NCCC-134
APPLIED COMMODITY PRICE ANALYSIS, FORECASTING AND MARKET RISK MANAGEMENT

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Suggested citation format:

Wilson, W. W., and D. Miljkovic. 2011. "Dynamic Inter-relationships in Hard Wheat Basis Markets." Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. [http://www.farmdoc.illinois.edu/nccc134].

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2011 NCCC-134 Conference on Applied Commodity Price Analysis,

Forecasting and Market Risk Management

St. Louis, MO, April 18-19, 2011

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Dynamic Inter-relationships in Hard Wheat Basis Markets

Abstract

The basis values for hard red spring wheat (HRS) have escalated radically, experienced extraordinary levels of volatility (risk), have been subject to a squeeze during 2008, and all these have important implications for market participants. These observations are particularly important to marketers in the Northern Great Plains in the United States, as well as for Canadian marketers. The purpose of this paper is to develop a model to explore the dynamic relationships and interdependencies among terminal market basis values for milling quality higher-protein wheat. Specifically, we seek to identify factors impacting basis values for 13, 14, and 15% protein HRS wheat in addition to the intermakret wheat spread between Minneapolis and Kansas City wheat futures. We specify a vector autoregression (VAR) model to explore these relationships. Exogenous structural variables are specified in addition to dynamic inter-relationships including seasonal variability, inter-temporal variability and dynamic interdependencies among these markets and relationships. The results of interest are that: 1) basis values for these wheat markets been trending up, and have become more volatile; 2) factors impacting this variability is primarily the protein level in HRS, and production of HRW and Canadian (on high protein basis); 3) HRW protein supplies are not significant in the basis equations, but, do have an impact on the interrmarket wheat futures spread; 4) Quality factors have a significant impact on basis values, notably vomitoxin, falling numbers and absorption. There are also dynamic interrelations that are important. Important is that all four prices converge quickly towards long-term equilibrium. In addition there are seasonal impacts, dynamic bases interactions, trends, and lagged impacts of protein levels.

INTRODUCTION

Grain futures have contract specifications that are fairly generic and are specified to allow for a large portion of the crop to be prospectively deliverable. In contrast, quality specifications for most cash grain contracts are more specific. In hard wheat, it is important that cash specifications reflect demand for milling and baking purposes, and are more stringent and premiums for these depend on quality requirements and supplies of these attributes. These vary through time and impact equilibrium spread relationships which are reflected in basis values and inter-market relationships.

For most commodities, basis values have become more volatile in recent years, for numerous reasons. Basis values for hard red spring wheat (HRS) have escalated radically and experienced extraordinary levels of volatility (risk) in recent years. The relationships among basis levels and futures spreads appear to be dynamically interdependent. All of these have important implications for market participants in the Northern Great Plains United States as well as Canadian marketers which are impacted by these values.

The purpose of this paper is to develop a model to explore the dynamic relationships and interdependencies among basis values and futures-market-spreads for milling quality higher-protein wheat. Specifically, we seek to identify factors impacting basis values for 13, 14, and 15% protein hard red spring (HRS) wheat in addition to the intermarket wheat spread between Minneapolis and Kansas City wheat futures. The paper makes several contributions. It measures the dynamic inter-market relationships in prices for different protein levels in hard wheat, and the futures market spreads between the Minneapolis Grain Exchange (MGEX) and the Kansas City Board of Trade (KCBT). It also measures impacts of protein supplies and production on the basis and differentials. Finally, it evaluates impacts of underlying quality factors that vary through time, on basis and intermarket futures price relationships. The results have implications for buyers and sellers of hard wheat, hedgers, and other market participants as well as in fundamental analysis of the wheat sector which frequently ignore these subtle but important effects.

BACKGROUND AND RELATED LITERATURE

There are a large number of theoretical and empirical studies about the basis in agricultural commodities. The theoretical relationships were developed in Working, 1949; Kaldor, 1939; Johnson, 1960; and Brennan, 1958, among others. In addition, there have been numerous empirical studies on basis behavior for grain commodities (e.g., Tilley and Campbell, 1988, Thompson, Eales and Hauser, 1990, Jiang and Hayenga, 1997, O'Brien, 2009, among others), and Garcia and Leuthold (2004) provide a summary of this literature. Most of the empirical studies have focused on either identifying determinants of basis or forecasting future basis levels. Thompson, Eales and Hauser (1990) examined linkages between cash and futures prices as well as spatial basis relationships for terminal markets and those for country elevators in Illinois; Jiang and Hayenga (1997) indicated seasonal patterns, storage costs, production and transportation rates had important effects on basis; and O'Brien (2009) examined spatial effects of corn and wheat basis relationships considering effects of market structures in Kansas. Lewis et al., (2010) suggest that local basis levels can be determined in part by basis values at nearby locations which they refer to as dominant-satellite relationships. The spatial effects of ethanol developments on basis were examined by McNew and Griffith (2005) and Lewis, et al. (2010).

A number of recent studies focused on the increasing divergence between cash and futures market values (Irwin, et al., 2009; Plato and Hoffman, 2010, Wilson and Dahl, 2011). The primary issue to these studies is the apparent lack of convergence in cash and futures in addition to the volatility of basis in soybean and corn. These issues are particularly true for Chicago wheat which allegedly was being caused by either excessive speculation by funds that are inherently long or delivery rules not conforming to commercial trade practices, amongst others.

In the case of wheat, each of Chicago (CME) and Kansas (KCBT) has had problems with the underlying specification not reflecting commercial cash contract terms. One of the specific terms is that of vomitoxin, a disease that is extremely problematic in wheat worldwide (Nganje et al, 2004), though it has been particularly devastating in production of HRS in the United States and CWRS in Canada. The MGEX has always had specific limits on this factor, but the other two wheat markets had not (see below). Partly in response to the difficulties of convergence, each of these exchanges is in the process of revising their contract specifications to capture this impact. The CME changed that specification from 3 part per million (ppm) to 2 ppm, which is compatible with Food and

Drug Administration guidelines, and effective with the September 2011 contract (CME). The KCBT voted to change the specification with respect to vomitoxin from 4 ppm to 2 ppm in December 2010.

A recent study that specifically focuses on dynamic interaction of protein supply on prices is that of Goodwin and Smith (2009). They evaluated effects of protein shocks on prices for hard red winter, hard red spring and soft red winter wheat. Their analysis used monthly average price levels (i.e., implicitly, futures plus basis), and derived an explanatory variable as the supply of protein (the product of average crop protein levels and quarterly supplies, by class) that was significant. They also assume that non-protein quality factors do not vary through time. Their results indicated that protein availability significantly affected price levels for hard red spring (HRS) and hard red winter (HRW) wheat, but not soft red winter (SRW). Of interest was that the shock to HRW price had little response to the HRS price, but, the opposite was not true. In addition, they made extensive analysis of dynamic responses to changes in protein supplies on price levels.

Analysis of effects of quality on prices and basis has been limited. The exception is one study that suggested possible short-run inefficiencies in markets due to possible quality differences (Aulton *et al.* 1997). There is a fairly comprehensive literature on the supply and demand for protein in wheat (in addition to Goodwin and Smith 2009 as described above). Parcell and Stiegert (1998), and Stiegert and Blanc (1997) have shown marginal impacts on price for protein additions vary by wheat class. Dahl, Wilson and Wilson (1999) indicate improved quality characteristics affects variety adoption favorably, and in turn availability of supply. Wilson, Wilson and Dahl (2009) evaluated effects of protein and other quality parameters on wheat import purchases. They found protein and selected functional characteristics have significant impacts on wheat purchase probabilities and in turn wheat import demand. Finally, Wilson, Dahl and Johnson (2007) found that there is not a very good correlation between the underlying protein measurement and that of protein quality which is ultimately demanded by buyers.

