Modeling Processor Market Power and the Incidence of Agricultural Policy: A Non-parametric Approach

Rachael E. Goodhue
Agricultural and Resource Economics
University of California, Davis
One Shields Avenue, Davis, CA USA 95616

Carlo Russo
Facoltà di Economia
University of Cassino
via S. Angelo - Località "Folcara"
03043 Cassino (FR) ITALY
russocar@unicas.it

Modeling Processor Market Power and the Incidence of Agricultural Policy: A Non-parametric Approach

This analysis examines the interactions between market power and agricultural policy in the U.S. wheat flour milling industry. It has two main objectives: to assess if the payments trigger a change in the underlying economic behavior of the milling industry, and to estimate if the spread between the price of wheat and the price of wheat flour is affected by the policy regime, all else equal. Results indicate that wheat millers alter their pricing behavior when the program is making payments and are able to extract a rent from government intervention. These findings are consistent with a static model of oligopsony power. Theory suggests that government payments reduce the elasticity of farmers' supply (Alston and James 2001). Consequently, the expectation is that, all else equal, the oligopsony mark-down is larger when the policy results in payments to farmers. In this context, deficiency payments can be used as a natural experiment for identifying millers' oligopsony power, similar to other policy measures (Ashenfelter and Sullivan 1987). Previous literature has tested for market power in the U.S. wheat flour milling industry (Brester and Goodwin 1993; Kim et al. 2001). Results have been mixed. However, these analyses did not take government policy into account.

Background: the U.S. Wheat Milling Industry

U.S. farmers harvested 2.1 billion bushels of wheat from 51 million acres in 2007. The total value of production including government payments was $13.7 billion (National Agricultural Statistics Service 2008). The milling industry displays a number of characteristics that are consistent with an ability to exercise market power at the national level. The 4-firm concentration ratio in the flour milling industry is reasonably high, and has increased over time. In 1974 the top four firms accounted for 34% of total milling capacity (Wilson 1995). In 1980, their share had increased slightly to 37%, further increasing to over 65% in 1991 (Brester and Goodwin 1993). More recent data regarding concentration are not available for the wheat flour industry alone; in 2007 the four-firm concentration ratio for the entire flour milling and malt manufacturing sector was 56.6% (IBISWorld 2007). Wheat is one of the major agricultural support program commodities, and government payments are a non-negligible share of farm income for wheat producers. For farms defined as primarily wheat producers, government payments were approximately 20% of average gross cash income in 2003 (Vocke, Allen, and Ali 2005). These numbers are quite dependent on the difference between the policy price set by the government and the market price; in 2007, average government payments equaled 5% of the market value of agricultural products sold for these farms (USDA 2007).

Some variant of a commodity loan program has been available to farmers since the 1930s. Under a loan program, a farmer pledges a specified quantity of wheat as collateral for a loan valued at that quantity multiplied by the loan price. Farmers can repay loans at the market price when it is lower. The resulting difference is referred to as a marketing loan gain. Alternatively, in some years the farmer could choose to receive a loan deficiency payment in lieu of an actual loan. The policy price on which these payments are calculated is the loan rate. The relevant market price is the "posted county price" set by the government, which reflects market conditions in a county by adjusting major market prices for transportation costs and temporary cost differences.

Methodology

The structure of the empirical test regarding the millers' margin is simple. Define Y as the millers' margin calculated as the difference between the price of a hundredweight of wheat products and the price of the equivalent quantity of wheat, d as a dummy variable defining the policy regime (d=1 if the policy's target price is above the procurement market price and d=0 otherwise), and X as a matrix of exogenous variables representing supply, demand and millers' marginal cost shifters. The null hypothesis

H_0: E($Y|X,d$=0) = E($Y|X,d$=1)

is tested versus the alternative hypothesis

H_1: E($Y|X,d$=0) < E($Y|X,d$=1),

where E($Y|X,d$) = $f(X,d)$ and f is a function linking the exogenous variables and the policy regime to the conditional mean of Y. Rejection of the null hypothesis is statistical evidence that, holding everything else constant, the millers' margin increases if the policy is binding. We interpret this result as a consequence of millers' oligopsony power.

We present a non-parametric approach that is able to compare the conditional expectations in the policy regimes even in the absence of information about the link function, and without imposing arbitrary exclusion restrictions in the matrix of the exogenous variables. Assume that the available information can be divided into two matrices: a $T{\times}S$ matrix of all observable exogenous variables (X) that may or may not affect millers' pricing behavior and a $T{\times}1$ vector representing the millers' margin (Y). The goal is to calculate the conditional mean of Y without knowing which variables in X are relevant and without knowing the function linking Y to X. This approach addresses the two problems separately using a two-step procedure (Russo 2008).

