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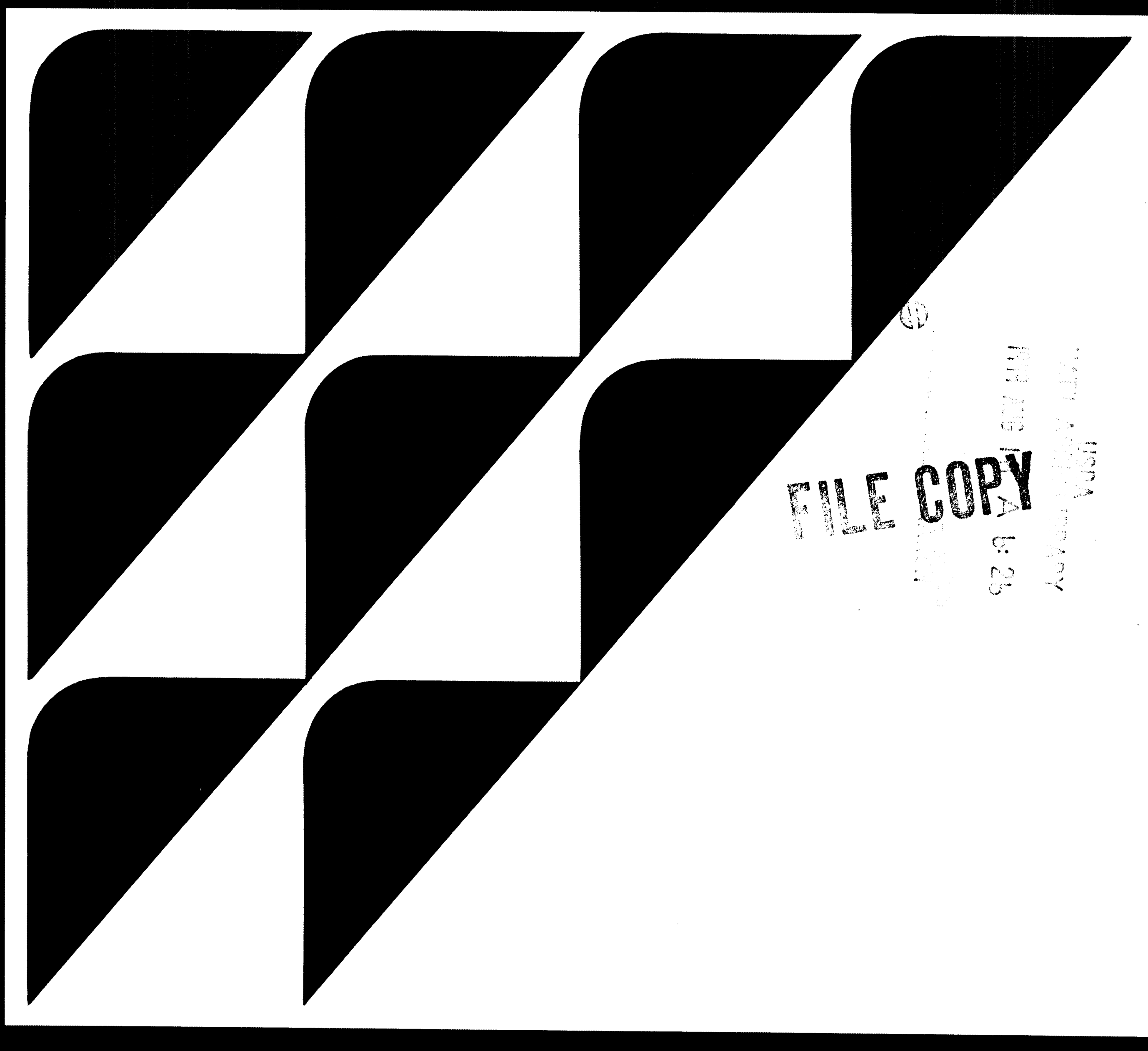
Forecasting Retail Fertilizer Prices

A Combined Time-Series Regression Analysis Approach

Harry Vroomen



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Forecasting Retail Fertilizer Prices: A Combined Time-Series Regression Analysis Approach. By Harry Vroomen. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1789.

Abstract

This study combines regression and time-series analysis to develop a shortrun price forecasting model of retail fertilizer prices. Time-series analysis is used to generate forecasted values for the wholesale prices of anhydrous ammonia, phosphoric acid, and potassium chloride. These forecasts are incorporated into regression equations to forecast the retail prices of 14 major fertilizer mixtures and materials. The retail price forecasts are combined to generate a forecast of the index of fertilizer prices paid by farmers. Results show that this method can perform with reasonable accuracy for short-term forecasting purposes.

