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EXPLOITING LONG RUN COINTEGRATION PROPERTIES OF A QUARTERLY U.S. SYSTEM OF WHEAT-RELATED PRODUCTS

Ronald A. Babula,
Robert A. Rogowsky
Robert F.J. Romain

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R. Babula was an Industry Economist with the Office of Industries, and on detail with the Office of Operations, and R. Rogowsky is the Director, Office of Operations, of the U.S. International Trade Commission. R. Romain is a Full Professor with the Center for Research in the Economics of Agrifood (CREA), and with the Department of Agricultural Economics and Consumer Science, Laval University, Quebec, Canada. The authors are grateful for the thorough review, advice, and guidance of Dr. David Bessler, Professor, Department of Agricultural Economics, Texas A&M University. Ms. Ophelia McCardell is thanked for expertly formatting this report, particularly in processing the graph work and tables.

ADDRESS CORRESPONDENCE TO:
OFFICE OF OPERATIONS OR OFFICE OF INDUSTRIES
U.S. INTERNATIONAL TRADE COMMISSION
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Abstract: The methods of the cointegrated vector autoregression/vector error correction (VAR/VEC) model are applied to quarterly U.S. markets for wheat and for wheat-using products of wheat flour, mixes and doughs, bread, wheat-based breakfast cereals, and cookies and crackers. This study extends the recent and earlier reduced-form VAR econometric work done on these same markets, by dichotomizing the system into a long run error-correction space of economic relationships and a short run/deterministic component. Results include an array of empirical estimates of the parameters (some structural) and relationships that drive the wheat-related markets and govern their inter-action. An array of empirical estimates of market impacts on policy, institutional, and trade events is also provided.

Key words: Cointegration, wheat-based U.S. markets, vector autoregression and error correction models.

Our purpose is to extend some recent quarterly econometric research on U.S. wheat-based markets with newer and advanced methods and updated samples. Rich, Babula, and Romain (RBR 2002) applied methods of vector autoregression or VAR modeling, to a quarterly system of U.S. markets for wheat, wheat flour, mixes and doughs (mixes/doughs), bread, wheat-based breakfast cereals (cereals), and cookies and crackers (cookies/crackers). They then provided detailed analyses of impulse response simulations and of other econometric estimates to illuminate the dynamic quarterly patterns with which this reduced form system interacts and some empirical estimates of principal market parameters which propel these markets. Babula, Bessler, and Payne (hereafter, BBP 2004) updated RBR's (2002) sample and methods. BBP (2002) extended RBR's findings by having combined Bernanke (1986) structural VAR methods with directed acyclic graph (DAG) analysis, to the same set of quarterly markets. Perhaps for the first time, we apply methods of Johansen and Juselius' (1990, 1992) cointegrated VAR model to the same market system, and exploit the cointegration properties that error-correct the system of individually nonstationary variables into a stationary system. Our results further dichotomize those of RBR (2002) and BBP (2004) into a set of long run structural error correction or cointegration relationships and into a set of short run/deterministic results (not focused on here) . These cointegration results provide a set of structural, along with reduced form, insights that enhance the precision of the findings of the previous RBR (2002) and BBP (2004) work. Our results include estimates of price elasticities of supply, cross-price transmission or response parameters, and a rich set of empirical effects of policy, trade, economic, and political events (hereafter, important market/institutional events).

This paper has seven ensuing sections. The first presents cointegrated VAR methods as a way to empirically model the quarterly U.S. system of wheat-related markets. The second section analyzes data behavior patterns to generate specification implications to avoid well-known potential econometric problems with compromised inference and biased estimates. The third section summarizes efforts to achieve an adequately specified levels VAR (and its unrestricted VEC equivalent) model to exploit what are later revealed to be the system's substantial cointegration properties. We provide a rigorous analysis of the model's statistical adequacy based on results from a battery of diagnostic mis-specification tests suggested by Juselius (2004, pp. 72-82) and Juselius and Toro (2005). In a fourth section, evidence from Johansen and Juselius' (1990, 1992) well-known trace tests from other sources is used to determine the number of cointegrating vectors or relationships (hereafter, CVs). The cointegration space is then restricted for reduced rank. The fifth section employs Johansen and Juselius' (1990, 1992) hypothesis test procedures on the rank-restricted cointegration space to illuminate the long run economic relationships that drive and tie-together the upstream and downstream wheat-based markets. A sixth section provides economic interpretations of the CVs that are fully restricted for rank and for statistically supported restrictions from the hypothesis tests. A summary and conclusions follow.

Time Series Econometrics, Modeled Markets, and Data Resources

It is well-known that economic time series often fail to meet the conditions of weak stationarity (i.e., stationarity and ergodicity) required of valid inference, and in some cases, unbiased estimates, from regressions using time-ordered data (Engle and Granger 1987; Granger and Newbold 1986, pp. 1-5). And while data series are often individually nonstationary, they can form vectors with stationary linear combinations, such that the vector of inter-related series are "cointegrated" and move in tandem as an error-correcting system (Johansen and Juselius 1990, 1992).

After repeating BBP's (2004) search for U.S. wheat-related market data, we chose an updated quarterly sample of the following endogenous variables (denoted throughout interchangeably by the parenthetical labels) defined and sourced as follows:

1. U.S. price of wheat (PWHEAT): reflected by the U.S. all-wheat price published by the U.S. Department of Agriculture, Economic Research Service (USDA, ERS 2004, 2005).

2. U.S. market-clearing quantity of wheat (QWHEAT): defined as the sum of beginning stocks, production, and imports, published by the USDA, ERS (2004, 2005).

3. U.S. wholesale price of wheat flour (PFLOUR): represented by the U.S. producer price index (hereafter, PPI) for wheat flour, series no. PCU3112113112111, published by the U.S. Department of Labor, Bureau of Labor Statistics (Labor, BLS 2005).

4. U.S. wholesale price of mixes and doughs (PMIXES): reflected by the U.S. PPI for flour mixes and refrigerated and frozen doughs and batters, series no. PCU3118223118226, published by Labor, BLS (2005).

5. U.S. wholesale bread price (PBREAD): defined as the U.S. PPI for bread, series PCU3118123118121, published by Labor, BLS (2005).

6. U.S. wholesale price of wheat-based breakfast cereals (PCEREAL): represented by the U.S. PPI for wheat flakes and other wheat breakfast foods, series no. PCU311230311230112, published by Labor, BLS (2005).

7. U.S. wholesale price of cookies and crackers (PCOOKIES): represented as the U.S. PPI for cookie and cracker manufactured products, series PCU311821311821, published by Labor, BLS (2005).

Data are quarterly, seasonally unadjusted, and placed into natural logarithms. Data were available for the 1985/86:01–2004/05:04 sample period.[1] Since data were not available for all variables prior to 1985/86, our analysis may have potential problems from small samples.

Analysis of Wheat-Based Time Series Data

Figures 1-7 provide the plotted endogenous variables: logged levels in the upper panels and differences in the lower panels. A weakly stationary series has a constant and finite mean and variance, has time-independent observations, and generates regression coefficient estimates that are time-invariant (Juselius 2004, chapters 3 and 4). Weakly stationary data frequently cycle and mean-revert. The following are highlights of nonstationary behavior with potential considerations for model specification:

[1] The U.S. wheat market year or MY extends from June 1 through May 31 of the ensuing calendar year. Hence, 1985/86:01 represents the first MY quarter extending from June through August, 1985; 1985/96:02 represents the second MY quarter extending from September through November of 1985; 1985/86:03 reflects the third MY quarter extending from December 1985 through February of 1986; and 1985/86:04 reflects the fourth MY quarter extending from March through May of 1986.

• PWHEAT, figure 1 and PFLOUR, figure 3: Prices follow time-enduring cycles; seldom mean-revert; display periods of variant market behavior (slope changes) possibly from policy and market events discussed later; trend through substantial subsamples; and display apparently non-constant variation levels (heteroscedasticity or ARCH effects). Differences suggest possible extraordinary effects of observation-specific events (hereafter "outlier" effects and observations). Model specification considerations include: various permanent shift dummy (i.e. binary) variables, outlier variables, and a linear trend.

• QWHEAT, figure 2: Wheat quantity is clearly saddled with seasonal effects and subperiods of trending. Specification considerations include centered seasonal variables and a linear trend.

• PMIXES, figure 4: PMIXES follows a clear upward trend; displays no cycling or mean-reverting behavior; and displays marked changes in slope and behavior, particularly during 1989/90-91/92 and after 2000/01, from market/institutional events discussed below. Differences suggest ARCH effects with more volatile behavior in early subsamples, and periodic instances of outlier effects during 1986/87– 1990/91, and towards the sample's end. Specification considerations include permanent shift and outlier binary variables, and a linear trend.

• PBREAD, figure 5 and PCOOKIES, figure 7: PBREAD and PCOOKIES display similar nonstationary behavior: clear trending; virtually no cycling and mean-reversion; and a number of slope changes (e.g. 1996/97 for PBREAD, late 2002/03 for PCOOKIES). Differences of both variables exhibit potentially extraordinary outlier and ARCH effects throughout, particularly during the early subsamples. Specification considerations include a number of permanent shift and outlier binary variables, along with a linear trend for both prices.

• PCEREAL, figure 6. PCEREALS tends to follow trends in substantial subsamples; displays little or no cycling or mean-reversion; and appears to experience changes in behavior and slope from market and policy events during 1995/96–1996/97, just as the 1996 U.S. farm bill and Uruguay Round were implemented. Differences reflect possible non-constant levels of variation, especially in early 1993/94 and early 1996/97. Specification considerations include a number of permanent shift and outlier binaries, and a linear trend.

The Statistical Model: The Unrestricted Levels VAR and VEC Equivalent[2]

Throughout, a number of terms are used: (1) the *unrestricted levels VAR* denotes a VAR model in logged levels; (2) the *unrestricted VEC* denotes the algebraic equivalent of the unrestricted levels VAR, before the cointegration space is restricted for rank or for statistically supported restrictions; (3) the *cointegrated VEC* is the unrestricted VEC with its cointegration space restricted for reduced rank; and (4) the *fully restricted cointegrated VEC* is the unrestricted VEC after the cointegration space's restriction for reduced rank and for the statistically supported restrictions from the hypothesis tests. The "p" denotes the number (seven) of endogenous variables; "p1" denotes the number of variables

[2]This section draws heavily on the work of Johansen and Juselius (1990, 1992) and Juselius (2004).

Figure 1
Plots of logged levels and differences: Wheat price.

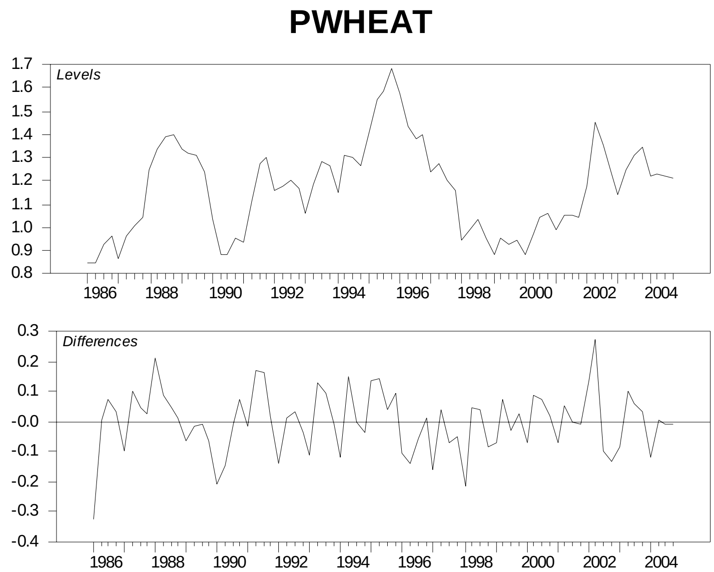


Figure 2
Plots of logged levels and differences: Wheat quantity.