The first step uses a constrained sliced inverse regression (CIR) to identify the linear combination of the exogenous variables (the CIR factors) that are the best predictors for the millers' margin (Li 1991). We collect the largest possible matrix X and use CIR to collapse it into a small (and manageable) set of factors. The model uses Naik and Tsai's (2005) c approach, which enables the classification of the exogenous variables in the matrix X as possible shifters of demand, farmer supply, and/or processor non-wheat marginal costs ex ante, using economic theory. Formally, given q linear constraints of the form $A'\beta = 0$ (where **A** is the $S{\times}q$ constraint matrix), the constrained edr directions are given by the principal eigenvector of $(I\text{-}P)\mathrm{cov}\big[E(z\,|\,y)\big]$, where **P**=$\tilde{A}(\tilde{A}'\tilde{A})^{-1}\tilde{A}$ and $\tilde{A} = \Sigma_{xx}^{-1/2}A$. Here, the output of the CIR is dimension-reduced shifters (DRS) that are linear combinations of exogenous variables that summarize the effects of demand, supply and marginal cost shifters. The use of this dimension-reduction technique eliminates the need to use arbitrary exclusion restrictions and specify functional forms in the estimation of the conditional expectation.

The second step uses the CIR factors as the independent variables in non-parametric Nadaraya-Watson regressions (NW) in order to compare how the millers' margin changes with changes in the independent variables for years in which the policy resulted in payments to farmers to those for years when it did not (Nadaraya 1964; Watson 1964; Li and Chen 2007). The use of kernel estimators does not require imposing assumptions about the unknown linking function. Consequently, it is possible

to estimate the conditional means and variances of the millers' margins under the two policy regimes. A simple test on the equality of means allows us to establish if the two estimates are significantly different.

The logic of this approach is intuitive. The obvious methodological approach to estimating how the exogenous variables affect the margin without imposing specific function forms is to use non-parametric regression techniques. Yet if S, the number of possible exogenous regressors, is large, this approach is likely to suffer from the *curse of dimensionality*: adding extra dimensions to the regression space leads to an exponential increase in volume, which slows the rate of convergence of the estimator exponentially. In order to avoid this curse, the original variables are compressed into a smaller number of factors that are linear combinations of the variables using CIR.

The link function F_0 is estimated by regressing **Y** non-parametrically on the L linear combinations of **X** instead of on the S original variables. Using the consistent estimates of the βs (instead of the true values) in a kernel regression does not affect the first-order asymptotic properties of the estimator and the error term has the same order of magnitude (Chen and Smith 2010). The output from this step allows the examination of how shifts in the significant SIR and CIR factors affect the millers' margin in binding and non-binding policy years.

Data

The dataset contains information on wheat prices, flour prices, and other variables for 1974 to 2005. Data are deflated using the producer price index (base year 1982) provided by the Bureau of Labor Statistics. The prices of wheat and wheat flour are those reported in the USDA's *Wheat Yearbook* for two major wheat milling locations: Kansas City and Minneapolis. The price of wheat is reported in terms of the cost to produce a hundredweight of flour, and flour and byproduct prices are reported directly. The price margin is defined as the difference between the price of a hundredweight of flour and byproducts and the price of the wheat used to produce it. Table 1 reports descriptive statistics for these price series by market. The average real price margin was $2.14/cwt. of flour in Minneapolis and $2.10/cwt. in Kansas City.

Table 2 reports descriptive statistics for other variables. The data sources are the USDA, the Bureau of Labor Statistics, the Census Bureau, the Energy Information Agency, the University of Michigan, and the World Bank. Increases in the per-acre cost of fertilizer (FERT), agricultural fuel (FUEL) and hired agricultural labor (HLB) are predicted to shift farmer supply upward. The policy price (POL) is predicted to increase supply when the policy is binding. Increases in hourly manufacturing wages (RHW), the price of gas (GAS), the transportation price index (TPI), and the bank prime loan rate (IR) are predicted to shift processors' non-wheat marginal cost up. Demand is predicted to shift out as population (USPOP), per capita income (USINC), wheat weight (WGHT) and protein content (PRTN) (as proxies for quality), the share of the population that identifies as Caucasian (CAUC), and per capita income in Japan (JINC), the largest importer of U.S. wheat during the sample period, increase. A Kansas City dummy variable (KANS) is included in order to allow for any location-dependent effects.

The dataset includes a dummy variable identifying the years when the policy is binding (BIN); that is, years in which the policy price is higher than the market price. The

years in which the policy was binding are defined using USDA yearly average data. A binding year (BIN =1) is defined as one in which the average market price in that location is lower than the average "policy" price. The policy price is defined as the average yearly loan rate from 1996 on, and as the maximum of the average yearly loan rate reported by the USDA and the target prices of deficiency payments prior to 1996 (before this date all production was eligible for deficiency payments so the program provided the same incentives as the marketing loan program). Because both the policy and the market prices vary over the sample period, one does not expect, necessarily, that binding policy years correspond exactly to those years with lower market prices.

Results

Table 3 reports the results. It includes the constrained edr directions and the t-statistics for each coefficient on the exogenous variables in each DRS.[1] Overall, the CIR performs well. The signs of the coefficients match predictions. In the demand DRS, the U.S. population, Japanese per capita income, the share of the U.S. population identifying as Caucasian, and wheat weight have statistically significant coefficients with the predicted signs. The Kansas City dummy has a statistically significant positive coefficient. In the farmer supply DRS all three input costs have statistically significant coefficients with the predicted sign. In the miller marginal cost DRS, wheat weight and wheat protein content have statistically significant coefficients. The costs of non-wheat inputs have statistically significant, negative coefficients, as predicted. The Kansas City dummy has a statistically significant negative coefficient.