Keywords: Fertilizer prices, forecasting, time-series analysis, regression

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Summary

U.S. fertilizer prices have been highly variable since the mid-1970's and have exhibited increased volatility throughout the 1980's. This variability complicates the planning process for fertilizer suppliers and users. Input manufacturers need to forecast fertilizer prices to plan production levels and decide on contract terms for future delivery. Farmers need to have an idea of the direction and magnitude of fertilizer price changes so they can decide on the crop mix and the timing of fertilizer purchases. Accurate fertilizer price forecasts can foster the efficient operation of the market.

This study presents a model which can be used to forecast retail prices of selected fertilizer products for the spring, the peak demand season for fertilizer. The model uses a combination of time-series, ARIMA (autoregressive-integrated moving-average), and regression analysis and, once operational, it can be updated easily. ARIMA models are estimated and used to forecast wholesale prices for anhydrous ammonia, phosphoric acid, and potassium chloride. The wholesale price forecasts are incorporated into regression equations to generate retail price forecasts for anhydrous ammonia, concentrated superphosphate, and potassium chloride. Forecasts of these products are in turn incorporated into regression equations of 11 other major fertilizer mixtures and materials. The retail price forecasts are combined to generate a forecast of the index of fertilizer prices paid by farmers (PPI).

Out-of-sample forecasts indicate that the model performs with reasonable accuracy for short-term forecasting purposes and works particularly well as an indicator of aggregate fertilizer price changes. Mean absolute percent forecast errors for each April in 1988-90 indicate that the retail price forecasts missed their marks by 4.1, 3.2, and 3.5 percent, respectively; only 3 of the 42 retail price forecasts missed their actual value by more than 7 percent. Forecasts of the fertilizer PPI missed their marks by only 3.0, 0.7, and 2.3 percent, respectively, in 1988, 1989, and 1990.

Forecasting Retail Fertilizer Prices

A Combined Time-Series Regression Analysis Approach

Harry Vroomen

Introduction

U.S. fertilizer prices have been highly variable since the mid-1970's and have exhibited increased volatility throughout the 1980's. For example, aggregate fertilizer prices, as measured by the index of fertilizer prices paid by farmers (PPI), fell 20 percent from May 1984 to April 1987, but rose nearly 21 percent from April 1987 to April 1989. Prices then changed direction again, falling 8 percent by April 1990. Wholesale fertilizer prices followed a similar pattern.

This variability complicates the planning process for fertilizer suppliers and users. For example, input manufacturers need to forecast fertilizer prices to plan production levels and decide on contract terms for future delivery. Farmers need to have some idea of the direction and magnitude of fertilizer price changes so they can decide on the crop mix and the timing of fertilizer purchases. Accurate fertilizer price forecasts can foster the efficient operation of the market.

Forecasting Tools

Analysts may base their forecasts on their own beliefs about the market or on mathematical or statistical models. Models used to forecast economic variables such as the price of fertilizer generally fall into two broad classes: those based on explicit behavioral assumptions and those based on extrapolating observed trends and patterns. In behavioral models, future movements in a variable are predicted by relating a set of explanatory variables in a causal framework. Prices, for example, are typically hypothesized to be determined simultaneously by supply and demand.

The development of a behavioral model of the fertilizer industry to forecast prices would take considerable time and energy and would have significant data requirements. In addition, insufficient data exists to account for seasonal factors in a behavioral framework. However, elements of extrapolative and behavioral modeling can be combined to take advantage of rich data sources and overcome data gaps. This hybrid modeling procedure allows incorporation of some variables known to influence economic behavior and specification of shortrun and seasonal movements in some variables we want to forecast.

In the case of fertilizer, consumption data for specific mixtures and materials are currently published on an annual basis (Tennessee Valley Authority, 1990). This precludes the estimation of a model that can account for seasonal factors, which are particularly important for fertilizer because demand is greatest at or near planting (Taylor and Vroomen). Furthermore, the consumption data do not become available until 6 months after the fertilizer year (July 1-June 30), thus limiting its usefulness in formulating shortrun forecasts. (Lags in the availability of supply data also exist.)

Wholesale price data for selected products are available on a weekly basis with a lag of only a few days (McGraw-Hill, Inc.). This permits the development of time-series models to produce forecasts that include the latest market information on prices.

Time-series (ARIMA[1]) models are based on the market inertia or observable seasonal patterns in the series under investigation rather than the linkages among economic variables. Leuthold and others found that this stochastic, noncausal framework could be used with greater ease and less cost than behavioral models in forecasting daily hog prices and quantities. Such models frequently outperform behavioral models in shortrun forecasting. This class of models can also be easily updated, permitting the forecast user to benefit from the latest information available.

