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Can Time Series Analysis of Price Be Useful in Guiding Allocation Decision? An Example with Gulf of Mexico Red Snapper

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Price Volatility Research

Objective:

Investigate the relation between volatility in the price of red snapper and the management regime and environmental shocks, using GARCH and VAR analysis, to help better understanding of the implications of allocation shocks in terms of price risk.

Data:

Red snapper daily price during the period of January 3, 2007 to July 31, 2012 (N= 2,037).

Use the conventional log differences of price as:

$$y_t = \ln P_t - \ln P_{t-1}$$

Find a high degree of autocorrelation in y_t .
AR(10) best representation of the data generating process.

Data- Figures

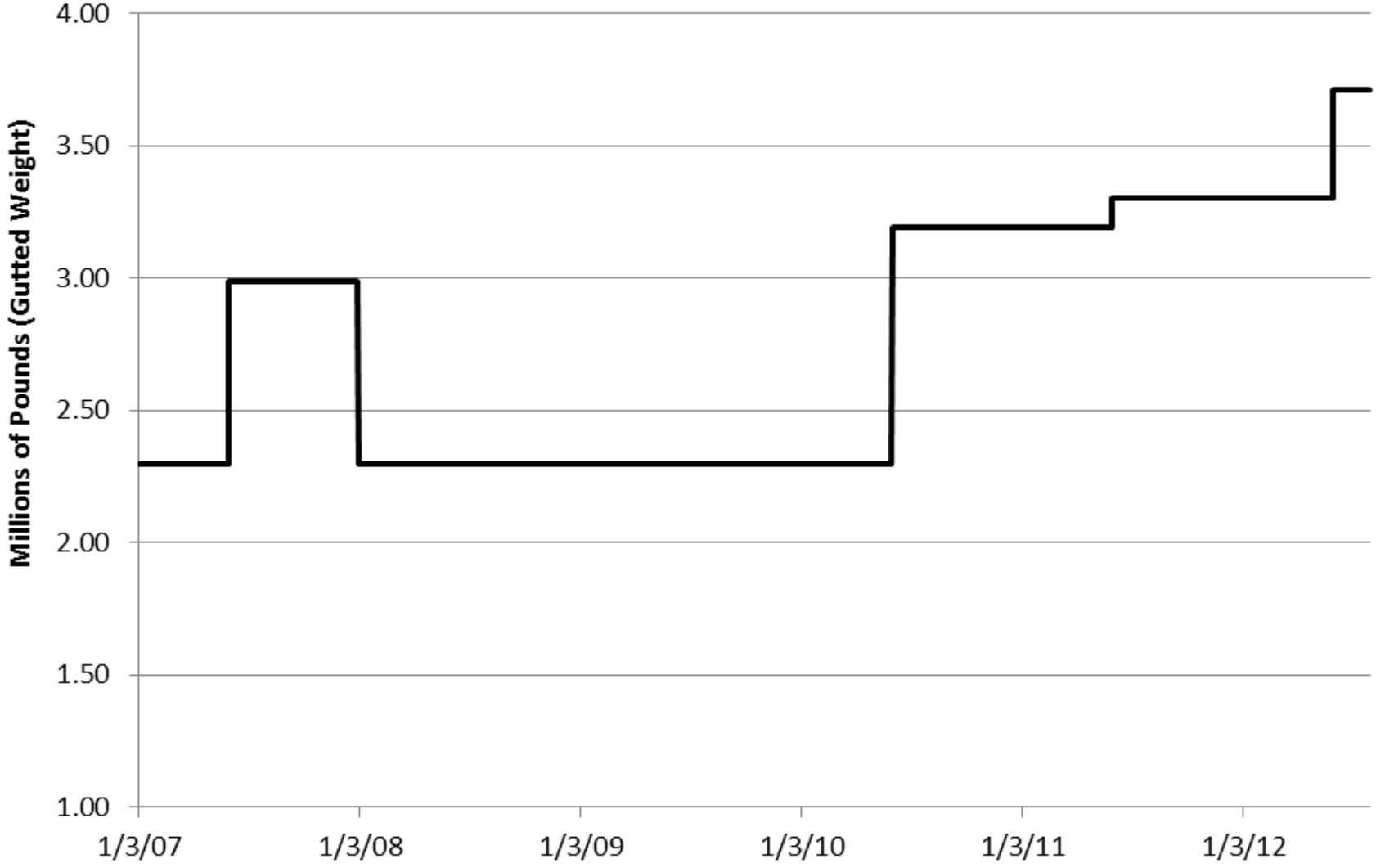

Figure 1. Commercial Quota for GOM Red Snapper (Source: NOAA, 2012)

