Impacts of the PIK Program on the Farm Machinery Market

Fred Kuchler and Harry Vroomen

Abstract. Many analysts have claimed the record number of crop acres taken out of production in 1983 as a result of the Payment-in-Kind (PIK) program affected the already declining sales of farm tractors. The authors use intervention analysis, a particular form of a transfer function, to model and test for hypothesized changes in processes. Three time series (two two-wheel drive monthly sales classifications and one four-wheel drive sales classification) were modeled as univariate Autoregressive-Integrated-Moving-Average (ARIMA) processes. These models were modified to incorporate the expected form of the PIK effects. Results showed that PIK significantly reduced unit sales of four-wheel drive tractors, but there was no statistical evidence of reduced sales for two-wheel drive tractors.

Keywords. Intervention analysis, Payment-in-Kind program, tractor sales

The Payment-in-Kind (PIK) program of 1983 idled over a third of the acreage normally planted to program crops, amounting to the largest annual program induced reduction in plantings (20). Participating farmers received in-kind payments in the form of Government-owned commodities on condition that they put land into conserving use rather than into production in 1983. The effects of the program went far beyond the farm gate, reducing demand for most farm inputs (fertilizer, pesticides, seed for program commodities, energy, and farm machinery). Although the U.S. Department of Agriculture (USDA) made initial estimates of PIK impacts, followup studies were not conducted (25). Followup studies validating initial assessments are useful for policy purposes because similar programs could be implemented in the future. Conditions precipitating PIK—excessive Government stocks, mounting commodity program costs, weak export demand, and increased production—persist.

This article examines the impacts of PIK on the domestic farm tractor market. We analyze domestic sales of farm tractors as three separable markets: 40-99 horsepower (hp) two-wheel drive tractors, 100-and-over hp two-wheel drive tractors, and four-wheel drive tractors. Initial assessments of PIK impacts by both industry and USDA predicted that the farm tractor industry would suffer a loss in sales (4, 19, 25). Some USDA forecasts were quite accurate, predicting the farm tractor industry would suffer less than other farm input industries, with only a 2-3 percent loss in sales, whereas other USDA analyses suggested that PIK would raise commodity prices and farm income, leading to an increase in machinery sales (20, 26). Here we provide evidence that the shortrun industry effects were relatively minor, as forecast. However, one segment of the farm tractor market experienced substantial sales losses despite the minor aggregate effects. The four-wheel drive tractor market exhibited losses comparable to those forecast for other farm inputs, whereas sales of two-wheel drive tractors were not significantly affected.

We use a particular form of a transfer function, often called intervention analysis, to model monthly sales patterns for the three farm tractor categories and the changes in those series resulting from PIK (2, 3). We use monthly sales series to separate PIK impacts from drought impacts, another major event in 1983 that may have reduced the demand for farm machinery. Unlike an annual econometric model, which might not make explicit the extent to which each of these factors was responsible for sales losses, intervention analysis allows us to test hypotheses about the magnitude and speed of adjustment to specific events.

Background

Large-to-record crop harvests in 1981 and 1982, combined with declining foreign demand for U.S. agricultural commodities, resulted in record commodity surpluses and lower commodity prices in the.
fall of 1982. To remedy this situation, the Government announced voluntary acreage reduction (ARP) and paid land diversion (PLD) programs for the major program crops for the following growing season. These programs alone were incapable of substantially improving commodity prices or of reducing Government commodity stock levels and storage costs.

Reducing acreage further through the ARP and PLD programs would have entailed far higher Government outlays at a time when Government deficit spending was becoming a serious problem. Consequently, the Government announced the PIK program for corn, wheat, grain sorghum, upland cotton, and rice on January 11, 1983, to supplement the previously announced ARP and PLD programs. With PIK, farmers received in-kind payments of commodities that would otherwise have been grown on PIK-idled acreage.

The response to PIK was overwhelming as enrollment far exceeded expectations. PIK and related acreage reduction programs idled 77.6 million acres in 1983, the largest amount of land ever taken out of production in one season by U.S. commodity programs (table 1). Although only 48.2 million of the 77.6 million acres idled could be directly attributed to PIK, this amount actually underestimates PIK’s impact on total idled acreage because of the program’s provisions. To participate in PIK, corn producers were required to participate in the 10-percent ARP and 10-percent PLD, whereas wheat producers were required to participate at levels of 15 and 5 percent, respectively. Participation in the ARP and PLD for corn and wheat was consequently greater in 1983 than it would have been without PIK.

