Modeling Processor Market Power and the Incidence of Agricultural Policy: An Exploratory Approach to the Behavioral Model Selection Problem

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Johnson (1979) identified six justifications for government policy, including agricultural policy. One of these was the provision of a stable minimum level of income commensurate with that of other groups in society. Equally classic analyses of the incidence of agricultural subsidies have focused on comparing the deadweight loss across policies, given the amount of income transferred to farmers (e.g., Wallace 1962; Gardner 1983). For the most part, these policy analyses have assumed that agricultural markets are competitive enough that any market power on the part of processors can be safely assumed away and the market treated as perfectly competitive (Rude and Meilke 2004). Given this assumption, the assessment of the cost of a particular support policy depends only on its deadweight loss and the size of the transfer to farmers. Russo, Goodhue and Sexton (2009), however, demonstrate theoretically that even small degrees of market power can enable processors to extract a considerable share of policy rents.

The reliance on the perfectly competitive framework for analyzing policy incidence is interesting from a historical perspective. Reducing the exercise of market power in order to increase economic efficiency was among Johnson's other justifications for agricultural support policies. The economic history of agriculture suggests that it would be appropriate to address processor market power when analyzing government support policies. Farmer protests against the exercise of market power by other parties predate the major agricultural support programs developed in the 1930s; for example, the Grange and Populist movements in the nineteenth century were driven in part by farmers' protests regarding their perceptions of the exercise of market power against them in transportation and procurement (Stewart 2008). This earlier movement resulted in the Interstate Commerce Act of 1887. The Capper-Volstead Act of 1922, which exempted

farmer cooperatives from antitrust regulations, was designed to enable farmers to organize collectively in order to exercise countervailing market power against buyers.

Assuming perfect competition when analyzing policy incidence has important implications for current policy debates. The decoupling of agricultural subsidies from production in the U.S. and E.U. has been a focus of agricultural trade negotiations, due to its perceived welfare-improving effects domestically and internationally. The vast majority of the economic analyses supporting decoupling have relied on the assumption that models of perfect competition may be used to analyze policy impacts. In the presence of market power, domestic social welfare may actually decline as a result of decoupling. Clearly the sign and magnitude of the effects will depend on the degree and nature of market power. In particular, processors and other intermediaries may exercise oligopoly power, oligopsony power, or both.

We examine the interactions between market power and agricultural policy in the U.S. wheat flour milling industry. Our empirical analysis 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, holding everything else constant. We find that wheat miller alter their pricing behavior when the program is making payments, and that they are able to extract a rent from government intervention. Results are consistent with a collusion-maintaining price war model of millers' strategic behavior. In addition, millers alter their behavior in response to differences in political constraints.

Previous literature has tested for market power in the U.S. wheat flour milling industry. Brester and Goodwin (1993) found that the degree of cointegration of the price

time series over space and across the vertical wheat chain was negatively correlated with the CR4 index and argued that the increase in concentration was lessening competition. However the authors note that “the price series remain highly cointegrated”, supporting the notion that the industry might in fact still be competitive. Kim et al. (2001) used a Poisson regression model to investigate the change in the industry structure and found evidence of oligopoly with price leadership. Stiegert (2002) tested for upstream and downstream market power in the US hard wheat milling industry and found that the null hypothesis of perfect competition could not be rejected. These analyses do not take into account the possibility of interactions between government support policies and the exercise of market power in the wheat market. Russo, Goodhue and Sexton (2009) did so using a standard NEIO approach. They estimated that processors distorted the wheat price downward by approximately 17% during years in which payments were made to farmers. This suggests that market power should be considered when analyzing the incidence of agricultural policies or designing new agricultural policies.

