Global Analysis of Agricultural Trade Liberalization: Assessing Model Validity

Thomas W. Hertel, Roman Keeney, and Ernesto Valenzuela[1]

[1] Hertel is Director and Distinguished Professor, Keeney and Valenzuela are Graduate Assistants and Ph.D. Candidates with the Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.

Abstract

This paper presents a validation experiment of a global CGE trade model widely used for analysis of trade liberalization. We focus on the ability of the model to reproduce price volatility in wheat markets. The literature on model validation is reviewed with an eye towards designing an appropriate methodology for validating large scale CGE models. The validation experiment results indicate that in its current form, the GTAP-AGR model is incapable of reproducing wheat market price volatility and that trade and poverty analysis taking these prices as inputs might be wrongly influenced. We conclude that model validation is tractable and an important component of analysis, as it points to areas to consider for refining analysis. In the specific case presented here, it seems that the Armington structure and trade elasticities are influential in whether the model over our under predicts price volatility for a specific region based on its net trade position for wheat.

1. Introduction

In light of the Doha Development Round of WTO negotiations, there continues to be strong demand for quantitative analysis of the impacts of global trade liberalization. The impacts of agricultural policies are once again at the fore – this time owing to their potential impacts on low income households -- particularly farm households -- in developing countries. While the case of US cotton subsidies has received the most attention from the failed Cancun talks, the general impact of rich country agricultural support in poor countries is now very much on the agenda in negotiating circles.

Central to this debate is the likely impact on world prices of removing wealthy country farm subsidies. The price impacts are quite complex, and vary greatly by commodity, developing country and rich country subsidy regime (Dimaranan, Hertel, and Keeney, 2003). However, the basic idea is that the larger the price impacts, the more likely it is that reforms will lead to a substantial reduction in poverty rates amongst producers in low income countries – a point driven home forcefully by William Cline in his recent book on this subject (Cline, 2003).

In a recent critique of Cline's book, Dani Rodrik (2003) compares the world price outcomes obtained in studies of global trade liberalization with the standard deviation of year to year price volatility in primary commodity markets, and argues that the effects of trade liberalization are likely to be dwarfed by other factors. Perhaps he overstates the case, but it is nonetheless quite instructive to make this comparison. In a recent study of commodity price volatility, Gilbert (2003) estimates the standard deviation of year-to-year price changes over the 1961-2002 period to be as follows: maize=15%, rice = 23%, soybeans=16%, sugar=43%, and wheat=16%. All of these are larger than the 10%

average price increase assumed by Cline in his study of trade liberalization, thus suggesting that other factors may play a more important role in these markets than trade policy. Table 1 presents two examples of commodity price changes from CGE studies next to the standard deviations calculated by Gilbert. The first column presents CGE results cited by Cline for his assumption of ten percent across the board price increases and the second column presents the results of an IATRC agricultural liberalization study using the GTAP model (Dimaranan, Hertel, and Martin, 2002). The final column is the standard deviation of annual price changes reported by Gilbert, and we see that the price volatility dominates the predicted price change for liberalization studies.

Rodrik's conclusion that the $300 billion in protection and support provided to OECD agricultural producers does not have a particularly strong impact on world prices, when viewed in the context of the inherent volatility of these markets, is subject to an important qualification. What if the models producing these price predictions are invalid? More specifically, what if they are incapable of producing the degree of price volatility observed historically? This might be the case if, for example, the demand elasticities used in these models were too large. In that case, the models' predictions of the price impacts of global trade liberalization would also be erroneous, thereby also calling into question all of the recent trade/poverty studies based on these global trade models. The goal of this paper is to explore the hypothesis of model validity for agricultural markets in detail.

In order to permit maximum clarity in our investigations, we focus on only one commodity – wheat. We then capitalize on the natural historical experiments offered by weather-induced variation in supplies, in order to explore the validity of a modified version of the widely used Global Trade Analysis Project (GTAP) model (Hertel, 1997).