Furthermore, a decline in soybean acreage from 70.9 million acres in 1982 to 63.8 million acres in 1983 was partly due to PIK. Although soybeans were not included in the PIK program, a significant amount of 1982 wheat acreage double-cropped with soybeans in the Southeast was set aside under PIK. Abandoned cotton land that was planted to soybeans in 1982 was either planted or set aside under PIK. And, although many growers substituted soybeans for corn on cornbase acreage (the acreage upon which corn program payments are based) in 1982, farmers participating in PIK had a strong incentive to use their entire corn base for program purposes, precluding substitution of soybeans for corn in 1983.

Planted acreage of some small grains increased sharply in 1983 because cover crops were required for idled acreage. Planted oats acreage increased 45 percent from 1982 to 1983, even though oats were not included in PIK. Acreage planted to barley increased 9 percent.

The direct and indirect effects of the 1983 PIK program resulted in a record drop in area planted to the principal crops, from about 369 million acres in 1982 to roughly 309 million acres in 1983, the lowest level since 1972. With substantially fewer acres planted, farmers used less seed, fertilizer, pesticides, farm machinery, and fuel.

Methods of Measuring Program Impacts

From a practical perspective, two obvious methods of measuring or estimating PIK impacts on the farm machinery market are unworkable. An econometric model would suffer from several problems. A major drought in 1983 reduced the expected harvest of many commodities and may have thereby affected demand for farm machinery in the latter half of 1983. Thus, an annual model identifying 1983 as unique, by incorporating a dummy variable in a farm tractor demand equation, might not separate PIK from drought impacts on farm machinery sales unless Government programs or weather influences on producer durables were already incorporated into the model. Econometric models of the farm machinery market have typically been built with annual data. Data availability precludes building a model identifying major farm machinery components based on more narrowly spaced data. Formally modeling all the influences of Government commodity programs or the effects of weather is likely to be impossible with the limited data implicit in an annual model. Government programs change in form and magnitude year by year, requiring many variables to adequately describe those programs. This description could easily use up more observations than exist. Regional or national weather indexes pose similar problems in

### Table 1—Idled acreage, 1983

<table>
<thead>
<tr>
<th>Crop</th>
<th>ARP</th>
<th>PLD</th>
<th>PIK</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Million acres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>4.4</td>
<td>5.9</td>
<td>21.9</td>
<td>32.2</td>
</tr>
<tr>
<td>Wheat</td>
<td>8.7</td>
<td>3.5</td>
<td>17.6</td>
<td>29.8</td>
</tr>
<tr>
<td>Cotton</td>
<td>2.7</td>
<td>0.1</td>
<td>4.1</td>
<td>6.8</td>
</tr>
<tr>
<td>Sorghum</td>
<td>8.8</td>
<td>1.3</td>
<td>3.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Rice</td>
<td>5.5</td>
<td>2.1</td>
<td>1.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Barley</td>
<td>5.5</td>
<td>6.0</td>
<td>0.0</td>
<td>11.1</td>
</tr>
<tr>
<td>Oats</td>
<td>1.1</td>
<td>2.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17.7</td>
<td>11.7</td>
<td>48.2</td>
<td>77.6</td>
</tr>
</tbody>
</table>

1ARP = acreage reduction program
2PLD = paid land diversion program
3PIK = Payment-in-Kind

Sources: (18, 21, 23, 31)
construction and additional difficulties in interpretation because weather influences are locationally heterogeneous at any given time.

A second approach, a formal statistical analysis, might compare preintervention and postintervention sales, perhaps using a t-test for a change in mean levels or other parametric or nonparametric methods. Box and Tiao noted problems with any such procedure.

However, the ordinary $t$ test would be valid only if the observations before and after the event of interest varied about means $\mu_{1}$ and $\mu_{2}$, not only normally and with constant variance but independently (3, p 70).

Data on monthly farm machinery sales violate these conditions (10). First and second moments depend on time, for all three series. Autocorrelation patterns exist even after the series are made stationary. Thus, the data do not support the assumptions required to employ classical statistical tests (10).