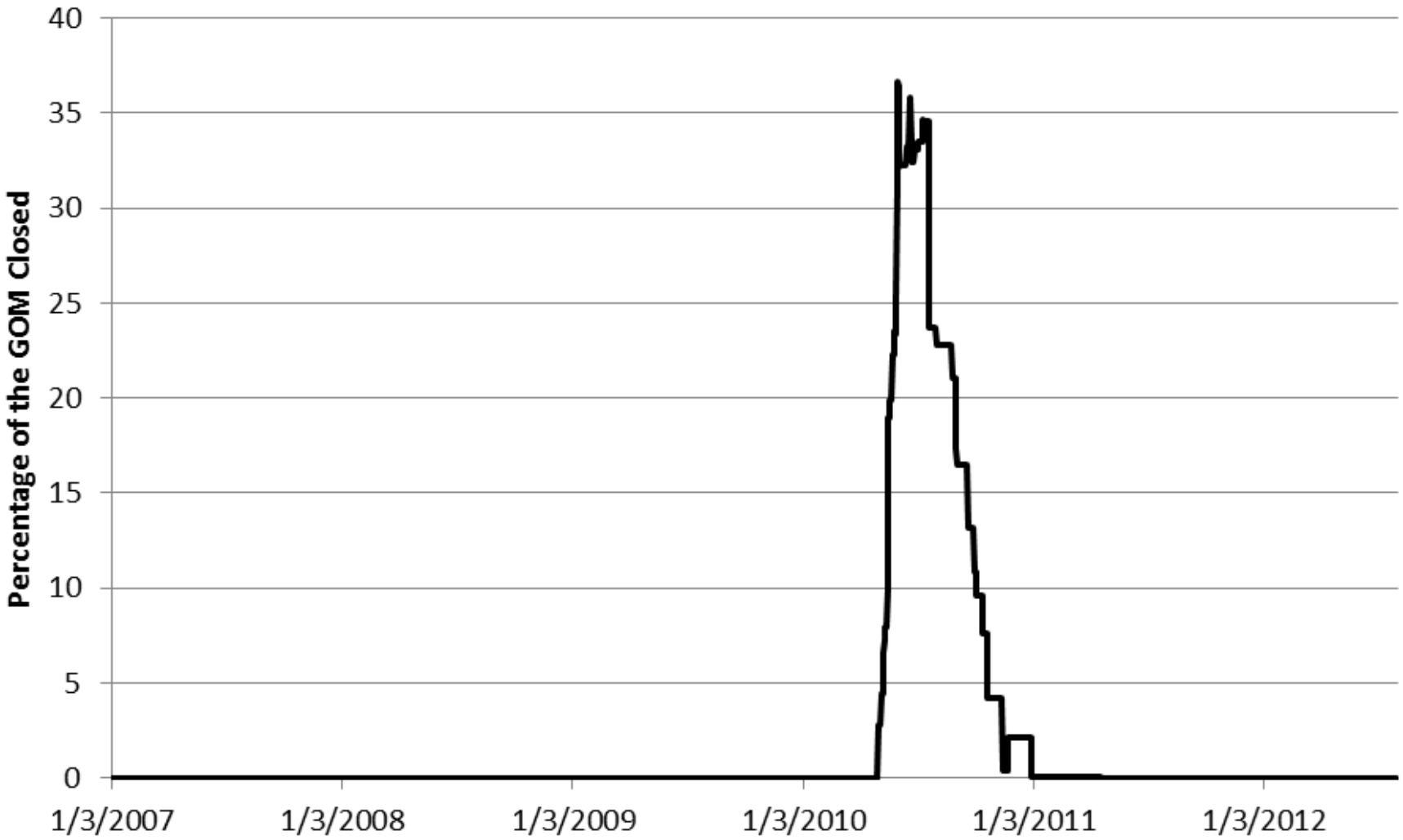

Figure 2. Percentage of GOM Closed Due to the Oil Spill

