A GLOBAL VAR MODEL FOR THE ANALYSIS OF WHEAT EXPORT PRICES

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Abstract

Food commodity price fluctuations have an important impact on poverty and food insecurity across the world. Conventional models have not provided a complete picture of recent price spikes in agricultural commodity markets, while there is an urgent need for appropriate policy responses. Perhaps new approaches are needed in order to better understand international spill-overs, the feedback between the real and the financial sectors and also the link between food and energy prices. In this article we present the results from a new worldwide dynamic model that provides the short and long-run impulse responses of the international wheat price to various real and financial shocks.

JEL Classification: G14, Q14, C12, C15.

Keywords: Global Dynamic Models, Price analysis, Wheat market.

1 Introduction

During the food crises of 2006-2008 and 2010-2011 there were large increases in the price of wheat, soybeans, rice and maize on the international markets. These surges in prices led to substantial increases in domestic prices. High food prices increased the number of people living in poverty, because they spend a larger portion of their income on food. The food crisis has also led to a significant increase in food insecurity and hunger. The FAO (2008) estimated that, because of the higher food prices, an additional 75 million people were eating a diet that is inadequate to meet their nutritional need. Thus understanding key trends in commodities prices has an important role to play in formulating sound policies.

Numerous factors have been proposed in the literature for explaining recent commodity price movements, but there is no general consensus on the relative weight that should be attributed to each of them.

The aim of the article is to use a global dynamic model to improve our understanding of wheat price changes. To be precise, we propose a new GLObal Wheat Market Model (GLOWMM) for studying the dynamics of wheat prices, through the dependence of each country's export price on all other countries export prices and on fundamental real and financial drivers, such as supply and demand factors, exchange rates, and oil prices. The model uses the Global Vector AutoRegressive (GVAR) methodology originally proposed by Pesaran et al. (2004) and Des et al. (2007). The GVAR model allows us to evaluate the first and second round inflationary effects on wheat export prices of various shocks, such as a reduction of the stock-to-use ratio, an increase in the oil price or a US currency devaluation relative to the main competitors' currencies. We focus on the wheat export price dynamics of the six main exporting countries: the United States, Argentina, Australia, Canada, Russia and EU, allowing for the influence of a Rest of the World region in order to take into account the of other countries on wheat prices.

We think that there are three main reasons why the GVAR model is useful for analyzing worldwide wheat prices. First, the model is specifically designed to analyze market fluctuations and interactions between countries. This is crucial, given the features of the world wheat market and the global dimensions of food price dynamics, which cannot be reduced to one exporter but rather involve more countries. Secondly, the GVAR lets us model the dynamism in wheat export prices caused by the effects exerted by country-specific and foreign-specific variables. As country-specific variables we can use: the impact on each country's export price of the usually proposed drivers, such as the stock-to-use ratio, the nominal exchange rate (measured relative to the US dollar) and the cost of inputs. However export prices can also be affected by what can be labeled foreign-specific variables, i.e. variables that are strictly connected to the domestic variables, such as the competitors' export prices, the effective exchange rate, or supply and/or demand shocks in other countries that may affect the domestic economy. GVAR can also account for global shocks such as a changes in oil prices or extreme weather events, i.e. shocks that will affect all or some countries but can be thought of as strictly exogenous with respect to the wheat market. Thirdly, although the GVAR model combines a number of atheoretical relationships, i.e. unlike structural models the approach does not attempt to make restrictions on the basis of economic theory, nevertheless it can be easily adapted and used to test well known economic concepts such as, for example, whether the law of one price (LOP) holds in the worldwide wheat market.

The article is organized as follows. In Section 2 we provide the motivation for this study and describe the econometric model. In Section 3 we present the data and we discuss the empirical results and the generalized impulse responses of wheat export prices to various shocks. Finally, Section 4 concludes.