Protein premiums in wheat are particularly important throughout the marketing system in the United States and Canada. Protein is relatively easily measurable within the marketing system and protein is positively correlated to end-use performance ultimately desired by buyers. These include absorption and farinograph measures, among others. Though protein levels are not perfectly correlated (Wilson, Dahl and Johnson 2007) they are a proxy that is easily measured within the marketing system. Protein premiums have increased during the 5 past years for varying reasons in part due to the growth in demand and reduced supplies, the latter caused by reduced acreage, changes in the composition of varieties, and generally wetter conditions in the key growing regions. In addition, during February 2008 there was a squeeze on the MGE futures market and the premiums reached near record levels.[1] These premiums have escalated and in recent years have been near record-high. Finally, the volatility of protein premiums has escalated in recent years. Using data in this study, the 12 month standard deviation from August 1995 and August 2010 changed as follows: Basis 13% increased from 14 to 22c/b; Basis 14% increased from 17 to 50c/b; Basis 15% increased from 18 to 67c/b; and in comparison the

[1] As summarized in J.P. Morgan, 2010, amongst others.

MGEX futures deceased from 35 to 29c/b. Hence, all bases have become more volatile, while the futures volatility decreased between these periods.

There are also important physical functions that can and do vary among hard wheat with different protein levels and affect dynamic relations. Technically, millers, as well as traders and handlers regularly blend wheat lots with different protein levels, both within and across classes, to meet physical and functional (absorption, stability etc.) requirements. Thus, as examples, it is routine to blend 13 and 14 or 15% HRS to create varying protein levels of flour. It is also common, but with a bit less frequency due to geography and logistics of shipping, to blend higher proteins of HRS with lower proteins of HRW. From a hedging perspective, millers, bakers, importers and traders take positions in both underlying physicals of wheat of different protein levels, and in MGEX and KCBT futures and make adjustments in the composition of these portfolios through time in anticipation of changes in relative values through time. These blending and hedging functions are what dynamically link these markets together.

Important differences exist in the contract specifications between the prevailing cash markets and specifications for futures market delivery. The Minneapolis Grain Exchange (MGEX) is the dominant market that reports prices for hard wheat protein levels. Cash prices are reported for what is referred to as *Milling Quality Wheat*. This is reported as a basis for HRS defined as being grade No. 1, having >300 falling numbers, <2 ppm vomitoxin, <1.5% dockage, and <1.5% damaged kernels. These contrast from the specifications for delivery against futures which are for grade No. 2, Min protein of 13.5 or 13.0% with the latter at a fixed 3c/b discount, damage is not specified beyond No. 2 grade limits, and falling numbers is not specified. There is a specification for vomitoxin. Specifically, Rule 2040 indicates that "wheat not fit for human consumption" which is defined by the Food and Drug Administration, is not deliverable. In addition to vomitoxin, two other important measures that differentiate cash and futures in HRS markets are absorption and falling numbers.[2] The former is a measure of gluten strength and is routinely measured by bakers, and used in many cases in flour purchase specifications. Falling numbers is a measure of the amount of sprout damage that has occurred, and is used in virtually all HRS cash wheat contracts throughout the marketing system. Thus, there are important differences among specifications for delivery, those normally specified in the cash market, and between specifications for the different wheat futures markets. The delivery specification is looser with respect to grade, falling numbers and damage. Hence, observed price differentials between cash and futures in addition to inter-futures-market relationships, are in part explained by the differences in

[2] Absorption is a measure of gluten strength and is frequently used in purchase specifications between millers and bakers. Bakers and importers generally desire greater values of this attribute and lesser values can result in being out-of-specification in flour sales. Falling number gives an indication of the amount of sprout damage that has occurred. As the amount of enzyme activity increases, the falling number decreases. Values below 200 seconds indicate high levels of enzyme activity which reduces mixing strength, cause sticky dough, and affects loaf volume and shelf life.

these quality specifications.

EMPIRICAL MODEL

The primary focus of our empirical model is to evaluate the dynamic relationships and interdependencies among terminal market basis values for milling quality HRS. Specifically, we seek to identify the factors impacting basis values for 13, 14, and 15% protein wheat in addition to the intermarket wheat spread between Minneapolis and Kansas City wheat futures. Important impacts of protein supply and quality attributes on the basis values and on the inter-futures market spread.

The nature of the above issue suggests that the vector autoregression (VAR) would be appropriate methodology to use in testing the question empirically. VAR is commonly used for estimating or forecasting systems of interrelated time series. The VAR approach sidesteps the need for structural modeling by treating every endogenous variable in the system as a function of the lagged values of all of the endogenous variables in the system.

The mathematical representation of a VAR is:

$$y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + Bx_t + \varepsilon_t \tag{1}$$

where y_t is a k vector of endogenous variables, x_t is a d vector of exogenous variables, A_1, …, A_p and B are matrices of coefficients to be estimated, and ε_t is a vector of innovations that may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all the right-hand side variables. Since only lagged values of endogenous variables appear on the right-hand side of the equations, simultaneity is not an issue and OLS yields consistent estimates. Moreover, even though the innovations ε_t may be contemporaneously correlated, OLS is efficient and equivalent to GLS since all equations have identical regressors (Enders, 2010; Hamilton, 1994).

The VAR to explore the relationships of interest is specified as following. Endogenous variables are basis values for hard wheat for different protein levels, and the Minneapolis-Kansas City intermarket price spread. Endogenous variables are defined as: $B_{13,}$ B_{14} and B_{15} are the basis for 13, 14 and 15% protein hard red spring (HRS) wheat; $F_s = F_{MGEX} - F_{KCBT}$ is the spread between the nearby futures contracts at the MGEX and KCBT. Exogenous variables are the supplies of hard wheat protein in the primary production regions, supplies of hard wheat, and quality attributes important in the basis market that are not as relevant in the futures. Exogenous variables are defined as: $Prod_{it}$ are the current (monthly) estimates of the annual production for wheat class i (where subscript i refers to Canadian Western Spring Wheat (CWRS) in Canada, and Hard Red Spring (HRS) and Hard Red Winter (HRW) wheat in the United States); $Prot_{it}$ is the crop average protein levels; V_{HRS}, FN_{HRS}, A_{HRS}, NO. 1_{HRS} are the average level of vomitoxin, falling numbers, absorption level, and the percent of No. 1 produced in the HRS crop respectively. These are in addition to the dynamic inter-relationships including seasonal variability, inter-temporal variability and dynamic interdependencies among these markets. The data is for period 1980-2010 of monthly observations.

Data on futures and basis were extracted from the MGEX and KCBT. The basis values are for No. 1 milling quality wheat and relative to the nearby futures position. Production levels were from the USDA and from Statistics Canada. Quality data were from the North Dakota Wheat Commission (1980-2010) for HRS, from Kansas Agricultural Statistics (1980—2010) for HRW and from the Canada Grains Commission (1980-2010) for Canada. The protein level for Canada is the average for all milling grades of CWRS. The measure of vomitoxin is the estimate of lost production due to vomitoxin and was from Marcia McMullen (2009, the lead research in plant pathology at North Dakota State University). Specifically, it is defined as VD*X, where VD_t is a dummy variable equal to 0 or 1 depending on whether vomitoxin prevalent in year t, and X_t is the number of bushels lost due to the incidence of vomitoxin. Thus, these impacts are allowed to vary through time.

A couple of features in the data are important. First are the quality differences in the specifications for cash market transactions, and those for futures market delivery which as defined above. The cash market is higher quality or more specific to particular quality parameters. For this reason, basis differentials vary through time and are in part attributable to these effects. Second, vomitoxin has evolved to be a critically important quality factor. This was originally important in HRS commencing from 1993 but has since become important in other classes, including SRW and HRW and is challenging their delivery processes. In our model, this is measured as the estimate of bushels lost in production due to the incidence of the diseases. In some years, it is nil, in others, vomitoxin was more common resulting in reduced supplies available for the market and for delivery.

Testing dynamic relationships among the variables of interest proceeds in four steps:

1. Test the data generation processes underlying the individual price series using unit root tests;
2. Identify causal linkages among the variables using Granger causality tests;
3. Estimate a VAR to determine statistical significance and dynamics/lag structure among the variables, and
4. Conduct the impulse response analysis to analyze the long-term impact of one-time shocks on endogenous variables within the system.

Unit Root Tests

Before we can test for correlation(s) and causality relations among the four price variables, we must confirm that all the price series are stationary and integrated of the same order. Testing for unit roots is done using the Augmented Dickey-Fuller (ADF) tests on the individual series (Dickey and Fuller, 1979). The null hypothesis of nonstationarity can be rejected for each of the four variables, *i.e.*, all variables are I(0) (table 1).