The methodology used here, known as intervention analysis, is an extension of the univariate autoregressive-integrated-moving-average (ARIMA) methods of time-series analysis of Box and Jenkins. The ARIMA noise model extension defined by the intervention analysis incorporates the impact of a specific event such as a Government policy change or a natural disaster—namely, events for which the onset timing and duration are known. Intervention analysis differs from other types of transfer functions because the form of the impact can be postulated and tested, rather than determined empirically. If observations were taken more often than once a year, the PIK and drought effects might also be separated. Intervention analysis has been used for a variety of social science applications (1, 8, 11, 33). McCleary and Hay summarize various results of applications to both the social and biological sciences (14). To estimate the impact of PIK on the domestic farm tractor market, we examine January 1973-December 1985 monthly sales data for the three major categories of tractors. Data were provided by the Farm and Industrial Equipment Institute.

The Model

We follow the approach developed by Box and Tiao, building a stochastic model for each of the three series while including the possibility of change of form specified a priori. That is, the models consist of both a deterministic element, within which the nature of the impact of a change in Government policy can be modeled, and a stochastic component, specifying background variation or noise. This procedure is iterative, proceeding by successive use of identification, estimation, and diagnostic checking. As Wichern and Jones note, there are four attractive features of model building with intervention analysis:

1. The lag structure (dynamics) linking the dependent variable to a given set of independent variables can be identified from the data and is not determined arbitrarily as common practice frequently dictates.
2. The appropriate noise structure is easily identified.
3. The final model will generally be a parsimonious representation of the data.
4. Comprehensive tests of model adequacy are available (33).

Each series is independently modeled in which

$$y_{t} = f(\delta, \omega, I, t) + N_{t}$$

where

- $y_{t}$ is the response variable or some appropriate transformation of the response,
- $f(\cdot)$ can allow for deterministic effects of time, $t$, and the effects of exogenous variables, $I$, that are specified here as interventions,
- $N_{t}$ represents the stochastic background variation or noise, and
- $\delta$ and $\omega$ are unknown parameters.

We suppose the noise model

$$N_{t} = y_{t} - f(\delta, \omega, I, t)$$

may be modeled as a mixed autoregressive-moving-average process

$$\Phi(B)N_{t} = \Theta(B)a,$$

where $B$ is the backshift operator, $[a]$ is a sequence of white noise, and $\Phi(B)$ and $\Theta(B)$ are polynomials of finite degree. The process is stationary in a small number of seasonal and nonseasonal differences. Seasonal autoregressive and moving-average effects can be factored multiplicatively, so the observed data are the realization of successively filtering $[a]$ through a nonseasonal and then a seasonal filter. One can develop the noise model by analyzing the autocorrelations and partial autocorrelations of the response variable.
The noise model is modified by certain a priori specifications to incorporate the effects of intervention. The effects of intervention variables can be specified in the form

\[ f(\delta, \omega, I, t) = \sum_{i=1}^{k} Y_{i} = \sum_{i=1}^{k} (\omega(B)\delta(B)I_{i}) \quad t = 1, 2, \ldots, n \]

The final output minus the noise component is represented by the sum of transferred inputs. The transfer \( Y_{i} \) to the output from \( I_{i} \) is generated by a linear difference equation. That is, the dynamics of the system are specified as

\[ \delta(B)Y_{i} = \omega(B)I_{i} \quad i = 1, 2, \ldots, k \]

where \( \delta(B) \) and \( \omega(B) \) are polynomials of finite degree in \( B \). The variables \( I_{i} \) are indicator variables taking values of 0 or 1 denoting the interventions, that is, the occurrence or nonoccurrence of a set of events.

We use a single transfer \( Y_{i} \) to the output from the input \( I_{i} \) where, in this case, \( I_{i} \) is a step function

\[ I_{i} = \begin{cases} 0, & t < T \\ 1, & t \geq T \end{cases} \]

such that \( T \) is the period in which policy changed. The appropriate transfer function is therefore

\[ Y_{i} = \frac{\omega(B)}{\delta(B)} \]

**Form of the Intervention**

The theory developed for our analysis is based on the impact patterns Box and Tiao discussed. These patterns can be described by two characteristics: onset and duration. The onset of an impact can be either abrupt or gradual, whereas the duration can be either permanent or temporary. Three forms of interventions can be parsimoniously modeled: (1) an abrupt and permanent change in the series, (2) a gradual and permanent change, and (3) an abrupt and temporary change. We hypothesized that, if PIK had an impact on farm tractor sales, it was of the latter form. Other applications of the abrupt and temporary change form of intervention include estimating impacts and speed of recovery from natural disaster (5).