DRS and the policy regime.   The results allow us to examine the relationships between the three DRS and the policy regime. Figures 1 to 3 illustrate the distribution of the DRS over time, differentiating between binding and non-binding policy years. The figures show that there is a concentration of binding years before the 1996 policy reform, when the policy target price was relatively high. The binding policy years are not associated with particularly low or high realizations of the demand or marginal cost DRS. Realizations of the supply DRS tended to be lower in non-binding policy years.

Figures 1 to 3 each plot the realizations of a single DRS for binding and non-binding policy years. Thus, they do not address the possibility that binding policy years are characterized by interactions between the realizations of the DRSs that lead to low prices. Figures 4 and 5 examine this possibility. Figure 4 plots the policy regime against the demand and farm supply DRS. To fix ideas, years in which the demand DRS has a large realization and the supply DRS has a small realization appear in the bottom right-hand quadrant of the graph. In a partial equilibrium graph of a market these points would correspond to market outcomes with relatively high prices and low quantities. For a given realization of the demand DRS, as the supply DRS realization increases in a partial equilibrium depiction of the market the price will fall and the quantity produced and consumed will increase as the supply curve shifts out. If the target price was

---

[1] The signs of the coefficients in the farmer supply DRS are reversed relative to the conventional format of theoretical predictions in the table. This is simply an artifact of the sliced inverse regression approach and does not affect the economic interpretation of the relationship between the exogenous and the endogenous variables.

constant, then binding years should be associated with high realizations of the supply DRS for a given realization of the demand DRS. This pattern does not appear in Figure 4. Figure 5 plots annual values of the demand and marginal cost DRS. This figure does not demonstrate any predictable pattern between the relationship between the two DRS and whether or not the policy is binding. Consistent with Figures 1 to 3, Figures 4 and 5 indicate that high target prices are a more important determinant of the policy regime than market conditions are.

NW Non-parametric Estimation Results

The second step of the procedure uses the CIR DRS as regressors in a Nadaraya-Watson kernel estimator of the price margin with a cross-validation bandwidth. This step defines the link function and allows us to compute the conditional mean of the millers' margin.

CIR DRS. Figures 6 to 8 plot how the reduced-form demand, processor marginal cost, and wheat supply DRS affect the flour-wheat price margin. Figure 6 addresses demand. The estimated magnitude of the price margin depends on program status. For any given value of the demand DRS, the flour-wheat price margin is larger when the program is binding than when it is not. For both the binding and non-binding policy regimes the margin first increases with the demand DRS, then decreases. In both cases the absolute values of the changes are small.

Figure 7 evaluates the effect of processors' marginal cost on the price margin. In the middle of the range, the price margin is higher for a given realization of the marginal cost DRS when the policy is binding but the opposite is true on the extremes. When the policy is binding the price margin is virtually constant across values of the marginal cost DRS. When it is not, the price margin first declines as input prices decline and quantity increases, then increases. Thus, for low realizations of the marginal cost DRS when the policy is not binding, the result is consistent with Brorsen et al. (1985), who found that an increase in milling costs increases the flour-wheat price margin on a one-for-one basis. However, for high realizations of the marginal cost DRS when the policy is not binding and for all realizations when it is binding the outcome is not consistent with Brorsen et al. (1985). The results are consistent with the possibility that a change in policy regime triggers a change in pricing behavior. For years when the policy is binding, millers appear to absorb as least as large of a share of a marginal cost increase as they do in years when the policy is not binding.

Figure 8 evaluates the effect of farmers' DRS of wheat supply on the price margin. As supply shifts out, the price margin first increases and then decreases in years when the policy is binding. In years when payments are not made the price margin follows the same general pattern, although it is much less responsive to changes in the supply DRS. These policy-dependent relationships between supply and the price margin suggest that millers' strategies differ depending on whether or not the policy is binding. The model generates a conditional expectation of the millers' margin of $2.02 per hundredweight of wheat when the policy is not binding and $2.25 when it is binding. The $0.23 per hundred-weight difference is statistically significant, with a t-statistic of 2.5701 obtained via bootstrapping.

Overall, the analysis of the patterns obtained from the CIR-NW algorithm suggests that the data are consistent with a simple static model of market power. The

figures suggest that millers are able to impose higher price margins in years in which the policy is binding. When payments are made, farmers respond to the target price, and are less likely to store their grain and wait for a higher price to be offered by buyers. This circumstance allows millers to exploit market power and reduce the price of wheat relative to the price of flour.

Conclusion

As a sector, agriculture is subject to a great deal of government intervention. Although expenditures have declined substantially in the past decade due in part to international trade negotiations, in the last three years Commodity Credit Corporation net outlays for wheat commodity programs have ranged between $0.7 and $1.2 billion (USDA 2010). Given the magnitude of these expenditures, there is an obvious public interest in efficient policy measures.