2 Motivation and methodology

This article contributes to the considerable empirical literature on the spatial analysis of price determination in commodity markets, and, specifically, the spatial analysis of wheat prices. Wheat is among the most important internationally traded grain commodities and the world market is characterized by a limited number of major exporting countries. Six regions, the United States, Canada, Australia, the European Union (EU), Russia (including Ukraine and Kazakhstan), and Argentina accounted for more than 88% of total world exports in 2010 (International Grain Council, World Grain Statistics, 2010). The logarithms of the wheat export price have shown a sensible level of synchronization especially during the astonishing rise in 2007 - 2008, the sudden decline in 2009 and the new rise in $2010-2011$. Their pairwise correlation coefficients during the period $2000-2012$ range between 0.88 and 0.97. Nevertheless there are differences in the shapes of single price series, and these may be connected to the heterogenous reactions of countries to shocks. For this reason considerable attention has been directed to explaining why prices may be imperfectly linked across space, and thus why wheat markets may be or may not be imperfectly integrated. For example, Ardeni (1989) and Goodwin (1992) analyzed wheather the law of one price holds in international wheat markets. In addition the market power implications of international wheat price linkages have been investigated, among others, by McCalla (1966), Carter and Schmitz (1979) and Alaouze et al. (1978), Kolstad and Burris (1986), Scoppola (2007) and, more recently, by Arnade and Vocke (2013).

Many researchers have proposed using the Vector Autoregressive methodology (VAR) for the analysis of spatial wheat prices. A lot of attention has been devoted to the causality issues among prices (Spriggs et al. 1982; Mohanty et al., 1995) or to the analysis of dynamic relationships among wheat prices in the international wheat markets, such as, for example, in Bessler et al. (2003). However, the analysis has been usually confined to investigating spatial wheat price dynamics without connecting them to the main driver factors such as the cost of inputs, demand and supply shocks or movement of financial variables such as the exchange rates.[1] The reasons for not including the main driver factors in VAR models is basically connected to lack of data, which means that a full systematic estimate of a global wheat model would not be feasible foe even a limited number of countries.

The Global Vector Autoregressive (GVAR) model can be used to overcome the above mentioned problems. The GVAR model was proposed by Pesaran, Schuermann and Wiener (2004), and further developed by Dées, di Mauro, Pesaran and Smith (2007), for analysing the transmission of domestic and international shocks and for identifying the separate contributions of demand, supply, monetary policy and exchange rate shocks to business cycle fluctuations. Basically the idea of the GVAR modeling approach is that each country can be modeled individually and estimated as a vector autoregression and the dynamics of home variables are linked to each other, as in any other VAR model. However, and unlike standard VAR models, each country model is linked to the others by including foreign-specific variables, such as, in our case, the competitors' wheat export prices or the effective exchange rate, which are related to the international trade pattern of the given country. In addition, global variables representing strictly exogenous international factors, such as oil prices or climate changes, can included in each of the country models. After having estimated the VAR country-models, their corresponding estimates are connected through link matrices, in our case basically given by the trade weight of each country or region in the global wheat export market, and then stacked together in order to build the global model. Below we provide a short presentation of how the GVAR model can be constructed and estimated.[2]

The specification of the GVAR model proceeds in two stages. In the first stage, i.e. the estimation stage, the reduced form vector autoregression VAR model, augmented by the exogenous, X, variables, labeled VARX(p, q), is estimated for each country i, and in the second stage all individual country VARX models are stacked and linked, using weighted matrices.

To be more precise, modelling each country i as a VARX(p, q),

$$\Phi_i (L, p_i) y_{it} = a_{i0} + a_{i1} t + \Lambda_i (L, q_i) y^*_{it} + \Psi_i (L, q_i) d_t + \epsilon_{it} \tag{1}$$

where the indexes $i = 1, ..., N;\ t = 1, ..., T$, a_{i0} is a $(k_i \times 1)$ vector of deterministic intercepts, a_{i1} is a $(k_i \times 1)$ vector of deterministic trends, y_{it} is a $(k_i \times 1)$ vector of country-specific (domestic) variables and corresponding $(k_i \times k_i)$ matrices of lagged coefficients, denoted by $\Phi_i (L, p_i) = I - \sum_{p=1}^{p_i} \Phi_i L^i$,

[1] Exceptions are Goodwin and Schroeder (1991) where the analysis also considers dynamic relationships between wheat prices and exchange rates and transportation costs and the work of Pietola et al. (2010) where a conditional mean model for international wheat prices and inventories has been analyzed.