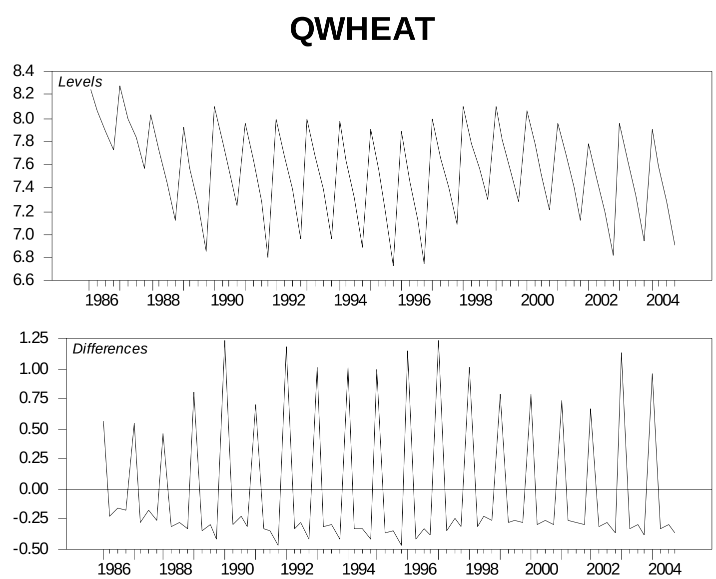


Figure 3
Plots of logged levels and differences: Wheat flour price.

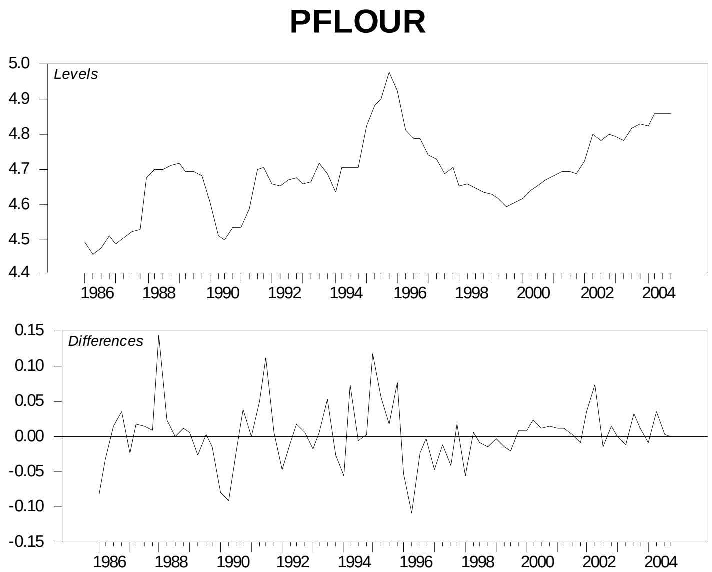


Figure 4
Plots of logged levels and differences: Price of mixes and doughs

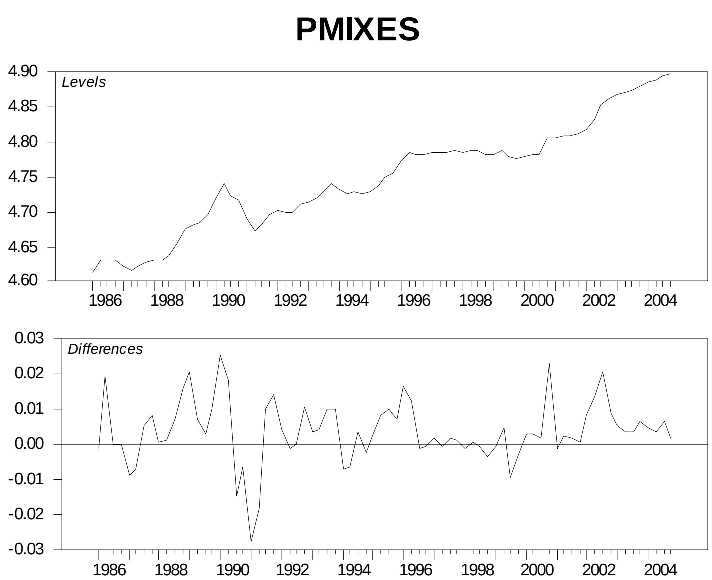


Figure 5
Plots of logged levels and differences: Bread price.

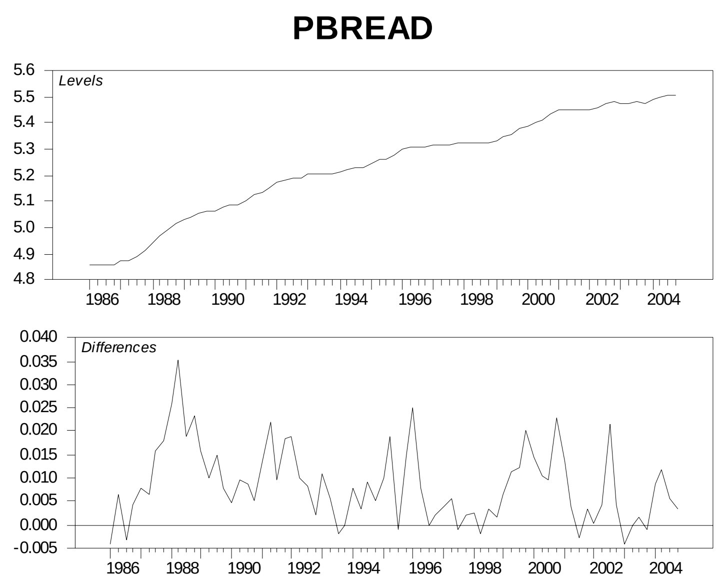


Figure 6
Plots of logged levels and differences: Price of wheat-based breakfast cereals.

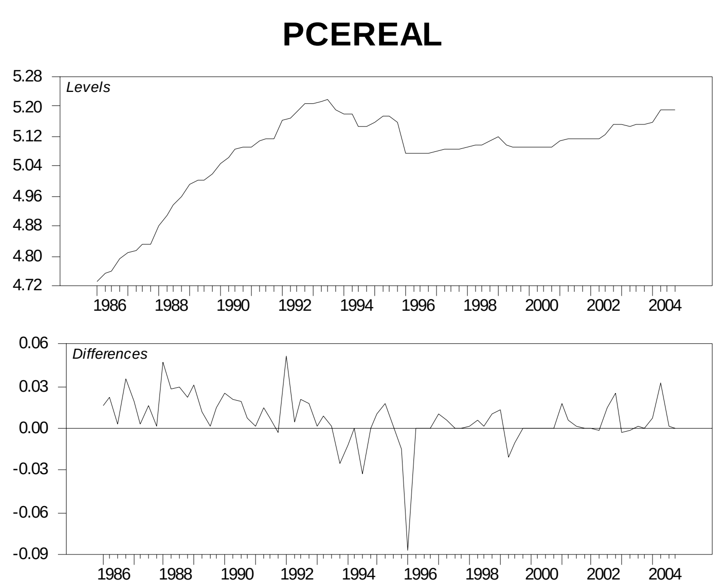
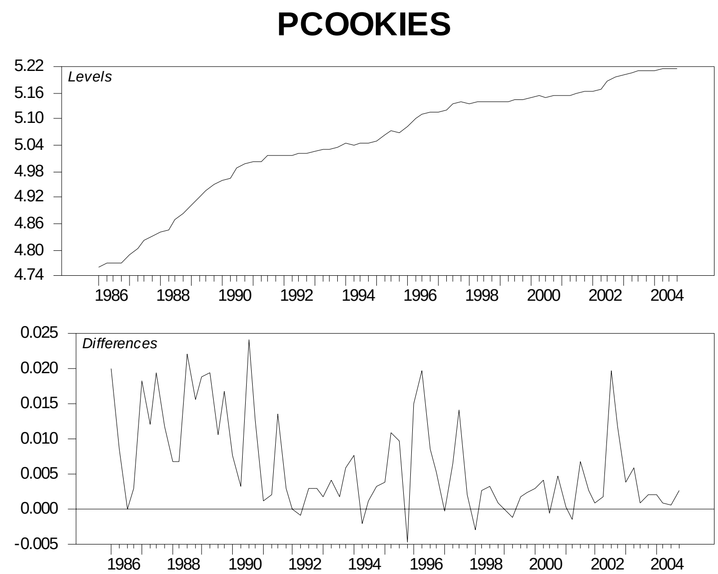


Figure 7
Plots of logged levels and differences: Price of cookies and crackers.



in the cointegration space (seven endogenous, and other deterministic variables introduced later); and "r" represents the cointegration space's reduced rank and the number of cointegrating vectors or CVs. Our chosen methods involve specification and estimation of an adequately specified levels VAR (and unrestricted VEC), such that residual behavior approximates well-known assumptions of multivariate normality (Juselius 2004, chapter 5).

The Levels VAR and unrestricted VEC of the wheat-based model system.

Following Bessler (1984) we posit the above wheat-related variables as the following VAR model, where each endogenous variable is a function of k lags of itself and of each of the remaining endogenous variables in the system:

(1) X(t) = a(1,2)*PWHEAT(t-1) + ... + a(1,k)*PWHEAT(t-k)+
a(2,1)*QWHEAT(t-1)+ . . . . + a(2,k)*QWHEAT(t-k)+
a(3,1)*PFLOUR(t-1) + ...+a(3,k)*PFLOUR(t-k)+
a(4,1)*PMIXES(t-1)+ . . . .+a(4,k)*PMIXES(t-k)+
a(5,1)*PBREAD(t-1)+ . . . . +a(5,k)*PBREAD(t-k) +
a(6,1)*PCEREAL(t-1)+ . . . . +a(6,k)*PCEREAL(t-k)+
a(7,1)*PCOOKIES(t-1)+ . . . . +a(7,k)*PCOOKIES(t-k)+
a(c)*CONSTANT + a(S)* SEASONALS + ϵ(t)

The asterisk and Δ denote multiplication and difference operators throughout. The $\epsilon(t)$ are white noise residuals. X(t) = PWHEAT(t), QWHEAT(t), PFLOUR(t), PMIXES(t), PBREAD(t), PCEREAL(t), and PCOOKIES(t). The a-coefficients are ordinary least squares (OLS) estimates with the first parenthetical digit denoting the seven endogenous variables as ordered above, and with the second referring to the lags 1, 2, ... , k. The a(c) denotes an intercept. The parenthetical terms on the endogenous variables refer to the lag: t to the current period-t, and t-k to the kth lag. Equation 1 also includes three quarterly centered seasonal variables and other potential permanent shift and outlier binaries not shown notationally. We applied Tiao and Box's (1978) lag selection procedure that uses a likelihood ratio test corrected for small samples, and results suggested a two-order lag structure (k=2).

Johansen and Juselius (1990) and Juselius (2004, p. 66) demonstrated that the VAR model in equation 1 is rewritten more compactly as an unrestricted VEC:

(2) $x(t) = \Gamma(1) * \Delta x(t-1) + \Pi * x(t-1) + \Phi * D(t) + \epsilon(t)$

The $\epsilon(t)$ are residuals distributed as white noise. The x(t) and x(t-1) are p by 1 vectors of the above seven wheat-based variables in current and lagged levels, $\Gamma(1)$ is a p by p matrix of short run regression coefficients on the lagged differences, and Π is a p by p error correction term to account for endogenous variable levels. The $\Phi*D(t)$ is a set of deterministic variables: three seasonals and a host of other trend and dummy variables which will be added to address the data issues identified above as the analysis unfolds. The rank-unrestricted Π or error correction term is decomposed as follows

(3) $\Pi = \alpha*\beta'$ where α is a p by r matrix of adjustment speed coefficients and β is a p by r vector of error-correction coefficients.