Granger Causality Tests

Our VAR analysis conducted in the next section is based on the assumption of the endogeneity of the variables in the model. We next tried to identify short-run causal relationships among the variables. Using Granger causality tests (Enders, 2010), we tested if the variables assumed to be endogenous in the VAR model, can alternatively be treated as exogenous. Our *a priori* expectation is a rejection of one-way causality among the four endogenous variables. For each equation, Wald statistics testing the joint significance of each pair of one- and two-period lagged endogenous variables are calculated (table 2). The results of the Granger causality tests determine the presence of two-way causality in most cases hence suggesting that the endogeneity assumption is appropriate.

VAR Estimation

Although all four variables were individually tested for the presence of unit roots, it is necessary to test VAR stationarity as well. If the VAR is not stationary, certain results, such as impulse response standard errors, are not valid. Following Lutkepohl and Reimers (1992), the inverse roots of the characteristic AR polynomial should have modulus less than one and lie inside the unity circle. The AR roots in this case are all less than one; thus the estimated VAR is stable.

According to the classic paper by Hall (1994), using only the model selection criteria to choose the optimal lag structure may not be the most appropriate way to proceed in VAR analysis due to the presence of the long-run adjustment parameters from the cointegration analysis. He suggested that a reasonable starting point be the maximum number of lags based on economic theory, prior expectations, or common sense. One may then decrease gradually the number of lags by simultaneously looking into the model selection criteria and maintaining the original rationale (*i.e.*, economic theory, prior expectations, or common sense) until the most satisfactory model is selected.

Following this procedure, we started with a lag length of 12 months in all equations assuming seasonality would be important. Numerous alternatives were explored. For purposes here, we present the results from 3 models. Model 1 includes only one-lagged impacts in the VAR specification. Model 2 included an interaction term between protein supplies and production of hard wheats in the United States and Canada (HRS, HRW and CWRS). This was included for a comparison to that of Goodwin and Smith who used an interaction term to depict protein supplies. Model 3 is the fully dynamic 12 month VAR specification depicted above. The fully dynamic model is superior to Models 1 and 2 based on model selection criteria, both the SIC and the AIC. Yet, while some of the results from that model are obvious and intuitive, others are more difficult to grasp intuitively. We discuss and interpret each of the three models.

RESULTS

The focus of the estimation is to simultaneously evaluate impacts of relevant exogenous variables on basis and futures spreads in hard wheat, as well as to capture the important dynamic relationships. The latter include both the expected seasonal differences as well as the dynamics of responses to shocks on the endogenous variables.

The levels of exports were included in earlier specifications but were not significant and their effects are not reported. The quality variables were included with each specification and retained where significant. The results are shown in Tables 3-5 and Figures 1-3. As it turns out, Vomitoxin, Absorption, and FN are significant in most of the results but the Percent No. 1 is not.

First, the impacts of structural variables are described and then we describe the dynamic relationships in addition to some of the impacts of shocks on the predicted relationships. The structural variables illustrate a couple of important observations. One is that there is a significant trend in several of the results. Specifically, both Model 1 and 3 have positive and significant trend coefficients for B_{15} and F_s in Model 1, and for B_{14}, B_{15} and F_s in Model 3. Specifically, MGEX is increasing relative to KCBT over time and the basis values for higher protein wheats is has an increasing trend. Second, Canadian production and protein level have only a couple of significant impacts on these relationships. In Model 3, the level of Canadian production has a negative impact on B_{15} and Canadian protein levels have a positive impact on B_{14} in Model 3. This is of interest in that Canada is a large producer of HRS, and its protein supplies vary through time. Reasons for its non-significance are not exactly clear. It may be due to that despite the variability in the supplies of protein through time, it does not apparently impact the US protein premium market. That may be a result of protein being measured and marketed with less intensity in Canada compared to that in the domestic US market.

Production and protein levels in HRS and HRW do impact the results. Specifically, in Model 1 HRW production has a negative impact on B_{13}, and a positive impact on Fs; and in Model 3, it has a positive impact on both B_{15} and F_s. There is an inverse relationship between HRS protein levels and basis values for each of B_{14} and B_{15} in each of Models 1 and 3. The signs for the different basis levels are interesting. That for B_{13} is quite small, but they increase substantially for B_{14} and B_{15}. The supply of HRS protein has a very large impact on B_{14} and on B_{15}, compared to the impact on B_{13} which is in fact insignificant. This reflects that the latter is physically more similar to the underlying futures specification, whereas the former are much different. Finally, protein levels do not have a significant impact on the futures market spread indicating that the impact of protein supplies is primarily on the basis value for the higher protein specifications.

Quality variables of particularly interest are VOMLOSS, Falling Numbers and Absorption. These were included in part in that these are important to end-users, are not measured directly and routinely in the marketing system, are reflected in cash market specifications, but, not completely in the futures specification. The results indicate that VOMLOSS has a positive impact on B_{13}, B_{14} (Models 1 and 2) and B_{15} (Model 1), but not on F_s and on B_{13} in Model 3. These indicate that reduced levels of production due to vomitoxin have the impact of increasing the basis for Milling Quality Wheat, with a possible exception of B_{15}. These also have no impact on F_s. Intuitively, this means that vomitoxin induced shortages have the impact of increasing cash market premiums, but, not impacting the premium for MGEX vs. KCBT.

The second quality variable is Absorption which is a desired end-use attribute. Absorption has a positive impact on B_{15} in each of Model 1 and Model 2 and on B_{15} and F_s in Model 3. Thus, high absorption values result in greater premiums paid for B_{15}, but, not the basis for lower proteins and or the futures spread. Finally, FN has a negative impact on B_{15} in Model 1 and B_{13} in Model 3. Thus, in crop years with lower FN values, there are premiums for these basis values. It is also of interest that the Percent of crop that grades No. 1 is not significant in any of the models. There is a difference in that futures specification requires No. 2, whereas the cash market specification requires No. 1. That this variable is insignificant is probably a reflection that the other quality and dynamic variables are more domineering in explaining the variability of these intermarket relationships.

Several aspects of the dynamic relationships are important. One is the seasonal impacts. These are apparent in each of the 3 models and we will explain them with respect to Model 3. These results show very persistent seasonal variability in the basis and inter-futures market spreads, though it is important that these are also impacted by the dynamics of the endogenous variables in the model. Specifically, HRS basis values are low during August and September, increase to reach a peak in November, decline into December, and then increasing to another peak in April. Similar behavior is observed for the basis with different protein levels with a few exceptions. Most important is that there appears to be a larger percentage increase in B_{13} and B_{14} from September to November. B_{15} appreciates as well but has a greater premium during September. In contrast, the seasonal behavior of the intermarket spread is not significant and less prevalent.

There are also important dynamic interactions. Models 1 and 2 suggest that the autoregressive nature of price behavior is present in all four cases where own lagged values (by one period) exhibit large positive impact on current price values. There is no cross-price impact among basis values, *i.e.*, B_{13} is not impacted by one-period lagged values of B_{14} or B_{15}, and B_{15} is not impacted by one-period lagged values of B_{13} and B_{14}. It is inconclusive to say if current values of B_{14} are impacted (positively) by one-lagged values of B_{15}, while B_{13} has no impact on B_{14}. Finally, Model 3 does not provide an intuitive pattern of dynamic interrelations among the different basis and the futures spread.

Of interest also is the dynamic impact of futures price spreads on basis levels. Specifically, the lagged value of the F_s has a significant and large impact on its own value; and, also on the lagged values of B_{13} and B_{14}. Thus, there is a carry-over effect from the futures market to the basis markets. On the other hand, the basis levels do not have a significant impact on the F_s.

Next, we determine how a shock to the i^{th} variable affects all the endogenous variables through the lag structure of the vector error correction model. As in traditional vector autoregressive analysis, Lutkepohl and Reimers (1992) showed that innovation accounting (*i.e.*, impulse responses) in vector error correction can be used to obtain information concerning the interactions among the variables. As a practical matter, the two innovations ε_{yt} and ε_{zt} may be contemporaneously correlated if y_t has a contemporaneous effect on z_t and/or z_t have a contemporaneous effect on y_t. In obtaining impulse response functions, Choleski decomposition is used to orthogonalize the innovations. The impulse responses are sensitive to the ordering of variables. Economic theory sometimes provides the rationale for the ordering. Usually, there is no such a priori knowledge and only intuition with respect to the research questions being addressed determine the ordering of variables.[3] There is no economic theory to guide us in this case; fortunately, the impulse responses remain very similar under different variables ordering regimes.