[2] A deeper analysis can be found in Pesaran et al.'s(2004) and Dées et al.'s (2007) articles.

where L is the lag operator; y_{it}^* is a $(k_i \times 1)$ vector of foreign variables, i.e. the exogenous X variables in the VARX specification, and corresponding $(k_i \times k_i^*)$ matrix of lag polynomial denoted by $\Lambda_i(L, q_i)$; $\Psi_i(L, q_i)$ is a matrix lag polynomial associated to the global exogenous variables d_t. Finally ϵ_{it} is a $(k_i \times 1)$ vector of zero mean, idiosyncratic country-specific shocks, which are assumed to be serially uncorrelated and with time invariant covariance matrix $\sum_{ii}$, i.e $\epsilon_{it} \sim iid(0, \sum_{ii})$. The weak exogeneity of y_{it}^* in the GVAR model implies no long-run feedback from y_{it} to y_{it}^*, without necessarily ruling out lagged short-run feedback between the two sets of variables. Thus the hypothesis allows country models to be estimated individually, and then at a later stage combined together in a global model. As discussed in the following section, the weak exogeneity of foreign-specific variables can then be tested in the context of each of the country specific VARX models.

The first step of the analysis is to fix the order of the matrices polynomial $\Phi_i(L, p_i)$, $\Lambda_i(L, q_i)$ and $\Psi_i(L, q_i)$. The Akaike information criterion (AIC) or the Schwartz Bayesian (SB) criterion can be used to do this. To show how the GVAR model is constructed, consider a generic country i with $p_i = 2$ and $q_i = 2$ fixed by using the AIC or the SB criterions, and assume for the sake of simplicity that $\Psi_i(L, q_i) = 0$. Thus equation (1) can be written as

$$y_{it} = a_{i0} + a_{i1}t + \Phi_{i1}y_{it-1} + \Phi_{i2}y_{it-2} + \Lambda_{i0}y_{it}^* + \Lambda_{i1}y_{it-1}^* + \Lambda_{i2}y_{it-2}^* + \varepsilon_{it}. \tag{2}$$

We group the domestic and foreign variablesfor each country as

$$\mathbf{x}_{it} = \begin{pmatrix} y_{it} \\ y_{it}^* \end{pmatrix}. \tag{3}$$

Therefore each country VARX model (2) becomes

$$\mathbf{A}_{i0}\mathbf{x}_{it} = a_{i0} + a_{i1}t + \mathbf{A}_{i1}\mathbf{x}_{it-1} + \mathbf{A}_{i2}\mathbf{x}_{it-2} + \varepsilon_{it}, \tag{4}$$

where

$$\mathbf{A}_{i0} = \left(I_{k_i}, -\Lambda_{i0}\right), \ \mathbf{A}_{i1} = \left(\Phi_{i1,}, \Lambda_{i1}\right), \mathbf{A}_{i2} = \left(\Phi_{i2,}, \Lambda_{i2}\right). \tag{5}$$

In the next step a vector of variables is defined

$$y_t = \begin{pmatrix} y_{0t} \\ y_{1t} \\ \vdots \\ y_{Nt} \end{pmatrix}, \tag{6}$$

and using the weight matrix $\mathbf{W}_i$ constructed as the export weight of each country relative to the exports of all competitor countries, we obtain the following identity

$$\mathbf{x}_{it} = \mathbf{W}_i y_t \quad \forall i = 0, 1, ..., N. \tag{7}$$

The previous relationship allows each country model to be written in terms of the global vector y_t, and thus it is the fundamental device through which each country's market is linked to the global GVAR model. Using now the identity (7) in each country VARX model (4) we obtain

$$\mathbf{A}_{i0}\mathbf{W}_i y_{it} = a_{i0} + a_{i1}t + \mathbf{A}_{i1}\mathbf{W}_i y_{it-1} + \mathbf{A}_{i2}\mathbf{W} y_{it-2} + \varepsilon_{it}. \quad (8)$$