Like other NEIO analyses, the test for market power in Russo, Goodhue and Sexton (2009) is, implicitly, a joint test regarding market power and the functional forms specified in the empirical model (Genesove and Mullin 1998). Consequently, the estimation is vulnerable to misspecification of cost, supply and demand relationships (e.g. Perloff, Karp and Golan 2007). Furthermore, the standard NEIO analysis leaves many questions regarding industry behavior and its impacts unanswered. When economic agents are strategic players, are market power parameters sufficient for describing their behavior? Theory suggests that this is not necessarily the case (e.g., Makowski 1987). Although the so-called ‘agnostic’ interpretation of the NEIO is an effort to avoid this

criticism, misspecification of the economic game can still lead to biased estimation. Often strategies may be more complex than simple Cournot strategies or may vary over time, such as collusion-sustaining price wars in oligopolies or oligopsonies (e.g., Green and Porter 1984). In such cases, the NEIO estimator is fundamentally biased (Corts 1999). Econometric models must capture the fundamental features of industry behavior in order to avoid bias (Kim and Knittel 2004). In the case of government intervention in agriculture, one important consideration that is omitted is the possibility that agents' strategic behavior may depend on the policy regime; this fact could result in complex, time-varying strategies that cannot be captured fully by NEIO estimators.

We utilize non-parametric techniques to characterize the pricing behavior of the wheat milling industry without introducing a priori assumptions about the nature of the economic game governing processors' conduct and without specifying functional forms. If processors react to exogenous shocks in different ways when a policy is in effect than when it is not, then we postulate a change in strategic behavior. Moreover, if – controlling for the exogenous shifters – the price margin under the policy regime is larger, we conclude that the millers are acting strategically to extract a rent from the policy at taxpayers' expense. We use our non-parametric results to develop a structural model that incorporates critical features of industry behavior and as independent variables for estimating it.

There are two steps to our non-parametric approach. In the first step, we use a sliced inverse regression (SIR) technique to reduce the number of exogenous variables used to estimate the effect of exogenous shifters for flour demand, wheat supply, and processor non-wheat marginal cost on the flour-wheat price margin (Li 1991). In the

second step we use the dimension-reduced shifters (DRS) obtained in the first step as the independent variables in non-parametric Nadaraya-Watson regressions (NW) in order to compare how the flour-wheat price margin changes with changes in the DRS for years in which the policy resulted in payments to farmer to those for years when it did not (Nadaraya 1964; Watson 1964).

The difference between the existing approaches to empirical analysis of industry behavior and our exploratory approach is evident. The existing literature is based on an inductive approach: the selection of the economic model is made before the empirical analysis and this choice guides the estimation. Our methodology is deductive: the estimation is performed before the selection of the theoretical model, and the model specification is based on the empirical findings. Consequently, our methodology is much more data-driven than a standard NEIO approach.

The SIR-NW approach is particularly useful when the researcher has no prior information about the underlying economic behavior or is not confident in the quality of the information available. Given the wide range of behavioral models offered by economic theory, our approach allows analysts to obtain additional information regarding which models are most likely to be appropriate prior to undertaking structural estimation.

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). Wheat production is concentrated geographically; the three major production regions are the southern Great Plains (Kansas and Oklahoma,

primarily) the northern Great Plains (Montana and the Dakotas), and the Northwest (primarily southeastern Washington). Flour milling is the primary domestic use of wheat, although some is also used for livestock feed and other purposes. The milling process generates both flour and byproducts. Byproducts account for approximately 10% of the revenue from flour milling (Brester and Goodwin 1993).

The milling industry displays a number of characteristics that are consistent with an ability to exercise market power. The 4-firm concentration ratio is 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). Three of these large firms are large multi-commodity agrofood firms: ADM, ConAgra and Cargill compete with each other across a number of markets, which potentially could strengthen their ability to collude. These firms have increased their share of the number of plants operated from 14% in 1974 to almost two-thirds in 1992 (Wilson 1995). Between 1974 and 1990 the number of mills declines by a quarter and the average plant capacity almost doubled (Wilson 1995). More recent data 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%, and wheat flour milling accounted for 60% of the sector (IBISWorld 2007). According to that source, concentration had continued to increase in the years prior to 2007.

There has been no consistent trend in per capita wheat consumption over the past forty years. Between the mid-1970s and 1997, per capita wheat consumption increased. There are a number of factors that may have contributed to this increase, including

increased consumption of meals away from home, increased awareness of the health benefits of eating grain-based foods, and the promotion of wheat products by industry organizations (Vocke, Allen and Ali 2005; Brester 1999). Even though consumption per capita increased between 1980 and 1997, wheat's share of total per capita grain consumption declined. Since 1997, per capita wheat consumption has declined, due in part to a new technology for extended shelf life bread that has reduced the share of unsold bread, and due in part to an increased interest in low-carbohydrate diets (Vocke, Allen and Ali 2005). Another factor in wheat's diminished share of total grain consumption has been increased consumer interest in eating a variety of grain products, driven in part by an increasingly diverse population (Putnam and Allshouse 1999).