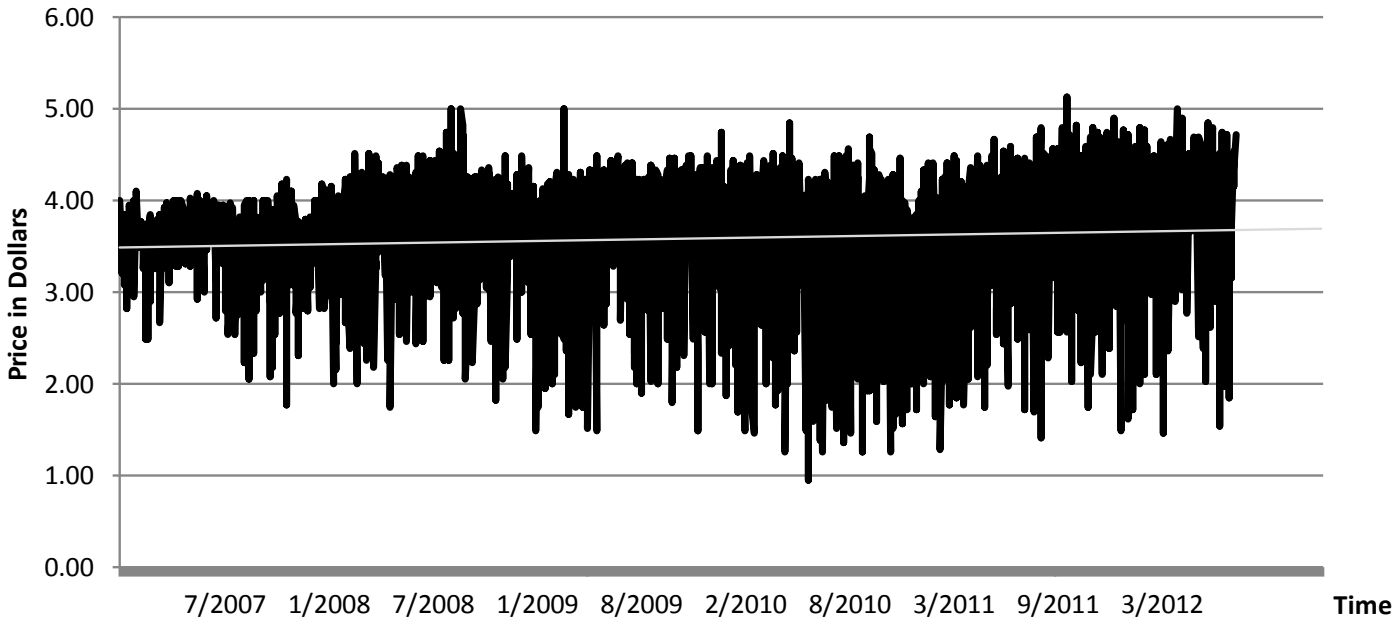

Figure 3. Price of Red Snapper

