Predicting Time Periods of Excessive Price Volatility: The Case of Rice

Dr. Ramon Clarete    Alfonso Labao

University of the Philippines, School of Economics

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Flow of Presentation

Overview
Methodology
Empirical Results
Conclusion and Constraints
Overview:

Importance of being forewarned of extreme food price-volatility: provides time to undertake cooperation to prevent herding and self-fulfilling crises, avoid repetition of 2008 rice crisis, and prevent welfare costs for the poor. G20 report stresses importance of accurate and timely market information.
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Our Methodology:

- Use daily rice future prices (5407 days from Sep 1991 to Mar 2013)
- Identify time-periods of excessive price volatility (via Martins-Filho, Maximo Torero, and Feng Yao's (IFPRI, 2010) methodology: Two-step spline-backfitted-kernel estimation / GPD distribution)
- Develop Early Warning Signals (via Particle Swarm Optimization (PSO))
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First Two Parts:

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Actual Prices:
Snapshot of actual prices:
Converted into Price Returns:
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where price returns refer to day-to-day price movements, or:
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Create Thresholds via MTY’s two-step methodology:
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threshold (high-order conditional quantile)

price returns
Create Thresholds via MTY’s two-step methodology:
Methodology:

MTY’s Two-step method:

\[ r_t = m_0 + d \sum_{a=1}^{m} a(X_{ta}) + (h_0 + d \sum_{a=1}^{h} a(X_{ta}))^{1/2} \epsilon_t \]

Estimate the high-order 95 percent quantile via Generalized Pareto Distribution (GPD):

\[ \hat{q}_t(\alpha) = \hat{\epsilon}_{k+1} + \hat{\beta}_t \hat{\gamma}_t \left( \left( 1 - \alpha \right) \left( k / N \right) - \hat{\gamma}_t - 1 \right) \]

Estimated 95 percent Conditional Quantiles:

\[ \hat{q}_t(\alpha/r_t-1, r_t-2) = \tilde{m}(r_t-1, r_t-2) + \left( \tilde{h}(r_t-1, r_t-2) \right)^{1/2} \hat{q}_t(\alpha) \]
Methodology:

MTY’s Two-step method:

Construct a nonparametric trend via spline-backfitted-kernel:

\[ r_t = m_0 + \sum_{a=1}^{d} m_a(X_{ta}) + (h_0 + \sum_{a=1}^{d} h_a(X_{ta})^{1/2})\epsilon_t \]

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    \hat{q}_t(\alpha/r_{t-1}, r_{t-2}) = \tilde{m}(r_{t-1}, r_{t-2}) + [\tilde{h}(r_{t-1}, r_{t-2})^{1/2}\hat{q}_t(\alpha)]
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How are Time Periods of Excessive Price Volatility (EPV) defined?

Martins-Filho, Maximo Torero and Feng Yao's definition of time periods of EPV:

**EPV Definition:**
Time-periods whereby the preceding 60 days experienced a significantly high amount of extreme positive price returns over the 95 percent conditional quantile.

... at least 7 instances of extreme positive price returns within a span of 60 days.
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3rd (Mar 1999 - Sep 1999) and 4th (Jun 2001 - Aug 2001) EPV cluster:
5th (Jul 2002 - Aug 2002) and 6th (May 2003 - Oct 2003) EPV cluster:
5th (Jul 2002 - Aug 2002) and 6th (May 2003 - Oct 2003) EPV cluster:

7th (Mar 2008 - Nov 2008) and 8th (Apr 2009 - May 2009) EPV cluster:
9th (Jul 2011) EPV cluster:
In Summary:

501 days of excessive price-volatility (EPV)