This analysis demonstrates that market power might redistribute the benefits of government intervention. It provides empirical evidence that U.S. wheat millers were able to increase their marketing margins on average by approximately 10 percent when farmers received payments through a marketing loan program. This expected increase in margins was computed controlling for the realizations of a broad set of supply, demand and processor marginal costs shifters in those years. In turn, these findings suggest that millers are extracting a rent from the deficiency payment/marketing loan gain policy. Thus, the analysis suggests that the general assumption that competitive models may be a good approximation for imperfectly competitive agricultural markets does not necessarily hold, particularly if distribution, as well as efficiency, is a concern.

References

Alston, J. and J. James. 2001. "The Incidence of Agricultural Policy." In B. Gardner and G. Rausser (editors), *Handbook of Agricultural Economics*, Elsevier North-Holland, New York: 1690-1749.

Ashenfelter O, and D. Sullivan. 1987. "Nonparametric Tests of Market Structure: An Application to the Cigarette Industry". *Journal of Industrial Economics* 35: 483-499.

Brester, G.W. 1999. "Vertical Integration of Production Agriculture into Value-added Niche Markets: the Case of Wheat Montana Farms and Bakery." *Review of Agricultural Economics* 21(1):276-285.

Brester, G.W. and B.K. Goodwin. 1993. "Vertical and Horizontal Price Linkages and Market Concentration in the U.S. Wheat Milling Industry." *Review of Agricultural Economics* 15(3):507-519.

Brorsen, W., J.-P. Chavas, W.R. Grant, and L.D. Schnake. 1985. "Marketing Margins and Price Uncertainty: the Case of the U.S. Wheat Market." *American Journal of Agricultural Economics* 67(3):521-528.

Chen, C. H. and K. C. Li. 1998. "Can SIR Be as Popular as Multiple Linear Regression?" *Statistica Sinica* 8:289-316.

Chen, P. and A. Smith. 2010. "Dimension Reduction Using Inverse Regression and Nonparametric Factors with an Application to Stock Returns." Working paper, University of California, Davis.

IBISWorld. 2007. "Flour Milling and Malt Manufacturing in the U.S." IBISWorld Industry Report No. 31121. September 19.

Kim, C.S., C. Hallahan, G. Schaible, and G. Schluter. 2001. "Economic Analysis of the Changing Structure of the U.S. Flour Milling Industry." *Agribusiness* 17:161-171.

Li, K.-C. 1991. "Sliced Inverse Regression for Dimension Reduction." *Journal of the American Statistical Association* 86(414): 316-327.

Naik, P.A. and C.L. Tsai. 2005. "Constrained Inverse Regression for Incorporating Prior Information." *Journal of the American Statistical Association* 100:204-211.

Nadaraya, E. 1964. "On Estimating Regression." *Theory of Probability and its Applications* 9(1):141-142.

National Agricultural Statistics Service. 2008. *Agricultural Statistics 2008*. United States Department of Agriculture. Government Pricing Office, Washington DC. Available at http://www.nass.usda.gov/Publications/Ag_Statistics/2008/2008.pdf.

National Agricultural Statistics Service. 2010. *Quick Stats*. Available at http://quickstats.nass.usda.gov/.

Russo, C. 2008. Modeling and Measuring the Structure of the Agrifood Chain: Market Power, Policy Incidence and Cooperative Efficiency. University of California Davis. Ph.D. dissertation.

Stiegert, K. 2002. "The Producer, the Baker, and a Test of the Mill Price-taker." *Applied Economics Letters* 9(6):365-368.

United States Department of Agriculture. 2007. Agricultural Census. Available at http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Custom_Summaries/Data_Comparison_Major_Crops.pdf.

United States Department of Agriculture. 2010. *Agricultural Outlook* available at http://www.ers.usda.gov/publications/ agoutlook/aotables/.

United States Department of Agriculture. 2009. "Wheat: Policy." Available at http://www.ers.usda.gov/Briefing/Wheat/Policy.htm#marketingalaldp.

Vocke, G., E.W. Allen, and M. Ali. 2005. "Wheat Backgrounder." Report WHS-05k-01, Economic Research Service, United States Department of Agriculture. December. 29 p.

Watson G.S. 1964. "Smooth Regression Analysis." *Sankhyā: The Indian Journal of Statistics, Series A* 26:359-372.

Wilson, W.W. 1995. "Structural Changes and Strategies in the North American Flour Milling Industry." Agribusiness 11(5):431-439.

Table 1: Descriptive Statistics:
Real Prices for Wheat and Wheat Products by Location, 1974-2005

	Wheat Price		Wheat Products Price		Price Margin	
	Minneapolis	Kansas City	Minneapolis	Kansas City	Minneapolis	Kansas City
Mean	9.30	8.87	11.44	10.98	2.14	2.10
Std. Dev.	1.57	1.51	1.64	1.43	0.49	0.24
N. Obs.	32	32	32	32	32	32

Source: USDA Wheat Yearbook 2006

Table 2: Descriptive Statistics: Explanatory Variables, 1974-2005.