The $\Pi = \alpha*\beta'$ term is interchangeably denoted as the levels-based long run component, error correction term, or cointegration space of the model. The $[\Delta x*(t-1), \Phi*D(t)]$ is collectively considered the short run/deterministic model component.

Data analysis and previous research by BBP (2004), RBR (2002), and Babula and Rich (2001) suggested possible inclusion of a linear trend and nine permanent shift binaries discussed below in equation 2's long run levels-based cointegration space. These same variables in differenced form and a set of three centered seasonals were considered for equation 2's short run/deterministic component. Analysis also led to consideration of various outlier binaries in the short run/deterministic component. The permanent shifters include (hereafter denoted by the upper-cased labels):

•URUGUAY: valued at 1.0 for 1994/95:02–2004/05:04 MY period and 0.0 otherwise, to capture the effects of the Uruguay Round's January 1995 implementation.

•NAFTA: valued at 1.0 for the 1993/94:02–2004/05:04 MY period, and 0.0 otherwise, to capture the effects of the North American Free Trade Agreement's implementation in January 1994.

•CUSTA: valued at 1.0 for the 1988/89:02–2004/05:04 MY period, and 0.0 otherwise, to capture the effects of the January 1989 implementation of the Canadian/U.S. Free Trade Agreement.

•QUOTA: valued at 1.0 for the 1994/95:02–1995/96:02 MY period, and 0.0 otherwise, to capture the effects of the two temporary U.S. tariff rate quotas (hereafter, TRQs) placed on certain imports of Canadian durum and non-durum wheat for the year ending September 11, 1995.

•FBILLS: valued at 1.0 for the 1996/97:01-2004/05:04 MY period , and 0.0 otherwise, to capture the effects of the last and current U.S. farm bills.

•TITLE7: valued at 1.0 for the 2002/03:02–2004/05:04 MY period, and zero otherwise, to account for effects of the U.S. implementation of preliminary and final antidumping and countervailing duties on certain imports of Canadian durum and/or hard red spring wheat, as a result of U.S. International Trade Commission Investigation Nos. 701-TA-430A and 430B, and 731-TA-1019A and 1019B (Final). See USITC (2003).

•DROU88: valued at 1.0 for the 1987/88:02–1989/90:04 MY period, and 0.0 otherwise, to account for the effects of the U.S. Midwest drought.

•HIDD9396: valued at 1.0 for the 1993/94:01–1996/97:01 MY period, and 0.0 otherwise, to account for the effects of the period of high levels of world grain/oilseed demands and prices.

•CONFECT: valued at 1.0 for 2001/02:01–2004/05:04 to account for sustained increases in confectionary and bakery production costs from (1) a steep, sustained rise in world cocoa prices that began in early 2001 from effects of the Ivory Coast Civil War, and (2) sustained non-cocoa confectionary increases in non-cocoa input costs that began in late-2002.[3]

The starting point for the unrestricted VEC was equation 2 with no deterministic trend or binary variables. A well-specified unrestricted VEC was ultimately achieved in a series of sequential estimations. These estimations added the seasonal variable and then a linear trend, various permanent shift binaries, and a number of quarter-specific outlier binaries – generally one variable for each estimation. An added variable was retained if the diagnostic test values moved in favorable patterns indicative of improved specification. Juselius (2004, chapters 4, 7, and 9) recommends the following battery of diagnostics: (a) trace correlation as an overall goodness-of-fit indicator, (b) likelihood ratio test of autocorrelation, (c) Doornik-Hansen (D-H) tests for equation residual normality, (d) and indicators of skewness and kurtosis. The estimations were stopped when the array of diagnostic values failed to further improve with inclusion of additional variables. After achievement of an adequately specified levels VAR and unrestricted VEC, tests for parameter constancy and for the presence of I(2) trends were performed.

There were two sets of sequential estimations aimed at achieving a statistically adequate VAR model. The first focused on including each of the above-mentioned permanent shift binary variables (and a trend), and all 10 were retained.[4]

[3] PCOOKIES and PMIXES are influenced by movements in confectionary and cocoa input costs. Analysis and information leading to the justification and formulation of this binary variable was received in private communications with market analysts of the U.S. International Trade Commission, Office of Industries, and with analysts from Labor, BLS during August, 2004.

[4] The ten included variables were URUGUAY, CUSTA, NAFTA, QUOTA, FBILLS, TITLE7, DROU88, HIDD9396, CONFECT, and TREND.

The second set further improved specification of the unrestricted VEC that included the ten just-mentioned variables. When a potential outlier was identified as extraordinarily influential based on a "large" standardized residual, an appropriately specified variable was included in equation 2's short run/deterministic component, and retained if the battery of diagnostic values indicated improved specification.[5] Five quarter-specific transitory outlier binaries were included.[6]

An adequately specified model should generate statistically normal residuals. Table 1 provides a battery of diagnostic test values for two estimations: the initially estimated unrestricted VEC before sequential estimations aimed at improved specification and with no deterministic variables, and for the unrestricted VEC judged as adequately specified after inclusion of centered seasonals, nine permanent shift and five outlier binaries, and a linear trend. [7] Table 1's results reveal clear benefits from efforts to improve specification: the model's ability to explain data variation increased 70 percent, as the trace correlation, a goodness of fit indicator for the 7-equation model, rose from 0.50 to 0.85.

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[5] We followed a procedure for examination and analysis of potential outlier events developed by Juselius (2004, chapter 6). An observation-specific event was judged as potentially "extraordinary" one if its standardized residual was 3.0 or more in absolute value. Such a rule for outliers was designed based on the 76-observation sample size using the Bonferoni criterion: $\text{INVNORMAL}(1\text{-}1.025)^{T}$, where T=76, INVNORMAL is a function for the inverse of the normal distribution function that returns the variable for the c-density function of a standard normal distribution. In our case, the Bonferoni variate was a 3.4 absolute value. Given that a number of seemingly influential quarter-specific events generated absolute standardized residual values within the 3.0–3.3 range, we opted to choose a conservative and flexible Bonferoni criterion of absolute standardized residual values of 3.0 or more, rather than 3.4 or more. Observations with absolute standardized residuals of 3.0 or more were considered potential outliers, and we devised an appropriately defined binary variable for the relevant observation (see Juselius 2004, chapter 6). The binary was then placed in the appropriate form in the differences-based short run/deterministic component of equation 2, the model was re-estimated, and the binary variable was retained if the battery of diagnostic values suggested improved specification.

[6] To conserve space, we do not include extensive variable-by-variable analyses and estimation results. All included outlier binary variables were of the transitory "blip" form following formulation procedures in Juselius (2004, chapter 6). The form is appropriate for the short run/deterministic component of the model. The variables are as follows denoted/named numerically for the quarter during which the outlier event's influences were likely manifest: DTR8701, DTR8801, DTR9003, DTR9201, and DTR0201. So for example, DTR8701 is defined as unity for 1987/88:01, and 0.0 otherwise. DTR8701 and DTR8801 likely captured quarter-specific expectationary influences of CUSTA's implementation and of the 1987-1990 drought on the U.S. wheat market not captured by the relevant permanent shift binary variables. DTR9003 likely captured influences on the cookies/crackers and mixes/doughs markets from wheat-related input cost effects from implementation of CUSTA and the 1990 U.S. farm bill that the relevant permanent shift binaries did not manage to capture. The effects captured by DTR9201 on PCEREALS likely arose from escalating prices of wheat, a major input cost for production of wheat-based breakfast cereals. DTR0201 likely captured effects on PWHEAT as the commodity boom of 2002-2004 unfolded.

[7] Each equation for the levels VAR and its unrestricted VEC equivalent was estimated over the 1986/87:03–2004/05:04 period. Four quarterly observations for the 1985/86 MY were set-aside for the Tiao and Box lag search. Given the two lags, the full sample was 76 observations and there were 74 observations in the estimation period.

Table 1.
Mis-specification Tests for the Unrestricted VEC: Before and After Specification Efforts.

Test and/or equation	Null hypothesis and/or test explanation	Prior to efforts at specification adequacy	After efforts at specification adequacy
Trace correlation	System-wide goodness of fit: large proportion desirable	0.5	0.85
ARCH tests for heteroscedasticity	Ho: no heteroscedasticity by 1st and 4th lags. Reject for $p < 0.05$	;ag 1: 101.2 (p=0.000) lag 4: 101.1 (p=0.000)	lag 1: 61.1 (p=0.12) lag 4: 55.8 (p=0.23)
Doornik-Hansen tests for normal residuals	Ho: residuals are normal. Reject for values above 9.2 critical value		
ΔPWHEAT		8.3	4.9
ΔQWHEAT		13.4	9.3
ΔPFLOUR		15.9	7.9
ΔPMIXES		9.4	13.4
Δ PBREAD		1.3	1.2
ΔPCEREAL		36.3	2.5
ΔPCOOKIES		1.8	2.2

A Doornik-Hansen (D-H) value tests the null hypothesis that the relevant equation's residuals are normal, which is rejected at the 1-percent level when the D-H value exceeds 9.2. In all cases but the ΔQWHEAT equation, residuals follow normal behaviour for the unrestricted VEC after efforts at improved specification.[8] D-H values improved noticeably for the ΔPFLOUR and ΔPCEREAL equations.

Table 1 provides indications on skewness and kurtosis of each equation's residuals. Results suggest both sets of values generated by the model that benefited from specification efforts fell within ranges considered acceptably indicative of approximately normal residual behaviour.

Specification efforts did improve ΔQWHEAT specification, but not adequately to have suggested approximately normal residuals. However, table 1 shows clear, substantial progress from specification efforts, and that the entire system generates approximately normal residuals as a system. We followed Juselius (2004, chapter 4) and concluded that overall evidence suggested that the VAR system achieved reasonable adequacy of specification despite ΔQWHEAT's weak evidence of normality.

[8] The ΔPMIXES equation residuals generated a 9.3 D-H value that nearly equals 9.2 critical value, and the test value's margin of excess over the critical value was too marginal to use as a sole criterion for conclusions of non-normal residual behavior. We opted to consider the equation's residuals as approximately normally behaving ones, given the generally favorable battery of other diagnostics generated by this ΔPMIXES equation.

Table 1.
Mis-specification Tests for the Unrestricted VEC: Before and After Specification Efforts (continued).

Test and/or equation	Null hypothesis and/or test explanation	Prior to efforts at specification adequacy	After efforts at specification adequacy
Skewness (kurtosis) values	skewness: ideal is 0.0; small absolute values ≤1.0 acceptable kurtosis: ieal is 3.0; values 3-5 acceptable.		
ΔPWHEAT		0.83 (4.46)	0.05 (3.9)
ΔQWHEAT		-0.80 (3.04)	-0.34 (4.5)
ΔPFLOUR		1.3 (6.0)	0.10 (4.2)
ΔPMIXES		0.38 (4.56)	0.15 (4.8)
Δ PBREAD		0.28 (3.1)	0.28 (3.0)
ΔPCEREAL		-1.36 (10.5)	0.39 (3.4)
ΔPCOOKIES		0.14 (3.35)	-0.12 (3.4)

Cointegration: Choosing and Imposing Reduced Rank on the Error Correction Space

The endogenous variables are shown below to be I(1), and so their differences are I(0). Cointegrated variables are driven by common trends, stationary linear combinations, or cointegration (Juselius 2004, p. 86). For the adequately specified unrestricted levels VAR, the Π-matrix in equations 2 or 3 is a p1 by p1 matrix equal to the product of a p1 by r matrix β of long run error correction coefficients that under cointegration, combine into r≤p stationary linear combinations of the seven wheat-related variables (Johansen and Juselius 1990, 1992). As a result of a reduced rank for Π, β'*x(t) is I(0), even though x(t)'s seven endogenous variables are nonstationary.