Finally by stacking each country-specific model in (8), we end up with the Global VAR for all endogenous variables in the system y_t,

$$\mathbf{G}_0 y_{it} = a_0 + a_1 t + \mathbf{G}_1 y_{it-1} + \mathbf{G}_2 y_{it-2} + \varepsilon_t \quad (9)$$

where

$$\mathbf{G}_0 = \begin{pmatrix} \mathbf{A}_{00}\mathbf{W}_0 \\ \mathbf{A}_{10}\mathbf{W}_1 \\ \vdots \\ \mathbf{A}_{N0}\mathbf{W}_N \end{pmatrix}, \mathbf{G}_1 = \begin{pmatrix} \mathbf{A}_{01}\mathbf{W}_0 \\ \mathbf{A}_{11}\mathbf{W}_1 \\ \vdots \\ \mathbf{A}_{N1}\mathbf{W}_N \end{pmatrix}, \mathbf{G}_2 = \begin{pmatrix} \mathbf{A}_{02}\mathbf{W}_0 \\ \mathbf{A}_{12}\mathbf{W}_1 \\ \vdots \\ \mathbf{A}_{N2}\mathbf{W}_N \end{pmatrix}, \mathrm{a}_0 = \begin{pmatrix} a_{00} \\ a_{10} \\ \vdots \\ a_{N0} \end{pmatrix}, \mathrm{a}_1 = \begin{pmatrix} a_{01} \\ a_{11} \\ \vdots \\ a_{N1} \end{pmatrix}, \varepsilon_t = \begin{pmatrix} \varepsilon_{0t} \\ \varepsilon_{1t} \\ \vdots \\ \varepsilon_{Nt} \end{pmatrix}.$$

If the $\mathbf{G}_0$ matrix is non singular, it can be inverted, thus obtaining the Global VAR model in its reduced form, i.e

$$y_t = b_0 + b_1 t + \mathbf{F}_1 y_{t-1} + \mathbf{F}_2 y_{t-2} + v_t \quad (10)$$

where

$$\mathbf{F}_1 = \mathbf{G}_0{}^{-1}\mathbf{G}_1,\ \mathbf{F}_2 = \mathbf{G}_0{}^{-1}\mathbf{G}_2,\ \mathrm{b}_0 = \mathbf{G}_0{}^{-1}a_0,\ \mathrm{b}_1 = \mathbf{G}_0{}^{-1}a_1,\ v_t = \mathbf{G}_0{}^{-1}\varepsilon_t.$$

Equation (10) can be solved recursively and used for the analysis of impulse responses, to compute the forecast error decompositions or to forecast the y_t variables.

3 The empirical model and its results

We consider six VARX models, one for each of the main export regions: Argentina, Australia, Canada, EU, Russia and the USA. In addition to the previous six main competitors, we specify a further VARX model, in order to take into account the effects exerted by all the other countries. These countries are all collected in a Rest of the World (ROW) region. These models are estimated at monthly intervals during the period from June 2000 to January 2012. The set of variables considered are the logarithms of export price quoted in US dollars, p^e_{it}, the wheat stock-to-use ratio z_{it} computed as the fraction of the stocks and total consumption. In this case we use the data from USDA that provides forecasts of stocks and consumption for the subsequent end-of-season. As highlighted in a recent work by Serra and Gil (2011), these data can be more effective in explaining price behavior than the actual data. We also include the fertilizer price p^f_{it} expressed in the local currency, the exchange rate e_{it} given by the bilateral exchange rate of the local currency in country i per unit of US dollar, and finally the index of food consumer prices p^c_{it}. This latter variable is included as a benchmark of food inflation in each country i.[3]

In the absence of strong a priori information that can identify the short-run dynamics of our system, we use the generalised impulse response function (GIRF) approach proposed by Koop, Pesaran and Potter (1996) and further developed by Pesaran and Shin (1996). The GIRF has the useful property of being invariant to the ordering of the variables and of the countries. This is of particular

[3]All the variables, with the exception of z_{it}, are log of indexes with base year July/2000-June/2001. A full description of data, as their sources, are presented in the Appendix.

importance in our system, where there is no clear economic "a priori" knowledge which can establish a reasonable ordering. We analyze the implications of three different external shocks in order to assess the dynamic properties of the GVAR model and the time profile of the effects of shocks on country-specific and foreign-specific variables and global oil shocks.