Wheat is one of the major agricultural support program commodities. For farms characterized as primarily wheat producers, government payments were approximately 20% of average gross cash income in 2003. Government payments to other wheat-producing farms were about 8% of average gross cash income (Vocke, Allen and Ali 2005). These numbers are quite dependent on the target price set by the government relative to the market price; in 2007, average government payments equaled 5% of the market value of agricultural products sold for farms characterized as primarily wheat producers (United States Department of Agriculture 2007).

U.S. farm policy is governed primarily by federal "farm bills" legislated every few years. Wheat producers were eligible for three basic types of program payments during our period of study (1974-2005), although implementation details differed. Beginning with the 1985 farm bill, direct and counter-cyclical payments were restricted to a share of production defined by base acres and base yields. Direct payments are not

linked to market conditions while counter-cyclical payments do depend on season average market prices. Federal commodity loan and marketing loan programs are the source of the third type of payment. Historically, these programs were intended to promote orderly marketing by providing farmers with income at harvest time that enabled them to repay operating loans without forcing them to sell their crops. Because farmers could wait to market their production, harvest time prices would not be depressed by credit-driven sales. In addition to promoting orderly marketing, loan programs have become an important source of farm income support in years with low marketing prices.

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 of wheat multiplied by the loan price. Farmers can choose to repay loans at the market price, rather than the loan price, when the market price is lower. Depending on the year, repayment could occur via forfeiting the actual physical product (a nonrecourse loan) and/or redeeming commodity certificates, as well as through an exchange of funds. The resulting difference in price is referred to as a marketing loan gain. Alternatively, for some years in our sample the farmer could choose to receive a loan deficiency payment in lieu of an actual loan. The policy price on which loan deficiency payments and marketing loan gain payments are calculated is the loan rate. The relevant market price for loan repayments is the “posted county price” set daily by the government. It is intended to reflect market conditions in a county by adjusting major market prices for transportation costs and temporary cost differences. Farmers can lock in the loan rate as the price for their production by choosing to repay their loan at the posted county price rather than the loan rate, resulting in a marketing

loan gain, or by requesting a loan deficiency payment in the amount of the difference between the two prices on a given day.

We focus on loan deficiency payments and marketing loan gains for three reasons. First, some variant of this program has been available to producers throughout the study period. Second, there has been no change in the share of production eligible for at least one of these payments. Finally, whether or not farmers receive payments is linked to the market price via the posted county price.

Empirical methodology

We wish to analyze the determinants of the flour-wheat price margin in the U.S. wheat milling industry without imposing any specific assumptions regarding the firms' behavior or functional forms for important relationships. We observe a set of variables that may or may not affect the pricing behavior of the industry and divide the available information at time t into two matrices: a $T \times S$ matrix of exogenous variables ($\boldsymbol{X}$) representing the shifters of demand, supply and marginal cost of processing, and a $T \times 1$ matrix of endogenous variables ($\boldsymbol{Y}$) representing the price margin. Using a two-step approach, which we refer to as the SIR-NW algorithm, we identify the effects of these variables on the price margin.

The intuition behind our two-stage approach is simple. 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 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, we compress the original set of variables into a smaller number of factors that are linear combinations of the variables using SIR (Li 1991). Chen and Smith (2007) showed that these factors can be used as non-parametric regressors, as we do when we use a Nadaraya –Watson (NW) estimation, procedure y in the second step of our approach.

Importantly, the use of SIR factors in the second-stage regression does not prevent us from linking the pricing behavior of the milling industry to the original *S* exogenous variables. The SIR factors are linear combinations of the original variables. The coefficients are estimated by decomposing the consistent estimator of $\boldsymbol{M}$, the variance-covariance matrix of $E(\boldsymbol{X}|\boldsymbol{Y})$. Accordingly, we can compute and directly interpret the coefficients for the original variables, and their significance can be tested (Chen and Li 1998). Thus, there is no need to impose a priori exclusion restrictions on $\boldsymbol{X}$ because the non-parametric estimation can control for a large number of variables.