Variable	Definition	mean	min	max	std. dev.
FERT	Cost of fertilizer (real $/acre)	16.0	9.3	23.0	3.0
FUEL	Cost of agr. fuel (real $/acre)	8.4	5.1	14.3	2.1
HLB	Cost of hired labor (real $/hour)	3.1	1.9	5.3	0.9
POL	Policy price (real $/cwt. flour)	9.6	6.0	13.5	2.2
RHW	Industry wages (real $/hour)	15.3	14.7	16.3	0.5
GAS	Gas price (real $)	112.2	76.4	193.7	25.9
TPI	Transportation price index	114.3	45.8	173.9	35.5
IR	Bank prime loan rate (%)	9.0	4.1	18.9	3.2
USPOP	U.S. population (millions)	251.9	213.3	293.9	25.3
USINC	U.S. per capita income (real $)	4.1	1.1	9.5	2.6
WGHT	Wheat weight (pounds/bushel)	60.4	58.4	61.6	0.7
PRTN	Wheat protein content (%)	12.1	11.2	13.4	0.6
CAUC	Caucasian share of population (%)	0.8	0.8	0.9	0.0
JINC	Japan per capita income (real $)	90.6	56.7	103.8	13.3

Table 3. Results: Constrained Inverse Regression

	Dimension Reduced Demand Shifter		Dimension Reduced Supply Shifter		Dimension Reduced Marginal Cost Shifter	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
FERT	0.00		0.22	3.81 *	0.00	
FUEL	0.00		0.14	3.35 *	0.00	
HLB	0.00		0.71	7.02 *	0.00	
POL	0.00		-0.17	-0.59	0.00	
RHW	0.00		0.00		-0.88	-3.46 *
GAS	0.00		0.00		-0.28	-3.28 *
TPI	0.00		0.00		-0.79	-3.92 *
IR	0.00		0.00		-0.48	-2.82 *
USPOP	0.03	3.16 *	0.00		0.00	
USINC	0.03	0.30	0.00		0.00	
WGHT	1.96	9.95 *	0.00		0.85	5.16 *
PRTN	-0.18	-0.74	0.00		-0.63	-3.82 *
CAUC	167.78	12.32 *	0.00		0.00	
JINC	0.19	20.49 *	0.00		0.00	
KANS	0.95	3.79	-0.43	-1.67	-1.04	-5.19 *

* Significant at 5% level

**Figure 1. Realizations of the CIR demand dimension-reduced shifter:
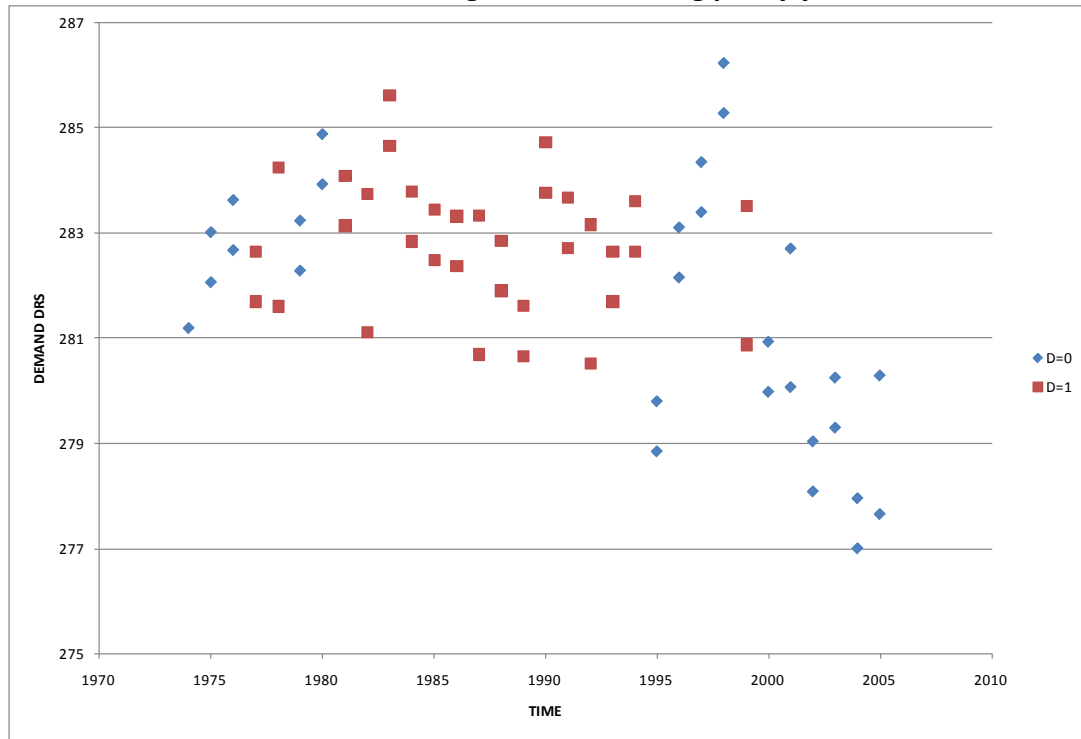1974-2005, binding and non-binding policy years**