First, the most important finding is that all four prices converge quickly (within a few months) towards the long-term equilibrium path following the one-time shock (innovation) to each of the endogenous variables. This indicates the stability of the system and a relatively short convergence period. Next, one standard deviation innovation to B_{13} appears to have a relatively larger impact initially on the levels of B_{13} and B_{14} than the innovations in other variables. Even then, this effect dampens quickly to negligible 2-4 cents after only six months. The innovation in B_{14} has the largest initial impact on the behavior of B_{15}. Interestingly, the shock in none of the basis has either significant or long-lasting impact on the futures spread, while the innovation to F_s has initially large but short-lasting impact on the future F_s values.

SUMMARY AND DISCUSSION

Understanding the dynamics and factors impacting basis values is important for market participants and researchers. While important in most all grain and oilseed commodities it is particularly important in the case of hard wheat. Indeed, in these markets basis values have become much more volatile in recent years, there are important seasonal and dynamic inter-relationships and there are important structural factors impacting basis values and inter-market wheat spreads. All of these affect market participants in terms of greater risk and formulating strategies regarding hedging and position taking.

The purpose of this study was to develop a model to explore the dynamic relationships and interdependencies among basis values and futures-market-spreads for milling quality higher-protein wheat. Specifically, we seek to identify factors impacting basis values for 13, 14, and 15% protein hard red spring (HRS) wheat in addition to the intermarket wheat spread between Minneapolis and Kansas City wheat futures. The model evaluates impacts of important underlying quality factors that vary through time, on basis and intermarket futures price relationships. The results have implications for buyers and sellers of hard wheat, hedgers, and other market participants as well as in fundamental analysis of the wheat sector which frequently ignore these subtle but important effects.

We specified a Vector Autoregression model (VAR) to explore these relationships. Endogenous variables are basis values for hard wheat for different protein levels, and the Minneapolis-Kansas City intermarket price spread. Exogenous variables are the supplies of hard wheat protein in the primary production regions, production of hard wheat, and quality attributes important in the basis market that are not as relevant in futures. These are in addition to the numerous dynamic inter-relationships including seasonal variability,

[3] The very idea of imposing a structure on a vector autoregressive system seems contrary to the spirit of Sims' (1980, 1988) argument against "incredible identifying restriction." Unfortunately, there is no simple way to circumvent the problem; identification necessitates imposing some structure on the system. The Cholesky decomposition provides a minimal set of assumptions that can be used to identify the primitive model.

inter-temporal variability and dynamic interdependencies among these markets. The data is for period 1980-2010 of monthly observations.

The results provide insight to factors explaining the volatility of wheat basis values, and their interrelationships. Of interest is that:

- Basis values for these wheat markets have an increasing trend, and, have become more volatile;
- Factors impacting this variability are the level of HRS protein in the United States, lagged by 1 month and 12 months, and the production of HRS. HRW and Canadian protein levels are not significant, though HRW production does have an impact on the basis for higher protein HRS;
- Quality factors have a significant impact on basis values, notably vomitoxin, falling number and absorption.
- There are dynamic interrelations which are important to market participants. These include increasing trends, seasonality, dynamic lags with respect to basis values for 13, 14, and 15% protein wheat and dynamic inter-relationships. The dynamics indicate that there are lagged responses particularly in the basis impacts, but, these are not substantive in the futures spread relationship.

The results have implications for both researchers and market participants. For researchers, these results provide a detailed explanation of these relationships and how they interact with the overall price level. It is clear the basis values are not constant, they are highly volatile; are impacted by fundamental factors, but yet had substantial variability and dynamic interrelationships. For market participants, the model could be used for forecasting, assessing risk management strategies and evaluating forward pricing/contracting alternatives. For markets, the results are clear that factors such as vomitoxin and other quality factors have an important impact on cash-futures market relationships which is apparent in the pressure for recent changes at two of the US futures exchanges. That the basis for higher protein wheat has been trending up, and has become more volatile has important implications for Canadian marketers and participants. The increasing basis favors production and marketing of higher protein wheat; but, the increasing volatility of basis indicates that traditional hedging mechanisms are less effective than previously.

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Table 1. Unit root tests based on levels

Variables	Lag length[a]	Exogenous Variables	ADF Statistic (levels)	Prob.[b]
B_{13}	1	Constant	-5.320	0.000
B_{14}	2	Constant and Trend	-5.194	0.000
B_{15}	1	Constant and Trend	-3.409	0.051
F_s	4	Constant and Trend	-3.756	0.020

[a] Optimal lag length was based on the Schwartz Information Criterion.

[b] MacKinnon (1996) one-sided p-values

Table 2. Pairwise granger causality tests (2 lags and 347 observations)

Null Hypothesis:	Obs	F-Statistic	Prob.
B_{14} does not Granger Cause B_{13}	347	10.5898	3.E-05
B_{13} does not Granger Cause B_{14}		7.74071	0.0005
B_{15} does not Granger Cause B_{13}	347	1.39299	0.2497
B_{13} does not Granger Cause B_{15}		2.63619	0.0731
F_s does not Granger Cause B_{13}	347	20.9723	3.E-09
B_{13} does not Granger Cause F_s		2.55436	0.0792
B_{15} does not Granger Cause B_{14}	358	8.11689	0.0004
B_{14} does not Granger Cause B_{15}		9.84748	7.E-05
F_s does not Granger Cause B_{14}	358	26.9699	1.E-11
B_{14} does not Granger Cause F_s		2.99490	0.0513
F_s does not Granger Cause B_{15}	358	17.9827	4.E-08
B_{15} does not Granger Cause F_s		1.32031	0.2684

Table 3. Model 1 results (One lag only)

	B_{13}	B_{14}	B_{15}	F_s
B_{13} (-1)	0.755102	0.067610	-0.107962	0.091566
	(0.07416)	(0.09602)	(0.13348)	(0.17706)
	[10.1818]	[0.70414]	[-0.80882]	[0.51715]
B_{14} (-1)	-0.048067	0.546179	0.101466	0.275235
	(0.09825)	(0.12720)	(0.17683)	(0.23456)
	[-0.48925]	[4.29390]	[0.57381]	[1.17343]
B_{15} (-1)	-0.018283	0.102047	0.739640	-0.170863
	(0.04941)	(0.06396)	(0.08892)	(0.11795)
	[-0.37006]	[1.59537]	[8.31782]	[-1.44858]
F_s (-1)	0.065664	0.070992	0.056060	0.602319
	(0.02002)	(0.02592)	(0.03604)	(0.04780)
	[3.27956]	[2.73858]	[1.55561]	[12.6003]
C	51.44672	13.93269	-184.7653	-21.20057
	(73.7944)	(95.5415)	(132.820)	(176.180)
	[0.69716]	[0.14583]	[-1.39110]	[-0.12033]
HRSPROT(-1)	-2.755034	-9.530567	-18.58338	-6.135506
	(2.94191)	(3.80889)	(5.29503)	(7.02364)
	[-0.93648]	[-2.50219]	[-3.50959]	[-0.87355]
HRWPROT(-1)	0.972293	2.018353	2.551065	-3.438631
	(1.76097)	(2.27992)	(3.16949)	(4.20420)
	[0.55214]	[0.88527]	[0.80488]	[-0.81790]
CANPROT(-1)	-2.089147	0.773252	3.876962	3.053528
	(2.67902)	(3.46853)	(4.82187)	(6.39601)
	[-0.77982]	[0.22293]	[0.80404]	[0.47741]
HRSPROD	-4.27E-06	-1.74E-05	2.93E-05	-6.16E-06
	(1.8E-05)	(2.3E-05)	(3.2E-05)	(4.2E-05)
	[-0.24242]	[-0.76443]	[0.92208]	[-0.14630]
HRWPROD	-1.83E-05	-9.81E-06	2.36E-07	3.60E-05
	(8.3E-06)	(1.1E-05)	(1.5E-05)	(2.0E-05)
	[-2.19136]	[-0.90873]	[0.01573]	[1.80971]
CANPROD	4.42E-06	5.55E-06	5.05E-06	-2.34E-05
	(9.9E-06)	(1.3E-05)	(1.8E-05)	(2.4E-05)
	[0.44528]	[0.43130]	[0.28270]	[-0.98713]
VOMLOSS	140.7362	130.8105	152.8361	-105.2813
	(42.1973)	(54.6328)	(75.9493)	(100.744)
	[3.33519]	[2.39436]	[2.01234]	[-1.04504]
ABSORP	0.109000	1.396681	5.720449	1.384595
	(0.89332)	(1.15658)	(1.60785)	(2.13274)
	[0.12202]	[1.20760]	[3.55784]	[0.64921]