Determination of cointegration rank is a three-tiered process. First, one conducts trace tests of Johansen and Juselius (1990, 1992). Second, one examines patterns of characteristic roots of companion matrices generated under relevant assumptions of reduced rank. And third, one examines plotted cointegrating relationships for elements of stationary behaviour.

Nested Trace Tests and Other Evidence for Choosing the Reduced Rank of Π.

Table 2 provides trace test evidence for rank determination. Trace test values are adjusted (increased) for the restriction of nine permanent shift binaries restricted to the cointegration space (see table 2's notes). Tests are nested and evidence at the five percent significance level is sufficient to soundly reject the first five nested hypotheses, suggesting that r≤4; is marginally sufficient to reject the sixth that r≤5 as the test value approaches the 42 critical fractile; and is insufficient to reject that r≤6. Trace results alone suggest that r=6 and that there are six CVs, although evidence marginally rejects that r≤5, suggesting that r may be less than 6. We follow Juselius' (2004, chapter 8) strong suggestion against sole reliance on trace test evidence.

Table 2 **Trace test statistics and related information for nested tests for rank determination.**			
Null hypothesis	Trace value	95% fractile (critical value)	Result
rank or r ≤ 0	370.6	166.5	Reject null that rank is zero
rank or r ≤ 1	279.8	133.7	Reject null that rank ≤ 1
rank or r ≤ 2	184.8	104.8	Reject null that rank ≤ 1
rank or r ≤ 3	120.6	79.9	Reject null that rank ≤ 1
rank or r ≤ 4	89.6	59	Reject null that rank ≤ 1
rank or r ≤ 5	45.7	41.9	(Marginally) Reject null that rank ≤ 1
rank or r ≤ 6	15.7	28.7	Fail to reject that rank ≤ 6

Notes. - As recommended by Juselius (2004, p. 171), CATS2-generated fractiles are increased by 9*1.8 or 16.2 to account for the 9 permanent shift binary variables restricted to lie in the cointegration space. Trace values are corrected with Bartlett's adjustment for small samples.

If r is an appropriate choice, then one expects p-r characteristic roots that are unity or near-unity in the companion matrix. When r is imposed, and there are p-r+1 roots that are unity or near unity, then rank should be reduced to r-1. Patterns of characteristic roots under alternative r-assumptions suggest that r is likely between 1 and 3 with evidence pointing especially to r=3.[9]

The plots of the three CVs are in figures 8, 9, and 10. The BETA*x(t) plots are for the model with short run effects, and the BETA*R1(t) plots are for the model corrected for short run effects, with Juselius (2004, chapter 8) favouring the latter as more reliable. Figures 8-10 suggest that all three CVs are for the most part stationary, and hence that r=3 rather than one or two: plots cycle and mean-revert frequently, and variation levels appear constant (Juselius 2004, chapter 8).[10] All three evidence sources above suggest that the reduced rank of equation 2's Π-matrix is likely three, with three stationary linear combinations of the seven I(1) wheat based variables error-correcting the system.

[9] This analysis follows methods of Juselius (2004, chapter 8). We thoroughly examined patterns of characteristic roots for companion matrices generated under all possible reduced-rank levels: 1, 2, 3, 4, 5, 6. Because of space considerations, we do not report these six matrices and full analyses. Companion matrices and characteristic roots under these alternative r-levels are available from the authors on request. Generally and summarily, patterns of characteristic roots under r=1 through 6 suggests that reduced rank is less than 6, and most likely within the range of 1-3, with evidence pointing particularly to a reduced rank of 3. If r=3 is appropriate, then one expects p-r or 4 characteristic roots of unity, with the fifth and subsequent roots less than unity. When r=3 was imposed, the first five of the characteristic roots were as follows, suggesting that r=3: 1.0, 1.0, 1.0, 1.0, 0.87, with the fifth, 0.87, below unity.

[10] We follow Juselius' (2004, chapter 8) procedures and realize that no economic relation is likely to follow perfectly stationary behavioral paths. Each CV generally behaves with stationarity, with a couple of short term deviations notwithstanding: some short-lived cycling in 1995 for CV1 and CV2, and some volatile behavior in 1993-1994 for CV3.

Figure 8
Plotted cointegrating relation 1 with and without correction for short run effects

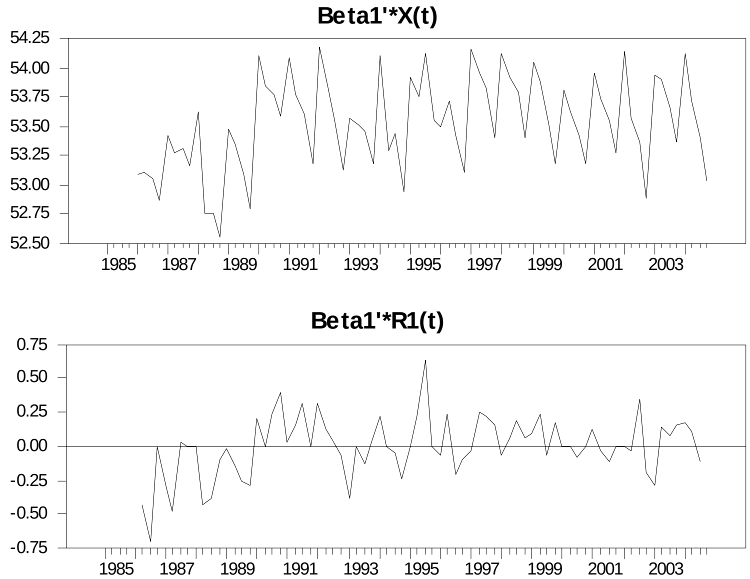


Figure 9
Plotted cointegrating relation 2 with and without correction for short run effects.

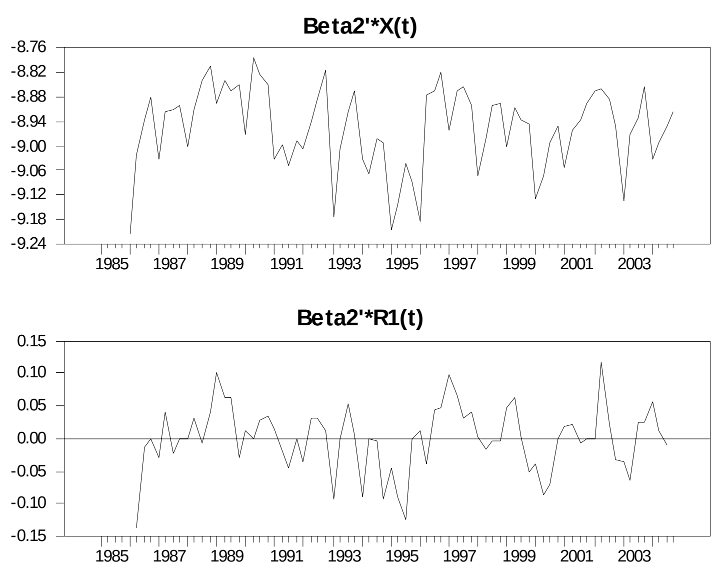
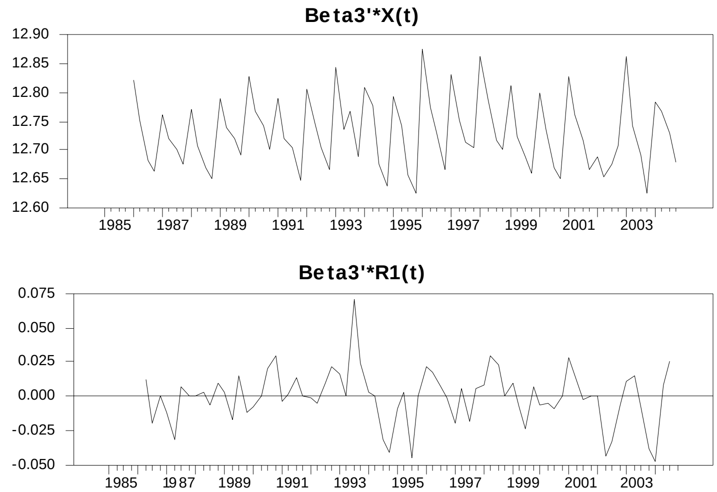


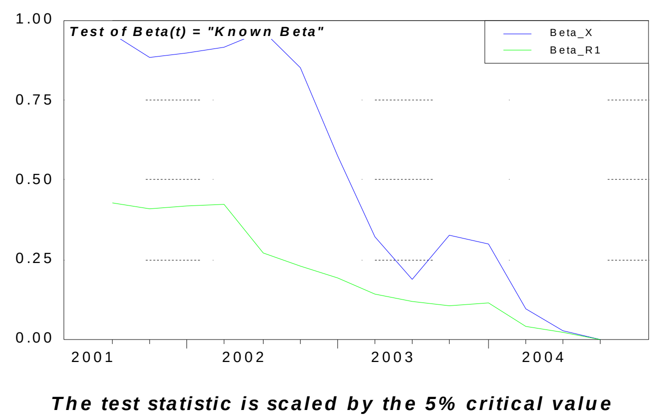
Figure 10
Plotted cointegrating relation 3 with and without correction for short run effects.



Further Diagnostic Tests for Parameter Constancy and I(2) Trends.

Two final diagnostic tests were applied to the cointegrated VEC and results suggested that the model achieved statistical adequacy: tests are for constancy of error correction parameter estimates and for the presence of trends that are integrated of order-2 or I(2). The "known" beta test detailed in Juselius (2004, pp. 186-190) tests if there is constancy or time-invariance of cointegration parameter estimates. This method tests if the full sample "baseline" model's cointegration relations could have been accepted as those of each recursively estimated model over the 2002/03:02-2004/05:04 period. Known-beta values in figure 11 are for the model versions including and corrected for short run effects (BETA_X and BETAR1) with Juselius (2004, chapter 8) favoring the corrected model as more reliable. Values are indexed by the 95 percent fractile, and should ideally be unity or less to indicate parameter estimate constancy. All values in figure 8 are below unity and suggest time-invariant estimates.

Figure 11
Recursively calcuated "known beta" tests of parameter constancy.



Nielson (2002) and Juselius (2004, chapter 16) note that imposing reduced rank restrictions on an unrestricted VEC's error correction space when there are I(2) trends encounters well-known and potentially serious econometric problems of compromised inference and in some cases biased parameter estimates because the data still have unit roots. Evidence form Nielson's series of tests for I(2) trends was sufficient to reject the null hypotheses of I(2) trends in all cases.[11]

Equations 4-6 are the three CVs that emerged after imposing rank and re-estimation with Johansen and Juselius' (1990, 1992) reduced-rank estimator. Statistically supported restrictions that emerged from the next section's hypothesis tests have not yet been imposed on these CVs.