**Figure 2. Realizations of the CIR wheat supply dimension-reduced shifter:
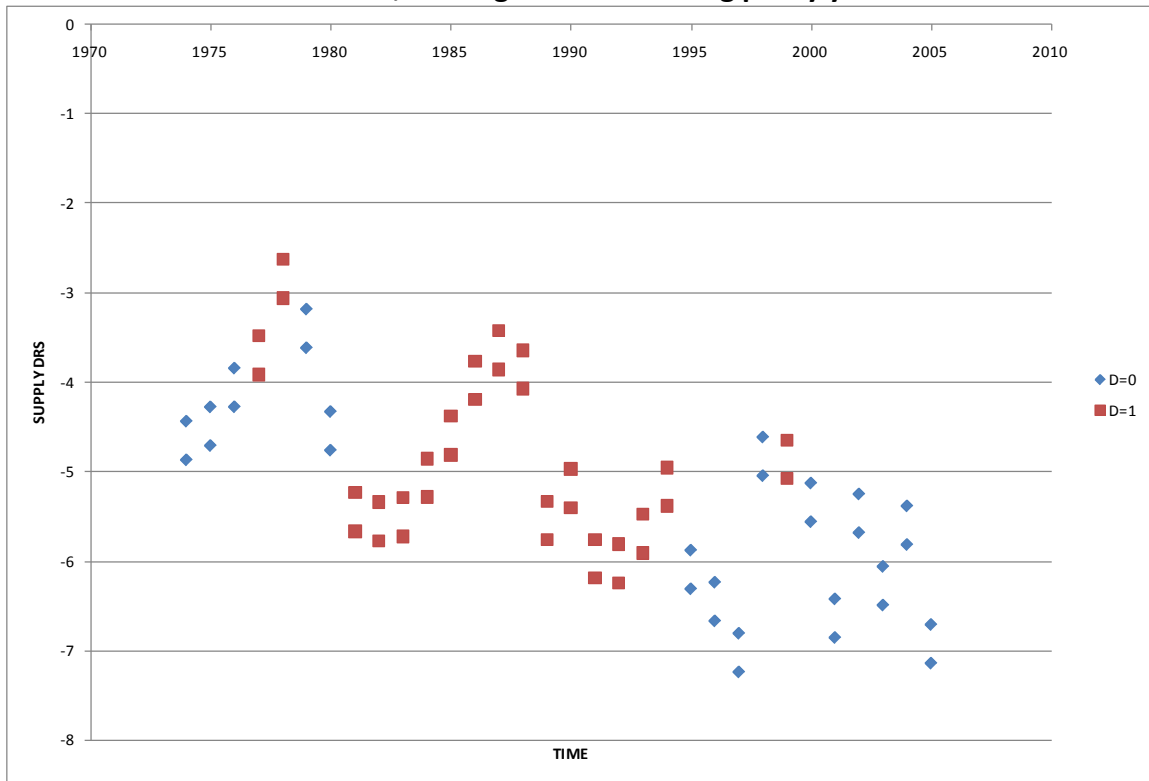1974-2005, binding and non-binding policy years**

Figure 3. Realizations of the CIR processor non-wheat marginal cost dimension-reduced shifter: 1974-2005, binding and non-binding policy years
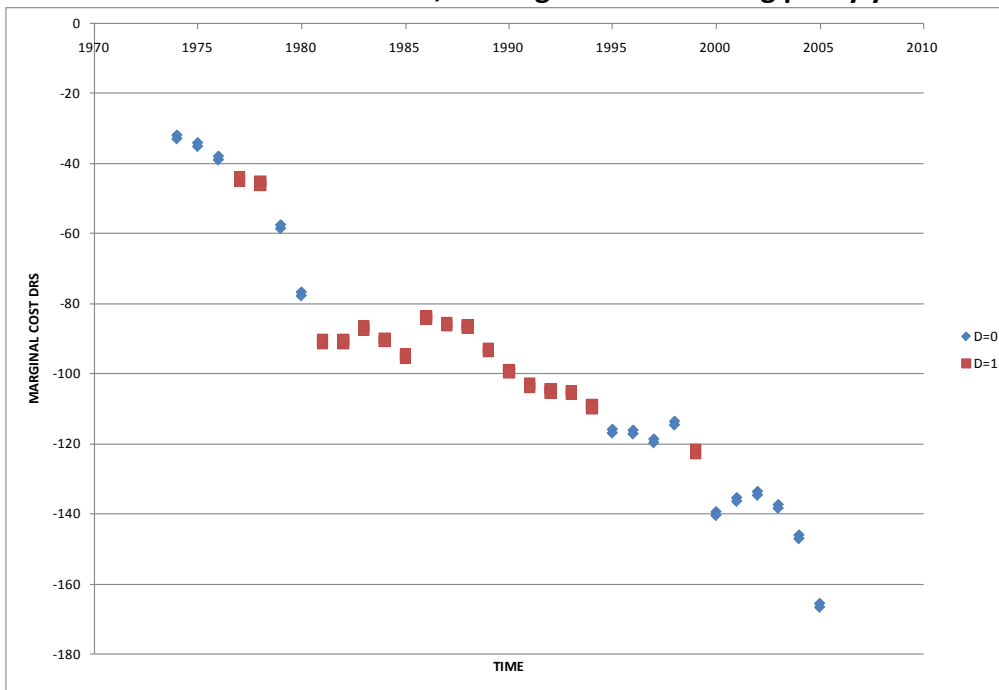