FN	0.010629	-0.003044	-0.072044	-0.010478
	(0.02170)	(0.02809)	(0.03905)	(0.05180)
	[0.48990]	[-0.10837]	[-1.84497]	[-0.20228]
NO1	0.093328	0.038323	0.004458	-0.092982
	(0.07507)	(0.09719)	(0.13512)	(0.17923)
	[1.24320]	[0.39429]	[0.03299]	[-0.51879]
TREND	0.001450	0.030775	0.057494	0.072260
	(0.01505)	(0.01949)	(0.02709)	(0.03594)
	[0.09631]	[1.57914]	[2.12212]	[2.01074]
D1	16.54450	15.04734	12.69774	8.340748
	(3.71798)	(4.81366)	(6.69185)	(8.87645)
	[4.44986]	[3.12597]	[1.89749]	[0.93965]
D2	17.18756	16.11411	15.26985	20.82285
	(3.71102)	(4.80465)	(6.67933)	(8.85984)
	[4.63149]	[3.35385]	[2.28614]	[2.35025]
D3	13.93565	13.78778	12.91581	-6.003690
	(3.71566)	(4.81065)	(6.68766)	(8.87090)
	[3.75052]	[2.86609]	[1.93129]	[-0.67678]
D4	16.55430	12.94120	10.10843	13.79546
	(3.71845)	(4.81427)	(6.69269)	(8.87758)
	[4.45194]	[2.68809]	[1.51037]	[1.55397]
D5	21.59607	20.45556	20.88240	0.552613
	(3.71631)	(4.81150)	(6.68884)	(8.87246)
	[5.81116]	[4.25139]	[3.12198]	[0.06228]
D6	12.11775	10.23152	7.966279	12.47491
	(3.73990)	(4.84205)	(6.73131)	(8.92880)
	[3.24012]	[2.11306]	[1.18347]	[1.39715]
D7	9.183579	8.407489	6.762674	0.467343
	(3.71314)	(4.80739)	(6.68313)	(8.86490)
	[2.47327]	[1.74887]	[1.01190]	[0.05272]
D9	4.966693	4.003364	14.91777	3.782926
	(3.71733)	(4.81282)	(6.69068)	(8.87491)
	[1.33609]	[0.83181]	[2.22963]	[0.42625]
D10	22.15590	19.58705	21.64762	5.749143
	(3.78572)	(4.90136)	(6.81376)	(9.03817)
	[5.85250]	[3.99625]	[3.17704]	[0.63610]
D11	22.80209	24.60294	23.85102	4.350190
	(3.74562)	(4.84945)	(6.74160)	(8.94245)
	[6.08766]	[5.07335]	[3.53789]	[0.48647]
D12	10.81639	9.118710	4.296132	0.748868
	(3.71889)	(4.81484)	(6.69349)	(8.87863)
	[2.90850]	[1.89388]	[0.64184]	[0.08435]
R-squared	0.784732	0.825463	0.892031	0.547284

Adj. R-squared	0.767457	0.811457	0.883367	0.510955
Akaike AIC	8.185174	8.701728	9.360592	9.925617
Schwarz SC	8.482157	8.998712	9.657576	10.22260

Figure 1. Impulse Responses (Model 1)

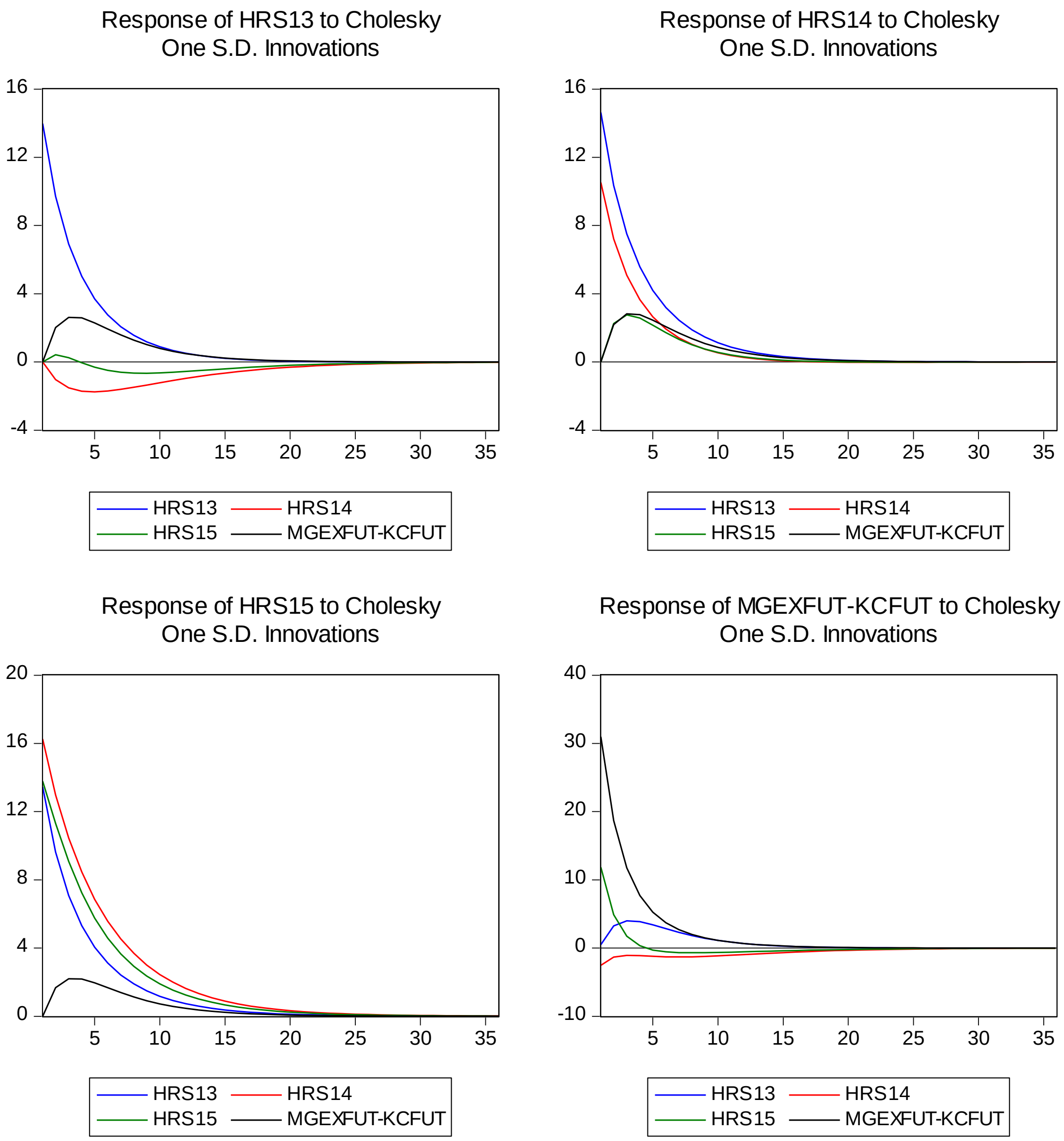

Table 4. Model 2 results (One lag only + the interaction protein-production term)