Nine (9) clusters of EPV

Of the above clusters of EPV, only four (4) are severe
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<table>
<thead>
<tr>
<th>Crisis No.</th>
<th>Start Date</th>
<th>End Date</th>
<th>Duration</th>
<th>No. of Breaches during EPV Cluster</th>
<th>Average Breach's Actual Future Price Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7/1/1993</td>
<td>2/1/1994</td>
<td>215</td>
<td>25</td>
<td>0.0380</td>
</tr>
<tr>
<td>2</td>
<td>7/15/1994</td>
<td>10/7/1994</td>
<td>84</td>
<td>7</td>
<td>0.0389</td>
</tr>
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<td>3</td>
<td>3/23/1999</td>
<td>10/11/1999</td>
<td>202</td>
<td>18</td>
<td>0.0300</td>
</tr>
<tr>
<td>4</td>
<td>6/18/2001</td>
<td>8/1/2001</td>
<td>44</td>
<td>4</td>
<td>0.0442</td>
</tr>
<tr>
<td>5</td>
<td>7/26/2002</td>
<td>8/21/2002</td>
<td>26</td>
<td>2</td>
<td>0.0315</td>
</tr>
<tr>
<td>6</td>
<td>7/23/2003</td>
<td>10/3/2003</td>
<td>72</td>
<td>5</td>
<td>0.0594</td>
</tr>
<tr>
<td>7</td>
<td>3/18/2008</td>
<td>9/11/2008</td>
<td>177</td>
<td>15</td>
<td>0.0344</td>
</tr>
<tr>
<td>9</td>
<td>7/15/2011</td>
<td>7/19/2011</td>
<td>4</td>
<td>1</td>
<td>0.0644</td>
</tr>
</tbody>
</table>
In Summary:

- 501 days of excessive price-volatility (EPV)
- Nine (9) clusters of EPV

... Of the above clusters of EPV, only four (4) are severe
Third Part:

- Use daily rice future prices
  (5407 days from Sep 1991 to Mar 2013)

- Identify time-periods of excessive price volatility
  (via Martins-Filho, Maximo Torero, and Feng Yao’s (IFPRI, 2010) methodology: Two-step spline-backfitted-kernel estimation / GPD distribution)

- Develop Early Warning Signals
  (via Particle Swarm Optimization (PSO))
Next Task: Looking for a Good Early Warning Signal
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lower order quantile
Next Task: Looking for a Good Early Warning Signal
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We set the mirror-image's lag at 60 days prior to an EPV cluster...
Next Task: Looking for a Good Early Warning Signal

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Parameters of the Early Warning Signals:
- Window of Observation
- Lower-Order Quantile Level
- Frequency of Breach

Together, these parameters generate a time-based variable, namely...
Next Task: Looking for a Good Early Warning Signal

Parameters of the Early Warning Signals:

- Window of Observation
- Lower-Order Quantile
- Frequency of Breach
- Scope
- Lead Time
- Mirror-Image
Next Task: Looking for a Good Early Warning Signal

Parameters of the Early Warning Signals:

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Together, these parameters generate a time-based variable, namely...
Next Task: Looking for a Good Early Warning Signal

... the scope’s time-coverage
What makes a good early warning signal:

accurate: scope's time-coverage covers an EPV cluster, minimal false alarms

good lead time: there's reasonable lead time before EPV cluster

comprehensive: signals pre-empt almost all EPV clusters

Basically...

We create a new set of trends (using spbk) and
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for parameters that meet above
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**Basically...**

We create a new set of trends (using spbk) and **solve** for parameters that meet above requirements
We expressed the criteria (accurate, comprehensive, good lead time), into a single additive objective function that can be minimized:

**Objective Function for Minimization:**

\[
 f(X) = \left[ \frac{\text{count}_1}{\text{laghvp}} \times 1.35 \right] + \left[ \frac{\text{count}_2}{\text{hvp}} \right] + \left[ \text{accuracy} \times 1.35 \right] + \\
\left[ \frac{\text{totalews}}{\text{totaldays}} \times 1.25 \right] + \left[ \frac{\text{totalscope}}{\text{totaldays}} \right]
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Where:

- **count\_1**: total no. of lagged mirror-images of time periods of EPV not covered by the scopes of the signals
- **laghvp**: total no. of lagged mirror-images of time periods of EPV
- **count\_2**: total no. of actual time periods of EPV not covered by the scopes’ time-coverage of the early warning signals
- **hvp**: total no. of actual time periods of EPV
- **accuracy**: predictive accuracy of the early warning signal with following ratio:
  \[1-((\text{no.of high.vol.periods captured by scope’s time-coverage}) / (\text{hvp})).\]
- **total ews**: total no. of early warning signals
- **total scope**: total no. of days covered by the scopes’ time-coverage of the early warning signals
- **total days**: total no. of days within the sample timeframe (1991 to 2013): 5407 future days
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**First two (2) terms - optimize good lead-time and comprehensiveness**
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First two (2) terms - optimize good lead-time and comprehensiveness

Last three (3) terms - minimize false alarms and improve accuracy.
We use R's PSO package to minimize the objective function...
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**PSO: Particle Swarm Optimization**

PSO is a meta-heuristic designed for functions that are hard to optimize using traditional optimization procedures (due to several peaks, non-linearities, long-forms, etc..)
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**PSO Parameter Search Range:**

- Window of Observation: from 1 to 40 future days
- Quantile Level: from 50 percent to 99 percent quantile
- Frequency of Breach: from 1 to 5
- Scope of Early Warning Signal: from 60 to 250 future days
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**Optimal Solution:**

*Window of Observation:* 11.61 future days  
*Quantile Level:* 91.31 percent  
*Frequency of Breach:* 4.18  
*Scope of Early Warning Signal:* 107.06 future days
After 1000 iterations, we obtain the following optimal solution:

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Given these parameters, an early warning signal will be activated...
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Given these parameters, an early warning signal will be activated...

... once the **91.31 percent** conditional quantile is breached **five (5)** times within **11.61** future days..
Just a review...
Just a review...

What makes a good early warning signal:

accurate: scope’s time-coverage covers an EPV cluster, minimal false alarms

good lead time: there’s reasonable lead time before EPV cluster

comprehensive: signals pre-empt almost all EPV clusters
We obtain these **Performance Statistics:**

- **Accuracy of EWS:** 94.44 percent
- **Predictive Power:** 99.40 percent
- **Comprehensiveness:** 99.40 percent of time periods of EPV are covered
- **Lead-time before EPV cluster:** average of 43 days from the earliest signal to start of high-volatility time-period
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Below is a summary of the different EPV clusters and the lead-times of the ews:

<table>
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<tr>
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<th>Date of Earliest Warning Signal for EPV</th>
<th>Lead-Time</th>
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<tr>
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<td>3/18/2008</td>
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- The unflagged 2011 EPV cluster is not severe..
- All EPV are **sufficiently covered** from beginning till end by the scopes of the ews..
for illustration...
1st (Jul 1993 - Feb 1994) and 2nd (Jul 1994 - Sep 1994) EPV Clusters:

3rd EPV Cluster (Mar 1999 - Sep 1999) and 4th (Jun 2001 - Aug 2001) EPV Clusters:
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5th (Jul 2002 - Aug 2002) and 6th (May 2003 - Oct 2003) EPV Clusters:
5th (Jul 2002 - Aug 2002) and 6th (May 2003 - Oct 2003) EPV Clusters:

7th (Mar 2008 - Nov 2008) and 8th (Apr 2009 - May 2009) EPV Clusters:
5th (Jul 2002 - Aug 2002) and 6th (May 2003 - Oct 2003) EPV Clusters:

7th (Mar 2008 - Nov 2008) and 8th (Apr 2009 - May 2009) EPV Clusters:
9th (Jul 2011) EPV Cluster:
Constraints:
Constraints:

- usage of daily future prices, not daily spot prices
- sensitivity analysis
- application to other commodities
Thank You.