More formally, the SIR-NW algorithm is implemented in two steps. The first step identifies the SIR factors. The second step describes the function linking the factors to the price spread using a Nadaraya-Watson regression. Each step provides information regarding the pricing behavior of the wheat milling industry.

Step 1: Dimension reduction and identification of the relevant SIR factors. Let $\boldsymbol{X}$ be the matrix including all observable exogenous variables and $\boldsymbol{H}$ be an unknown subset of $\boldsymbol{X}$ that includes the explanatory variables of the true data-generating process. If, in the absence of reliable information about $\boldsymbol{H}$, the econometrician uses all of the variables in $\boldsymbol{X}$

as regressors, then the result will be inefficient because of the inclusion of irrelevant variables.

The SIR approach is based on the premise that a relatively small number of linear combinations of $\boldsymbol{X}$ can identify the matrix $\boldsymbol{H}$. That is, it is possible to capture the information that is relevant for the estimation of $\boldsymbol{Y}$ using a small number of factors constructed from the variables in the initial dataset. Following Li (1991), we write the estimation equation as:

$$\boldsymbol{Y}=F_0(\boldsymbol{X}\boldsymbol{\beta}, e) \tag{1}$$

where β is an $S\times L$ matrix of unknown parameters. The identification is based on the tests for the number of SIR factors and for exclusion restrictions on the $\boldsymbol{\beta}$s. The number of these factors is at most equal to the number of the variables obtained from the test for exclusion restrictions. The L column vectors of $\boldsymbol{\beta}$ are known as the "efficient dimension reduction" (edr) directions, the linear combinations of $\boldsymbol{X}$ are called inverse regression covariates, and F_0 is the link function. In practice, the estimation equation is usually represented in the form:

$$y_t = F_0\left(\beta_1' x_t, \beta_2' x_t, ..., \beta_k' x_t, e\right), \tag{2}$$

where y_t and x_t are the row vectors of $\boldsymbol{Y}$ and $\boldsymbol{X}$, respectively, and the β_is are the L column vectors of $\boldsymbol{\beta}$ (for convenience, we will drop the subscript t from x_t and y_t.) Defining z as the row vectors of the matrix $Z = \Sigma_{xx}^{-1/2}\left[x - E(x)\right]$, where $\Sigma_{xx}^{-1/2}$ is the variance-covariance matrix of $\boldsymbol{X}$, yields:

$$y = F_0\left(\eta_1' z, \eta_2' z, ..., \eta_k' z, e\right).$$

The covariance matrix of $E(z|p)$ is degenerate in any direction orthogonal to $(\eta_1, \eta_2, \ldots, \eta_L)$ because a movement of p in that direction will not affect the expected value of z (Li 1991). Consequently, the covariates can be reduced to an L dimension space ($L \leq S$) without losing information. The ηs are the eigenvectors associated with the L non-zero eigenvalues of the variance-covariance matrix of $E(z|y)$, so the edr directions can be found by re-scaling the ηs, i.e. $\beta_k = \Sigma_{xx}^{-1/2}\eta_k$.

Li (1991) provides a five-step algorithm (the sliced inverse regression) for obtaining consistent estimates of the βs and $\mathrm{cov}\left[E(z|y)\right]$. After standardizing $\boldsymbol{X}$ into $\boldsymbol{Z}$, the range of $\boldsymbol{Y}$ is divided into h slices and the sample mean of z is calculated for each slice. Li (1991), Donald (1997) and Chen and Smith (2007) have developed statistical tests to identify the number of significant edr. Chen and Li (1998) have devised the test for exclusion restrictions.

In order to facilitate an economic interpretation of the regression results, we use Naik and Tsai's (2005) constrained inverse regression approach (CIR), a special version of SIR, in order to classify our exogenous variables as shifters of demand, farmer supply, and/or processor marginal cost (excluding wheat) ex ante, using economic theory. Given a linear constraint of the form $A'\beta = 0$ (where $\boldsymbol{A}$ is the constraint matrix), the constrained edr directions are given by the principal eigenvector of $\boldsymbol{(I-P)}\ \mathrm{cov}\left[E(z|y)\right]$, where $\boldsymbol{P}=\tilde{\boldsymbol{A}}(\tilde{\boldsymbol{A}}'\tilde{\boldsymbol{A}})^{-1}\tilde{\boldsymbol{A}}$ and $\tilde{A} = \Sigma_{xx}^{-1/2}A$.