One would expect that the duration of the impact was temporary because the program was implemented only for the 1983 growing season. The onset of the impact must have been abrupt because the program surprised farmers, commodity demanders, farm machinery manufacturers, and dealers, and it required immediate decisions by farmers. A PIK program was considered by the Administration and Congress during the fall of 1982, but no action was taken (24). Instead, the Secretary of Agriculture announced the program on January 11, 1983. Corn cash and nearby futures prices increased 30-35 cents a bushel by mid-February. Had the program been anticipated, such a rapid movement would have been unlikely; prices would have risen before the announcement, rather than immediately after.

Compared with PIK programs in the sixties, the 1983 program covered more commodities and gave larger benefits to farmers, inducing a rapid signup. Program signup for most commodities was terminated before the end of February (30). Farmers who agreed to PIK conditions needed far fewer farm machinery services in the 1983 crop year. Because PIK-idled land did not produce marketable crops, many major soil-preparing, planting, and harvesting operations were not done on the land. At the time of program signup, the needs of program participants for many types of farm machinery would have been projected a year into the future. Thus, demand should have fallen abruptly with the announcement of PIK. However, a gradual recovery during the year might have been expected if dealers lowered prices, trying to recover some of their lost sales and minimize inventory expenses.

Farm tractors in the three categories examined here have different uses. Four-wheel drive tractors are primarily used in the production of grains, and, to a lesser extent, in the production of the major row crops. Larger two-wheel drive tractors can be used for both these activities and for other types of farming. The impact of PIK on the larger two-wheel drive series, therefore, should be smaller than that on the four-wheel drive series. The smallest impact would be expected on the small two-wheel drive tractors, used less to produce crops idled by PIK.

One can model the abrupt but temporary impact as a distributed lag response by using a first-order transfer function, the backshift operator appears to the power 1. The abruptness of the transfer requires the intervention input variable to be modified. A unit pulse is defined as

\[ (1 - B)I_{i} = \begin{cases} 1, & t = T \\ 0, & \text{otherwise} \end{cases} \]

Applying the first order transfer function to \((1 - B)I_{i}\) implies the following impact assessment model

\[ y_{t} = \frac{\omega}{1 - \delta B} (1 - B)I_{t} + N_{t} \]

The immediate impact \( \omega \) decays at a rate \( \delta \).
A Stochastic Model for the Noise Component

The first step in the model-building procedure is to develop models that adequately describe the stochastic behavior of each time series studied. More precisely, these models must account for the sources of variation or "noise" in the response variable. The sources of noise, quite common in monthly economic time series, are trend, cycle, seasonality, and random error. If unaccounted for, the first three of these noise sources could obscure the intervention under analysis.

We fit each ARIMA noise model using the entire data series. Where the autocorrelation function (ACF) and the partial autocorrelation function (PACF) are overwhelmed and distorted by the impact of an intervention, one generally uses the preintervention series to identify the noise component, avoiding biased estimates. The intervention component can then be added for reestimation of all parameters, with estimation made over the entire (preintervention and postintervention) time series. In the three series examined, however, there was no evidence that the two-stage estimation procedure was required. Preintervention ACF's and PACF's were nearly identical to their postintervention counterparts. Parameter estimates from the noise model were changed little by the addition of the intervention component. A logarithmic transformation was made to each series because the natural logs displayed more spatial homogeneity.

Appropriate models for the 100-and-over hp two-wheel drive and the four-wheel drive tractor series were identified as ARIMA(0,1,2)(0,1,1)_12:

\[
N_t = \frac{(1 - \Theta_1 B - \Theta_2 B^2)(1 - \Theta_{12} B^{12}) \alpha_1}{(1 - B)(1 - B^{12})}
\]

Intercept terms were not used because they did not significantly differ from zero.