(4) QWHEAT = -1.77*PWHEAT + 2.30*PFLOUR - 4.94*PMIXES + 4.51*PBREAD - 0.28*PCEREAL -10.80*PCOOKIES -0.49*URUGUAY + 0.59*CUSTA -0.11*NAFTA + 0.52*QUOTA +1.25*FBILLS + 0.65*TITLE7 +0.07*DROU88 + 0.40*HIDD9396 - 0.26*CONFECT + 0.01*TREND

(5) PWHEAT = 0.10*QWHEAT + 2.24*PFLOUR -3.18*PMIXES + 1.78*PBREAD -2.51*PCEREAL + 3.60*PCOOKIES -0.12*URUGUAY - 0.02*CUSTA -0.04*NAFTA + 0.05*QUOTA -0.26*FBILLS + 0.17*TITLE7 -0.09*DROU88 + 0.19*HIDD9396 -0.04*CONFECT -0.01*TREND

(6) PFLOUR = 0.53*PWHEAT - 0.12*QWHEAT + 0.09*PMIXES - 1.11*PBREAD + 0.14*PCEREAL -0.76*PCOOKIES + 0.06*URUGUAY + 0.03*CUSTA - 0.08*NAFTA -0.03*QUOTA +0.08*FBILLS - 0.08*TITLE7 -0.03*DROU88 - 0.02*HIDD9396 - 0.05*CONFECT + 0.02*TREND

Hypothesis Tests and Inference on the Economic Content of the Three Cointegrating Relations[12]

We begin with equations 4-6, the three unrestricted CVs, conduct a series of hypothesis tests on $\Pi = \alpha'*\beta$, and then re-estimate the system with the statistically-supported restrictions imposed.

Hypothesis tests on the beta coefficients take the form:

(7) $\beta = H*\varphi$

Above, β is a p1 by p1 vector of coefficients on variables included in the cointegration space; H is a p1 by s design matrix, with "s" being the number of unrestricted or free beta coefficients; and φ is an s by r matrix of the unrestricted beta coefficients. The hypothesis test value or statistic is:

(8) $-2\ln(Q) = T*\sum[(1-\lambda_i^{*})/(1-\lambda_i)]$ for i = 1, 2, and 3 (=r).

The asterisked (non-asterisked) eigenvalues (λ_i, i = 1-3) are generated by the model estimated with (without) the tested restriction(s) imposed.

[11] Nielson's (2002) test for I(2) trends compares the I(2) model of H(r,s): p variables, r I(0) directions, s I(1) directions, and p-r-s I(2) directions, against the unrestricted model of H(p). In our case, p=7 and r = 3. The null hypotheses are H(r,s)|H(p) and one rejects the null when models are too restricted. Rejecting all models where (p-r-s)>0 implies evidence that is sufficient to reject I(2) trends. To conserve space, we do not report results and analysis of the 28 tests where (p-r-s)>0. In all cases, however, evidence at both the one- and five-percent significance levels was sufficient to reject the null hypothesis of I(2) trends. Also see Juselius (2004, chapter 16).

[12] This methods section closely follows the thosed developed and/or refined in Johansen and Juselius (1990, 1992) and Juselius (2004, chapter 11).

Likewise, the hypothesis tests concerning the α or adjustment speed coefficients permit a characterization of relative speeds of error-correcting adjustment with which the system responds to a given shock. The null hypothesis or H(0) is:

(9) $H(0): \alpha = A^*\psi$

Above, A is a p by s design matrix; s is the number of unrestricted coefficients in each of the r=3 columns of the α matrix; and ψ is the s by r matrix of the non-restricted or "free" adjustment speed coefficients. Equation 8's test statistic also applies here, and is distributed asymptotically as a chi-squared distribution with degrees of freedom equal to the number of imposed coefficient restrictions. Hypothesis tests on the betas, followed by tests on the alphas, are provided below.

Hypothesis Tests on the Betas.

There are three sets of hypothesis tests on the beta coefficients. The first set of six examines if each endogenous variable is stationary under the imposed rank of three. Second, there are 17 "exclusion" hypothesis tests of whether each of the variables included in the CVs have zero-valued β-estimates. A third set is performed on individual β-estimates in equations 11-13, with any statistically supported stationarity and/or exclusion restrictions imposed.

Tests of Stationarity. Juselius (2004, pp. 220-222) recommends a likelihood ratio test of each endogenous variable's stationarity within a system setting and given the imposed rank (here r=3). She recommends such a test over univariate stationarity tests (e.g. Dickey-Fuller tests) which are independent of the cointegrated system's chosen rank. The recommended likelihood ratio tests examine if each endogenous variable itself constitutes a separate stationary cointegrating relation, with a unity value for the tested variable's betas. Equation 7 is rewritten as follows:[13]

(10) $\beta^c = [b,\varphi]$

With a rank of r=3, equation 8's test value is distributed under the null hypothesis of stationarity as a chi-squared variable with three degrees of freedom. Evidence was sufficient to reject that all seven endogenous variables were stationary, leading to our conclusion that they are nonstationary.[14]

Tests of Beta Exclusions. There are p1=17 variables in equation 2's cointegration space, and so in turn, as many exclusion tests are performed. Failure to reject the null that a variable's betas are zero-

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[13] This test can be conducted in CATS2 (beta version) in two settings: with and without inclusion of the nine deterministic variables and trend restricted to the cointegration space. We chose to include these deterministic variables in the tests, due to the institutional importance of events for which the variables were defined, and as discussed in earlier research (BBP, 2004; RBR 2002). Note that results from both sets were similar. In equation 10, β^c is the p1 by r (17 by 3) beta matrix with one of the variable's levels restricted to a unit vector; b is a p1 (or 17) by 1 vector with a unity value corresponding to the relevant variable whose stationarity is being tested; and φ is a p1 by (r-1) or 17 by 2 matrix of the remaining two unrestricted cointegrating vectors.

[14] Equation 8's test value was distributed under the null hypotheses as a chi-squared variable with three degrees of freedom, and were calculated as follows (with parenthetical p-values): 32.5 (0.000) for PWHEAT; 31.88 (0.000) for QWHEAT; 25.54 (0.000) for PFLOUR; 17.6 (0.000) for PMIXES; 23.35 (0.000) for PBREAD; 20.4 (0.000) for PCEREAL; and 11.07 (0.03) for PCOOKIES. The null hypothesis was rejected for p-values below 0.05, corresponding to the five-percent significance level.

valued suggests that the variable should be excluded from the cointegration space.[15] On balance, evidence suggested that all variables should be, at least initially, retained in the cointegration space.[16]

Set of Sequential Hypothesis Tests on Individual Beta Coefficients. Since no variables were excluded or stationary, one must now meet the rank condition of identification by imposing at least r-1 identifying restrictions directly on each of equations 4-6. (Juselius 2004, pp. 245-246). These added hypotheses arose from theory, market knowledge, prior research, and/or suggestions implied by coefficient estimates in equations 11-13 and are tested using equations 7-8 (Juselius 2004, pp. 245-246). A restriction to be tested is imposed, the model re-estimated with the well-known Johansen-Juselius reduced rank estimator,[17] and the test value for the hypothesized restriction calculated. If statistically supported at the 5-percent level of statistical significance (hereinafter, the 5-percent level), the restriction is retained. We repeated this process on the three CVs. Space limitations preclude reporting results for all sequential estimations, although table 3 summarizes this multi-iterative process. We intensely scrutinized the finally restricted error correction space for economic content in equations 11-13 below.

Test set 1 (TS-1) provides the first set of zero restrictions on selected β-estimates: three on PCOOKIES, PMIXES, and PCEREAL in CV1 normalized on QWHEAT; two on QWHEAT and TREND in CV2 normalized on PWHEAT; and three on QWHEAT, PCOOKIES, and PMIXES in CV3, normalized on PFLOUR. These restrictions imply low levels of influence on the normalized variables, and were chosen based on previous research's analyses of forecast error variance (FEV) decompositions and/or impulse response simulations generated by VAR models of the same markets (BBP 2004, pp. 14-18; RBR 2002, pp. 109-111). TS-1 restrictions meet the rank condition of identification, although as is often the case, the test value fails to initially accept the restrictions, suggesting the need for added economic content through other restrictions to generate a statistically accepted set at the chosen 5-percent significance level (when p-values $\succ$ 0.05).

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[15] The hypothesis test value in equation 7 would include a 17 by 3 β-vector; a 17 by 16 design matrix, H, with 16 being the number of unrestricted beta coefficients in each relation; and a 16 by 3 matrix φ of 16 unrestricted coefficients in each of the three cointegrating relationships (Juselius 2004, chapter 10) Basically, the φ matrix is the β-matrix without the beta coefficients for the variable being tested for exclusion.

[16]The exclusion test values (and parenthetical p-values) for the following fifteen variables reflected evidence at the five percent significance level that was sufficient to reject the null hypotheses of zero-valued beta coefficients: 28.03 (0.000) for PWHEAT; 29.1 (0.0000) for PFLOUR; 23.1 (0.0000) for PMIXES; 17.1 (0.001) for PBREAD; 22.65 (0.0000) for PCEREAL; 27.28 (0.0000) for PCOOKIES; 9.75 (0.03) for URUGUAY; 9.12 (0.03) for NAFTA; 8.3 (0.04) for QUOTA; 30.12 (0.000) for FBILLS; 17.76 (0.000) for TITLE7; 8.9 (0.03) for DROU88; 20.15 (0.000) for HIDD9396; 9.95 (0.04) for CONFECT, and 20.5 (0.000) for TREND. Evidence at the five percent significance level was not sufficient to reject the null hypothesis of zero-valued beta coefficients for QWHEAT, with a test value of 5.7 and p-value of 0.12 and for CUSTA with a test value of 7.0 and a p-value of 0.07. We decided to include CUSTA, given the marginal test value that suggested evidence that was suficient to reject the null of zero beta's at the seven percent significance level. We also chose to retain QWHEAT in the error-correction space. QWHEAT was retained, despite the test value's p-value of 0.12 because of substantial evidence by Babula, Bessler, and Payne (BBP 2004, pp. 12-18). Their analyses of impulse response simulations and/or forecast error variance decompositions generated by a Bernanke structural VAR of these same markets suggested that QWHEAT has rich and bidirectional causal interplay at long run and short run horizons in the system. In particular, QWHEAT's causal importance to the system appeared to escalate at the longer run horizons of the BBP analysis of FEV decompositions, suggesting that we should perhaps retain QWHEAT in the long-run error-correction space, at least initially. To exclude QWHEAT from our long run space based solely on exclusion test evidence would seem overly simplistic and would ignore the strong findings of BBP's similar and recent award-winning study. As well, this test value for QWHEAT approaching rejection at the 10 percent level may indicate that the variable should be included in some and excluded from other CVs. Results from the third set of hypothesis tests presented below indeed verified that QWHEAT should remain in CV1 and be excluded from CV2 and CV3.

[17]This reduced-rank estimator is summarized in Johansen (1988), Johansen and Juselius (1990, 1992), and Juselius (2004, chapters 8-10). We do not summarize this well-known reduced rank estimator here.

Test sets 2 through 8 postulate, impose, re-estimate, and then test a series of zero restrictions on beta coefficients in CV1, CV2, and CV3 that arise from theory, counsel from recognized market experts, and patterns of the estimated beta t-values (statistically insignificant ones, generally). Table 4's results reflect that the increasing sets of imposed restrictions gain statistical strength, with TS-8's test value in table 3 accepting the restrictions at the one-percent significance level. More economic content is yet required for acceptance at the chosen 5-percent level.

Test set 8's beta estimates suggested the following testable hypothesis in CV1 that was added to render test set 9: β(TITLE7) = β(NAFTA). This restriction suggests that the events concurrent with the AD/CVD investigation and NAFTA's 1994 implementation had, on average, equal quarterly effects on QWHEAT, CV1's dependent variable.[18] Adding this restriction to TS-8 rendered TS9, and reestimation with TS-9 supported this last equality restriction: t-values of -5.9 for both restricted CV1 coefficients. All TS-9 restrictions were statitically supported at the 2-percent level.

