

Econometric Investigation of the Dynamic Effects of the 1983 Payment-In-Kind Program on the Wheat Economy

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A stochastic, dynamic, and control-system econometric model of the wheat sector is developed to assess the effects of the Payment-in-Kind program. Empirical results reflect the complex dynamics of the responses. Reduced storage costs and deficiency payments for the U.S. government and increased income for wheat farmers are benefits from the PIK program in the short-run. Increased direct government transfers from the public to support the program were required. The long-run economic implications are not clearly desirable. This is due primarily to the highly sensitive international wheat market.

One of the most significant commodity program developments in the last two decades was the 1983 Payment-in-Kind (PIK) program. It was announced in January 1983. The program was largely the result of a serious and worsening problem of farm surpluses. Questions, however, have been raised about the specific impact of the PIK program for wheat. Dramatic as the program's announcement was, the price and the stock situations for wheat did not improve substantially. These facts, coupled with the high cost of the program, have led policy makers to question the overall effectiveness of PIK as a long-term policy tool.

Much attention has been directed at the impacts of PIK on the wheat economy. Some of the cost of the PIK program will be saved in the following years through

reduced storage, deficiency and diversion payments. This is relevant. Without the PIK program, large surplus stocks could have been held indefinitely. In a market where production occurs only once a year, any factor that has an impact on production will have important dynamic effects on price, export, domestic disappearance, and inventory accumulation. The primary goal of this study is to investigate the dynamics of the PIK program for wheat in an empirical model via dynamic multiplier analysis. Only the net effects of the single event (1983 PIK program) are considered.

A structural model of wheat price, demand, supply and stock was estimated and its final-form was generated in order to investigate the time path of adjustments in the wheat subsector induced by the 1983 PIK program. The final-form reveals how the structural model estimates the responses of the system to shocks. The multiplier effects of the final-form were proposed originally by Goldberger as a means of assessing the impact of a discrete policy intervention. The method has been widely applied in many studies. For literature on multiplier applications see Chambers and

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Just; Maclaren; Kenkel; Andersen and Carlson; Gallagher *et al.*; Wong; and Hall. Excellent reviews of wheat econometric models and commodity programs can be found in the papers by Morzuch *et al.*; Houck (1972, 1976) *et al.*; Lidman *et al.*; Garst *et al.*; Gallagher *et al.*; and Blakeslee.

The results indicate that the PIK program has extremely important effects on farm price as well as on supply and demand in the short-run. However, the long-run effects are not as dramatic. This is because the dynamic responses of stock accumulation, domestic utilization, and farm prices are cyclic-types rather than monotonic-types. The results also suggest that the PIK program in the long-run does not have a significant price support effect for the wheat sector.

The Econometric Model

To evaluate the impacts of the PIK program on the U.S. wheat sector, a systems model was developed which regards the primary purpose of the program as a production adjustment. Two ways to identify this adjustment are by changing either the intercept term or the disturbance term in the production equation. The latter was applied here because the nature of the PIK program is to be considered relatively closer to the random shock than to structural change in the production process.

Production Response Equation

To specify a production equation for wheat is particularly complex and difficult. The complexities are caused by the frequent changes of commodity programs from administration to administration, with different political philosophies and control variables for implementation. The difficulties are magnified by individual farmer's reactions to market, program, and the weather variability. Accordingly, the sample data used are for a relatively short

time span, 1974 to 1982, to avoid the program complexities. The disturbance term U_{it} is introduced to reflect the stochastic nature of production. The equation is estimated by ordinary least squares, and the result is:

$$\begin{aligned} \text{PRO}_t = & -444.11 + 0.511\text{PRO}_{t-1} \\ & (-0.90) \quad (2.07) \\ & + 256.13\text{PF}_{t-1} + 249.87\text{WTP}_t + U_{it} \\ & (2.71) \quad (1.97) \\ & R^2 = 0.88 \quad (1) \end{aligned}$$

The figures in parentheses are "t" statistics; PRO is wheat production in millions of bushels; PF is the season average price per bushel received by farmers (dollars); WTP is the weighted target price computed as in the research of Houck and Ryan. Because the PIK program does not change any aspects of previously announced programs, we still include the regular program in the production equation. The announced target price is multiplied by an adjustment factor of one minus the acreage reduction rate to secure the weighted target price.

