr>
<tr>
<td>USA</td>
<td>0.097</td>
<td>0.269</td>
<td>0.299</td>
<td>0.334</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Country-specific models

- Order of integration
  - All time-series integrated of order 1

- Lag orders $\text{VARX}(p_i,q_i)$
  - Distinction between the domestic prices ($p_i$) and the other variables ($q_i$)
  - Maximum lag order of 3
  - Initial lag order determined by comparing BIC values

$\Rightarrow \text{VARX}(3,0)$
Country-specific models

Co-integrating relationships

<table>
<thead>
<tr>
<th>Country</th>
<th>Co-integrating variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>$P_{ar,t}, P_{ar,t}^*$</td>
</tr>
<tr>
<td>Australia</td>
<td>$P_{au,t}, P_{au,t}^*$</td>
</tr>
<tr>
<td>Canada</td>
<td>$P_{ca,t}, P_{ca,t}^*, PO_t, ER_t$</td>
</tr>
<tr>
<td>Europe</td>
<td>$P_{eu,t}, P_{eu,t}^*$</td>
</tr>
<tr>
<td>US</td>
<td>$P_{us,t}, P_{us,t}^*, PO_t$</td>
</tr>
</tbody>
</table>
Estimation of country-specific equations

\[
\Delta P_{ar,t} = -0.186 (P_{ar,t-1} - 0.890 P_{ar,t-1}) + 0.265 \Delta P_{ar,t-1} + 0.593 \Delta P_{ar,t} + \varepsilon_{ar,t}
\]

\[
\Delta P_{au,t} = 18.834 - 0.180 (P_{au,t-1} - 0.501 P_{au,t-1}) + 0.237 \Delta P_{au,t-1} + 0.450 \Delta P_{au,t} + 0.530 \Delta PO_t + \varepsilon_{ar,t}
\]

\[
\Delta P_{ca,t} = -0.225 (P_{ca,t-1} - 1.730 P_{ca,t-1} + 32.125 \Delta P_{ca,t-1} + 32.125 \Delta P_{ca,t-2} + 0.547 \Delta P_{ca,t-1})
\]

\[
\Delta P_{ca,t} = -0.128 \Delta P_{ca,t-1} + 0.171 \Delta P_{ca,t-2} + 1.142 \Delta P_{ca,t} - 99.203 \Delta P_{ca,t} - 0.970 \Delta PO_t + \varepsilon_{ca,t}
\]

\[
\Delta P_{eu,t} = -0.146 (P_{eu,t-1} - 0.855 P_{eu,t-1}) + 0.227 \Delta P_{eu,t-1} + 0.752 \Delta P_{eu,t} + \varepsilon_{eu,t}
\]

\[
\Delta P_{us,t} = -0.297 (P_{us,t-1} - 0.967 P_{us,t-1} - 0.033 \Delta PO_{t-1}) - 0.024 \Delta P_{us,t-1}
\]

\[
\Delta P_{us,t} = -0.113 \Delta P_{us,t-2} + 0.978 \Delta P_{us,t} + \varepsilon_{us,t}
\]
## Testing weak exogeneity

<table>
<thead>
<tr>
<th>Country</th>
<th>T Statistics $P_{i,t}^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>0.17</td>
</tr>
<tr>
<td>Australia</td>
<td>0.78</td>
</tr>
<tr>
<td>Canada</td>
<td>-1.36</td>
</tr>
<tr>
<td>Europe</td>
<td>2.1**</td>
</tr>
<tr>
<td>US</td>
<td>-2.8 ***</td>
</tr>
</tbody>
</table>

** Significant at a 5% significance level
*** Significant at a 1% significance level
Testing weak exogeneity

- Possible solutions:
  - Using an instrumental variable for $P_{us,t}^*$
  - Estimating $P_{us,t}^*$ endogenous
  - Removing $P_{us,t}^*$ (Chudik and Smith, 2013)
    - $P_{us,t}^*$ is the only foreign variable in equation US
    - No effect of foreign prices on US domestic price
Country-specific equations

\[\Delta P_{ar,t} = -0.186 \left( P_{ar,t-1} - 0.890 P_{ar,t-1}^* \right) + 0.265 \Delta P_{ar,t-1} + 0.593 \Delta P_{ar,t}^* + \varepsilon_{ar,t}\]

\[\Delta P_{au,t} = 18.834 - 0.180 \left( P_{au,t-1} - 0.501 P_{au,t-1}^* \right) + 0.237 \Delta P_{au,t-1} + 0.450 \Delta P_{au,t}^* + 0.530 \Delta PO_t + \varepsilon_{ar,t}\]

\[\Delta P_{ca,t} = -0.225 \left( P_{ca,t-1} - 1.730 P_{ca,t-1}^* + 32.125 \Delta R_{ca,t-1} + 0.547 \Delta PO_{t-1} \right)\]
\[\quad - 0.128 \Delta P_{ca,t-1} + 0.171 \Delta P_{ca,t-2} + 1.142 \Delta P_{ca}^* - 99.203 \Delta R_{ca,t}\]
\[- 0.970 \Delta PO_t + \varepsilon_{ca,t}\]

\[\Delta P_{eu,t} = -0.146 \left( P_{eu,t-1} - 0.855 P_{eu,t-1}^* \right) + 0.227 \Delta P_{eu,t-1} + 0.752 \Delta P_{eu,t}^* + \varepsilon_{eu,t}\]

\[\Delta P_{us,t} = -0.297 \left( P_{us,t-1} - 0.967 P_{us,t-1}^* - 0.033 \Delta PO_{t-1} \right) - 0.024 \Delta P_{us,t-1}\]
\[- 0.113 \Delta P_{us,t-2} + 0.978 \Delta P_{us,t}^* + \varepsilon_{us,t}\]
Solving the GVAR

\[
\begin{pmatrix}
P_{i,t} \\
P_{i,t}^*
\end{pmatrix} = W_i X_t = W_i
\begin{pmatrix}
P_{ar,t} \\
P_{au,t} \\
P_{ca,t} \\
P_{eu,t} \\
P_{ar,t}
\end{pmatrix}
\]

\[
X_t = G^{-1}a_1 + G^{-1}H_1 X_{t-1} + G^{-1}H_2 X_{t-2} + G^{-1}H_3 X_{t-3} + G^{-1}a_2 E R_t
\]

\[
+ G^{-1}a_3 E R_{t-1} + G^{-1}a_4 P O_t + G^{-1}a_5 P O_{t-1} + G^{-1} \varepsilon_t
\]
Impulse response functions

Impulse response of wheat export prices to a positive standard error shock (32.4%) to the Argentinian wheat price.
Reliability of weights

- Weight are a key element in the model
  - Restrict the model
  - Influences small economy assumption
- Comparison with un unrestricted model
  - Individual $P_{i,t}$’s not all significant
  - $P_{eu,t}$ underestimated for all domestic prices
Conclusion

Advantages of GVAR approach:

- ability to include as many countries and variables as desirable
- the possibility to include both short-run as well as long-run relationships
- the compactness and flexibility of the model
Conclusion

Disadvantages:

- The lack of a proper solution to the rejection of the weakly exogeneity assumption
- Questionable reliability of the constructed weights
Thank you