Figure 4. CIR: policy regime and demand and supply DRS: binding and non-binding policy years
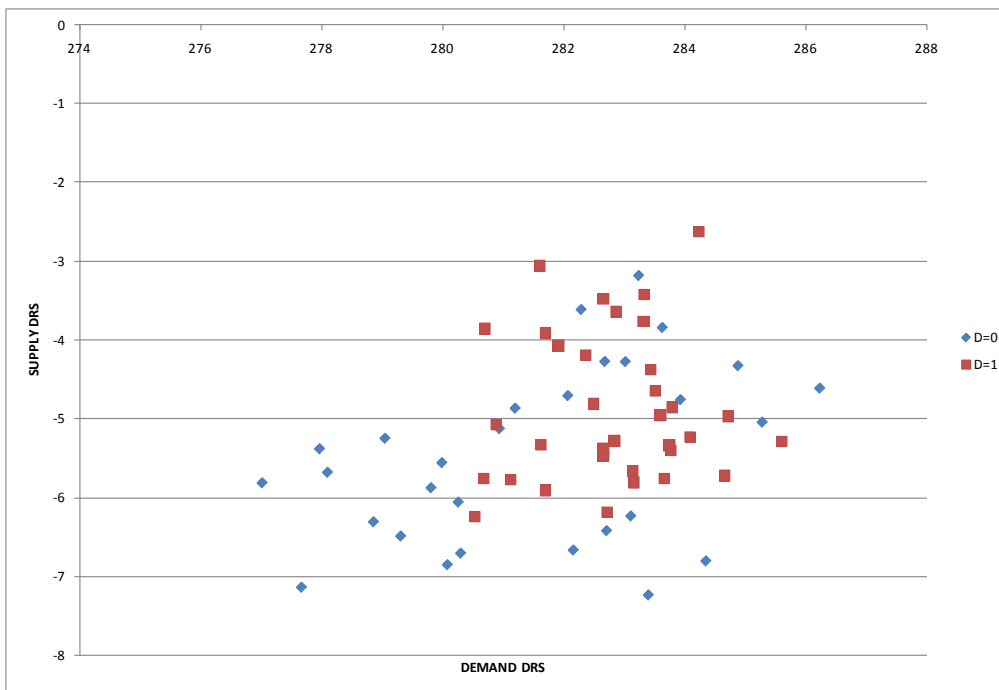
Figure 5. CIR: policy regime and demand and marginal cost DRS: binding and non-binding policy years
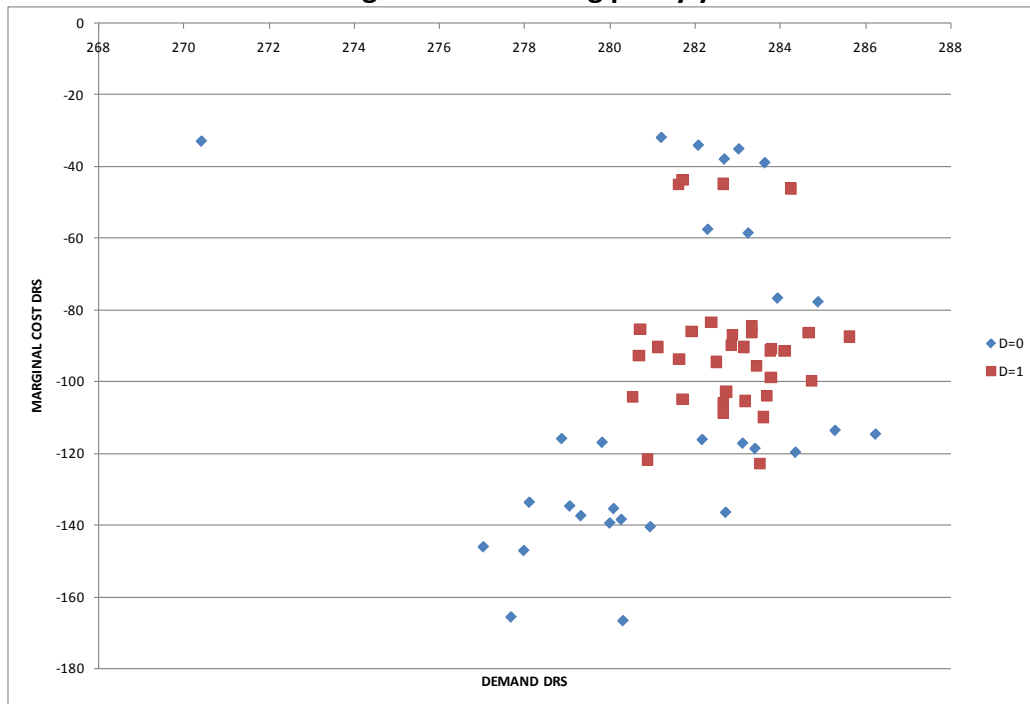