The noise model for the 40-99 hp two-wheel drive series was slightly more complicated and was identified as:

\[
N_t = \frac{(1 - \Theta_1 B - \Theta_2 B^2)(1 - \Theta_{12} B^{12} - \Theta_{20} B^{20}) \alpha_1}{(1 - B)(1 - B^{12})}
\]

Table 2 shows maximum-likelihood estimates and associated diagnostic statistics of the ARIMA models. The estimate of \( \Theta_1, \Theta_2, \Theta_{12}, \) and \( \Theta_{20} \) are all statistically significant and lie within the bounds of invertibility. Respective Q-statistics for each model are not statistically significant at the 95-percent level, indicating that the residuals of each model do not differ from white noise.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimated coefficients</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>Q-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-wheel drive, 40-99 hp</td>
<td></td>
<td></td>
<td></td>
<td>11.65</td>
</tr>
<tr>
<td>( \Theta_1 )</td>
<td>0.5633</td>
<td>0.0809</td>
<td>6.96</td>
<td></td>
</tr>
<tr>
<td>( \Theta_2 )</td>
<td>2.551</td>
<td>0.0813</td>
<td>31.44</td>
<td></td>
</tr>
<tr>
<td>( \Theta_{12} )</td>
<td>5.742</td>
<td>0.0804</td>
<td>7.14</td>
<td></td>
</tr>
<tr>
<td>( \Theta_{20} )</td>
<td>2.417</td>
<td>0.0825</td>
<td>2.93</td>
<td></td>
</tr>
<tr>
<td>Two-wheel drive, 100-and-over hp</td>
<td></td>
<td></td>
<td></td>
<td>14.40</td>
</tr>
<tr>
<td>( \Theta_1 )</td>
<td>5.849</td>
<td>0.0805</td>
<td>72.60</td>
<td></td>
</tr>
<tr>
<td>( \Theta_2 )</td>
<td>2.449</td>
<td>0.0816</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>( \Theta_{12} )</td>
<td>6.395</td>
<td>0.0778</td>
<td>8.22</td>
<td></td>
</tr>
<tr>
<td>Four-wheel drive</td>
<td></td>
<td></td>
<td></td>
<td>11.90</td>
</tr>
<tr>
<td>( \Theta_1 )</td>
<td>3.751</td>
<td>0.0826</td>
<td>4.54</td>
<td></td>
</tr>
<tr>
<td>( \Theta_2 )</td>
<td>2.128</td>
<td>0.0831</td>
<td>2.56</td>
<td></td>
</tr>
<tr>
<td>( \Theta_{12} )</td>
<td>6.655</td>
<td>0.0834</td>
<td>7.98</td>
<td></td>
</tr>
</tbody>
</table>

Blanks indicate not applicable.

1Value of Q-statistic based on 24 residual autocorrelations.
Estimating the Impact Model

The impact model is the sum of the intervention and noise components. The estimated impact model for the two series of larger tractors is

\[ y_t = \frac{\omega}{1 - \delta B} (1 - B) I_t + \frac{(1 - \Theta_1 B - \Theta_{12} B^{12} - \Theta_{20} B^{20})}{(1 - B) (1 - B^{12})} a_t \]

The estimated model for the small tractor series is

\[ y_t = \frac{\omega}{1 - \delta B} (1 - B) I_t + \frac{(1 - \Theta_1 B - \Theta_{12} B^{12} - \Theta_{20} B^{20})}{(1 - B) (1 - B^{12})} a_t \]

The impact model was estimated with the PIK impacts beginning in the first full month following the announcement, February 1983 (table 3). The 40-99 hp two-wheel drive series shows no observable PIK impact. T-statistics on both impact parameters show that the null hypothesis (no impact) cannot be rejected. The 100-and-over hp two-wheel drive series shows no evidence of an immediate impact. The rate-of-decay parameter exceeds the bounds of system stability, even though its t-statistic is large, it fails to suggest an impact. Again, a conclusion of no impact is warranted. The four-wheel drive series supports the hypothesis of an immediate, but not long-lived, impact. Both impact coefficients are significant at the 99-percent confidence level.