	B_{13}	B_{14}	B_{15}	F_s
B_{13} (-1)	0.733834	0.034017	-0.091643	-0.076033
	(0.06890)	(0.09040)	(0.12857)	(0.16824)
	[10.6514]	[0.37628]	[-0.71280]	[-0.45192]
B_{14} (-1)	-0.026498	0.549931	-0.008419	0.367601
	(0.09457)	(0.12410)	(0.17648)	(0.23094)
	[-0.28019]	[4.43151]	[-0.04770]	[1.59173]
B_{15} (-1)	-0.014483	0.139097	0.882919	-0.179601
	(0.04491)	(0.05894)	(0.08382)	(0.10968)
	[-0.32245]	[2.36012]	[10.5340]	[-1.63747]
F_s (-1)	0.063148	0.070736	0.047879	0.653831
	(0.01845)	(0.02421)	(0.03443)	(0.04506)
	[3.42228]	[2.92145]	[1.39046]	[14.5102]
C	7.753766	-6.240080	-133.9300	-77.43480
	(48.9372)	(64.2148)	(91.3231)	(119.505)
	[0.15844]	[-0.09718]	[-1.46655]	[-0.64796]
HRSPROT*HRSPROD(-1)	1.29E-06	1.07E-06	3.72E-06	1.37E-06
	(1.1E-06)	(1.4E-06)	(2.0E-06)	(2.7E-06)
	[1.18317]	[0.74771]	[1.83220]	[0.51432]
HRWPROT*HRWPROD(-1)	-2.46E-06	-1.70E-06	-2.61E-07	2.65E-06
	(6.3E-07)	(8.3E-07)	(1.2E-06)	(1.5E-06)
	[-3.90134]	[-2.05927]	[-0.22233]	[1.72384]
CANPROT*CANPROD(-1)	3.11E-07	-1.27E-07	-5.24E-07	-1.78E-06
	(6.5E-07)	(8.6E-07)	(1.2E-06)	(1.6E-06)
	[0.47563]	[-0.14804]	[-0.43001]	[-1.11446]
VOMLOSS	133.7318	79.65995	20.11956	-96.47774
	(31.5750)	(41.4324)	(58.9231)	(77.1065)
	[4.23536]	[1.92265]	[0.34145]	[-1.25123]
ABSORP	-0.009899	0.174769	2.100989	0.730082
	(0.72290)	(0.94858)	(1.34902)	(1.76532)
	[-0.01369]	[0.18424]	[1.55742]	[0.41357]
FN	0.005769	0.001654	-0.064154	0.014941
	(0.02060)	(0.02703)	(0.03844)	(0.05030)
	[0.28006]	[0.06120]	[-1.66890]	[0.29702]
NO1	0.067939	0.023526	0.031962	-0.115757
	(0.07060)	(0.09264)	(0.13175)	(0.17241)
	[0.96230]	[0.25395]	[0.24259]	[-0.67141]
TREND	-0.011683	0.006844	0.027431	0.046329

	(0.01410)	(0.01850)	(0.02631)	(0.03442)
	[-0.82874]	[0.37000]	[1.04274]	[1.34581]
D1	16.58531	15.21681	12.21264	8.735892
	(3.66982)	(4.81549)	(6.84836)	(8.96173)
	[4.51938]	[3.15997]	[1.78330]	[0.97480]
D2	17.26906	16.35596	14.91861	21.14366
	(3.66316)	(4.80676)	(6.83593)	(8.94547)
	[4.71425]	[3.40270]	[2.18238]	[2.36362]
D3	14.21708	14.24865	12.92194	-6.429542
	(3.66763)	(4.81262)	(6.84427)	(8.95638)
	[3.87637]	[2.96068]	[1.88799]	[-0.71787]
D4	16.78496	13.36709	9.921038	14.12081
	(3.66846)	(4.81371)	(6.84582)	(8.95840)
	[4.57548]	[2.77688]	[1.44921]	[1.57626]
D5	21.93618	21.05732	21.00712	0.712184
	(3.66526)	(4.80951)	(6.83984)	(8.95059)
	[5.98489]	[4.37827]	[3.07129]	[0.07957]
D6	12.96306	11.04512	7.458518	12.62768
	(3.69301)	(4.84592)	(6.89163)	(9.01835)
	[3.51016]	[2.27926]	[1.08226]	[1.40022]
D7	9.262243	8.691476	6.478593	0.739355
	(3.66391)	(4.80774)	(6.83733)	(8.94730)
	[2.52796]	[1.80781]	[0.94753]	[0.08263]
D9	5.169982	4.550516	15.82875	2.958357
	(3.67055)	(4.81645)	(6.84971)	(8.96350)
	[1.40850]	[0.94479]	[2.31086]	[0.33004]
D10	22.34834	19.71944	20.94574	4.757495
	(3.73424)	(4.90003)	(6.96858)	(9.11905)
	[5.98470]	[4.02435]	[3.00574]	[0.52171]
D11	22.95950	24.69858	22.58789	4.651700
	(3.68682)	(4.83780)	(6.88007)	(9.00323)
	[6.22746]	[5.10534]	[3.28309]	[0.51667]
D12	10.84673	9.097895	2.855411	1.501095
	(3.65858)	(4.80074)	(6.82737)	(8.93427)
	[2.96474]	[1.89510]	[0.41823]	[0.16802]
R-squared	0.787581	0.823088	0.885471	0.532622
Adj. R-squared	0.772640	0.810645	0.877415	0.499748
Akaike AIC	8.154756	8.698148	9.402487	9.940396
Schwarz SC	8.418741	8.962133	9.666473	10.20438

Figure 2. Impulse Responses (Model 2)

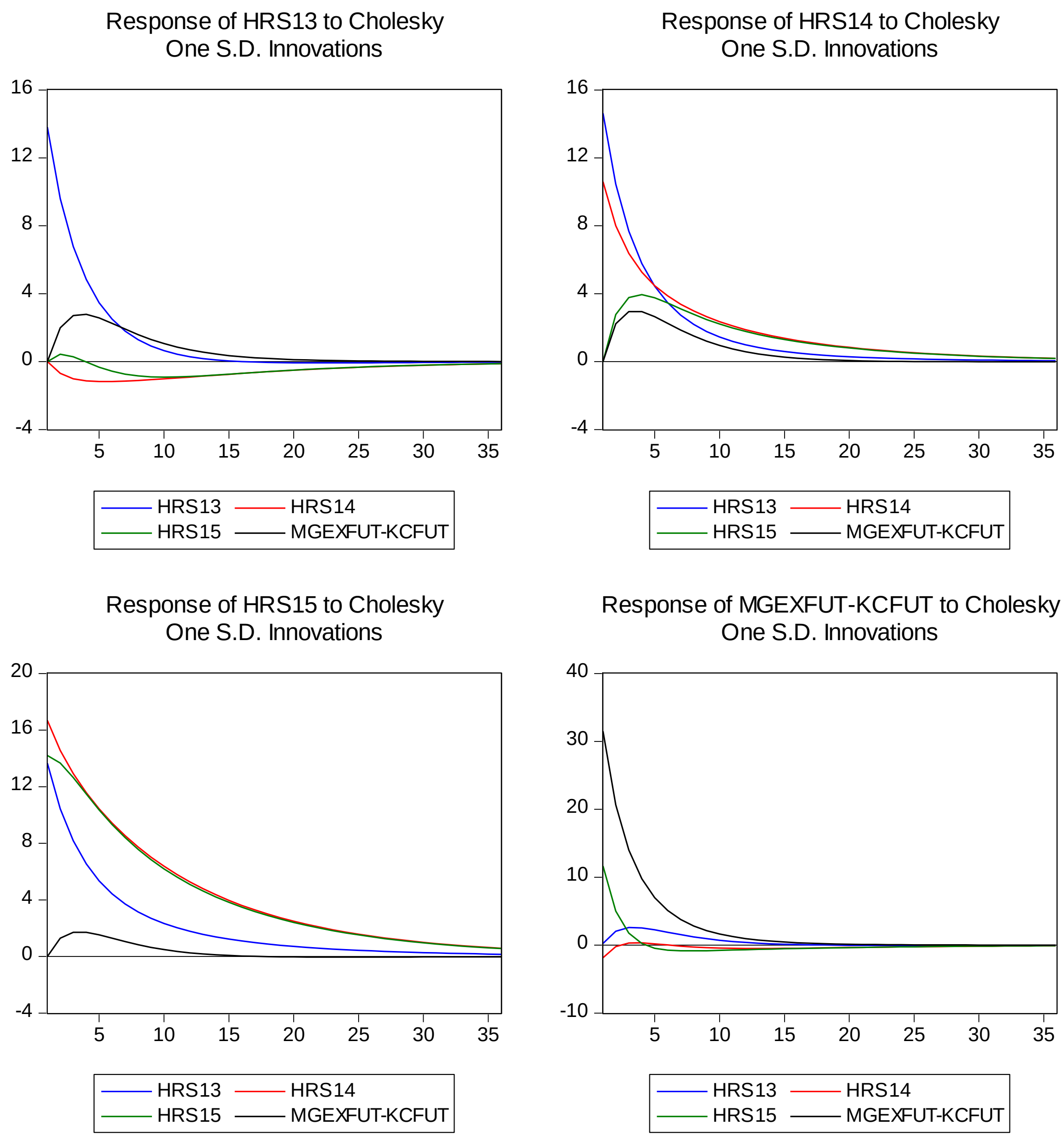

Table 5. Model 3 results (Twelve lag)