This study is designed to develop a shortrun price forecasting model for 14 major fertilizer mixtures and materials. Price forecasts are generated for the spring, the peak demand season for fertilizer. Time-series analysis is conducted to forecast wholesale prices of three selected fertilizer materials. These forecasts are then incorporated into regression equations at the retail level to construct an operational model which can be used to forecast retail fertilizer prices. These retail price forecasts are then combined to generate a forecast of the PPI for fertilizer.

The Model

The model used to develop retail price forecasts for the selected products can be separated into sequential components: (1) ARIMA models for the wholesale price of a representative material for each fertilizer nutrient class (nitrogen, phosphate, and potash); (2) regression models for the retail price of a representative material for each nutrient class which incorporate the wholesale price forecasts generated from the ARIMA models; and (3) regression models to estimate how movements in the retail prices of the representative products in each nutrient class affect the retail prices of other selected fertilizer mixtures and materials. The retail price forecasts are combined to forecast the PPI for fertilizer. The logical relationships between these components are shown in figure 1.

Wholesale Price Models

Monthly ARIMA models are developed for the wholesale prices of the basic materials of the nitrogen, phosphate, and potash fertilizer sectors. These materials--anhydrous ammonia (AA), phosphoric acid (PA), and potassium chloride (PC)--each have unique production characteristics and are derived

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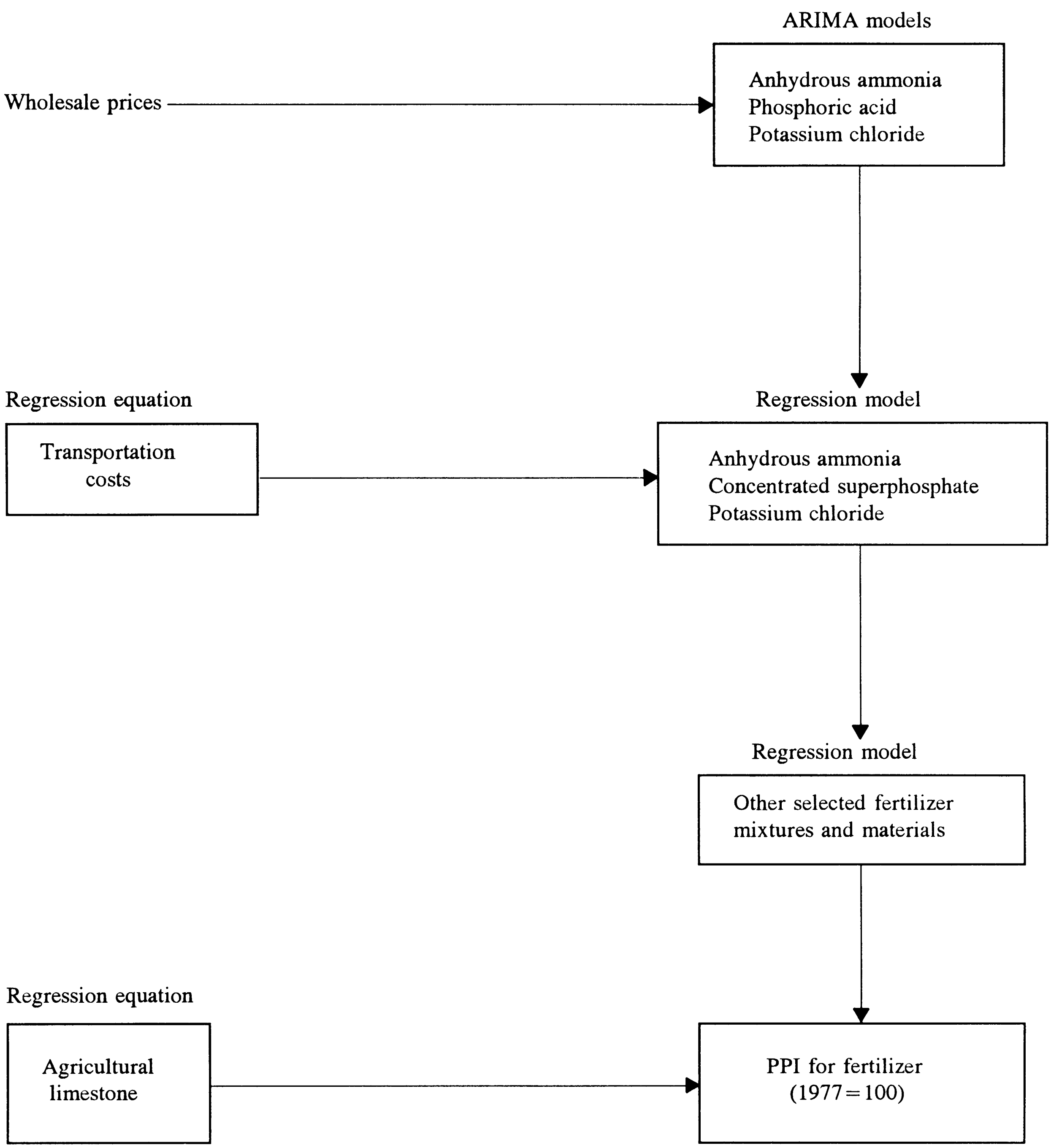
[1]Autoregressive-integrated moving-average.