U.S. Export Demand Equation

Unlike the complexities and difficulties in estimating the production equation, the rest of the behavioral equations, whose relevant structural variables are continuous over the analysis period, are estimated from the same period of 1950 to 1979. We did not attempt to consider all dimensions of international trade. Rather, we developed and estimated a relatively simple empirical equation. The price elasticity of demand for U.S. wheat exports was estimated by Konandreas and Schmitz as -3.04 , and -2.80 by Tweeten. An exactly restricted least squares method was used to estimate the export demand equation with an a priori coefficient on PFOB.¹

¹ An elasticity of -3.00 was imposed at the centroid and resulted in an a priori coefficient of -595 on the variable, PFOB.

$$\begin{aligned} \text{CEV}_t &= 1017.9 - 595\text{PFOB}_t \\ &\quad (10.12) \\ &+ 1.13\text{CEV}_{t-1} + 1252.65\text{DV}_t + U_{2t} \\ &\quad (3.39) \quad (4.99) \end{aligned} \quad (2)$$

where PFOB is the f.o.b. price at Gulf; CEV is commercial export volume in millions of bushels; and DV is a dummy variable, where the years of strong exports were represented by DV = 1, those for lower exports by DV = 0. Validation of this equation is based on $R^2 = 0.77$ obtained for the CEV variable by correlating it with the respective estimated value obtained from the above equation. The overall fit of this equation seems to be adequate.

Private Storage Equation

The estimates for the storage function and four associated functions are derived by means of the Limited Information Maximum Likelihood method under the assumption that the disturbances of the five behavioral equations are uncorrelated each year. The algebraic statement of private storage is based on current production, price difference, storage cost, carry-in stocks, and commercial exports.

$$\begin{aligned} \text{PRST}_t &= -68.7 + 0.554\text{PRO}_t - 108.3\text{dPD}_t \\ &\quad (-0.46) \quad (7.36) \quad (-3.88) \\ &- 77.87\text{IR}_t + 0.732\text{PRST}_{t-1} - 0.08\text{CEV}_t \\ &\quad (-4.23) \quad (12.39) \quad (-1.0) \\ &+ U_{3t} \quad R^2 = 0.97 \end{aligned} \quad (3)$$

The variable PRST is millions of bushels of wheat stored by the private sector; dPD is the domestic price difference by which speculative gains are reflected; IR is the interest rate which is a proxy for the storage cost.

Domestic Demand Equation

No distinction is made between wheat for food and wheat for other uses. A time variable is used to account for linear time trend.

$$\begin{aligned} \text{DD}_t &= 175.87 - 27.216\text{PD}_t + 0.77\text{DD}_{t-1} \\ &\quad (2.45) \quad (-2.74) \quad (6.42) \\ &+ 3.28\text{T} + U_{4t} \\ &\quad (2.82) \quad R^2 = 0.82, \end{aligned} \quad (4)$$

where DD is the total domestic demand in millions of bushels; and PD is the Kansas City price in dollars per bushel.

Price Equations

Three levels of price structure are constructed in the following price equations to analyze the price relationships. For wheat, the forces of demand and supply are brought together in central markets to establish the domestic price. The Kansas City price is used in this study. Prices at the farm level as well as at Gulf ports are closely linked to the central market price quotations.

$$\begin{aligned} \text{PD}_t &= -1.013 - 0.0095\text{PRO}_t + 0.0096\text{ED}_t \\ &\quad (-1.25) \quad (-2.45) \quad (2.57) \\ &+ 0.0084\text{dSTOCK}_t + 0.82\text{PD}_{t-1} \\ &\quad (2.22) \quad (5.10) \\ &+ 0.0114\text{DD}_t + U_{5t} \quad R^2 = 0.77 \end{aligned} \quad (5)$$

$$\begin{aligned} \text{PF}_t &= -0.21 + 0.827\text{PD}_t + 0.176\text{PF}_{t-1} \\ &\quad (-2.92) \quad (36.05) \quad (6.67) \\ &+ U_{6t} \quad R^2 = 0.99 \end{aligned} \quad (6)$$

$$\begin{aligned} \text{PFOB}_t &= -0.5 + 0.9404\text{PD}_t + 0.262\text{PFOB}_{t-1} \\ &\quad (-3.84) \quad (9.83) \quad (3.01) \\ &+ U_{7t} \quad R^2 = 0.94, \end{aligned} \quad (7)$$

where ED is excess demand including commercial exports and government program exports in millions of bushels and dSTOCK is change of millions of bushels of wheat stored. All the data used in the previous estimation processes are from various issues of the *Wheat Situation* and USDA's *Agricultural Statistics*. The reasons for having lagged endogenous variables in the above behavioral equations are to account for the past impacts either

in the inertia sense (like habit formation DD_{t-1} , and carry-in stock $PRST_{t-1}$) or in the political sense, or both [such as CEV_{t-1} in (2), the rationale for which is drawn from the international trade market share theory²].