The remainder of the paper is set as follows. Section two reviews the practice of model validation and its application to large scale CGE models. Section three briefly describes the CGE model being tested for validity. Section four outlines the methodology employed in the validation exercise, namely the use of stochastic simulations focusing on annual variability in supply. The final two sections present results and conclusions respectively.

2. Background on Model Validation

Gass (1983) provides the starting point for a discussion of the validation of simulation models. He stresses the need for credibility in policy related simulations. He argues that such models can never be validated. However, by subjecting simulation models to *invalidation* tests we can become more confident that the model is not invalid, thereby improving the credibility of the model. He further highlights the benefits of the policy model validation noting that such exercises serve to facilitate: 1) understanding of the model by potential users, 2) exposition of the strengths and weaknesses of the model, 3) an assessment of the model's limitations in a predictive capacity, and 4) information on the proper level of confidence to attach to results. McCarl (1984) adds that a sound validation experiment applied to a model can point the way for adaptations that produce better predictions in an area where the model was previously deemed limited.

The notion of replicative validity is put forward by Gass (1983) as the central concern in models used to inform policy. This is essentially an attempt to answer the question of how closely data from the simulated and real systems match, and what can be learned by analyzing the errors between predicted and real outcomes. This should generally involve some conceptual accounting measure of the differences between actual and model results (McCarl, 1984).

Despite their widespread use in the trade liberalization debate, CGE trade models have not traditionally been validated as a matter of course. While the operations research literature continues to devote considerable attention to the validation of simulation models (see e.g. reviews by Kleijnen, 1998; 1999) there are few cases of CGE models being tested against the historical record. Kehoe *et al*. (1995) note that a primary cause for lack of validation of these models is the prominent view that the standard shortcomings of CGE models render them unsuitable for accurate predictions. These authors find this explanation unacceptable given the considerable effort and numerical complexity involved in building a CGE model. They proceed to validate a CGE model of the Spanish economy in terms of conditional predictions, by attempting to control their single region CGE model for behavior it could not be expected to reproduce in the case of Spanish tax reform.

The Kehoe *et al*. (1995) experiment deals primarily with shocks in a single economy, making the process of isolating events and introducing their impacts into the model exogenously considerably more straightforward than for a global model. We rarely have the kind of natural experiment that is needed to validate a large scale partial, or general equilibrium model. In the case of multilateral trade liberalization, the policy changes are usually very modest, and are phased in over a long period of time – particularly when compared to the other short term factors perturbing the world economy, including wars, currency crises, trade embargoes and so on.

Gehlhar (1997) points out the difficulty in validating a model with policy shocks in a global trade model, noting the problems created by policy interactions and determination of policy implementation. His validation experiment focuses instead on growth in the East Asian economies in the 1980s, using a backcasting simulation to evaluate the veracity of GTAP model results versus observed data. He finds that the model performs adequately, especially with respect to directions of change for variables. He then alters the model, separating labor inputs into skilled and unskilled components, and increasing the trade elasticities by twenty percent from their base values, and finds that for the particular case of East Asian growth that these alterations significantly improve correlation between predicted and actual results.

In a more recent effort, Liu, Arndt, and Hertel (2004) formalize the approach of Gehlhar, developing an approximate likelihood function to assess the quality of model performance over the (backcasting) period from 1992-1986. The set of optimum trade elasticity values is obtained by maximizing this approximate likelihood function. In addition, two statistical tests are performed. The first of these tests compares the standard GTAP elasticity vector with the estimated trade elasticity vector. It rejects the null hypothesis of equality between the two sets of trade elasticities. The second test examines the widely maintained hypothesis known as the “rule of two”, by which the elasticity of substitution across imports by sources is set equal to twice the elasticity of substitution between domestic goods and imports. The authors fail to reject this common rule of thumb.