	B_{13}	B_{14}	B_{15}	F_s
B_{13} (-1)	0.627969 (0.11519) [5.45176]	0.080348 (0.14142) [0.56816]	0.289507 (0.21431) [1.35088]	0.146525 (0.35323) [0.41481]
B_{13} (-2)	-0.143898 (0.13592) [-1.05872]	-0.371609 (0.16687) [-2.22694]	-0.730217 (0.25288) [-2.88761]	-0.700491 (0.41681) [-1.68062]
B_{13} (-3)	0.183475 (0.13416) [1.36755]	0.276461 (0.16472) [1.67840]	0.293313 (0.24962) [1.17505]	0.848903 (0.41143) [2.06331]
B_{13} (-4)	0.014969 (0.13431) [0.11145]	-0.079233 (0.16490) [-0.48050]	0.064689 (0.24989) [0.25887]	0.206687 (0.41188) [0.50181]
B_{13} (-5)	-0.216545 (0.13391) [-1.61705]	-0.074317 (0.16441) [-0.45202]	-0.207165 (0.24915) [-0.83148]	-0.826692 (0.41066) [-2.01307]
B_{13} (-6)	0.439152 (0.13087) [3.35553]	0.430298 (0.16068) [2.67800]	0.282322 (0.24350) [1.15944]	0.419883 (0.40134) [1.04620]
B_{13} (-7)	0.087048 (0.13031) [0.66799]	-0.024584 (0.15999) [-0.15366]	-0.013029 (0.24245) [-0.05374]	-0.272714 (0.39962) [-0.68243]
B_{13} (-8)	-0.120777 (0.13212) [-0.91412]	-0.022635 (0.16221) [-0.13954]	-0.135598 (0.24582) [-0.55161]	0.546545 (0.40517) [1.34892]
B_{13} (-9)	-0.192431 (0.12940) [-1.48713]	-0.301586 (0.15887) [-1.89837]	-0.136958 (0.24075) [-0.56888]	-0.389381 (0.39681) [-0.98127]
B_{13} (-10)	0.335190 (0.12532) [2.67459]	0.181557 (0.15386) [1.17998]	0.019880 (0.23317) [0.08526]	0.289482 (0.38432) [0.75323]
B_{13} (-11)	0.021585 (0.12127) [0.17799]	-0.035371 (0.14889) [-0.23757]	0.047491 (0.22563) [0.21048]	-0.274997 (0.37189) [-0.73947]
B_{13} (-12)	0.003785 (0.10624) [0.03563]	0.220887 (0.13043) [1.69349]	0.430545 (0.19766) [2.17818]	0.105210 (0.32579) [0.32293]
B_{14} (-1)	0.106705 (0.13627) [0.78304]	0.698194 (0.16730) [4.17321]	-0.077915 (0.25354) [-0.30731]	0.446464 (0.41789) [1.06838]

B_{14} (-2)	0.165340	0.527037	1.103063	0.484132
	(0.16607)	(0.20389)	(0.30898)	(0.50926)
	[0.99562]	[2.58496]	[3.57007]	[0.95065]
B_{14} (-3)	-0.244518	-0.534849	-0.582386	-0.634831
	(0.16771)	(0.20591)	(0.31204)	(0.51432)
	[-1.45795]	[-2.59751]	[-1.86638]	[-1.23432]
B_{14} (-4)	0.004224	0.212126	0.304914	0.191559
	(0.16796)	(0.20621)	(0.31250)	(0.51508)
	[0.02515]	[1.02868]	[0.97572]	[0.37190]
B_{14} (-5)	0.201468	0.002043	-0.183643	0.438120
	(0.16847)	(0.20684)	(0.31345)	(0.51664)
	[1.19585]	[0.00988]	[-0.58588]	[0.84802]
B_{14} (-6)	-0.549730	-0.533073	-0.216523	-0.286285
	(0.16302)	(0.20014)	(0.30330)	(0.49991)
	[-3.37224]	[-2.66350]	[-0.71389]	[-0.57267]
B_{14} (-7)	0.165135	0.327244	0.221021	0.239521
	(0.16369)	(0.20097)	(0.30455)	(0.50198)
	[1.00883]	[1.62834]	[0.72572]	[0.47716]
B_{14} (-8)	0.181091	-0.085390	0.024375	-0.748900
	(0.16991)	(0.20860)	(0.31613)	(0.52105)
	[1.06580]	[-0.40934]	[0.07711]	[-1.43729]
B_{14} (-9)	-0.055486	0.048300	-0.283005	0.642108
	(0.17131)	(0.21033)	(0.31873)	(0.52535)
	[-0.32389]	[0.22964]	[-0.88790]	[1.22225]
B_{14} (-10)	-0.241045	-0.051879	0.432152	-0.466113
	(0.16199)	(0.19888)	(0.30139)	(0.49677)
	[-1.48800]	[-0.26085]	[1.43384]	[-0.93829]
B_{14} (-11)	-0.018138	0.007167	-0.390505	0.349642
	(0.15316)	(0.18805)	(0.28497)	(0.46970)
	[-0.11842]	[0.03811]	[-1.37034]	[0.74440]
B_{14} (-12)	0.003884	-0.230066	-0.448822	-0.189339
	(0.12630)	(0.15506)	(0.23498)	(0.38730)
	[0.03076]	[-1.48374]	[-1.91004]	[-0.48887]
B_{15} (-1)	-0.045982	0.039350	0.777804	-0.299139
	(0.06454)	(0.07924)	(0.12008)	(0.19792)
	[-0.71247]	[0.49661]	[6.47746]	[-1.51143]
B_{15} (-2)	0.006821	-0.111031	-0.348984	-0.199526
	(0.07908)	(0.09709)	(0.14713)	(0.24251)
	[0.08625]	[-1.14359]	[-2.37189]	[-0.82275]
B_{15} (-3)	0.054064	0.177138	0.141001	0.092250
	(0.07868)	(0.09659)	(0.14638)	(0.24127)
	[0.68717]	[1.83387]	[0.96326]	[0.38236]
B_{15} (-4)	0.039036	-0.034980	-0.029412	0.169425

	(0.07958)	(0.09770)	(0.14806)	(0.24404)
	[0.49052]	[-0.35802]	[-0.19864]	[0.69425]
B_{15} (-5)	-0.071642	0.016327	0.098221	-0.469883
	(0.07987)	(0.09806)	(0.14860)	(0.24493)
	[-0.89699]	[0.16650]	[0.66097]	[-1.91844]
B_{15} (-6)	0.101794	0.036665	-0.146244	0.245561
	(0.07780)	(0.09552)	(0.14476)	(0.23859)
	[1.30835]	[0.38384]	[-1.01028]	[1.02921]
B_{15} (-7)	-0.076976	-0.118094	0.004135	0.011171
	(0.07830)	(0.09613)	(0.14568)	(0.24011)
	[-0.98311]	[-1.22848]	[0.02838]	[0.04652]
B_{15} (-8)	-0.014445	0.011555	-0.094441	0.176136
	(0.07711)	(0.09467)	(0.14347)	(0.23648)
	[-0.18732]	[0.12205]	[-0.65825]	[0.74484]
B_{15} (-9)	0.042138	0.141120	0.324257	-0.295051
	(0.07549)	(0.09269)	(0.14046)	(0.23151)
	[0.55816]	[1.52255]	[2.30853]	[-1.27445]
B_{15} (-10)	0.045158	-0.101140	-0.353287	0.265383
	(0.07323)	(0.08991)	(0.13625)	(0.22457)
	[0.61665]	[-1.12494]	[-2.59296]	[1.18174]
B_{15} (-11)	-0.016716	0.054666	0.232800	-0.138189
	(0.07048)	(0.08653)	(0.13114)	(0.21615)
	[-0.23716]	[0.63172]	[1.77524]	[-0.63933]
B_{15} (-12)	-0.017445	0.053678	0.212690	0.005450
	(0.05837)	(0.07167)	(0.10860)	(0.17901)
	[-0.29885]	[0.74900]	[1.95838]	[0.03045]
F_s (-1)	0.112229	0.130199	0.076442	0.512408
	(0.02405)	(0.02953)	(0.04475)	(0.07376)
	[4.66585]	[4.40888]	[1.70811]	[6.94672]
F_s (-2)	-0.164654	-0.234165	-0.206120	0.266176
	(0.02822)	(0.03465)	(0.05251)	(0.08654)
	[-5.83439]	[-6.75833]	[-3.92556]	[3.07561]
F_s (-3)	0.097037	0.189399	0.228778	-0.071499
	(0.03200)	(0.03929)	(0.05955)	(0.09815)
	[3.03198]	[4.82016]	[3.84204]	[-0.72849]
F_s (-4)	-0.073197	-0.107449	-0.182461	-0.109153
	(0.03400)	(0.04174)	(0.06325)	(0.10426)
	[-2.15297]	[-2.57423]	[-2.88455]	[-1.04695]
F_s (-5)	0.103671	-1.62E-05	-0.046498	-0.151683
	(0.03486)	(0.04279)	(0.06485)	(0.10689)
	[2.97427]	[-0.00038]	[-0.71699]	[-1.41907]
F_s (-6)	-0.027956	0.077022	0.121389	0.075378
	(0.03625)	(0.04451)	(0.06745)	(0.11118)