Identities

Three economic identities are required to close the model. These equations are of the definitional type and therefore hold exactly without disturbance terms. The first of these states that this year's price minus last year's price is the price difference, namely:

$$dpD_t = PD_t - PD_{t-1} \tag{8}$$

The second is the definition of $dSTOCK$. Several studies have provided that P.L. 480 wheat is generally considered as an addition to, rather than a substitute for, the commercial wheat exports (Tontz *et al.*; Wang and Frederick; Witt and Eicher). Thus, government program exports will not be considered as a "normal" demand component because they would otherwise be part of the additional stocks.

$$dSTOCK_t = PRST_t - PRST_{t-1} + GAD_t - GPE_t, \tag{9}$$

where GAD means government owned stock acquisitions and GPE means government program exports.

The third identity constrains the U.S. total supply and total demand to be equal of each other.

$$PRO_t - DD_t - ED_t - dSTOCK_t = 0 \tag{10}$$

The above wheat econometric model is assumed with exogenous additive disturbances in the dynamic behavioral equations. The structural form model is not, in this study, the direct focus of analysis. Instead, two alternative representations are crucial to the ensuing analyses: the re-

duced-form and state-space representations. We can solve the system to obtain the reduced-form:

$$Y_t = AY_{t-1} + BX_t + cb_t + DU_t, \tag{11}$$

where Y_t is a 10×1 vector of endogenous variables; X_t is a 3×1 vector of current control variables including WTP , GPE , and GAD ; b_t is a 4×1 vector of exogenous variables not subject to control including IR , DV , T , and constant; A is a 10×10 matrix of coefficients for the lagged endogenous variables; B is a 10×3 matrix subject to the X_t vector; c is a 10×4 matrix of coefficients for the exogenous variables not subject to control; D is a 10×7 matrix of coefficients for the disturbance term; U_t is a 7×1 vector of disturbance. The coefficients of the reduced-form are given in Table 1, and they are useful because they represent estimates of the total effects of predetermined variables on the endogenous variables of the system, whereas the structural form generally represents only first-round effects.

Qualification of the Dynamic Model

From equation (11), the state-space representation is derived as:

$$Z_t = AZ_{t-1} + ABX_{t-1} + Acb_{t-1} + ADU_{t-1} \tag{12}$$

$$Y_t = IZ_t + BX_t + cb_t + DU_t, \tag{13}$$

where Z is a 10×1 state vector; I is a 10×10 identity matrix. The state-space representation is useful because it provides information for an analysis of controllability, observability, and stability of the system. For details of the derivation of those properties, the reader is referred to Aoki; Barnett; Cadzow and Martens; Holly *et al.*; Rausser and Hochman; Theil; Tinbergen; and Sengupta and Fox. Stripped to the barest essential meaning of controllability, this is concerned with the ability of the control instruments in influencing the specified values of the state

² It is assumed that U.S. wheat exports are not perfect substitutes for exports from other countries in each importing country on historical or political grounds.

TABLE 1. Matrix of Estimated Coefficients of the Reduced-form Equations.

Equa- tions	PRO ₋₁	PF ₋₁	WTP	PFOB ₋₁	CEV ₋₁	DV	GPE	GAD	IR	PRST ₋₁
PRO	0.511	256.13	249.87	0	0	0	0	0	0	0
CEV	0.192	96.216	93.864	-47.94	0.347	384.46	-0.0952	-0.649	50.598	0.1741
PRST	0.305	152.82	149.08	24.768	-0.179	-198.6	-0.0108	-0.073	-72.13	0.7517
DD	0.009	4.6806	4.5662	5.2619	-0.038	-42.20	-0.0046	-0.031	2.4614	0.0084
PD	-0.00034	-0.17195	-0.16775	-0.19331	0.00139	1.550	0.000170	0.00116	-0.09043	-0.00031
PF	-0.00028	0.03361	-0.13871	-0.15984	0.00115	1.282	0.000140	0.00096	-0.0747	-0.00025
PFOB	-0.00032	-0.16170	-0.15775	0.08056	0.00131	1.458	0.000159	0.00109	-0.0850	-0.00029
dPD	-0.00034	-0.17195	-0.16775	-0.1933	0.00139	1.550	0.000170	0.00116	-0.09043	-0.00031
dSTOCK	0.30488	152.82	149.08	24.768	-0.1793	-198.60	-1.0108	0.92623	-72.12	-0.24823
ED	0.1967	98.630	96.22	-30.03	0.2173	240.85	1.0154	-0.894	69.666	0.2397