Test set 9's coefficient estimates in CV2 normalized on PWHEAT suggest that the following is clearly a testable hypothesis: β(PCEREAL) = -β(PCOOKIES), which implies that PWHEAT is influenced by the difference in PCOOKIES and PCEREAL.[19] Adding this latter condition to TS-9 renders test set 10. The test value improves, as evidence accepts the restrictions at the 3-percent level.

Test set 10's coefficient estimates suggested that β(QUOTA) = β(TITLE7) in CV3, suggesting that the set of two temporary U.S. TRQs on certain imports of Canadian wheat, and the array of AD/CVD duties during 2002-2004 had (collectively with other concurrent events) approximately equal market impacts.[20] The addition of this equality restriction in CV3 to TS-10 rendered test set 11, which generated restricted coefficients which were statistically significant (t-values of -6.2), and a test value which accepted restrictions at an increased 4 percent significance level (p-value = 0.042).

[18] The sequential estimation under test set 8's restrictions yielded the following CV1 results: coefficient value of -0.881 on β(TITLE7) with a t-value of -4.5, and of -0.883 on β(NAFTA) with a t-value of -5.5. Clearly, these significant beta coefficients in CV1 should be tested for equality.

[19] The sequential estimation under test set 9's generated for CV2 the following: β(PCOOKIES) = 15.8 (t = 7.1) and β(PCEREAL) = -16.8 (t=-12.8). This places the following as a testable hypothesis: β(PCOOKIES) = -β(PCEREAL), which suggests that CV2's dependent variable, PWHEAT, is a function of the difference of these two prices. The economic and/or market importance of this restriction is discussed below when the finally-restricted CVs are examined.

[20] Test set 10's estimates generated the following in CV3: β(TITLE7) of -0.20 (t = -3.9) and β(QUOTA) = -0.19 (t =-3.3). This suggests a testable hypothesis of β-equality thta, when added to TS-10, rendered test set 11.

Table 3.
Sequential Hypothesis Tests on Beta Estimates in the Error-Correction Space of the U.S. System of Wheat-Based Products.

Tested restrictions restriction numbers (Marginally added restriction(s) in bold	Explanation, reasoning	Test values, test results, and interpretation of coefficient estimates.
Test set 1(TS-1): Various restrictions suggested by previous research and needed to meet rank condition of identification.		
3 in CV1: β(PCEREAL)=β(PMIXES)= β(PCOOKIES) = 0 2 in CV2: β(QWHEAT)=β(TREND)=0 3 in CV3: β(QWHEAT)=β(PCOOKIES)= β(PMIXES) = 0	Suggested by BBP(2004) FEV analysis. Suggested by data analysis and BBP(2004), RBR(2001). BBP(2004), RBR(2001)	Test value of 19.2 (df=2) with p=0.000 suggests more restrictions need to be found for a statistically supported set at the five percent significance level. Estimate interpretation:t[β(CUSTA)]=0.1 in CV1; add zero restriction for PMIXES.
Test set 2: previous TS-1 restrictions plus β(CUSTA)=0 in CV1.		
4 in CV1: 3 TS-1 restrictions retained, plus **β(CUSTA)=0** 2 in CV2: 2 TS-1 restrictions retained. 2 in CV3: 2 TS-1 restrictions retained.	Weak t-value on β(CUSTA), prior estim'n.	Test value of 19.1 (df=3) with a p=0.003 suggests some progress towards statistical acceptance. More restrictions needed for a statistically acceptable set. Estimate interpretation: t[β(HIDD9396)]= 1.8, in CV1; add zero restriction on HIDD9396.
Test set 3: TS-2 restrictions plus β(HIDD9396)=0 in CV1.		
5 in CV1: 4 prior TS-2 restrictions retained. **β(HIDD9396)=0** 2 in CV2: 2 TS-2 restrictions retained. 3 in CV2: 3 TS-2 restrictions retained.	Weak t[β(HIDD9396)] , prior estimation	Test value of 19.9 (df=4) with p-value of 0.001 suggests some progress; more restrictions needed for statistically supported set. Estimate interpretation: t[β(CUSTA)]=-0.6. In CV2; add zero restriction on CUSTA.
Test set 4: TS-3 restrictions plus β(CUSTA) in CV2.		
5 in CV1: 4 TS-3 restrictions retained, plus **β(CUSTA) = 0** 3 in CV2: TS-3 restrictions retained 3 in CV3: TS-3 restrictions retained	Weak t[β(CUSTA)], prior estimation	Test value of 19.9 (df=5) with p-value of 0.0013 suggests some progress in statistical support; more restrictions needed for statistically supported set. Estimate interpretation: t[β(QUOTA)] = -2.2 in CV2.; add as zero restriction.
Test set 5: TS-4 restrictions plus β(QUOTA) = 0 in CV2.		
5 in CV1: 5 TS-4 restrictions retained. 4 in CV2: 3 TS-4 restrictions retained, plus **β(QUOTA) = 0** 3 in CV3: 3 TS-4 restrictions retained.	Weak t[β(QUOTA)], prior estimation.	Test value of 21.1 (df=6) with p-value of 0.02 suggests progress: statsistical acceptance at 2% level. More restrictions needed for acceptable set at 5% level. Estimate interpretation: t[β(URUGUAY)] = 1.0; add as zero restriction.
Test set 6: TS-5 restrictions plus β(URUGUAY) = 0 in CV2		
5 in CV1: 5 TS-5 restrictions retained. 5 in CV2: 4 TS-5 restrictions retained, plus **β(URUGUAY) = 0** 3 in CV3: 3 TS-5 restrictions retained.	Weak t[β(URUGUAY)], prior estimation	Test value of 21.3 (df=7), p-value = 0.0033. More restrictions needed for statistically supported set. Estimate interpretation: t[β(DROU88)] = -0.02 in CV3; add as zero restriction.

Table 3.
Sequential Hypothesis Tests on Beta Estimates in the Error-Correction Space of the U.S. System of Wheat-Based Products (cont'd).

Tested restrictions restriction numbers (Marginally added restriction(s) in bold	Explanation, reasoning	Test values, test results, and interpretation of coefficient estimates.
Test set 7: TS-6 restrictions plus β(DROU88) = 0 in CV3.		
5 in CV1: 5 TS-6 restrictions retained. 5 in CV2: 5 TS-6 restrictions retained 4 in CV3: 3 TS-6 restrictions retained, plus **β(DROU88) = 0**	Weak t[β(DROU88)], prior estimation	Test value of 21.3 (df=8), p-value = 0.007. More restrictions needed for statistically supported set. Estimate interpretation: t[β(FBILLS)] = 1.3 in CV3; add as zero restriction.
Test set 8: TS-7 restrictions plus β(FBILLS) = 0 in CV3		
5 in CV1: 5 TS-7 restrictions retained. 5 in CV2: 5 TS-7 restrictions retained 5 in CV3: 4 TS-7 restrictions retained, plus **β(FBILLS) = 0**	Weak t[β(FBILLS)], prior estimation	Test value of 21.4(df=8), p-value = 0.01. More restrictions needed for statistically supported set at 1% level. Estimate interpretation: β(TITLE7) = β(NAFTA) in CV1; add as equality restr'n
Test set 9: TS-8 restrictions plus β(TITLE7) = β(NAFTA) in CV1.		
6 in CV1: 5 TS-8 restrictions retained, plus **β(TITLE7) = β(NAFTA)** 5 in CV2: 5 TS-8 restrictions retained 5 in CV3: 5 TS-8 restrictions retained	Examination of last estimates: average market impacts of TITLE7 and NAFTA events about equal on QWHEAT.	Test value of 21.6 (df=10) with p-value of 0.02 suggests progress in statistical acceptance at 2%; more restrictions needed for acceptance at 5% level. Estimate interpretation: β(PCEREAL) = -β(PCOOKIES) in CV2; add as equality restriction.
Test set 10: TS-9 restrictions plus β(PCEREAL) = -β(PCOOKIES) in CV2.		
6 in CV1: 5 TS-9 restrictions retained. 6 in CV2: 5 TS-9 restrictions retained, plus **β(PCEREAL) = -β(PCOOKIES)** 5 in CV3: 5 TS-9 restrictions retained.	Examination of last estimates. Equality restriction suggests that PWHEAT is dependent on the difference in prices of wheat cereal and cookies/crackers.	Test value of 21.6 (df=11) with p-value of 0.03 suggests progress in statistical acceptance at 3% level; more needed for acceptance at 5% level. Estimate interpretation: β(QUOTA) =β(TITLE7) in CV3; add as equality restr'n
Test set ll: TS-11 restrictions plus β(QUOTA) =β(TITLE7) in CV3.		
6 in CV1: 5 TS-10 restrictions retained. 6 in CV2: 6 TS-10 restrictions retained 6 in CV3: 5 TS-10 restrictions retained, plus **β(QUOTA) =β(TITLE7)**	Examination of last estimates: average market impacts were about the same from QUOTA and TITLE7 events.	Test value of 21.6 (df=12) with p-value of 0.042 suggests progress: statistical acceptance at 4% level. More restrictions needed for acceptance at 5%. Estimate interpretation: : β(QUOTA) =β(TITLE7) = -β(NAFTA) in CV3.
Test set 12: TS-11 restrictions plus β(QUOTA) =β(TITLE7) = -β(NAFTA) in CV3.		
6 in CV1: 6 TS-11 restrictions retained. 6 in CV2: 6 TS-11 restrictions retained 7 in CV3: 6 TS-11 restrictions retained, plus **β(QUOTA) =β(TITLE7) = -β(NAFTA)**	Examination of last estimates: average market impacts of QUOTA events or of TITLE7 events were about negated by NAFTA events.	Test value of 21.6 (df=13) with p-value of 0.063 suggests statistical acceptance at more than the desired 5% level: at 6% level. Estimate interpretation: β(PBREAD) = -β(PCEREAL) in CV3
Test set 13: TS-12 restrictions plus β(PBREAD) = -β(PCEREAL) in CV3		
6 in CV1: 6 TS-11 restrictions retained. 6 in CV2: 6 TS-11 restrictions retained 8 in CV3: 7 TS-11 restrictions retained, plus **β(PBREAD) =-β(PCEREAL)**	Examination of last estimates: average market impacts depend on difference between bread and wheat cereal product prices.	Test value of 22.5 (df=14) and p-value of 0.07 reflects that we have achieved evidence of a statistically supported set of restrictions at 7% level (above desired 5% level).

Test set 11's coefficient estimates suggested further that β(QUOTA) = β(TITLE7) = -β(NAFTA) in CV3. [21] The interpretation of this multi-parameter restiction is left to the next subsection on economic content. Adding this restriction in CV3 to TS-11 rendered test set 12 in table 3. The re-estimation restricted for this equality condition generated statistically significant coefficients, and strong support for, this restriction: t = -7.3 for betas on QUOTA and TITLE 7; t = -7.3 on NAFTA. The test value's p-value (0.063) reflected evidence that accepted all restrictions at the 6-percent level.

Test set 12's coefficient estimates suggested that in CV3, perhaps β(PCEREAL) = -β(PBREAD), which implies that market effects through PFLOUR hinge on the difference between PBREAD and PCEREAL.[22] An economic interpretation of this restriction follows below. Adding this restriction to TS-12 rendered test set 13. Evidence suggested that the last CV3 restriction was statistically significant (t-values of ±10.3), and that TS-13's restrictions were accepted at the 7-percent significance level (p-value of 0.07), which exceeds our decision rule of 5-percent.