The work of Liu, Arndt and Hertel (2004) draws on techniques used in the real business cycle (RBC) literature. In this paper, we continue this tradition of drawing on the RBC work, which aims to develop models that are capable of mimicking correlations and volatility among consumption, output, investment, and labor in time-series data. Kydland and Prescott (1982) develop an approach to RBC model calibration that involves mapping out the model's responses for particular historical shocks and comparing them against stylized facts over the same time period. Parameters are selected so that steady-state distributions of simulated outcomes match that of actual outcomes when Hicks-neutral stochastic shocks are made to aggregate production. As with econometrics, an advantage of this approach is that it enables both calibration and validation (i.e., parameterizing a model, and then testing the specification). Unlike econometrics, the approach can be applied in situations of limited data, and does not require an *ad hoc* disturbance term to be grafted onto the model. In this paper, we take this same approach to validate a CGE model in terms of its ability to reproduce historical price variation.

3. Benchmark CGE Model

This study draws on the GTAP 5.4 database (Dimaranan and McDougall, 2002), featuring 1997 as the benchmark year. We aggregate the database to depict the 17 regions and 24 sectors with a primary focus on maintaining large wheat producing regions, as well as retaining sufficient detail in the agri-food sectors.

Standard GTAP Model of Global Trade

Our initial point of departure in this research is the GTAP model of global trade (version 6.2). GTAP is a relatively standard, multi-region model which includes explicit treatment of international trade and transport margins, a "global" bank designed to mediate between world savings and investment, and a relatively sophisticated consumer demand system designed to capture differential price and income responsiveness across countries. As documented in Hertel (1997) and on the GTAP web site[2], the model includes: demand for goods for final consumption, intermediate use and government consumption, demands for factor inputs, supplies of factors and goods, and international trade in goods and services. The model employs the simplistic but robust assumptions of perfect competition and constant returns to scale in production activities. Bilateral international trade flows are handled using the Armington assumption by which products are exogenously differentiated by origin.

Modifications to Emphasize Agriculture

Given the focus on agricultural commodity markets in this paper, alterations are made to the standard GTAP model to focus on the intricacies of these markets. Several structural features have been highlighted in the agricultural economics literature for their importance in analysis of trade liberalization: factor mobility and substitution in production, crop-livestock sector interactions, consumer demands, and trade elasticities. The manner in which these features are introduced into the model is outlined in Keeney and Hertel (2004) and is discussed briefly below.

Recent work by the OECD (2001) on the cost and world market impacts of agricultural support highlights the role of factor market issues in an empirical partial equilibrium model. This work focuses on the segmentation that occurs in land, labor, and capital markets between the agricultural and non-agricultural economy, and provides the region specific factor supply elasticities used to calibrate our model’s constant elasticity of transformation function that allocates factors between agricultural and non-agricultural uses. We also follow their notion of factor substitution, focusing on substitution possibilities among farm-owned and purchased inputs, as well as between the two. We

[2] http://www.gtap.agecon.purdue.edu/products/models/

calibrate the constant elasticity of substitution cost functions for sectors to the region-specific Allen elasticities of substitution provided by the OECD.

Interaction between livestock and crop sectors received considerable attention in the literature following European CAP reform in 1992 and has continued to be an area of concern (Peeters and Surry, 1997). We follow the approach of Hertel and Rae (2000) in modeling the substitution possibilities for feedstuffs in livestock production as an additional CES nest in the livestock sector cost function. We calibrate this region-generic parameter to an average substitution elasticity calculated from Surry's (1992) three-stage model describing the behavior of European livestock producers, composite feed mixers, and grain producers.

The role of consumer demand for final goods is prominent in the agricultural economics literature. Consumer demand systems and estimates based on those are examined to address a variety of issues including the potential impacts from world price changes accompanying trade liberalization. The unique role of food in the consumer budget has been emphasized in much of this work especially as it relates to the distribution of incomes (Cranfield et al, 2002; Seale, Regmi, and Bernstein, 2003). We employ a recent set of estimates from a cross-country study of demand, keying on own-price and income elasticities of demand for food. We calibrate the parameters of the GTAP CDE demand system to the elasticities for the eight food aggregates and an additional non-food aggregate based on the study by Seale, Regmi, and Bernstein (2003).