Month-to-month variability in all three series is so severe as to preclude identifying PIK impacts simply by visual inspection of the series or their transformations. Examining monthly inventory-to-purchase ratios, however, supports the PIK impacts shown statistically (7) This ratio jumped from 0.82 in January 1983 to 0.94 in February 1983 for four-wheel drive tractors. The jump was one of the largest 1-month changes in the history of the series. The ratio stayed at historically high levels throughout 1983, but by October had returned to levels comparable to the

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimated coefficients</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>Q-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two wheel drive, 40-99 hp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Theta_1 )</td>
<td>0.5620</td>
<td>0.0812</td>
<td>6.92</td>
<td>10.88</td>
</tr>
<tr>
<td>( \Theta_2 )</td>
<td>2459</td>
<td>815</td>
<td>3.02</td>
<td></td>
</tr>
<tr>
<td>( \Theta_{12} )</td>
<td>5670</td>
<td>613</td>
<td>7.01</td>
<td></td>
</tr>
<tr>
<td>( \Theta_{20} )</td>
<td>2343</td>
<td>856</td>
<td>2.74</td>
<td></td>
</tr>
<tr>
<td>( \omega )</td>
<td>0966</td>
<td>1121</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>( \delta )</td>
<td>0516</td>
<td>12069</td>
<td>04</td>
<td></td>
</tr>
<tr>
<td>Two wheel drive, 100-and-over hp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Theta_1 )</td>
<td>5703</td>
<td>0808</td>
<td>7.06</td>
<td></td>
</tr>
<tr>
<td>( \Theta_2 )</td>
<td>2598</td>
<td>823</td>
<td>3.16</td>
<td></td>
</tr>
<tr>
<td>( \Theta_{12} )</td>
<td>6657</td>
<td>771</td>
<td>8.64</td>
<td></td>
</tr>
<tr>
<td>( \omega )</td>
<td>-0021</td>
<td>0035</td>
<td>-22</td>
<td></td>
</tr>
<tr>
<td>( \delta )</td>
<td>-11279</td>
<td>585</td>
<td>-7.12</td>
<td></td>
</tr>
<tr>
<td>Four-wheel drive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Theta_1 )</td>
<td>4933</td>
<td>0648</td>
<td>4.76</td>
<td></td>
</tr>
<tr>
<td>( \Theta_2 )</td>
<td>1989</td>
<td>857</td>
<td>2.32</td>
<td></td>
</tr>
<tr>
<td>( \Theta_{12} )</td>
<td>6347</td>
<td>857</td>
<td>7.41</td>
<td></td>
</tr>
<tr>
<td>( \omega )</td>
<td>-5388</td>
<td>1883</td>
<td>-2.86</td>
<td></td>
</tr>
<tr>
<td>( \delta )</td>
<td>6369</td>
<td>2536</td>
<td>2.51</td>
<td></td>
</tr>
</tbody>
</table>

Blanks indicate not applicable

1Value of Q-statistic based on 24 residual autocorrelations
previous year The inventory-to-purchase ratio for other series showed no observable impacts

**Interpretation of Model Results**

Calculating PIK impacts on four-wheel drive sales would require nothing more than the impact parameter estimates, if the log transformation were not required The intervention component

\[ Y_t = y_t - N_t \]

can be rearranged as

\[ Y_t = \delta y_{t-1} + \omega(1-B)I_t \]

Prior to the intervention, this formulation results in

\[ Y_t = \delta(0) + \omega(0) = 0 \]

Applying this formulation to the postintervention series yields the following sequence

\[
\begin{align*}
Y_T &= \delta(0) + \omega - \omega \\
Y_{T+1} &= \delta(\omega) + \omega(0) = \delta \omega \\
Y_{T+2} &= \delta(\delta \omega) = \delta^2 \omega
\end{align*}
\]

where each postintervention effect is

\[ Y_{T+i} = \omega^{b-i} \quad i = 1, 2, \ldots \]

and

\[ \lim_{i \to \infty} Y_{T+i} = 0, \quad |\delta| < 1 \]

Using the log metric, however, amounts to estimating a model of the form

\[ \ln y_t = Y_t + \ln N_t \]

in which the intervention component represents the percentage difference between the series level and the level of the series in the absence of PIK Thus, estimating results in the raw metric requires exponentiating the full impact assessment model When the noise component is exponentiated, the additive shocks are converted into multiplicative shocks Using the noise component as a model of the preintervention process allows it to be used as a benchmark from which the PIK impacts can be measured The noise process represents the levels tractor sales might have reached without the PIK program The impact component of the model merely multiplies the existing process and

\[
\begin{align*}
\text{postintervention series level} &= \exp(\ln Y_t) \exp(\ln N_t) \\
\text{preintervention series level} &= \exp(\ln N_t)
\end{align*}
\]

\[ = \exp(\omega^b - 1) \quad i = 1, 2 \]