Hypothesis Tests on the Adjustment Speed or α Coefficients.

A principal hypothesis on the estimated adjustment speed coefficients is if each of the variables is weakly exogenous. A variable is weakly exogenous if it influences the error-correction process without itself adjusting or responding to the process, thereby implying a one-way causal relation to the equilibrating relation. Equivalently, one tests if, given the statistical significance of at least some of a variable's β-estimates, the variable's r=3 α-coefficients are all zero (Juselius 2004, pp. 231-232). Evidence in all cases was sufficient to reject the null of weak exogeneity.[23]

Economic Analysis of the Three Cointegrating Relationships for the U.S. Soy-Based Markets

The fully restricted CVs are equations 11-13. To conserve space, we present CV1, CV2, and CV3 in abbreviated form, with DCV1, DCV2, and DCV3 reflecting vectors of econometric estimates for permanent shift binaries that we deemed to be of lesser relevance and/or interest, but whose inclusion was required to achieve a statistically adequate model.[24] The CVs are followed by the α-estimates. Parenthetical t-values reflect that most estimates have achieved clear statistical strength.

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[21] Test set 11's restrictions and sequential estimation generated the following CV3 results: Β(QUOTA) = β(TITLE7) = -0.195 (t= -6.2), and β(NAFTA) = 0.196 (t=3.3).

[22] Test set 12's coefficient estimates generated the following in CV3: β(PCEREAL) = 2.92 (t=11.1) and β(PBREAD) = -3.4 (t=-7.3).

[23] The weak exogeneity test values and (parenthetical) p-values were as follows: 32.9 (0.000) for PWHEAT, 16.2 (0.001) for QWHEAT, 26.5 (0.000) for PFLOUR, 7.4 (0.06) for PMIXES, 10.1 (0.02) for PBREAD, 15.1 (0.002) for PCEREAL, and 36.6 (0.000) for PCOOKIES. Evidence was sufficient at the 5-percent level or less to reject the null of zero-valued α-coefficients for all endogenous variables except PMIXES. Evidence was sufficient at the 6-percent level to reject PMIXES weak exogeneity – a very marginal result. BBP (2004, pp. 16-19), however, provided an analysis of FEV decomposition patterns generated by a Bernanke structural VAR (with directed acyclic graph analysis) of the same markets, and revealed evidence of endogenous participation of PMIXES in the system, particularly among other wheat-using value-added product prices. Given the marginal test value and this added BBP evidence of PMIXES' endogenous participation, we chose to treat PMIXES as endogenous and not weakly exogenous. As a result, evidence, on balance, supports the hypothesis that all seven wheat-based variables are not weakly exogenous.

[24] In the vector definitions that follow, t-values are included parenthetically. DCV1 is a vector of the following CV1 permanent shift binary variable coefficient estimates: 1.0*URUGUAY (t= 6.1); -1.6*FBILLS (t = -8.95); -0.34*DROU88 (t=-2.8). DCV2 is a vector of the following CV2 permanent shift binary variable coefficient estimates: -2.45*FBILLS (t= -9.1); -0.53*DROU88 (t= -3.98); 1.63*HIDD9396 (t= 8.1). DCV3 is a vector of the following CV3 permanent shift binary variable coefficient estimates: -0.21*CUSTA (-3.0); -0.57*HIDD9396 (t= -8.4); 0.31*URUGUAY (t=4.0).

Limitations of imprecision in interpreting the coefficient estimates on binary (dummy) variables are well known (USITC 1995). Typically, partial effects cannot be solely attributed to an event for which a binary is defined, but must be collectively attributed to that event and all other relevant events that concurrently occurred during the period (USITC 1995; Babula 1997).[25] For ease of exposition, we provide uni-event attribution with multi-event attribution implied.[26]

There are three CV's: the first appears to be the beginnings of a U.S. wheat supply, and the other two, long run price transmission relationships. We focus on the relationships as demand and price transmissions first, followed by a separate discussion on the information collectively inherent in an array of the coefficient estimates on the permanent shift binary variables from all CVs.

(11) QWHEAT = 5.76*PWHEAT - 10.95*PFLOUR -13.04*PBREAD - 0.91*NAFTA -0.91*TITLE7
(10.0) (-10.24) (-9.2) (-5.98) (-5.98)

- 0.72*QUOTA - 0.30*CONFECT + 0.18*TREND + DCV1
(-4.47) (-2.70) (9.89)

(12) PWHEAT = 3.19*PFLOUR - 10.9*PMIXES + 6.84*PBREAD + 18.03*(PCEREAL - PCOOKIES) - 1.15*NAFTA
(5.2) (-5.8) (7.86) (±13.4) (-5.78)

+ 0.56*TITLE7 - 0.55*CONFECT + DCV2
(8.1) (-2.96)

(13) PFLOUR = 0.49*PWHEAT + 5.0*(PBREAD - PCEREAL) - 0.33*QUOTA -0.33*TITLE7 + 0.33* NAFTA -
(4.6) (±10.3) (-7.1) (-7.1) (7.1)

+ 0.19*CONFECT + 0.02*TREND + DCV3
(2.2) (8.9)

ALPHAs

	Alpha1	Alpha2	Alpha3
△PWHEAT	0.0997	-0.1407	-0.1031
	(3.8849)	(-6.5953)	(-2.1826)
△QWHEAT	-0.0356	0.0471	0.3062
	(-0.7805)	(1.2400)	(3.6431)
△PFLOUR	-0.0123	-0.0501	-0.0293
	(-0.9774)	(-4.8001)	(-1.2669)
△PMIXES	-0.0040	0.0028	0.0102
	(-1.0472)	(0.8823)	(1.4613)
△PBREAD	-0.0119	0.0060	0.0078
	(-4.0674)	(2.4786)	(1.4557)

[25] For example, NAFTA was defined for the quarterly period encompassing the trade agreement's January 1994 implementation. Yet other events undoubtedly occurred that influenced the modeled wheat-based markets since January 1995: September 11 tragedy, currency market effects, oil price movements, the 1997 Asian financial crisis, etc. The coefficient on NAFTA in a CV cannot be solely attributed to the NAFTA alone, but must be interpreted more imprecisely as the effects of NAFTA and other collective concurrent events having occured during the subsample for which the binary variable was defined. See USITC (1995).

[26] For example, the -0.91 NAFTA coefficient in CV1 is stated as having captured the negative effects of the trade agreement, when in fact, we imply the net negative effects from NAFTA and all other relevant events concurrent with NAFTA binary's period of definition.

△PCEREAL	-0.0230	0.0199	0.0647
	(-4.6858)	(4.8955)	(7.1729)
△PCOOKIES	-0.0072	0.0125	0.0280
	(-3.6892)	(7.6537)	(7.7581)

We note initially that the first CV has a more precise structural interpretation as a wheat supply curve, probably because the available information set included both prices and quantities for the wheat market. Earlier research noted that such quantity data generally do not exist for commodity-based value added products: they are typically considered business proprietary and excluded from the public domain (BBP, 2004; RBR, 2002; Babula and Rich 2001). As a result, we followed established research procedure and modeled the downstream markets with reduced form price relationships, which in turn, likely rendered cointegrating relationships (CV2, CV3) that had less precise, non-structural interpretations. Pinning-down such structural relationships as price elasticities of supply from reduced form relationships is difficult, and characterized equations 12-13.

Our less precise interpretations for equations 12 and 13 is common in cointegration analysis, as noted by Juselius (2004, p. 175):

> "It is important to note that the cointegration rank is not in general equivalent to the number of theoretical equilibrium relations derived from an economic model . . . . Thus, cointegration between variables is a statistical property of the data and only exceptionally can be given a direct interpretation as an economic equilibrium relation. The reason for this is that a theoretically meaningful relation can be (an often is) a linear combination of several 'irreducible' cointegration relations."

And as such, a single relation may reflect elements from both the demand and supply sides of a market. Our economic analysis below makes first-cut progress in illuminating long run structural relationships among U.S. wheat-based markets (particularly with CV1). We leave more complete economic structural interpretations for the more reduced form CVs (equations 12, 13) to future research when more comprehensive information sets and certainly larger time series samples will be available.

CV1: The First Cointegrating Relation, A U.S. Wheat Supply

Equation 11 or CV1 achieved notable statistical strength, and despite some perhaps ambigously interpreted elements from the both sides of the market, appears to be a U.S. wheat supply. There is a positive and very statistically significant own price elasticity of 5.8. This parameter may initially appear overly elastic – a concern which may be abated after considering that these CVs are very long run and extend beyond a single annual cycle of planting decisions. The elasticity may also appear less implausible when one consults the relative QWHEAT/PWHEAT variation levels, with PWHEAT movements constrained by the U.S. loan rate price support program.[27] What is evident is that in the very long run, and after intense efforts on separating-out market impacts of numerous, specific, and important market/institutional events, QWHEAT appears highly responsive to PWHEAT changes..

[27] For example, the modeled variables' have standard errors of 19.6 percent for PWHEAT and 40 percent for QWHEAT, which may partially account for the very elastic price-elasticity of supply in the very long run.

The quantity of wheat in CV1 appears negatively but sensitively related to movements in major wheat-based products, PFLOUR and PBREAD. When price levels of wheat flour and bread products fall, demand for flour and bread may rise to augment volume of wheat ultimately used as an input. These statistically strong influences of flour and bread price behavior on QWHEAT is consistent with BBP's (2004, pp. 16-18) analysis of FEV decompositions that suggested high levels of influence by PFLOUR and PBREAD variation on QWHEAT behavior.

CV2: A Reduced-Form Price Transmission Relationship Normalized on PWHEAT.

Equation 12 or CV2 appears to be a reduced form relationship among wheat-related prices reflecting elements of both demand and supply. U.S. wheat price appears positively related to PFLOUR and PBREAD. This positive price transmission coincides with recent analyses of FEV decompositions that suggested that flour and bread price movements are prime determinants of wheat price behavior, and from analysis of impulse response simulations that suggest a positive PWHEAT/PFLOUR relationship (RBR's 2002 and BBP's 2004, pp. 14-16) .

PWHEAT appears negatively related in this reduced form relation to the value-added manufacturing product prices further downstream for mixes/doughs. A structural interpetation of this negative relationship is not straightforward. As production costs raise PMIXES, perhaps mixes/doughs supply shifts negatively, leading to less wheat ultimately delivered as an input and a fall in PWHEAT.

PWHEAT appears positively related in this reduced form relation to the difference between PCEREAL and PCOOKIES, and again, a structural interpretation is not straightforward. The price of wheat-based cereals embodies prices of products with generally a lower degree of value-added processing and a higher wheat-related proportion of production costs than the more processed product array represented by PCOOKIES. As demand conditions tighten in the wheat-intensive cereal market relative cookies/crackers market, more wheat is demanded as an input and a higher wheat price may result. Findings from BBP's (2004, pp. 16-19) analysis of FEV decompositions suggested that PCEREAL and PCOOKIES behavior had important collective influences on PWHEAT, with PCEREAL's influences having dominated that of PCOOKIES.

CV3: A Reduced-Form Price Transmission Relationship Normalized on PFLOUR.

CV3 posits flour price as positively related to PWHEAT, with each percentage change in PWHEAT eliciting, on average historically, a 0.49 percent, similarly-directed change in PFLOUR. This reduced form response elasticity coincides closely with prior comparable estimates generated by reduced form VAR impulse response simulations of 0.40 by BBP (2004, p. 14) and RBR (2002, p. 110).