More specifically, let us consider the solution of the GVAR model given by (9). The GIRFs can be defined as

$$GIRF\left(y_t; u_{ilt}, n\right) = E\left(y_{t+n} | \varepsilon_{ilt} = \sqrt{\sigma_{ii,ll}}, \Im_{t-1}\right) - E\left(y_{t+n} | \Im_{t-1}\right).$$

where $\Im_{t-1}$ is the information set at time $t-1$, $\sqrt{\sigma_{ii,ll}}$ is the diagonal element of the variance-covariance Σ_ε corresponding to the lth equation in the ith region, and n is the horizon. From the previous definition it follows that the GIRFs of a unit (one standard error) shock at time t to the lth equation with effects on the jth variable and at time $t+n$ is given by the jth element of

$$GIRF\left(y_t; \varepsilon_{ilt}, n\right) = \frac{e_j' \mathbf{A}_n \mathbf{G}_0^{-1} \Sigma_\varepsilon e_l}{\sqrt{e_l' \Sigma_\varepsilon e_l}} \; n = 0, 1, ...; l, j = 1, 2, ..., k, \tag{11}$$

where $e_l = (0, 0, ..., 0, 1, 0..., 0)'$ is a selection vector with unity as the lth element in case of a country specific shock.[4] A global shock can also be entertained. In this case the selection vector can be defined as $e_l = (0, w_{i0}, ..., 0, w_{i1}, 0, ..., 0)'$ with $\sum_{j \neq i} w_{ij} = 1$. For example, a devaluation of the US dollar can be thought of as a shock for all exchange rate equations, assigning a share of the shock equal to its export weight to each country.

For reason of space we only analyze a reduction in the US stock-to-use ratio. This is a typical shock to a domestic variable that will affect the home market as well as foreign countries. Using the GIRF we analyze how this shock spreads around the world, manifesting itself in higher wheat prices. The second shock we simulate is a US dollar devaluation against competitor currencies. This can be seen as a global shock, which will affect prices (and quantities). The final shock we present is a perturbation in the oil price. Due to limitations of space, we only present the GIRF impulse responses of wheat export prices for the various regions analyzed, and we focus on the first year after the shock. Naturally the GIRF can be used to analyze the effect of any of the previous (or other) shocks on the other endogenous variables such as, for example, the stock-to-use ratios. These impulse responses are available upon request.

The first shock we consider is a negative shock to the USA stock to utilization ratio. A recent analysis of the possible effects of a reduction of the stock-to-use ratio on price spikes is contained in Trostle (2008), Mitchell (2008) and Abbott et al. (2008). In our case a one-standard deviation shock corresponds to a 4.3% decrease in the stock-to-use ratio.[5] In Figure 1., we indicate the effects of this shock on the wheat export prices with a solid line, while the 90% bootstrapped confidence intervals are represented by the thinner lines.[6] Unsurprisingly, a negative shock to the US stock-to-use ratio raises the export prices in all countries. In the US the response impact is +0.3%, and after twelve months the rise in the wheat export price is +2.8%. There are similar shapes for the EU, +0.1% the response impact, and +2.3% after 12 months. The same is true for Australia and Canada. The only country that is less sensitive to a US stock-to-use shock is Argentina.

Figure 1 about here

[4] The $\mathbf{A}_n$ matrices are calculated recursively as $\mathbf{A}_n = \mathbf{F}_1 \mathbf{A}_{n-1} + \mathbf{F}_2 \mathbf{A}_{n-2} + ... + \mathbf{F}_p \mathbf{A}_{n-p}$, $n = 1, 2, ...$, with $\mathbf{A}_0 = \mathbf{I}_n$, $\mathbf{A}_n = \mathbf{0}$ for $n < 0$.