Figure 6. N-W Non-parametric estimation of the relationship between the flour price-wheat price margin (PM) and the DRS for demand
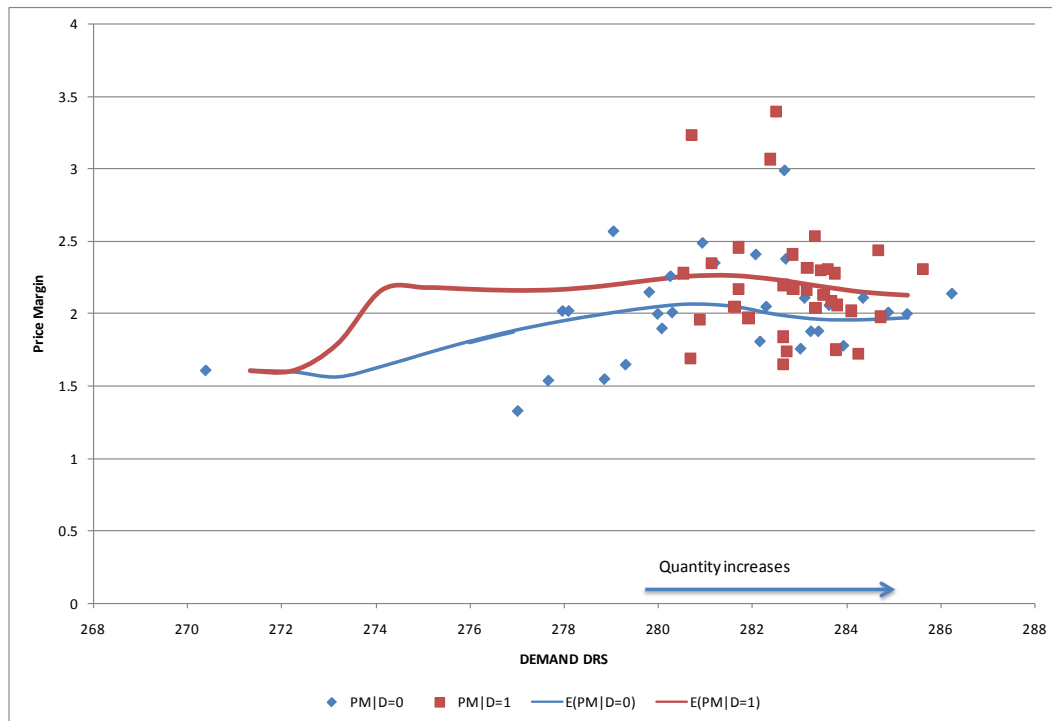
Figure 7. N-W non-parametric estimation of the relationship between the flour -wheat price margin and the DRS for processor marginal cost
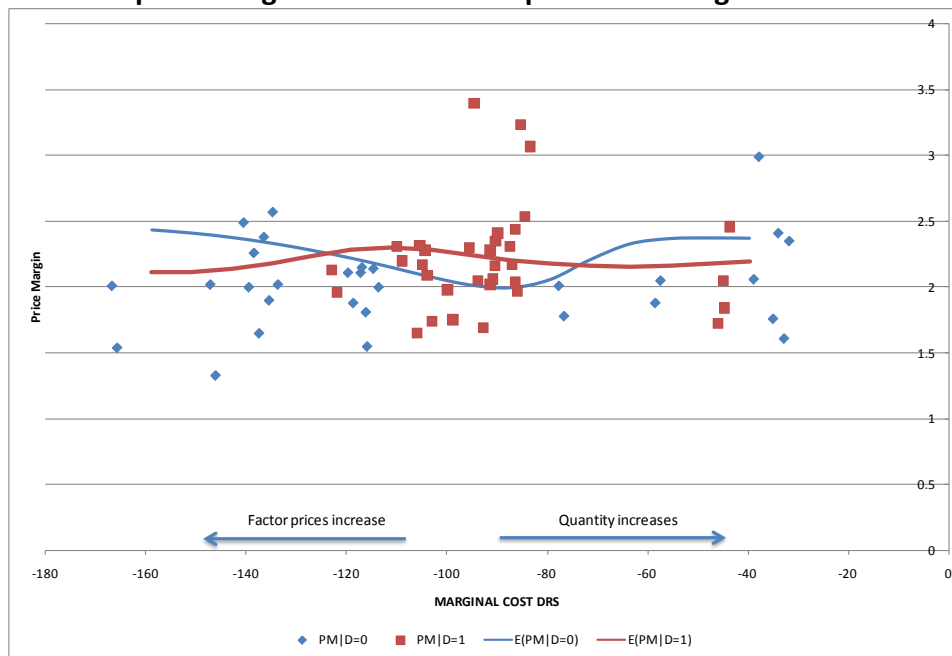

Figure 8. N-W non-parametric estimation of the relationship between the flour price-wheat price margin and the DRS for wheat supply