Step 2: Estimating F_0. We estimate the link function F_0 by regressing $\boldsymbol{Y}$ non-parametrically on the L linear combinations of $\boldsymbol{X}$ 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 that the error term has the same order of magnitude (Chen and Smith 2007). F_0 describes how the price spread varies with the linear combinations of the observable variables. The output from this step of our estimation procedure allows us to examine how shifts in demand, farmers' supply, and millers' marginal costs affect the flour-wheat price margin.

Data

We construct a dataset for the time period 1974 to 2005 that contains information on wheat prices, flour prices, and other variables. Data have been deflated using the producer price index with base 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 locations: Kansas City and Minneapolis. These cities are traditional areas of geographic concentration for wheat milling because they are major markets near wheat production regions (Wilson 1995). The price of wheat is reported in terms of the cost to produce a hundredweight of flour, while flour and byproduct prices are reported directly, so the data are immediately comparable. Thus we can compute a price margin 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. Average real prices in Minneapolis are higher, although the difference is not statistically significant at the 90% confidence level. Real price margins are similar in the two markets: the average was equal to 2.14 dollars per hundredweight of flour in Minneapolis and 2.11 dollars in Kansas City. Figure 1 illustrates the real price trends in the two markets.

Table 2 reports descriptive statistics for the other variables in the dataset. The data sources are USDA, Bureau of Labor Statistics, the Census Bureau, the Energy Information Agency and the University of Michigan. Increases in the cost of fertilizer, fuel, hired agricultural labor, and land are predicted to shift farmer supply upward. An increase in wheat weight is predicted to shift down processors' non-wheat marginal cost curve, while increases in protein content, industry wages, the price of gas, the transportation price index, and the bank prime loan rate are predicted to shift it up. Demand is predicted to shift out as population, per capita income, wheat weight and protein content (as proxies for quality), and the share of the population that identifies as Caucasian increase. The Kansas City location dummy is included to allow for any location-dependent demand effects. Table 3 reports the pairwise correlation matrix of the variables we include in the initial SIR analysis.

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. We use annual averages to identify these years. Although the posted county prices are announced daily, data limitations require the use of less frequent data. Consequently we use USDA yearly average data in order to define years in which the policy was binding. We define a binding year (BIN =1) 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 course of our sample, we do not expect, necessarily, that binding policy years correspond exactly to those years with the lower market prices.

Figures 2 and 3 confirm that expectation. Figure 2 plots the policy price against the market price for the Kansas City market, distinguishing between binding and non-binding years. All of the points signifying years when the policy was binding are above the 45 degree line, and all of the points signifying years when the policy was not binding are below it. Figure 3 plots the same information for the Minneapolis market. The figures are quite similar. While for the very highest market prices the policy is never binding, there is no clear pattern between the realized market price and whether or not the policy binds. The policy price appears to be the primary determinant. This pattern is consistent with the policymaking process for the first several years in our sample. Prior to the 1985 Farm Bill agricultural price support program parameters were set for the next few years in each farm bill, and were not adjusted for market conditions (Love and Rausser 1997).

The dataset includes 64 observations over a 32-year period, one each year for each location.[1] Choosing the frequency of data was a difficult modeling decision. We use annual data in order to balance competing concerns regarding our unit of observation. Because wheat is storable, more frequent observations are more likely to be influenced by short-term storage decisions by farmers and millers. Farmers market their entire wheat crop within a year, except under very unusual conditions, and millers seldom hold flour more than one or two months (Brorsen et al. 1985). Inventories of wheat do extend across crop years; we do not address them due to the complications created by presence of government-owned and exporter-owned stocks. On the other hand, as discussed above,

[1] Data from 2006 on have been excluded from the sample because of the intense within-year volatility in commodity prices.

the actual policy is implemented on a county-day basis. Incorporating this complexity into our analysis would be difficult, if not impossible, due not least to the increasing importance of storage as the frequency of observations increases. An additional practical difficulty is that some of the variables we wish to use are provided on an annual basis, such as wheat quality. Specifying a unit of observation that is more frequent than a year makes it more difficult to collect information on exogenous variables.