[5] During the period of analysis, the average value of the variable was 55.1%

[6] The confidence interval is calculated using the sieve bootstrap method with 1000 replications. See Dées et al. (2007) for a detailed description of the GVAR bootstrapping procedure.

4 Concluding Remarks

In this article we employ the Global Vector Autoregressive (GVAR) methodology to analyze the world wheat market. The aim of the article was not to carry out a structural exercise, but rather to assess what variables are typically associated with wheat price movements. Thus we focus on the short and long-run responses of wheat export prices to a decrease in the wheat stock-to-use ratio, to an increase in oil prices and, to a nominal US dollar devaluation. All these shocks have been proposed in the literature as explaining recent commodity price movements. The impact effects and time profiles of these shocks are presented using generalized impulse response functions. We find that all these factors have inflationary effects on wheat export prices, although the impact over time and among the countries differs, depending on the type of shocks. At a global level the inflationary effect of the stock-to-use ratio seems to be greater than an oil price or a US dollar devaluation shock. Thus our results indicate that falling wheat stock levels (relative to consumption levels) should be a major concern when analyzing international wheat prices. This finding may have important implications for economic policy. Because of the strong and persistent economic impact of depletions in stock-to-use, agricultural policy makers should monitor the level of wheat stocks.

The model we have outlined in this article can be used for a variety of simulation and forecasting-monitoring exercises which are aimed at exploring different aspects of the global wheat market. The model can also be extended in various directions. First, rolling weights can be used, rather than the simple yearly average that we used in the article. This improvement will allow possible changes in the importance of countries in wheat trade to be appreciated. Second, dummy variables can be introduced in the single country VARX models, in order to take into account episodes of, for example, panic buying or bans on exports. Thirdly, regime-switching GVAR models have been recently proposed by Binder and Gross (2013). They can be particularly useful in allowing for possible recurring or non-recurring structural changes, such as different volatility regimes, in all or a subset of countries. Furthermore, nonlinear GVAR can be developed, (see Favero, 2012), for analysing possible asymmetries in the transmission of shocks to the wheat price. Finally, the model can be widened to include export-import quantities, with the aim of analyzing changes in trade patterns after shocks in the worldwide wheat market. We leave these as areas for future analysis.

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Data Appendix

In this appendix we describe the data sources and key steps in the analysis of data.

Wheat Export Prices:
- Argentina: Trigo Pan wheat up river; Russia: Black Sea milling wheat; Australia: ASW wheat Eastern States; Canada: CWAD wheat St Lawrence; EU: France standard grade wheat Rouen; USA: SRW wheat Gulf.
- Index : 2000.7 - 2001.6 = 100.
- Source: International Grain Council.

Stock to utilization ratio
- Ratio of Predicted Ending Stocks on Predicted Consumption.
- Source: USDA, Grain World Markets and Trade.

Nominal Exchange rate
- Nominal exchange rate : Local currency per unit of US dollar; Argentina: Pesos; Russia: rublo; Australia: Australian dollar; Canada: Canadian dollar; EU: euro; Rest of World: weighted average of Brasil: reals; China: yuan; India: rupees; Mexico: pesos; Turkey: liras; weight are give by the wheat production of each country on the total production of these countries.
- Index : 2000.7 - 2001.6 = 100.
- Source : IMF Financial Statistics and Financial Statistics of the Federal Reserve Board.

Fertilizer prices
- DAP (Diammonium Phosphate) price.
- Price transformed in local currency using the local exchange rate against the US dollar.
- Index : 2000.7 - 2001.6 = 100.
- Source: World Bank Commodity Price Data (Pink Sheet).

Oil price
- Crude oil price. Nominal US dollar.
- Index : 2000.7 - 2001.6 = 100.
- Source: World Bank Commodity Price Data (Pink Sheet).

Food consumption prices
- Eurostat and National statistics.
- Index : 2000.7 - 2001.6 = 100.