As well, flour price appears positively related to the difference between PBREAD and prices of wheat-using value added products reflected by PCEREAL. BBP (2004, pp. 16-19) uncovered evidence for these markets that PBREAD takes on a weakly exogenous role by influencing other variables, with little or no feedback from the latter to PBREAD.[28] Their results and further analysis suggested that bread price may be a widely-watched "bell weather" indicator of general bakery market conditions. Our more precise, and BBP's (2004) more general results are consistent with these prior findings. In CV3, PBREAD generates a very significant t-value, suggesting an influence on CV3's error correction process

[28]This weakly exogenous PBREAD behavior is confined soley to CV3, and is not general to all three CVs, such that tests for weak exogeneity did not support such behavior for PBREAD generally throughout the error correction space.

and on PFLOUR. As well, PBREAD's low-valued and insignificant adjustment speed coefficient in CV3 (t=1.46) suggests that PBREAD is weakly exogenous in CV3 and influences but does not respond to CV3 error correction mechanisms. As widely-watched demand bread market conditions rise and reflect improved market conditions for bakery-related agents generally (ceteris paribus), PBREAD rises, the PBREAD/PCEREAL wedge widens, and PFLOUR rises as perhaps more flour is demanded for multiple wheat-based markets. The importance of PWHEAT, PBREAD, and PCEREAL movements in determining PFLOUR behavior coincides with BBP (2004, pp, 16-17) analyses of FEV decompositions for PFLOUR.

Analysis of Error-Correction Estimates on Deterministic Components.

Most binary β-estimates in equations 11-13 achieved strong statistical significance. Given that non-binary variables were modeled in logarithms, we used Halvorsen and Palmquist's (1980) well-known method to convert the binary β-estimates into average percent change effects on the dependent variable from concurrent events associated with the sub-sample for which the binary was defined. [29] (Hereafter, HP calculated effects.) Based on prior VAR econometric research on these same markets and market analysis by USDA, ERS (2004, 2005), we restricted numerous permanent shift binaries to the cointegration space. For space considerations, we focus on the implied effects associated with the AD/CVD case (TITLE7 binary), the NAFTA agreement (NAFTA binary), the sustained increases in confectionary production costs that began in early-2001 (CONFECT binary), and the two temporary U.S. tariff rate quotas imposed on certain imports of Canadian wheat (QUOTA binary).

Effects of the antidumping/countervailing duty case. The filing of the AD/CVD case against certain U.S. imports of Canadian wheat ultimately led to a series of preliminary or final AD/CVD duties on certain imports of Canadian durum and/or hard red spring wheat from 2002/03:02 through the end of the sample (see USITC 2003 for a case summary). The HP calculated effects from β-estimates in CV1-CV3 were rather pronounced: on average, the AD/CVD and related concurrent events resulted in quarterly QWHEAT levels that were 59.7 percent lower; quarterly PWHEAT levels that were 75 percent higher; while quarterly U.S. flour prices were 28.2 percent lower. The preliminary and final tariffs[30] were relatively more modest than the HP calculated effects, and likely insufficient to have generated such large AD/CVD effects. As clear from USITC (2003) and USDA (2004, 2005a) analyses, other concurrent events such as the tight world grain supplies and high world levels of wheat prices and wheat demand during 2002/03 - 2004/05 likely added influences that magnified these HP calculated effects for TITLE7 on QWHEAT (CV1) and PWHEAT (CV2).

An interesting result is the negative TITLE7 β-estimate and -28.2 percent HP calculated effect on CV3's PFLOUR. After U.S. AD/CVD tariffs were imposed on certain U.S. imports of Canadian wheat on 2002/03:02, official trade data from the USITC (2005) clearly reflected a shift in imports Canadian wheat

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[29]More specifically, consider the β(CONFECT)-estimate of -0.30 in equation 11. Halvorsen and Palmquist's (1980) method takes "e," the base of the natural logarithm, and raises it to the power of the value of the coefficient (here the power of -0.30), subtracts 1.0, and multiplies the result by 100. What results is an average percentage change effect, here –25.9 percent, on the dependent variable (QWHEAT in equation 11). This suggests that the sustained run-up in confectionary input costs that began in 2001 resulted in an ultimate drop in the supply of wheat, presumably as demand for wheat-based confectionary products fell off, rendering less wheat supplied as an input. As noted earlier, other relevant and concurrent factors/events over this 2001:01-2004:04 subsample for which CONFECT was defined also contribute to this effect.

[30] The array of preliminary and final AD/CVD tariffs imposed on certain U.S. imports of durum and/or hard red spring wheat was rather complicated and is not recounted here. Interested readers should see USITC (2003). The final tariffs imposed were on imports of Canadian hard red spring wheat and amounted to just over 14 percent.

to imports of wheat flour, which were not covered by the AD/CVD orders. More specifically, average annual U.S. imports of wheat flour quantity for 2002-2004 coinciding with the imposed AD/CVD duties were 50 percent above the pre-duty average annual imports. (USITC 2005).[31] Such sustained increases in U.S. wheat imports associated with the AD/CVD orders' implementation resulted in the perhaps unexpected negative PFLOUR effects.

Effects of the January 1994 implementation of NAFTA. This binary was defined to capture effects of concurrent events during the period from the January, 1994 implementation of NAFTA to the end of the sample, a truly "crowded" subsample when many concurrent events other than NAFTA likely influenced the modeled markets. The U.S. imported steadily increasing volumes of Canadian wheat, while the U.S. government also tapered down levels of farm price supports with implementation of the U.S. farm bills of 1996 and 2002. As well, there was a mini-world commodity boom during 1994-1995 when world demand, export, and price levels were elevated; a subsequent and sustained commodity boom during from 2002 through late-2004; and the well-known and precipitous drop in U.S. wheat exports to Asia after the 1997 Asian economic and currency crisis, among others. The events associated with NAFTA suggested negative QWHEAT effects (CV1). As U.S. purchases of Canadian wheat escalated, perhaps the drop in supply price to farmers from concurrent declining levels of wheat program price support and increasing imports led to a drop in U.S. production that was disproportionally larger than the import increase, so as to have generated a negative QWHEAT effect. Previous research and USDA, ERS (2005a, b) data clearly demonstrate that PWHEAT fell during a substantial period after NAFTA's 1994 implementation, and thereby registered as a negative PWHEAT effect in CV2 (see figure 1). Parts of the NAFTA variable's period of definition included U.S. tariff rate quotas and AD/CVD duties on certain imports. These two actions likely elicited more imports of wheat flour, not covered by these barriers, at the expense of wheat imports, so as to have negatively influenced PFLOUR in CV3.

Effects of the 2001-2002 sustained increases in confectionary production costs. During early 2001, a marked and sustained rise in cocoa prices began in response to disruptions from the Ivory Coast civil war, and in late-2002, there was another run-up in various non-cocoa confectionary input costs.[32] CONFECT was defined to capture the effects of these confectionary input cost increases (and other relevant concurrent events) for wheat-based confectionary products included in PMIXES and PCOOKIES. The HP calculated effects on CONFECT suggested that the input cost increases and concurrent events associated with CONFECT resulted, on average, in a 26 percent lower QWHEAT levels and 42 percent lower PWHEAT. These negative impacts suggest that run-ups in confectionary input prices may have negatively shifted wheat-using confectionary supplies, and resulted in less QWHEAT used as production inputs, with lower PWHEAT levels.

Effects associated with two temporary U.S. tariff rate quotas on Canadian-sourced wheat. Two U.S. TRQs were imposed on certain U.S. imports of Canadian wheat for the year ending September 11, 1995. As expected, events associated with QUOTA suggested negative impacts on QWHEAT in CV1 as imports were restricted, and on PFLOUR as importers shifted to importing more wheat flour not covered by the tariff rate quotas (as noted above in the TITLE7 coefficient estimate analysis). HP calculated effects were rather pronounced however: -51 percent for QWHEAT in CV1 and -28 percent on PFLOUR

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[31] These calculations were based on USITC (2005) data for 1996-2004.

[32] The source of this analysis and information was compiled by a U.S. International Trade Commission industry analyst responsible for monitoring markets for sugar and confectionary products, in two emails received by an author on August 18 and 19, 2004. A more in-depth analysis on the effects on U.S. sugar-based product markets of these two run-ups in confectionary input costs is provided in Babula and Newman (2005). Given that many confectionary products, both cocoa-based and non-cocoa, use wheat, we included CONFECT in our analysis, and with clear statistical support as seen from our statistical results.

in CV3. A number of other concurrent events may have magnified these effects suggested by the QUOTA beta estimates: the 1995 start of a commodity boom with high world demand and price levels for wheat, and possible expectationary market influences of the then-anticipated 1996 U.S. farm bill which noticeably lessened the U.S. wheat program support levels (among other events).

CV3 incorporates the statistically supported restriction rewritten as: -0.33*(QUOTA + TITLE7 - NAFTA). This restriction suggests that events (i) associated with QUOTA and TITLE7 had similar and decreasing effects on PFLOUR as imports shifted from wheat to wheat flour during periods of TRQs and AD/CVD duties, (ii) NAFTA raised PFLOUR by about as much as the events associated with of the two trade remedies decreased it and (iii) net PFLOUR effects arise from the combined negative effects associated with TITLE7 and QUOTA as offset by positive effects from NAFTA-related events.

Summary and Conclusions

We extend previous quarterly VAR econometric research by Babula, Bessler, and Payne (2004) and Rich, Babula, and Romain (2002) on U.S. markets for wheat and wheat-using value-added products of flour, mixes/doughs, bread, wheat-based breakfast cereals, and cookies/crackers. We applied, apparently for the first time, Johansen-Juselius methods of the cointegrated VAR to updated samples of these same markets. We exploited the modeled system's cointegration properties, and incorporated a wide array of binary variables to capture empirically estimated effects of important market/institutional events. These results illuminated a long run error correction space which provided structural and reduced form estimates on how these markets run and interact. Results included parameter estimates from three cointegrating relations – a U.S. wheat supply curve and two transmission relationships among U.S. wheat-based prices, along with an array of estimated effects from the cited market/institutional events.

The first CV, the apparent beginnings of a wheat supply curve, suggested that in the very long run, market-clearing wheat quantities (QWHEAT) are highly and positively related to changes in PWHEAT, which in turn is heavily influenced by the U.S. wheat program. QWHEAT was negatively influenced by movements in flour and bread prices. The long run price elasticity of U.S. wheat supply appeared to be nearly 6.0.

CV2 suggested that wheat price is positively related to PFLOUR and the difference in PCEREAL and PCOOKIES, and negatively related to PMIXES. In CV3, flour price appears positively related to PWHEAT, with each percentage change in PWHEAT eliciting, on average historically, similarly directed changes of 0.49 percent in PFLOUR – a response that closely corresponds to previous estimates by BBP (2004, p. 14) and RBR (2002, p. 110).

We provided a number of empirically estimated market effects associated with the AD/CVD case (TITLE7 binary), NAFTA agreement implementation (NAFTA binary), 2001 sustained rises in confectionary production costs (CONFECT binary), and the two TRQs imposed on U.S. certain imports of Canadian wheat (QUOTA binary). While the AD/CVD case and concurrent events resulted, as perhaps expected, in QWHEAT declines and in PWHEAT increases, effects on PFLOUR were negative as importers shifted towards imports of wheat flour not covered by the AD/CVD orders. NAFTA's coefficients suggested negative effects on QWHEAT and PWHEAT. The 2001-2002 sustained rises in confectionary input prices appeared to result in ultimate declines in QWHEAT used as confectionary inputs and decreased PWHEAT levels. The temporary U.S. tariff rate quotas on U.S. imports of Canadian wheat appeared to restrict QWHEAT through impeded imports, while PFLOUR fell as importers switched to imports of wheat flour not covered by the quotas.

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