Equa- tions	PD ₋₁	DD ₋₁	T	Constant	U ₁	U ₂	U ₃	U ₄	U ₅	U ₆	U ₇
PRO	0	0	0	-444.11	1	0	0	0	0	0	0
CEV	-133.84	-0.6812	-2.905	204.82	0.3756	0.3071	-0.64975	-0.8856	-77.352	0	-182.71
PRST	93.0939	-0.0773	-0.329	-546.35	0.5966	-0.158	0.92623	-0.1005	-8.7821	0	94.4089
DD	-6.5112	0.7360	3.1386	121.765	0.0182	-0.0337	-0.0316	0.9569	-3.7629	0	20.0567
PD	0.23921	0.0012	0.0052	1.98768	-0.0067	0.0012	0.0016	0.0016	0.13824	0	-0.7368
PF	0.1978	0.0010	0.0042	1.43302	-0.0055	0.0010	0.00096	0.0013	0.11431	1	-0.6092
PFOB	0.22495	0.0011	0.0048	1.36652	-0.0063	0.0011	0.00109	0.0014	0.13000	0	0.3070
dPD	-0.7607	0.0012	0.0052	1.98768	-0.0067	0.0012	0.00116	0.0016	0.13824	0	-0.7368
dSTOCK	93.0939	-0.0773	-0.329	-546.35	0.5966	-0.158	0.92623	-0.100	-8.7821	0	94.4089
ED	-86.583	-0.6587	-2.808	-19.528	0.3850	0.1923	-0.8946	-0.856	12.5451	0	-114.46

variables. The controllability matrix is directly derived from the state-space representation:

$$Q = [A^6B, A^7B, \dots, A^2B, A^1B],$$

where Q is a 10×24 controllability matrix; the initial state begins in 1974 and the final state ends in 1982. Because the maximum number of the linearly independent rows of the Q matrix established by the different time-lagged dynamic multipliers is equal to the dimension of the state vector Z , the dynamic system is therefore completely controllable.

The second property is observability which in general terms means that it is possible to recover unobservable system data uniquely from a set of observed data. The observability matrix is also derived from the state-space representation:

$$V = \begin{bmatrix} I \\ IA \\ \vdots \\ IA^7 \\ IA^8 \end{bmatrix},$$

where I is a 10×10 identity matrix and V is a 90×10 observability matrix. The system is completely observable because the V matrix has rank given by the A matrix.

The third property is stability. The eigenvalues of the A matrix presented in equation (11) are the most frequently used criteria to judge the stability problem which only associates explicitly with the lagged endogenous variables. The rank of the A matrix is seven because of the three identity specifications. Solution for the eigenvalues resulted in the following, namely, 0.238, 0.155, 0.495, 0.816, 0.716, and $0.117 \pm 0.601i$. These magnitudes are consistent with asymptotic stability with damped oscillations.

Dynamic Effects of the PIK Program

The USDA enrollment report released in early-1983 indicated that 25.7 million

acres of wheat had been signed up for the PIK program. After accounting for the tight restrictions on alternative uses of idled land in the pertinent program details, a "30" percent slippage rate was assigned in this study.³ Thus, the effective annual acreage set aside by the program was about 18 million acres. Wheat production in 1983 was estimated to fall 540 million bushels, given the assumed yield of 30 bushels per acre.⁴

The final-form was obtained by additional manipulation of equation (11). We successively substitute for Y_{t-r} ($r = 1, 2, \dots$) into equation (11) to yield the final-form:

$$Y_t = \sum_{r=0}^{\infty} A^r B X_{t-r} + \sum_{r=0}^{\infty} A^r c b_{t-r} + \sum_{r=0}^{\infty} A^r D U_{t-r} \tag{14}$$

Such dynamic multipliers in equation (14) give the effect at time t of a change in policy variables at time $t - r$. However, the multipliers associated with a sustained change are of greater interest. In what follows, a six-year time horizon is arbitrarily chosen and the final-form equation is consolidated as:

$$Y_{t+6} = \sum_{k=1}^6 A^{6-k} B X_{t+k} + \sum_{k=1}^6 A^{6-k} c b_{t+k} + \sum_{k=1}^6 A^{6-k} D U_{t+k} + A^6 Y_t \tag{15}$$

The multipliers in equation (15) allow for the intertemporal effects of the PIK program to be expressed over specified future time periods. The impact multipliers associated with the program are given by the vector $D U_{t+6}$, and the delay multipliers are given by the vector $A^{6-k} D U_{t+k}$ ($k = 1, \dots, 5$).