Export weights
- Wheat trade: main origin and destination.
- Source: International Grain Council.

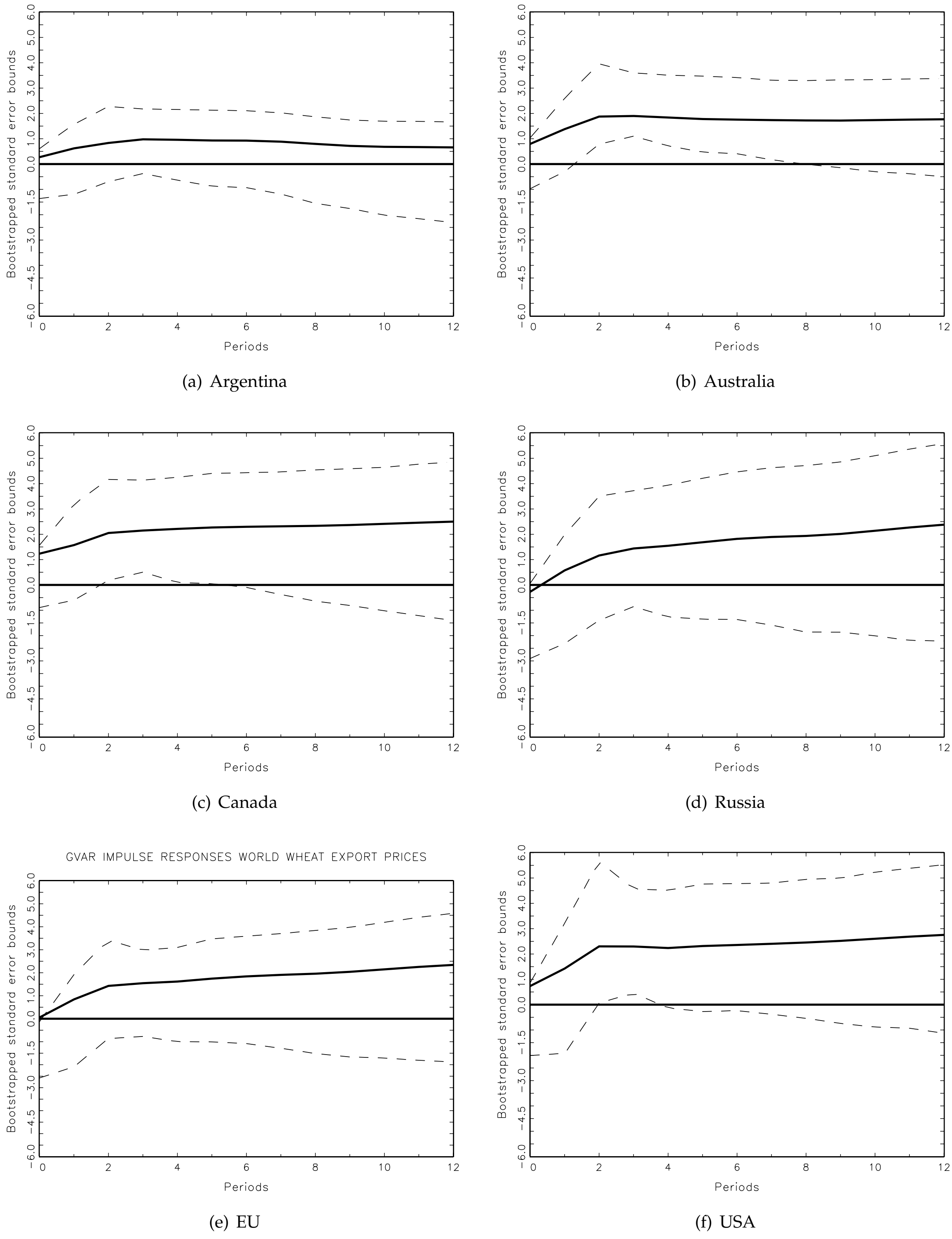

Figure 1: GVAR Impulse Responses of Export Prices to a USA Stock-to-Use Negative Shock.