Figure 1
Model structure



from different natural resources (Andrilenas and Vroomen). AA, the basic material of the nitrogen industry, is synthesized through a chemical process that combines atmospheric nitrogen with hydrogen (derived from natural gas) and is the source of nearly all nitrogen fertilizer used in the United States. It may be applied directly to the soil or converted into other nitrogen fertilizers such as ammonium nitrate and nitrogen solutions.

Nearly all phosphate fertilizer is produced by first treating phosphate rock with sulfuric acid to produce PA. The resultant PA is then further processed into various phosphatic fertilizer materials. Potash ore is mined and can be used with less processing or refining than nitrogen or phosphate. It can be directly applied as PC, which accounts for 94 percent of all single-nutrient potash use in the United States, or used in the production of other fertilizer products.

Wholesale prices were selected from the most relevant market for each material (McGraw-Hill, Inc.). Free on board (f.o.b.) prices for AA are determined at New Orleans, U.S. gulf, near most of the domestic ammonia capacity (Tennessee Valley Authority, 1989). F.o.b. PA prices are similarly determined at central Florida, where most of the PA capacity is located. However, wholesale prices for PC are determined at Saskatchewan, Canada. Canada is the world's largest potash exporter and Canadian imports dominate the U.S. market for PC. Imports of PC from Canada typically account for 85 percent of total U.S. potash use, and thus drive domestic potash prices (Vroomen, 1989a). Thus, the wholesale potash price data used are f.o.b. Saskatchewan, coarse potassium chloride (muriate of potash).

Retail Prices of Selected Single-Nutrient Materials

While AA, PA, and PC are the basic materials of the fertilizer industry, retail prices are not available for PA. However, prices at the retail level are available for concentrated superphosphate (CS), which is produced by treating phosphate rock with PA. CS is the most popular single-nutrient phosphate material and is also used in the production of other products. Therefore, AA, CS, and PC were selected as the representative materials at the retail level for the three nutrient classes.

The retail prices of AA, CS, and PC would reflect price changes at the wholesale level if retailers followed a markup pricing scheme. However, retail prices should also be affected by changes in marketing costs not reflected in f.o.b. prices. Transportation costs represent a significant share of the final price a farmer pays for fertilizer, and rail is the predominant method of transporting fertilizer in the United States (Andrilenas and Vroomen). Marketing costs are thus represented by the cost of rail transportation.

The retail price models for AA, CS, and PC are specified as:

$$RP_i = f(WP_j, \text{TRANS}, e) \quad (1)$$

where:

RP = retail price of fertilizer material $\underline{i}$
WP = wholesale price of fertilizer material $\underline{j}$
TRANS = total rail freight rate index, Dec. 1984=100 (U.S. Dept. of Labor)
i = AA, CS, or PC, respectively

j = AA, PA, or PC, respectively
e = a stochastic disturbance term.

Retail Prices of Other Fertilizer Products

In addition to AA, CS, and PC, equations are specified for the following 11 fertilizer mixtures and materials: 0-20-20, 5-10-10, 5-10-15, 6-24-24, 8-32-16, 10-10-10, 10-20-10, 16-20-0, 18-46-0, ammonium nitrate, and nitrogen solutions (32 percent). These products were selected because they are among the leading fertilizer products used in the United States and because they complete the list of products included in the U.S. Department of Agriculture's (USDA) PPI for fertilizer.

Many different fertilizer products are produced from AA, PA, CS, and PC. Retail prices of single-nutrient fertilizer materials within a nutrient class are highly correlated. Prices of fertilizer mixtures (for example, 6-24-24) are also highly correlated with price movements of the nutrients contained in those mixtures. Since retail prices are not available for PA, the model for the 11 additional fertilizer products is specified as:

$$RP_i = f(RP_j, e) \quad (2)$$

where:

RP = the retail price of fertilizer product <u>i</u> or <u>j</u>
i = the 11 additional selected fertilizer products
j = AA, CS, and/or PC[2]
e = a stochastic disturbance term.