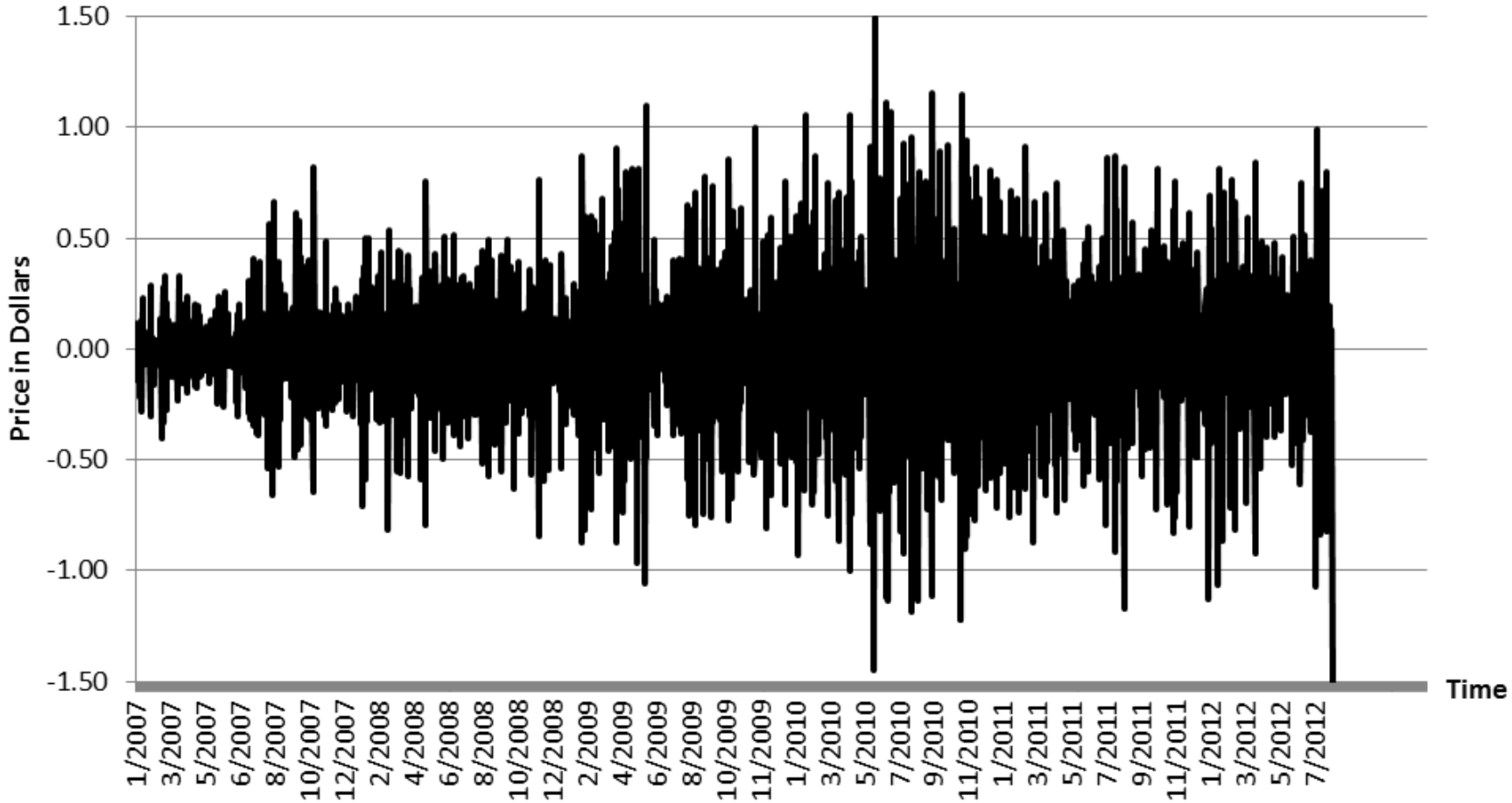

Figure 4. Log Difference of Red Snapper Price

Models:

1. Basic generalized autoregressive conditional heteroskedasticity (GARCH) model:

$$y_t = \psi_0 + \psi_k y_{t-k} + \varepsilon_t \,, \qquad (1)$$

where $k = 1, \ldots, 10$, and

$$\delta_t^2 = \omega_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \delta_{t-j}^2 + \nu_t \,, \qquad (2)$$

where $\omega_0 > 0, \alpha_i, \beta_j \geq 0$, and $\sum \alpha_i + \sum \beta_j < 1$

2. Introducing quota reduction and DWH oil spill into the GARCH model:

$$y_t = \psi_0 + \psi_k y_{t-k} + \lambda_1 QR_t + \lambda_2 O_t + \varepsilon_t \,, \qquad (3)$$

where $k = 1, \ldots, 10$, and

$$\delta_t^2 = \omega_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \delta_{t-j}^2 + \theta_1 V_t + \nu_t \,, \qquad (4)$$

where $\omega_0 > 0, \alpha_i, \beta_j \geq 0, and \sum \alpha_i + \sum \beta_j < 1$.

3. EGARCH model:

$$y_t = \psi_0 + \psi_k y_{t-k} + \lambda_1 QR_t + \lambda_2 O_t + \varepsilon_t , \qquad (5)$$

where $k = 1, \ldots, 10$, and

$$\log(\delta_t^2) = \omega_0 + \sum_{j=1}^{q} \beta_j \log(\delta_{t-j}^2) + \sum_{i=1}^{p} \alpha_i \left| \frac{\varepsilon_{t-i}}{\delta_{t-i}} \right| + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{t-k}}{\delta_{t-k}} + \theta_1 V_t + \nu_t , \qquad (6)$$

where $\omega_0 > 0, \alpha_i, \beta_j \geq 0, and \sum \alpha_i + \sum \beta_j < 1$.

$\left| \frac{\varepsilon_{t-i}}{\delta_{t-i}} \right|$ indicates the symmetric effects of innovations on the conditional variance.

$\frac{\varepsilon_{t-k}}{\delta_{t-k}}$ accounts for asymmetric (leverage) effect, in terms of the magnitude (size bias) of the response to shocks.

Later IFQ-GT and volatility variance were added to the model.

4. TGARCH model:

$$y_t = \psi_0 + \psi_k y_{t-k} + \lambda_1 QR_t + \lambda_2 O_t + \varepsilon_t \,, \qquad (7)$$

where $k = 1, \ldots, 10$, and

$$\delta_t^2 = \omega_0 + \sum_{j=1}^{q} \beta_j \delta_{t-j}^2 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{r=1}^{r} \gamma_k \varepsilon_{t-k}^2 I_{t-k} + \theta_1 V_t + \nu_t \,, \qquad (8)$$

where $\omega_0 > 0, \alpha_i, \beta_j \geq 0, and \sum \alpha_i + \sum \beta_j < 1$.

the differential effect of good news, $\varepsilon_{t-1} > 0$, and bad news, $\varepsilon_{t-1} < 0$,

is represented by a dummy variable, where I = 1, if $\varepsilon_t < 0$, otherwise 0.

5. The vector autoregressive (VAR) model:

Conducted unit root tests and established existence of cointegrating vectors and then adopted:

$$y_t = \psi_0 + \sum_{t=1}^{k} \psi_{1,k} y_{t-k} + \sum_{t=1}^{k} \lambda_{1,k} QR_{t-k} + \sum_{t=1}^{k} \lambda_{2,k} O_{t-k} + \sum_{t=1}^{k} \lambda_{3,k} IFQ_{t-k}^{GT} + \sum_{t=1}^{k} \theta_{1,k} V_{t-k} + \varepsilon_t, \quad (9)$$

Results:

- While volatility is rather persistent (0.99), it is mean reverting.