Our analysis has two important, related limitations. First, we do not consider the role of wheat quality, which affects millers' decisions, as well as farmers' and buyers' decisions. The only way in which quality enters our analysis is through the two wheat price series we examine. The USDA time series for Kansas City prices is for No. 1 hard winter wheat and the Minneapolis price series is for No. 1 dark northern spring wheat. Thus, the location dummy may include quality-related effects, as well as other factors that differ between the two locations. Second, we do not address exports. Because a significant share of U.S. wheat production is exported, our results could be biased by this omission. On the other hand, to the extent that exports increase the competitiveness of the market for wheat we should simply be less likely to see any evidence of oligopsony power being exercised by millers.

Constrained Sliced Inverse Regression Results

Table 4 reports the CIR results. Using economic theory, we categorize the exogenous variables as consumer demand, farmer supply and processor marginal cost shifters. If theory predicts that a variable will not affect one of these curves, such as per capita income not affecting farmer supply, then its coefficient is constrained to be zero. In this

way we obtain immediately interpretable dimension-reduced shifters (DRS) that are linear combinations of the variables economic theory predicts will influence demand, farmer supply, and processor marginal cost. CIR ensures that the DRS are the linear combination with the highest predictive power for flour-wheat price margin.

Overall, the CIR regression performs well. The signs of the coefficients mostly match predictions, with three exceptions: the population coefficient in the demand DRS, the cost of land coefficient in the supply DRS, and the prime loan rate coefficient in the marginal cost DRS. Most of the exogenous variables are statistically significant contributors to the DRS in question. There are four exceptions. The location dummy and wheat protein content are insignificant contributors to the demand DRS. FUEL has an insignificant coefficient in the supply DRS, perhaps because growers may not adjust their per-acre use of fuel once they have made their initial acreage allocation decisions. In contrast, fertilizer application and acreage allocation decisions may be made jointly. The time trend variable is also an insignificant contributor to the supply DRS. This insignificance is consistent with the lack of an observable trend in wheat acreage over the entire study period; wheat acreage peaked in the early 1980s, and declined after that. This suggests that there are no changes over the sample period that are not captured by changes in the other variables included in the supply DRS.

The CIR results allow us to examine the relationships between the three DRS and the policy regime. Figures 4 to 6 illustrate the distribution of the DRSs over time, differentiating between binding years (BIN=1) and non-binding years (BIN=0). 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 one or more of the DRS,

Figures 4 to 6 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. Figure 7 examines this possibility. It plots the policy regime against the demand and farm supply DRS. To fix ideas, years in Figure 7 where 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. Consistent with Figures 4 to 6, Figure 7 indicate that high target prices are a more important determinant of the policy regime than market conditions are. Binding years are associated with high realizations of the demand DRS for a given realization of the supply DRS. If the target price was constant, then binding years should be associated with low realizations of the demand DRS for a given realization of the supply DRS.

To test this conclusion we ran a logit regression of the policy-regime variable (BIN) on the DRS, the policy price (POL) and a dummy variable identifying the years after the 1996 farm bill reform (D96). Table 5 summarizes the results. The model has strong predictive power (98% of predictions were correct), and the only significant variables are the demand DRS and the policy price. The logit regression shows that the

policy regime is independent of exogenous shocks in supply and millers' marginal costs, and is determined by demand conditions and policy variables.

NW Non-parametric Estimation Results

We used the DRS as regressors in a Nadaraya-Watson kernel estimator of the price margin with a cross-validation bandwidth. Figures 8 to 10 plot how the reduced-form demand, processor marginal cost, and wheat supply shifters affect the flour-wheat price margin. Each figure reports these relationships for two cases: when the program is binding, and when it is not binding.

Demand. Figure 8 addresses demand. The direction of the response of the price margin to an increase in the demand DRS does not depend on whether or not the policy is binding. The price margin increases with the DRS for demand. Consequently, millers retain part of the increase in price due to the outward shift in demand. This behavior is consistent both with an increasing marginal cost of processing and with the exercise of market power. The estimated magnitude of the price margin depends on program status. For any given value of the demand DRS, the price margin is at least as high when the program is binding than when it is not. Interestingly, the increase in the price margin for binding years is roughly linear while it is non-linear for non-binding years.