The impact and delay multipliers which

³ The slippage estimates are based on work by Garst and Miller, and by Richardson and Ray.

⁴ The level of U_{it} in equation (1) is therefore specified as -540 million bushels.

TABLE 2. Effects of the 1983 PIK Program on Wheat Economy in Different Periods.

Time Horizon in Years	Production	Commercial Exports	Stock Accumulation	Domestic Demand	Farm Price
	(million bushels)				(\$/bu.)
1	-540	-203	-322.0	-9.8	0.30
2	-199	-259	40.5	-6.5	0.02
3	-97	-168	56.5	1.5	-0.19
4	-99	-94	-0.5	4.2	-0.12
5	-83	-83	8.3	3.1	-0.02
6	-47	-85	39.7	2.5	-0.01
Cumulative Effect ^a	-1,065	-892	-177.5	-5.0	-0.02

^a Based upon six-year cumulative effects resulting from a first period shock.

form the foundation of dynamic quantitative policy analysis are presented in Table 2. The current period effects of the PIK program are described by the impact multipliers. As suggested in Table 2, the impact effect is substantial. A reduction of wheat inventories of more than 300 million bushels is associated with the rise in the price received by farmers of about 30 cents per bushel. To compensate for this dramatic upsurge in price level, demand is curtailed. Hence, exports decrease by about 200 million bushels and domestic demand falls by 9.7 million bushels.

The delay k-periods multiplier matrices take into account the effects of the lagged exogenous variables on the lagged endogenous variables and their joint effects on the current levels of the endogenous variables. The subsequent period effects of the PIK program are described by the delay multipliers. Comparing the relative magnitudes of the impact and delay multipliers, the second and subsequent period effects are important, but the level of importance declines over time. As inflationary tendencies (farm price) take over, the system tends to cycle toward some asymptotic long-run value and the PIK effects start to wear off. Signs of the delay multipliers indicated a complex process of dynamic adjustment in prices, domestic demand, and inventory levels. By adding the

impact and delay multipliers together over time, the cumulative effects are obtained. They reinforce the initial (impact) multiplier effects on production and exports; however, they decrease the initial multiplier effects on price, domestic disappearance, and stock accumulation.

The short-run picture of the dynamic effects of the program is tremendously different from the long-run picture. For example, the farm price will rise 30 cents per bushel in the first year, but the cumulative effect on the price after 6 years will be down 2 cents per bushel. This is because the effective demand will decrease about 1,074.5 (= 892 + 177.5 + 5) million bushels, and that is more than the decreased supply which will be 1,065 million bushels. Specifically, the biggest component in the decreased effective demand is commercial exports.

Conclusions and Implications

This paper presents a stochastic and dynamic econometric model of the U.S. wheat economy and estimates dynamic effects of the 1983 PIK program in the context of a complicated interaction between government program and market forces. The results indicate that the PIK program will have different impacts on the particular variables. While the estimated model

is asymptotically stable, some significant cyclical forces are clearly operative and they suggest a rather complex and long-term adjustment. The dynamic adjustment of farm price is particularly interesting, and in this context, it appears that no strong empirical support for the expectation of the PIK program is found. Another implication is that storage payments and diversion payments might be saved by the program, but deficiency payments might increase even more than without the program.

A dramatic decrease in commercial export volume is a result of the PIK program. This is an unexpected result and one which has a critical influence on the other multipliers. In part, it explains the decrease in farm prices and the increase in cumulated stocks in the subsequent periods because they are affected by the reduced effective demand. Inspection of the export demand elasticity (equation 2) suggests that the higher farm price in the first period, through dynamic interaction with other variables, will lead to further eroding of the demand for exports in later periods. Thus, the key point in determining the success of the wheat PIK program in the long-run is the elasticity of export demand.

A major policy implication of this study is that, given the keen competition in the international wheat market, only a single domestic policy (like the PIK program) without appropriate accompanying trade policies (like an export subsidy) is unlikely to achieve its policy goal of price and income improvement for the agricultural producer. PIK may represent a good short-term policy, but the long-term economic implication is quite another story. More work is needed prior to writing a permanent PIK into the 1985 Farm Bill. Comprehensive planning and implementation of coordinated domestic and international policies are required to solve future farm problems.

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