- Oglend and Sikeland (2008) estimate the degree of volatility persistence in the salmon market at 0.81, while Buguk, et al. (2003) arrive at the degree of volatility persistence of 0.98 for the catfish market and 0.38 for the menhaden market.

- The half-life estimates from the EGARCH models suggest that mean reversion occurs within approximately ten days, thus the market is fairly efficient.

Results:

- Reductions in quota during the study period have increased the conditional mean of the red snapper prices.

- Quota reduction generates a negligible shock and statistically insignificant effect on price volatility, which disappears quickly with a reversion time of roughly nine days.

- Results from the VAR model show that the impulse response to quota reduction is very low and volatility quickly returns to normal.

Results:

- Surprises in the trading volume have a larger effect on price volatility than the forecastable component; approximately 0.14 vs. 0.10, respectively. Overall, market depth insignificant.
- An innovation from the oil spill closure produces a larger response on the price volatility, but after a few days the volatility gradually returns to the long-run equilibrium.
- IFQ-GT has increased the mean of the log difference in red snapper price, price volatility has diminished in response to the new IFQ program.
- Reject the presence of asymmetry in the red snapper price response to shocks.

Additional Thoughts:

1. Can the welfare effects of price risk be recovered? What are the limitations?

Measurement and management of risk:

- beta estimation (relative to a benchmark asset)

$$r_{a,t} = \alpha_a + \beta_a r_{m,t} + \varepsilon_{a,t}$$

- Choice of benchmark (S&P 500- U.S. large-cap stocks; an index of stocks plus bonds), benchmark for fish prices, PPI?
- Multiple beta model if different risk factors present (welfare effect of changes in the occupational fatalities (risk), Value of Statistical Life)
- Determining the value of risk reduction, cost of hedging to reduce shocks to stakeholders' wealth

- Value at Risk (VaR) measures the potential loss in value of a risky asset or portfolio over a defined period for a given confidence interval.
- Variance-Covariance Method is one popular approach to calculate VaR

$$VaR_{1-\alpha} = P \cdot \delta_P \cdot Z_\alpha$$

P = correlation coefficients between assets
δ_P = standard deviation or volatility of an asse
Z_α = number of standard deviations on the left of the mean

2. Can analysis of price movement provide signals? Is there a relation between price and abundance?

A. Non-renewable resources:
- discovery cost vs. extraction costs
- Price path (marginal cost and scarcity rent)
- Natural resource scarcity measurement literature (Slade, 1982)
- LR Dynamics of resource scarcity- VAR and ECM models (Moazzami and Anderson, 1994)

B. Renewable natural resources:

- A different dynamics, growth rate vs. harvest rate (role of stock)- biological model
- Maximum sustainable yield and dynamic efficient sustainable yield and markets
- Population dynamics, stock assessment, use of harvest rate and mortality rate (ignore market variables- price)
- Natural resource optimal control modeling, Fishery vs. mining models, cost effect and scarcity effect of change in abundance mutually exclusive (Lyon, 1999)

Price-Abundance Relation Research

- Examined the relationship between ex-vessel prices for red snapper and estimates of abundance of the species between 1978 and 2010.
- Adopted the VAR and VAR-X frame-works for log-differenced time series, Abundance (East and West FL), Effort, Imports, Quota, and IFQ

- Found negative correlation of changes in West FL ex-vessel prices and East Gulf abundance.
- This finding is robust to the inclusion and exclusion of data describing fishing effort, total commercial quota, snapper imports, and the introduction of the IFQ system in 2007.

Impulse response functions ……

3. When to conduct reallocation and when stock assessments are infrequent?

- Account for model uncertainty, frequent fine tuning of quota/allocation introduces uncertainty.
- It also requires effort/resources (from NOAA).
- Then, a band can be created around the estimates where no action would be taken.
- On the other hand, less fine tuning requires more drastic actions later.