The importance of international trade elasticities that describe the substitution possibilities between goods differentiated by origin have also received considerable attention for the important role they have in simulation models in determining the terms of trade impacts of liberalization. Hertel *et al*. (2003) provides recent estimates of this substitution relationship at the same level of disaggregation as the sectors in the GTAP model. Those authors also show how the estimated gains from trade liberalization hinge critically on the value of these parameters. We make use of their region-generic estimates of the elasticity of substitution amongst imported goods from different sources which is modeled using the Armingtion/CES structure.[3]

4. Validation Method

The method we employ in our validation experiment is that of a stochastic simulation, using shocks derived from a time series model on wheat production to measure the randomness in annual output. The residuals from the fitted time series model are evaluated to determine the characteristics of the distribution reflecting output variability for wheat, by producing region. Solving the CGE model with respect to this distribution of wheat production disturbances, gives a measure of the variability of market price changes for wheat, by region. This model-based standard deviation is then compared to observed outcomes on year to year price changes in order to validate (or invalidate) the model. The following sub-sections describe our method of measuring production variability to input to the model, the manner in which we calculate actual price volatility for comparison with the model results, and the stochastic simulation method we employ using the CGE model.

[3] Unfortunately, due to a lack of data on domestic purchases and prices, those authors are unable to estimate the elasticity of substitution between domestic goods and imports. As with the standard GTAP model, these parameters are still obtained using the "rule of two" referred to earlier (i.e. the import-import elasticities are assumed to be twice as large as the import-domestic elasticities).

Determining Commodity Supply Variability

Vanzetti (1998) examines wheat production between 1960 and 1994, characterizing production variability via a linear trend. Our analysis of Food and Agriculture Organization data (FAOSTAT, 2004) found this approach to be insufficient as a great deal of serial correlation was present in the residuals, indicating that information on market impacts on supply were being carried by the residuals. Figure 1 highlights the serial correlation present in the residuals when a linear trend is fit to Japanese wheat production data. Serial correlation is clearly evident, as a positive residual is typically followed by another positive residual. Indeed, in Japan, wheat supply appears to be on a 10-12 year cycle.

However, we do adopt Vanzetti's (1998) idea that wheat market volatility is largely a supply-side phenomenon and that removing the systematic changes in output (those related to acreage response), leaves prediction errors that represent yield fluctuations that can be attributed primarily to weather. We fit a region-specific time series model to FAO data (FAOSTAT, 2004) on annual wheat production. The goal here is to remove any productivity changes in wheat that have occurred over time as well as any market elements that impact wheat output since those are expected to be captured in the CGE model. We fit an Autoregressive Moving Average (ARMA) process to the output data, and use the residuals to calculate the variance of wheat production by region.

The choice of Box and Jenkins' ARMA representation for modeling wheat output is based on our goal of predicting the systematic portion of annual supply response, and leaving only unexplained annual variability in the residual to be attributed to weather. These models have become popular for their forecasting properties relative to econometric specifications, relying on past values of the endogenous variable as well as past prediction errors to arrive at a current forecast (Kennedy, 1997). Adopting the notion that past values of output carry sufficient information on explanatory variables describing wheat production, as well as the idea that current prediction errors arise from weather shocks impacting yields, the ARMA approach to modeling wheat output seems a good choice. Figure 2 depicts our prediction model for the same Japanese wheat production data.

Table 2 shows the relevant results of these estimated models, as the standard deviation of production changes and the bounds on a symmetric triangular distribution which is taken as the model input. These distributions are centered on zero, and are in percentage change form so that the endpoints of the distribution indicate the maximum relative change in output that can be induced in the model drawing from the historical production data.

Determining Wheat Price Volatility

We choose the 1990-2001 period for calculating our measure of wheat price volatility. Our experiment is policy neutral, and this period most closely matches the benchmark data while providing enough observations to get an accurate representation of price volatility. By 1990, policy changes had limited government stockholdings of wheat by major exporters relative to earlier periods reflected in the production data. As a result wheat stocks available to buffer the market are decreased and prices are likely to be more volatile.