	[-0.77111]	[1.73042]	[1.79962]	[0.67800]
F_s (-7)	-0.120506	-0.107531	0.026058	-0.123869
	(0.03709)	(0.04554)	(0.06901)	(0.11374)
	[-3.24904]	[-2.36144]	[0.37761]	[-1.08905]
F_s (-8)	0.036053	-0.034586	-0.040901	0.108710
	(0.03784)	(0.04646)	(0.07041)	(0.11605)
	[0.95270]	[-0.74439]	[-0.58090]	[0.93674]
F_s (-9)	0.049419	0.193250	0.112357	0.090662
	(0.03839)	(0.04713)	(0.07142)	(0.11772)
	[1.28731]	[4.10022]	[1.57308]	[0.77012]
F_s (-10)	0.024313	0.000958	0.124828	-0.035445
	(0.04151)	(0.05097)	(0.07724)	(0.12730)
	[0.58566]	[0.01880]	[1.61618]	[-0.27843]
F_s (-11)	-0.094811	-0.089261	-0.110028	-0.036261
	(0.04047)	(0.04969)	(0.07530)	(0.12411)
	[-2.34266]	[-1.79642]	[-1.46121]	[-0.29217]
F_s (-12)	0.010469	-0.044113	-0.090266	0.065564
	(0.03237)	(0.03974)	(0.06022)	(0.09926)
	[0.32346]	[-1.11011]	[-1.49894]	[0.66055]
C	87.11248	24.56757	-262.1215	-239.0874
	(67.7816)	(83.2177)	(126.111)	(207.860)
	[1.28519]	[0.29522]	[-2.07850]	[-1.15023]
HRSPROT(-1)	-5.469171	-9.391612	-17.72595	-18.03692
	(2.87769)	(3.53304)	(5.35408)	(8.82479)
	[-1.90054]	[-2.65823]	[-3.31074]	[-2.04389]
HRWPROT(-1)	2.769597	3.192474	1.367909	-1.465990
	(1.61181)	(1.97888)	(2.99886)	(4.94282)
	[1.71831]	[1.61328]	[0.45614]	[-0.29659]
CANPROT(-1)	0.403142	1.959140	2.798930	2.394146
	(2.61872)	(3.21508)	(4.87224)	(8.03061)
	[0.15395]	[0.60936]	[0.57446]	[0.29813]
HRSPROD	-4.52E-05	-3.36E-05	6.42E-05	2.02E-05
	(1.8E-05)	(2.2E-05)	(3.3E-05)	(5.5E-05)
	[-2.53464]	[-1.53400]	[1.93461]	[0.36915]
HRWPROD	1.46E-06	1.18E-05	1.29E-05	4.98E-05
	(8.7E-06)	(1.1E-05)	(1.6E-05)	(2.7E-05)
	[0.16682]	[1.10618]	[0.79185]	[1.86137]
CANPROD	3.45E-06	-5.16E-07	-1.11E-05	-3.44E-05
	(8.4E-06)	(1.0E-05)	(1.6E-05)	(2.6E-05)
	[0.41100]	[-0.05007]	[-0.70920]	[-1.33559]
VOMLOSS	100.9196	44.38324	-12.54194	30.17767
	(45.3949)	(55.7329)	(84.4594)	(139.209)
	[2.22315]	[0.79636]	[-0.14850]	[0.21678]

ABSORP	-0.302890	0.905890	6.832260	6.537446
	(0.88113)	(1.08179)	(1.63938)	(2.70209)
	[-0.34375]	[0.83740]	[4.16758]	[2.41940]
FN	-0.065109	-0.063769	-0.050483	0.043419
	(0.02740)	(0.03364)	(0.05098)	(0.08403)
	[-2.37613]	[-1.89555]	[-0.99023]	[0.51672]
NO1	0.130613	0.107067	0.008251	-0.120352
	(0.06744)	(0.08280)	(0.12548)	(0.20681)
	[1.93673]	[1.29310]	[0.06576]	[-0.58194]
TREND	0.021367	0.043896	0.052056	0.126211
	(0.01492)	(0.01832)	(0.02776)	(0.04575)
	[1.43210]	[2.39635]	[1.87524]	[2.75846]
D1	14.53786	12.26168	12.07440	14.42365
	(3.76327)	(4.62028)	(7.00173)	(11.5405)
	[3.86310]	[2.65388]	[1.72449]	[1.24983]
D2	14.04322	11.60083	7.405062	20.15830
	(3.63081)	(4.45766)	(6.75529)	(11.1343)
	[3.86779]	[2.60245]	[1.09619]	[1.81047]
D3	12.12879	10.33380	7.929939	-2.784769
	(3.78862)	(4.65141)	(7.04890)	(11.6182)
	[3.20138]	[2.22165]	[1.12499]	[-0.23969]
D4	18.39126	12.57157	9.033693	18.74537
	(3.81748)	(4.68684)	(7.10259)	(11.7067)
	[4.81765]	[2.68231]	[1.27189]	[1.60125]
D5	16.98272	11.73689	7.620651	-0.970328
	(3.98402)	(4.89131)	(7.41244)	(12.2175)
	[4.26271]	[2.39954]	[1.02809]	[-0.07942]
D6	10.42011	6.350459	2.496572	16.39936
	(3.93212)	(4.82759)	(7.31589)	(12.0583)
	[2.65000]	[1.31545]	[0.34125]	[1.36000]
D7	4.674896	4.100127	5.309193	7.874259
	(3.62922)	(4.45571)	(6.75232)	(11.1294)
	[1.28813]	[0.92020]	[0.78628]	[0.70752]
D9	2.820464	3.119897	11.13574	3.653125
	(3.58449)	(4.40079)	(6.66910)	(10.9923)
	[0.78685]	[0.70894]	[1.66975]	[0.33234]
D10	17.68537	15.96656	21.03100	11.72972
	(3.76474)	(4.62209)	(7.00447)	(11.5450)
	[4.69763]	[3.45440]	[3.00251]	[1.01600]
D11	19.13481	20.30276	20.37989	12.08101
	(3.90359)	(4.79256)	(7.26281)	(11.9708)
	[4.90185]	[4.23630]	[2.80606]	[1.00920]

D12	4.606015	0.860839	-1.697537	13.70036
	(3.89776)	(4.78540)	(7.25195)	(11.9529)
	[1.18171]	[0.17989]	[-0.23408]	[1.14619]
R-squared	0.872014	0.913744	0.942402	0.651245
Adj. R-squared	0.835145	0.888897	0.925810	0.550781
Akaike AIC	7.818560	8.228898	9.060300	10.05971
Schwarz SC	8.666353	9.076691	9.908093	10.90750

Figure 3. Impulse Responses (Model 3)