In this form, retrieving the impact in terms of the raw metric is accomplished once the noise process levels are established To calculate the raw metric noise process benchmark, we first exponentiated one-step-ahead full model conditional expectation forecasts (15) For notational purposes, let \( y_t(1) \) denote the forecast of \( y_{t+1} \) made in period \( t \), namely, the one-step-ahead forecast

Then, the one-step-ahead forecast error is

\[ a_t = [y_t - y_{t-1}(1)] \]

and the one-step-ahead minimum mean-square-error forecast is

\[ z_{t-1}(1) = \exp[y_{t-1}(1) + 0.5\sigma_{y_{t-1}}^2] \]

Finally, the impacts of the loss in unit sales are calculated as the noise model forecast minus the full model forecasts

\[ z_{T+1-i}(1) / \exp(\omega^b) - z_{T-1+i}(1) \quad i = 0, 1, 2, \ldots 9 \]

Table 4 shows these latter estimates

The mean absolute percentage error (MAPE) can be used to show that the intervention component makes the model's predictive ability return to its pre-1983 levels If one compares actual sales with one-step-ahead sales forecasts from the noise model, the MAPE in the period up to and including January 1983 is 17.4 percent The MAPE jumps to 23.6 percent for the 10 months from February to November 1983 Reestimating the model with the intervention component lowers the average error to 15.4 percent for the 10-month period affected directly by PIK

The results also show, as maintained earlier, one can distinguish between the impact of PIK and that of the drought The intervention model, estimated with monthly data, permits us to determine the source of the sharp drop in the sales of four-wheel drive tractors The 1983 drought hit the crop in July, the most critical month for temperature and moisture in the five Corn Belt States (22) The hot, dry weather resulted in the lowest average per-acre corn yield in the Nation since 1974
Table 4—Estimated loss in unit sales of four-wheel-drive tractors due to the Payment-in-Kind (PIK) program

<table>
<thead>
<tr>
<th>Month</th>
<th>Actual sales</th>
<th>Full model forecast</th>
<th>Projections without PIK</th>
<th>Sales loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit sales</td>
<td>Percent</td>
<td>Unit sales</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>193</td>
<td>192</td>
<td>330</td>
<td>41.7</td>
</tr>
<tr>
<td>March</td>
<td>389</td>
<td>356</td>
<td>502</td>
<td>29.0</td>
</tr>
<tr>
<td>April</td>
<td>393</td>
<td>534</td>
<td>665</td>
<td>19.6</td>
</tr>
<tr>
<td>May</td>
<td>416</td>
<td>334</td>
<td>384</td>
<td>13.0</td>
</tr>
<tr>
<td>June</td>
<td>462</td>
<td>392</td>
<td>429</td>
<td>8.5</td>
</tr>
<tr>
<td>July</td>
<td>361</td>
<td>402</td>
<td>426</td>
<td>5.5</td>
</tr>
<tr>
<td>August</td>
<td>286</td>
<td>324</td>
<td>336</td>
<td>3.5</td>
</tr>
<tr>
<td>September</td>
<td>506</td>
<td>421</td>
<td>431</td>
<td>2.3</td>
</tr>
<tr>
<td>October</td>
<td>777</td>
<td>689</td>
<td>698</td>
<td>1.4</td>
</tr>
<tr>
<td>November</td>
<td>459</td>
<td>445</td>
<td>449</td>
<td>0.9</td>
</tr>
<tr>
<td>Total</td>
<td>4,232</td>
<td>4,089</td>
<td>4,650</td>
<td>561</td>
</tr>
</tbody>
</table>

Blanks indicate not applicable

1 Source (9)

However, these estimates indicate that PIK’s impacts on sales of four-wheel drive tractors had already dropped to less than 6 percent by July. Furthermore, the 1983 wheat crop was not affected by the drought as record yields were recorded for hard red winter wheat in many areas of the Great Plains (29). We can infer from the timing of the drought and the decline in the effects of PIK that the PIK program was responsible for the estimated reduction in unit sales.