Estimated Models

This section presents the results of the models estimated for the study. Results of the time-series models are presented first, followed by the regression results for the retail prices of AA, CS, and PC, the representative materials for the three fertilizer nutrient classes. Finally, the regression results for the retail prices of the remaining fertilizer mixtures and materials are presented.

Time-Series Results for Wholesale Prices

The value of the wholesale price series for the selected fertilizer materials was modeled as a function of both lagged random disturbances (moving average) and own past values (autoregressive) as well as current disturbance terms. The ARIMA models were developed through the iterative technique of identification, estimation, and diagnostic checking popularized by Box and Jenkins.

Monthly ARIMA models for AA and PA were fit using the entire data series for February 1977-October 1989. Appropriate models for these products were identified as:

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[2]When the price of a single-nutrient material or mixture containing only one or two nutrients is estimated, only the price of the product(s) representing the nutrient(s) contained in that material is included.

$$(1-\phi_1B-\phi_2B^2)(1-\phi_{12}B^{12})(1-B)AA_t = e_t, \text{ and}$$

$$(1-\phi_1B-\phi_3B^3-\phi_6B^6)(1-B)\ln PA_t = (1-\theta_{12}B^{12})e_t,^3$$

where B, the backshift operator, shifts the subscript of a time-series observation backward in time so that $B^xY_t=Y_{t-x}$, ϕ and θ are autoregressive and moving-average parameters, respectively, and e_t is a sequence of white noise.

The ARIMA model for PC was modified to account for the effects of an antidumping case against Canadian potash producers. Farmers faced record potash prices during spring 1988 as a result of a successful U.S. antidumping case against Canadian potash producers. In February 1987, two New Mexico-based potash companies filed a petition with the U.S. International Trade Commission alleging that potash imports from Canada were sold in the United States at less than fair market value (dumped), thereby injuring the domestic potash industry (U.S. Department of Commerce). On August 20, 1987, the U.S. Department of Commerce (DOC) announced a preliminary finding that Canadian potash had been dumped in the United States at margins ranging from 9.1 to 85.2 percent of fair market value. Thereafter, the posting of bonds or cash deposits was required on all potash brought into the United States from Canada.

In January 1988, the antidumping case was suspended when eight Canadian potash producers and DOC signed an agreement prohibiting Canadian producers from dumping potash in the United States at more than 15 percent of the preliminary margins set for each producer by DOC in August. After the agreement, wholesale potash prices fell somewhat, but remained significantly above preintervention levels (Vroomen, 1988).

To account for these disruptions, intervention components were added to the model. The theory of intervention developed in this analysis is based on the impact patterns discussed by Box and Tiao. These patterns can be described by two characteristics, onset and duration. The onset of an intervention can be either abrupt or gradual, whereas the duration can be either permanent or temporary.

The wholesale potash price series was affected by two distinct interventions: (1) the price hike initiated by Canadian potash producers in September 1987, following the preliminary finding by DOC in August, and (2) the agreement between DOC and the Canadian producers signed in early January 1988. The observed response of the price series indicates that the effect of the first intervention was abrupt; wholesale prices increased from an average of $57 in August to $72 in September, and stood at $88 by October. Interventions of this nature can be modeled with a zero-order transfer function, where the intervention component is represented as a step function such that $I_t = 0$ prior to the event and = 1 thereafter. "If the change agent is not an event in the strictest sense, however, the analysis may lead to invalid conclusions. A more valid analysis can be insured by modifying the step function, ..., to accommodate known properties of the change agent" (McCleary and Hay, p. 142). Zimring used this theory of change approach to analyze the impacts of the Washington, DC gun control law because information on the actual level of enforcement was available.

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[3]A logarithmic transformation was made to the phosphoric acid series because the natural logs displayed more spatial homogeneity.

Visual inspection of monthly wholesale potash prices indicates that while the decision by Canadian potash producers to raise prices in response to the antidumping case was abrupt, it took 2 months for the full effect of this event to be passed on in the form of higher wholesale prices, with approximately half the increase occurring by September 1987. Thus, the first intervention was defined as:

$$I_{1,t} = 1/2 \text{ during September 1987}$$
$$= 1 \text{ after September 1987, and}$$
$$= 0 \text{ otherwise.}$$

This formulation also models the first intervention as a permanent event. The permanent designation was selected because of the way the second intervention affects the series. The second intervention is the agreement between DOC and the Canadian producers signed in January 1988 which restricted the latter from dumping potash in the United States at more than 15 percent of the preliminary margins set for each producer in August. Because producers presumably increased prices before the agreement to cover the preliminary margins, the January agreement merely acted to lower their respective margins, permitting them to lower prices somewhat. Thus, the second intervention is a change in series level from the new level obtained after the effect of the first intervention.