The non-linearity in non-binding years may be because millers' marginal costs do not increase linearly, perhaps due to capacity constraints. According to Brorsen et al. (1985), the milling industry operated significantly below capacity on average, so that explanation would not apply to the first part of our sample, although we do not have information regarding production versus capacity for later years. In order to be complete

this explanation must also address why the relationship between the demand DRS and the price margin when the policy is binding does not have a similar flat region.

This non-linearity is also consistent with a binding policy increasing the industry's ability to maintain collusion. When the price of flour is relatively low, it may be more difficult for millers to sustain collusion in the wheat market because it is harder to distinguish between a low realization of the demand DRS and a miller defecting from the collusive agreement in the wheat market. Because millers have relatively high overhead costs and operate on low margins, they may benefit from selling a larger number of units, even at a slightly higher variable cost per unit. A miller gains from defecting and paying a slightly higher wheat price. When the policy is binding, it reduces the gains from defection, because farmers' elasticity of *within-year* wheat supply is reduced. That is, marketing loans provide farmers with a greater incentive to store grain than they would have in the absence of the program, although support obtained through loan deficiency payments does not have the same effect (Saak 2003).

Marginal cost. Figure 9 evaluates the effect of processors' marginal cost on the price margin. The observations for both regime types are clustered with respect to the realized values of the processor marginal cost DRS, with the non-binding years at the extreme values of the DRS and the binding years in the middle. This pattern suggests caution when interpreting the results.

There are differences between the binding policy and non-binding policy regimes. For much of its 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 extreme left of the range, where the marginal cost DRS is small. In the middle of the distribution, when the

policy is not binding the margin first increases steadily with an increase in the marginal cost, then flattens. This result is somewhat 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. In contrast, when the policy is binding the (higher) margin remains flat when the marginal cost increases, and then declines slightly. These predictions indicate that a change in policy regime triggers a change in pricing behavior. For years when the policy is binding, millers appear to begin with larger margins and absorb a larger share of a marginal cost increase.

Supply. Figure 10 evaluates the effect of farmers' RDS of wheat supply on the price margin. We have established already that variations in the target price is an important determinant of whether or not the policy was binding during our period of analysis. Our concern here that in the 1980s and early 1990s when there were relatively high target prices, there are a few years where the realization of the supply DRS is quite low but nonetheless the program binds. Because these observations are driven by the very high target prices for those years and there are no observations in that range for non-binding policy years, it is difficult to infer the meaning of the resulting difference in the margin. Consequently, we focus attention on the middle of the analyzed range.

As supply shifts out, the price margin first increases and then decreases in years when the policy is binding. In contrast, in years when payments are not made the price margin first decreases very slightly, remaining virtually flat, as supply shifts downward, and then increases slightly. Overall, the price margin is much less responsive to changes in the supply DRS when the policy is not binding. 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 figure suggests that millers are able to impose higher price margins in years in which the policy is binding, unless the supply DRS is exceptionally small. In these cases, the price margins are at roughly the same level.

There are at least two reasons why one might observe a break in collusion when the supply DRS has a low realization: one driven by millers' cost structure and one driven by imperfect information. When the supply DRS is low relatively little wheat is available, which may require processors to compete to procure wheat by offering a higher price. This decision could be driven by the large overhead costs that millers incur, which may require that the milling plants must operate at least at a minimum efficient scale. In other words, collusion may break down even in the absence of an information problem when the wheat supply is very limited.

Implications. Overall, the analysis of the patterns obtained from the SIR-NW algorithm suggests that the data are consistent with a simple model of imperfect collusion as a repeated game. 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. This may explain why, holding everything else constant, expected price margins are higher during the binding years. On average, the difference in the price margins between the two regimes is 30.6 cents per hundredweight of flour, approximately 3.36% of the price of the wheat used to produce that flour. We obtained the standard deviation for the change in price margin between the two policy regimes using bootstrapping techniques, and were able to reject the null hypothesis of no change in the price margin at the 99% confidence level (with a t-statistic of -3.77). Millers'

incentive to defect is reduced in years when the policy binds because the benefit of offering farmers a higher price is limited relative to the benefit of defecting and offering a higher price when the policy is not binding.