Table 4 shows the calculated effects of PIK on sales of four-wheel drive tractors. Actual sales appear with one-step-ahead forecasts from the full (no noise + intervention) model. The column showing percentage losses reveals what we anticipated: the initial effects diminish quickly so that within 10 months the impact is less than 1 percent. Converting the percentage losses into units and adding them to the one-step-ahead forecasts from the full model provides an estimate of the number of four-wheel drive tractors that could have been sold in the absence of the PIK program. Sales losses due to PIK are estimated at 561 units, or 12 percent of sales for the February through November 1983 period. We conclude that the 561 units represent lost sales rather than merely postponed sales. Had the PIK program altered only the timing of purchases, the post-intervention sales pattern would have differed from the observed pattern. Instead of returning to the pre-intervention pattern, a relatively higher pattern would have been observable. No such chance can be observed. Noise model parameters are almost insensitive to the addition of post-PIK observations.

An approximation of PIK’s dollar cost to the farm machinery industry (or, at least to the farm tractor portion of the industry) can be estimated. July 1984 prices of different-sized, but comparably equipped, farm tractors are available from Stark’s Off-Highway Ledger (17). These prices would likely approximate 1983 prices, as prices reported by USDA for 170-240 power take-off (PTO) or belt hp showed less than a 0.5-percent increase from June 1983 to June 1984 (32). USDA prices include larger two-wheel drive tractors, diluting the price changes for four-wheel drive tractors, but the absence of a significant price change indicates that list prices were changed little.

Discounting could take a variety of forms other than lower list prices. However, if major discounting would not have been in effect without PIK, then the list price provides an appropriate opportunity cost. Stark’s 1984 dealer prices for four-wheel drive tractors ranged from $70,300 to $83,900. List prices ranged from $91,250 to $108,900. Thus, a sales loss of 561 units translates into $51-$61 million in lost revenues, evaluated at list prices. These prices show a 29-30-percent markup from dealer to list price, suggesting a similar split in lost revenues to the farm tractor industry.

Conclusions

The effects of PIK on the farm machinery industry were modest, as other analysts forecast. However, the effects were not homogeneous throughout the industry. It is not surprising that the portion of the industry specializing in machinery used primarily for program crops was negatively affected. Sales of four-wheel drive tractors, already declining, fell by an estimated 561 units, or by revenues of $51-$61 million. Because the program effects on sales were transitory, disappearing within a year, we conclude that program-induced effects had few real long-term effects. For example, inventories of four-wheel drive tractors rose with the
announcement of PIK and remained at historically high levels, suggesting that employment in the farm machinery industry did not absorb the entire effect of reduced sales.

One reason for studying the impact of past policy changes is to better forecast impacts of future ones. Estimates of these policy impacts yield information applicable to future short-run policies. Because the PIK program was unexpected, one can capture its effects on the farm machinery industry by examining changes in a single variable. Had PIK been expected, other adjustments might have occurred, either in manufacturing levels or in sales incentives. Uncovering the effects of a better anticipated program would be more difficult. That is, properly timed sales incentives could maintain sales in the face of an acreage reduction program. Because some sales incentives might be offered to counteract program impacts, these incentives must be considered as transfers from sellers to buyers and, therefore, as real program effects. Such changes in relative prices are sometimes difficult to measure. Because program opportunity costs here are obvious, inferences about future policies are possible.

References


(9) Implement and Tractor Various issues.


(20) Agricultural Outlook May 1983

(21) Cotton Background for 1985 Farm Legislation, AIB-476 Sept. 1984

(22) Feed Situation and Outlook Report, Fds-290 Aug 1983

(23) Feed Situation and Outlook Report, Fds-299 Mar 1986

(24) History of Agricultural Price Support and Adjustment Programs, 1933-84, AIB-485 Dec 1984

(25) "An Initial Assessment of the Payment-in-Kind Program," Unnumbered report, Apr 1983

(26) Inputs Situation and Outlook Report, IOS-1 June 1983

(27) Oil Crops Situation and Outlook Report, OCS-1 May 1983


(30) Wheat Situation and Outlook Report, WS-266 Nov 1983


In Earlier Issues

Earlier Technology

Because of the computer's limited drum surface and its associated storage-capacity restrictions, a complete program for the solution of simultaneous equations using the limited-information method is not feasible. Certain areas of computation have been adapted to the machine thus far. At present, the best that can be hoped for is to continue to section off various phases of computation and link them into a program series similar to the one established for least squares.

Hyman Weingarten
Vol. 12, No. 1, Jan. 1960