The assumption of a policy neutral environment presents two potential problems for our extra-model determination of price volatility—multilateral trade liberalization and regional trade agreements that impact agriculture. Mitchell and Mielke (2004) provide analysis of these potential impacts noting that liberalization occurring due to the Uruguay round for wheat was relatively modest, and that most wheat liberalization has occurred within regional trade agreements. Domestic support disciplines on wheat are not considered to be large, as most wheat exporters have focused elsewhere in meeting URAA commitments. Following this, our assumption of a policy neutral environment whereby weather is the source of production variability in the model will be violated to the extent that regional trade agreement changes encroach on production and price variability, and we will be unable to remove policy induced price volatility in our analysis.

The criterion for validation is the observed real standard deviation in year to year price changes. The regional price data from FAOSTAT (2004) presents a problem of aggregation since other information is not present to generate consistent price indices for aggregate model regions. We deal with this when comparing model results with observed price changes by referencing a range of price changes based on those calculated for component countries of an aggregate region. The twelve years of data give us eleven price changes to consider. Table X, presents wheat price volatility as measured by the standard deviation of percent changes in annual prices in both nominal and real terms, with point estimates for disaggregated regions, and ranges for aggregate regions.

Stochastic Simulation

This estimated distribution of supply shocks drawn from the time series model of wheat output for each region, provides the basis for a stochastic simulation experiment using the CGE model. This stochastic simulation of the model solves for a number of supply shocks using the Gaussian Quadrature approach to integral approximation giving us solutions for the endogenous variables that are themselves distributions. It is the second moment of model generated market prices for wheat that we key on in our analysis of model generated price volatility.

The modeling approach draws inspiration from the earlier work of Tyers and Anderson (1992), as well as Vanzetti (1998), who model uncertainty in world food markets by sampling from a distribution of supply shocks. The use of the Gaussian Quadrature approach outlined in DeVuyst and Preckel (1997), is an efficient means of generating sensitivity results which only requires the assumption that distributions of endogenous variables are well approximated by a third-order polynomial in the varying shock, and that the shock has a symmetric distribution.

5. Results

The results presented here focus on the replicative validity of the model generated price volatility. Looking at Table 1 and Table 4 we see that our measure of real price volatility calculated for regions large in wheat markets (Australia, Canada, and U.S.) closely match Gilbert's calculation for wheat. There is a question of what real vs. nominal measures of price volatility are best suited for model validation. The model is in real terms, so we would ideally choose that measure but the calculation of real price volatility could potentially be dominated by changes in relative exchange rates used to deflate nominal prices. At this stage, we report both but focus primarily on comparisons with the real measure of price volatility.

The fourth column of Table 4 reports the model generated results for price volatility, with point estimates of the standard deviation for all of the model regions.

Considering only those regions for which we have an FAO point estimate of price volatility, we see that the model is in agreement that Japan and South Asia experience the lowest price volatility.

The fifth column reports the ratio of measured volatility in the model to that of real price volatility from the FAO data. A result less than one here indicates that the model under predicts volatility and over predicts for a ratio greater than one. The first observation this leads to is the natural division that occurs between net exporters and net importers with respect to under and over prediction. Argentina, the United States, Canada, and Australia are all large economies with a net export position in world wheat markets. If we consider that through NAFTA Mexican wheat markets are well integrated to those of the United States, we have a fairly complete characterization of under prediction being a akin to being a net exporter. Similarly, China, South Asia, Brazil, and Japan are all net importers of wheat and the model has consistently over predicted price volatility in those regions.

Among the regions where an FAO based point estimate is not available the European Union is notable, as this region is a net exporter for which the model over predicts price volatility. The EU could easily be a special case as their net export position is largely a device of policy (Mitchell and Mielke, 2004), which might confound the calculation of price volatility from the FAO data. The ordering of results along the lines of the net trade position would seem to indicate that the handling of trade in the model either through the Armington structure or the trade elasticities is guiding our predictions of volatility and an important component of our prediction errors. This is a result to be checked with additional work on other tradable agricultural commodities.