The second intervention was also hypothesized to be abrupt and permanent. The effect of this agreement was hypothesized to be abrupt because it permitted Canadian producers to immediately lower their prices on potash sales to the United States, requiring only that they cover 85 percent of the dumping margins they were initially assessed back in August 1987. Visual inspection of the data support this hypothesis. It was considered to be a permanent event because under this agreement, the antidumping case was suspended until January 1993. Thus, the second intervention was defined as:

$$I_{2,t} = 0 \text{ before January 1988, and}$$
$$= 1 \text{ otherwise.}$$

Adding the intervention components to the noise component results in the following model for the wholesale potash price series:

$$PC_t = \omega_1 I_{1,t} + \omega_2 I_{2,t} + \frac{(1-\theta_1 B^1-\theta_3 B^3-\theta_5 B^5-\theta_6 B^6-\theta_{12} B^{12}-\theta_{24} B^{24})}{(1-B)} e_t.$$

Table 1 shows maximum-likelihood estimates and associated diagnostic statistics for each of the time-series models. The estimates of the autoregressive (ϕ) and moving-average (θ) parameters are all statistically significant and lie within the bounds of invertibility. Respective Q-statistics for each model are not significant at the 95-percent level, indicating that there is no observable structure remaining in the residuals; the residuals are white noise. The impact coefficients for PC are significant at the 99-percent confidence level, indicating that the trade case with Canada had a significant effect on f.o.b. potash prices.

Table 1--Estimated time-series models for wholesale prices of anhydrous ammonia, phosphoric acid, and potassium chloride

Parameter	Estimated coefficients	Standard error	t-statistic	Q-statistic[1]
		Measure		
Anhydrous ammonia:				16.77
ϕ_1	0.6827	0.0808	8.45	
ϕ_2	-0.1825	0.0807	2.26	
ϕ_{12}	0.2590	0.0871	2.98	
Phosphoric acid:				15.86
θ_{12}	-0.2284	0.0845	2.70	
ϕ_1	0.2836	0.0775	3.66	
ϕ_3	-0.1423	0.0788	1.81	
ϕ_{12}	0.1440	0.0791	1.82	
Potassium chloride:				25.06
θ_1	-0.1987	0.0725	2.74	
θ_3	0.3323	0.0820	4.05	
θ_5	-0.1609	0.0799	2.01	
θ_6	-0.2041	0.0828	2.47	
θ_{12}	-0.2000	0.0766	2.61	
θ_{24}	-0.2955	0.0881	3.35	
ω_1	28.0826	3.6597	7.67	
ω_2	-6.3770	2.3550	2.71	

ϕ = autoregressive parameters.
θ = moving-average parameters.
ω = impact coefficients.
[1]Value based on 24 residual autocorrelations.

Regression Results for AA, CS, and PC

From 1977 to 1985, retail fertilizer prices were reported for March, May, October, and December. Since 1986, however, retail prices have been available for only April and October (Vroomen, 1989b; USDA). To form a continuous data set, I averaged March and May retail prices to construct an April price for years preceding 1986, while I used reported prices for April for subsequent years. The retail price equations in (1) were estimated with biannual data (April and October) for 1977-89.

Visual inspection of the PC data indicated that only part of the wholesale price increase resulting from the trade case against Canada may have been passed on to the retail level. The equation for PC was consequently modified to test whether the wholesale-retail price relationship was altered by the trade case. This modification was accomplished by the inclusion of a dummy variable, D_1, which was set to equal 0 before October 1987 and 1 otherwise.

Preliminary results indicated that the disturbances of the CS equation followed a first-order autoregressive process. In addition, first-order autocorrelation could not be ruled out for the AA equation. All equations in (1) were thus estimated with a maximum-likelihood autoregressive technique (SAS Institute, Inc.). Autoregressive techniques use the time series part of a model as well as the systematic part in generating predicted values and so are useful forecasting tools.

Table 2 shows the estimated coefficients and t-statistics for each of the retail price equations. R^2's indicate that the explanatory variables explain most of the variation in the retail prices of AA, CS, and PC. All coefficients have the hypothesized signs and are statistically significant at the 5-percent level. The coefficient of D_1 indicates that only part of the f.o.b. price increase for PC resulting from the trade case was passed on to the retail level. In addition, the autoregressive parameter for the CS equation was also statistically significant.

Regression Results for Other Fertilizer Products

Retail price equations in (2) were estimated with data for September 1967-October 1989. This period was determined by data availability; retail price data for nitrogen solutions (32 percent) were not reported before September 1967 (USDA). However, because of changes in the frequency of data reporting, retail prices for these equations were for April and September in 1965-76, a March-May average and October in 1977-85, and April and October in 1986-89. Preliminary results indicated that the disturbances of all equations in (2) followed a first-order autoregressive process. These equations were also estimated with a maximum-likelihood autoregressive technique.