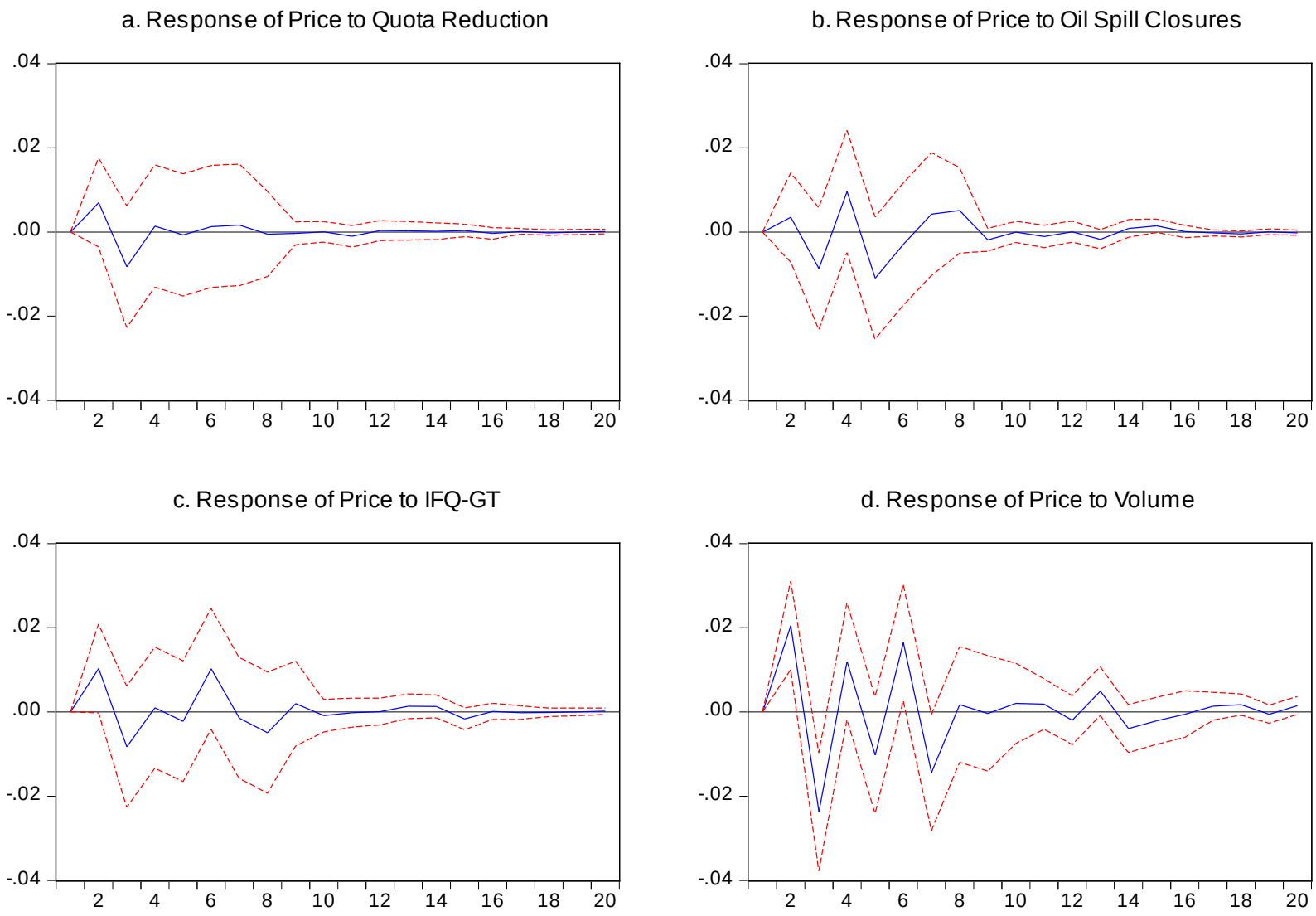

Figure 7. Generalized Impulse Response of Price Volatility