Figure 3 depicts the same information as Table 4, in a scatter plot with points and ranges for intersection of the two measures of price volatility. The 45 degree line plotted through the graph indicates a one-to-one comparison between the two measures. Points and ranges lying below indicate that the model over predicts volatility while those lying above indicate an under prediction. Viewing the results in this form emphasizes the importance of net trade position in wheat in determining over or under prediction of price volatility in the model.

In terms of metrics of validation, correlation and regression results are prominent in the literature (Gehlhar, 1997). Here we estimate a regression equation to test for unity in the slope parameter, and report the results in Table 5. The regression is performed three times with the first estimation (Pt. Est.) considering only those points for which we have point estimates in the FAO data. The second estimation (Best Case) takes the endpoints closest to the 45 degree line as the FAO observation for the regression while the third estimation (Worst Case) takes the FAO endpoint farthest from the 45 degree line.

We restrict these models to produce an equation that passes through the origin, due to the small number of observations we are considering. This restriction is based on the fact that the GTAP model will always reproduce zero price volatility for an output event leading to this in the real data. The results show that we fail to reject a null hypothesis of unity for the slope coefficient in all cases. The models vary in performance as we would expect, with the slope coefficient nearest to one being for the “Best Case” model. However we treat these statistical results with the appropriate skepticism, given the small number of observations available, and focus on the qualitative results in drawing our conclusions.

6. Conclusions

The results we have presented offer a mixed bag, four of the model measures of price volatility are within 25% of that measured in the FAO data. Roughly half of the model predictions are above and half below the FAO calculations for price volatility. The coincidence regarding under prediction for a region and it position as a net exporter is a striking result, that certainly points to model specific areas to be further evaluated.

Qualitatively, for the specific case of wheat price volatility the model would have to be deemed invalid. In essence, if wheat prices were an important component of a study of poverty impacts of agricultural liberalization, one would want to be careful about drawing conclusions that hinged on the GTAP model's wheat price predictions as it stands, since the model is unable to reproduce the observed market price volatility.

In the same vein, we must be careful what we accept as truth in the 'real' data as well. Our measure of price volatility is simplistic, and it does not account for price changes over the time series that can be attributed to policy changes. Mitchell and Mielke (2004) note the importance of preferential trading areas in wheat liberalization that have occurred over the past ten years, and these are not accounted for in our measure of price volatility. Two obvious cases where these could be important are the EU and Brazil, one an important exporter and the other an important importer and both heavily involved in regional trade agreements.

These considerations point to important avenues for continued research on validating the GTAP model. First, we need to construct a decomposed measure of price volatility that reflects the policy neutral environment we are assuming for the simulation model. Second, the trade specifications of the GTAP model are highlighted for their importance in the prediction accuracy of wheat price volatility. This experiment will be extended to other important primary agricultural commodities to check consistency of the coincidence between over and under prediction and net trade position, and the resulting implications for the specification of import demands via the Armington assumption as well as the elasticities used in the model.

In summary, this paper has pointed to the value of model validation as an important step in analysis of trade liberalization. We have concluded that the model does not appear to be valid for the intended use of generating wheat price effects for further use in trade and poverty studies. The validation exercise has pointed to important further work to complete the testing of model validity, and important areas of the model to be investigated for the cases where it is deemed invalid.

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Table 1. Model Predictions of Agricultural Price Changes

Commodity	Model Based Prediction of Price Changes (% Change)		Standard Deviation of Annual Price Changes (%)
	Cline	Dimaranan *et al.*	Gilbert
Wheat	2.0– 8.0	25.2	15.2
Rice	2.0– 8.0	5.5	14.2
Sugar	2.0– 8.0	5.9	22.3
Beef	7.0	8.4	8.5
Milk	23.0	13.1	--