Table 2--Estimated retail price equations for anhydrous ammonia, concentrated superphosphate, and potassium chloride

Dependent variable	Explanatory variables[1]				Estimated autoregressive parameter	R^2
	Intercept	i-f.o.b.	TRANS	D_1		
Anhydrous ammonia	54.517	0.818 (9.01)[2]	0.698 (4.12)		0.136 (0.64)	0.863
Concentrated superphosphate	12.904	56.60 (9.27)	0.394 (2.15)		0.493 (2.65)	0.945
Potassium chloride	7.874	1.610 (11.35)	0.255 (3.00)	-18.330 (3.97)	-0.053 (0.24)	0.918

[1]Prescript i = anhydrous ammonia in the first equation, phosphoric acid in the second equation, and potassium chloride in the last equation. TRANS = the total rail freight rate index (December 1984=100). D_1 is a dummy variable representing the trade case against Canadian potash producers.

[2]Numbers in parentheses are t-statistics.

Multicollinearity is a potential problem when more than one nutrient price is included on the right-hand side of an equation, because the prices of AA, CS, and PC are correlated, making it difficult to separate out the effects of each material. However, the equations in (2) are estimated solely for their predictive ability and not for the reliable estimation of the parameters. Table 3 shows the coefficients for each of the 11 retail price equations. R^2's suggest that all 11 equations exhibit significant predictive power.

Table 3--Estimated retail price equations for selected fertilizer mixtures and materials

Dependent variable	Explanatory variables[1]				Estimated autoregressive parameter	R^2
	Intercept	AA	CS	PC		
0-20-20	31.820		0.405 (8.91)[2]	0.282 (3.09)	0.765 (7.60)	0.995
5-10-10	45.161	0.031 (0.67)	0.243 (3.39)	0.141 (1.36)	0.428 (3.00)	0.990
5-10-15	36.590	0.045 (0.96)	0.264 (3.65)	0.176 (1.67)	0.727 (6.71)	0.993
6-24-24	8.878	0.139 (5.56)	0.434 (9.42)	0.481 (9.85)	0.242 (1.58)	0.998
8-32-16	13.144	0.139 (4.69)	0.625 (11.75)	0.291 (5.07)	0.412 (2.86)	0.998
10-10-10	53.045	0.091 (1.86)	0.273 (3.61)	0.063 (0.57)	0.455 (3.23)	0.991
10-20-10	38.769	0.068 (0.87)	0.459 (3.76)	0.186 (1.05)	0.620 (4.99)	0.988
16-20-0	74.000	0.174 (2.13)	0.360 (3.10)		0.651 (5.49)	0.988
18-46-0	4.808	0.102 (2.26)	1.037 (17.38)		0.606 (4.88)	0.997
Ammonium nitrate	54.276	0.490 (11.84)			0.467 (3.42)	0.982
Nitrogen solutions (32%)	50.841	0.425 (8.06)			0.356 (2.47)	0.963

[1]AA = anhydrous ammonia, CS = concentrated superphosphate, and PC = potassium chloride.

[2]Numbers in parentheses are t-statistics.

Developing Model Forecasts

Fertilizer price forecasts are generated from the estimated equations using the following procedure. First, the ARIMA models for AA, PA, and PC are used to forecast f.o.b. prices through April. Next, these forecasts are incorporated into the equations in (1) to generate retail price forecasts for AA, CS, and PC for April. The system of equations in (1) also requires forecasts of the total rail freight rate index (TRANS). Forecasts for TRANS were generated from:

$$TRANS_t = 6.89 + \underset{(42.56)}{0.944} * TRANS_{t-1}$$

where:

t = April and October 1977-89.

Retail price forecasts for AA, CS, and PC are then used to generate retail price forecasts for other major fertilizer mixtures and materials from (2). Finally, the retail price forecasts generated are combined to construct a forecast of the PPI for fertilizer. In addition to the 14 retail prices forecast, the fertilizer PPI includes the price of agricultural limestone (AL) (USDA). Forecasts for AL were generated from:

$$AL_t = 1.68 + \underset{(24.27)}{0.901} * AL_{t-1}$$

where:

t = April and October 1977-89.

Although the fit for the equations in tables 1-3 appears adequate, the usefulness of a forecasting model lies in its predictive power. To evaluate forecasting performance, I used the full model to make a set of out-of-sample forecasts. I then compared these forecasts with actual values to determine the magnitude and direction of forecast error.