Table 2. Wheat Production Uncertainty

Region	Mean Prod. (mn bushels)	Normalized Std. Error	Triangular Distribution	
			Lower Endpoint[a] (mn bushels)	Upper Endpoint[a] (mn bushels)
Australia	14.54	26.10	5.24	23.83
China	72.20	8.93	56.41	87.99
Japan	0.64	12.63	0.44	0.83
South Asia	56.26	6.88	46.77	65.74
Canada	22.14	16.98	12.93	31.35
United States	56.61	12.27	39.59	73.63
Mexico	3.24	15.07	2.04	4.44
Argentina	9.95	20.54	4.94	14.95
Brazil	2.63	30.43	0.67	4.59
Rest of Latin America	2.17	11.79	1.54	2.79
European Union	73.50	7.44	60.10	86.90
Other Europe	30.05	13.73	19.95	40.15
Russia	81.23	15.06	51.26	111.20
Middle East and No. Africa	36.53	9.19	28.31	44.75
So. Africa	3.69	12.18	2.59	4.79

[a] Endpoints are calculated for the symmetric triangular distribution using the variance of production. The formula for the endpoint is $Bound = Mean \pm \sqrt{6 * Variance}$.

Table 3. Price Volatility

Region	Standard Deviation of Annual Wheat Price Changes	
	Real	Nominal
Australia	21.4	16.5
China	14.5	21.4
Japan	3.4	3.6
South Asia	7.1	7.2
Canada	16.6	14.9
United States	15.8	16.3
Mexico	22.3	34.2
Argentina	34.4	34.5
Brazil	15.5	26.8
Rest of Latin America	9.0-36.6	8.9 - 29.7
European Union	5.9-7.8	5.9 - 8.2
Other Europe	18.6-41.7	19.9 - 42.6
Russia	NA	Problems
Middle East and No. Africa	4.9-10.4	4.2-29.1
So. Africa	15.5 - 17.8	13.7 - 24.3

Table 4. Comparison of Model Price Volatility with FAO Data

	Price Volatility			Ratios		
	FAO Real	FAO Nominal	Model	Model/ Real	Model/ Nom.	Over/ Under
Argentina	34.4	34.5	19.61	0.57	0.57	-
Mexico	22.3	34.2	13.44	0.60	0.39	-
United States	15.8	16.3	10.70	0.68	0.66	-
Canada	16.6	14.9	12.70	0.77	0.85	-
Australia	21.4	16.5	20.00	0.93	1.21	?
China	14.5	21.4	16.16	1.11	0.76	?
South Asia	7.1	7.2	8.35	1.18	1.16	+
Brazil	15.5	26.8	36.84	2.38	1.37	+
Japan	3.4	3.6	9.99	2.94	2.77	+
Rest of Latin America	9.0-36.6	8.9 - 29.7	36.84	IN	HIGH	+
European Union	5.9-7.8	5.9 - 8.2	11.36	HIGH	HIGH	+
Other Europe	18.6-41.7	19.9 - 42.6	7.32	LOW	LOW	-
Mid East and No. Africa	4.9-10.4	4.2-29.1	19.07	HIGH	IN	+
So. Africa	15.5 - 17.8	13.7 - 24.3	8.72	LOW	LOW	-

Table 5.

Model	Slope	St. Err.	T-Stat.[b]	R Squared
Pt. Est.	0.76	0.16	1.51	0.76
Best Case	0.85	0.12	1.30	0.81
Worst Case	0.64	0.2	1.77	0.45

[b]T-statistic for null hypothesis that the slope coefficient = 1.

Figure 1. Linear Trend of Japanese Wheat Production

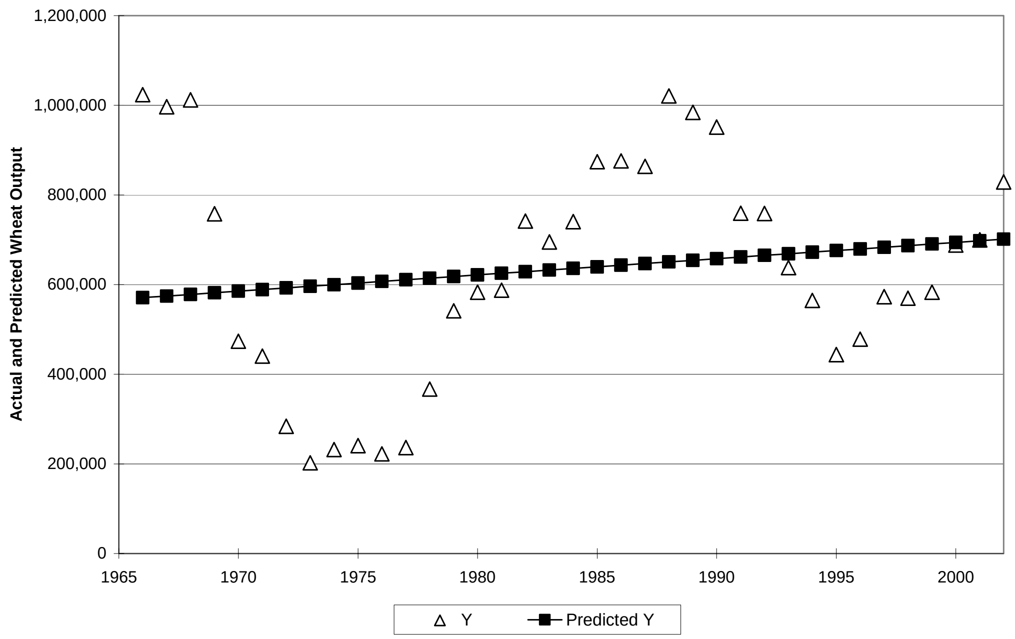

Figure 2. ARMA Model of Japanese Wheat Production

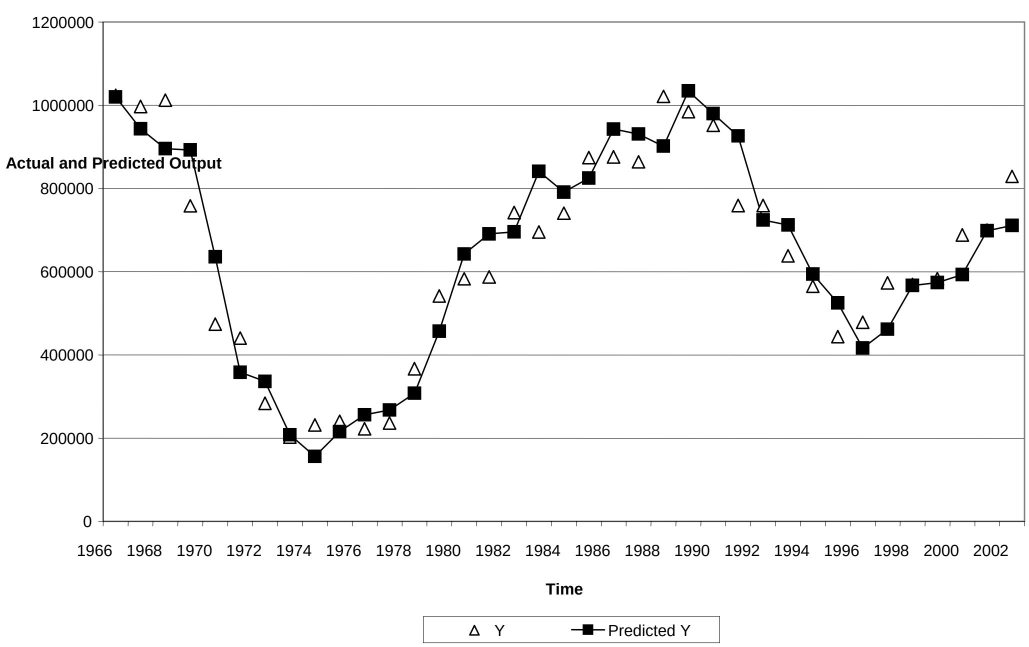

Figure 3. Model Validation Results: Comparison of Measured Volatility in Real Wheat Prices