Out-of-sample forecasts were generated 6 months ahead at a time. This procedure was repeated three times for each set of equations as the time period for each was sequentially updated. That is, the models were estimated based on data through October 1987 and used to forecast prices for April 1988. Prices for April 1989 were forecast with models estimated through October 1988. Price forecasts for April 1990 were similarly developed from models estimated through October 1989. Sequentially updated forecasting incorporates new information in parameter estimates and is the efficient way to use this model because it is easily updated. However, the model can also be used by updating only the ARIMA models.

Tables 4-6 list actual and forecasted values for all products considered and the PPI for fertilizer. Overall, the predictive performance of the model appears satisfactory. Mean absolute percent errors for each April of 1988-90 indicate that the retail price forecasts missed their marks by 4.1, 3.2, and 3.5 percent, respectively; only 3 of the 42 retail price forecasts missed their actual value by more than 7 percent. Forecasts of the fertilizer PPI missed their marks by only 3.0 , 0.7, and 2.3 percent, respectively, in 1988, 1989, and 1990. The accuracy of the fertilizer PPI forecasts stems partly

Table 4--Actual and forecast retail fertilizer prices, April 1988

	Forecast	Actual	Error
PPI-fertilizer[1]	128	132	-3.0
	Dollars per ton		Percent
Product:			
Anhydrous ammonia	198	208	-4.8
Concentrated superphosphate	214	222	-3.6
Potassium chloride	143	157	-8.9
Ammonium nitrate	162	166	-2.4
Nitrogen solutions (32%)	126	139	-9.4
0-20-20	170	182	-6.6
5-10-10	137	138	-0.7
5-10-15	151	150	0.7
6-24-24	196	208	-5.8
8-32-16	214	223	-4.0
10-10-10	149	151	-1.3
10-20-10	178	188	-5.3
16-20-0	215	217	-0.9
18-46-0	244	251	-2.8
Mean absolute percent error			4.1

[1]1977=100.

Table 5--Actual and forecast retail fertilizer prices, April 1989

	Forecast	Actual	Error
PPI-fertilizer[1]	142	141	0.7
	Dollars per ton		Percent
Product:			
Anhydrous ammonia	210	224	-6.3
Concentrated superphosphate	231	229	0.9
Potassium chloride	174	163	6.7
Ammonium nitrate	178	189	-5.8
Nitrogen solutions (32%)	167	159	5.0
0-20-20	188	182	3.3
5-10-10	147	144	2.1
5-10-15	159	155	2.6
6-24-24	222	217	2.3
8-32-16	237	232	2.2
10-10-10	163	163	0.0
10-20-10	197	190	3.7
16-20-0	223	226	-1.3
18-46-0	261	256	2.0
Mean absolute percent error			3.2

[1]1977=100.

Table 6--Actual and forecast retail fertilizer prices, April 1990

	Forecast	Actual	Error
PPI-fertilizer[1]	133	130	2.3
	Dollars per ton		Percent
Product:			
Anhydrous ammonia	198	199	-0.5
Concentrated superphosphate	208	201	3.5
Potassium chloride	148	155	-4.5
Ammonium nitrate	188	180	4.4
Nitrogen solutions (32%)	164	143	14.7
0-20-20	173	175	-1.1
5-10-10	146	140	4.3
5-10-15	151	149	1.3
6-24-24	198	198	0.0
8-32-16	214	212	0.9
10-10-10	164	157	4.5
10-20-10	187	181	3.3
16-20-0	225	220	2.3
18-46-0	226	219	3.2
Mean absolute percent error			3.5

[1]1977=100.

from the fact that positive forecast errors cancel out negative forecast errors in the index construction. Nevertheless, the model does provide an accurate forecast of the direction and magnitude of aggregate fertilizer prices, making it a useful forecasting tool.

Conclusions

Accurate shortrun fertilizer price forecasts are useful to both fertilizer users and producers. Producers need accurate price forecasts to make efficient production plans. Such forecasts could also aid in improving managerial decisionmaking on the farm. The pricing model outlined in this article provides a tool that can be used to forecast spring prices of selected fertilizer products with reasonable accuracy. Out-of-sample forecasts indicate that the model performs particularly well as an indicator of aggregate fertilizer price changes.

The model uses a combination of time-series (ARIMA) and regression analysis and, once operational, it can be updated easily. ARIMA models are estimated and used to forecast wholesale prices for AA, PA, and PC. The wholesale price forecasts are incorporated into regression equations to generate retail price forecasts for AA, CS, and PC. Forecasts of these products are in turn incorporated into regression equations of 11 other major fertilizer mixtures and materials. The 14 retail fertilizer price forecasts are combined to construct a forecast of aggregate fertilizer prices (PPI).

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