The data suggest that collusive behavior during binding years may be state-dependent, since in limited supply states the margin reverts to the "non-binding-year" level. There are multiple explanations for this break. Imperfect information about supply may trigger price wars, if millers are unable to distinguish a fall in supply from competitors' aggressive behavior in the procurement market. However, the abundance of publicly available data regarding wheat production makes this hypothesis unlikely. An alternative explanation is that there is a minimum efficient scale for wheat milling, which may trigger an increase in competition if wheat is scarce. Millers may have an incentive to raise prices in order to ensure the minimum level of supply. Storage is costly, inventories from previous years are not generally sufficient to meet demand, and the U.S. imports a minimal share of its total wheat use.

The SIR-NW algorithm alone does not provide enough information to support the hypothesis that millers exert market power during the non-binding years. Unless specific functional forms for processors' marginal cost are assumed (e.g., decreasing or constant returns to scale or the absence of capacity constraint), the emerging patterns in the price-spread does not offer definitive evidence of collusive behavior. The results of the SIR-NW algorithm indicate that millers are able to increase flour-wheat price margins in years when the policy is binding. In turn, this suggests that millers are extracting a rent from the deficiency payment/marketing loan gain policy in the years it is in effect. The results also suggest that millers may be using price wars to maintain collusion.

Evidence for a Dynamic Game?

Another possibility to consider is that millers are playing a complex dynamic game in order to maximize their returns from production and the deficiency payment policy. The millers face a tradeoff: they can extract very high rents from the policy, but increase the risk that the program will be ended and they will be unable to collect any rents in the future. Alternatively, they can collect lower rents and face a lower risk of the policy's termination. In addition, they may be able to influence the years in which the policy is in effect by manipulating prices in the procurement market.

We propose that firms are acting collusively in both dimensions, and sustain collusion through the use of price wars when trigger quantities are reached. On the procurement side, firms wish to reduce the wheat price. When the quantity falls below the trigger level, then firms bid up prices. As in a standard trigger game, the bidding process ends up in a non-cooperative equilibrium, and the price margin reverts to the non-binding-year level. During the price wars, the millers sacrifice all policy rents. High wheat prices may be due to a defection by one or more millers (perhaps due to a difference in the rate of use of inventories), an effort to influence policy formation, or simply a small realization of the supply DRS, which is largely observable.

In equilibrium, the returns to colluding in a given period must outweigh those from three possibilities for defection: the higher margins from not increasing production when the policy is binding (by defecting the firm increases its own profit but increases the probability that the policy will be terminated in the future), increasing production in

order to increase total returns, regardless of whether or not the policy is binding, and reducing production in order to induce a binding policy year.

The increase in the flour-wheat price margin in binding policy years benefits millers. Because the policy is intended to transfer income to farmers, the question naturally arises: if the government, politicians, and voters perceive that millers benefit too much from a policy designed to aid farmers, is it more likely the policy will be terminated? When commodity prices crash and consumer prices for food change little or not at all, political and media attention often focuses on the behavior of processors and others in the agrofood marketing chain, as well as on speculators. Given that their choices regarding their margins can influence their expected future gains from policy, we argue that millers face a need to collude in order to ensure that price margins do not become too large. This is similar to a limit pricing model, in which a monopolist undertakes to deter potential entrants, perhaps by investing in a technology that increases his cost of production at the monopoly level, but reduces his cost of production at higher levels, which gives him greater ability to make entry unprofitable. Just as the monopolist increases current costs in order to protect future profits, millers may reduce current benefits in order to protect future policy rents. In the next section, we use our non-parametric analysis as the basis for a structural model of the wheat milling industry and examine a specific hypothesis regarding when millers will collude.

Structural Estimation: Strategic Responses to Policy Negotiations

The SIR-NW algorithm allowed us to specify a set of hypothesis regarding the economic behavior of wheat millers. In this section we use a simple parametric model to test them.

Essentially, we wish to examine if millers' behavior appears to influence whether or not the policy is binding in a given year. The greater the extent to which millers collude, the more likely it is that the policy will bind and they will be able to extract policy rents. On the other hand, as noted earlier, it may be the case that the more often they extract policy rents- and, perhaps, the larger those rents-the more likely it is that the policy will be revoked or reformed. This leads to the hypothesis that millers will choose to limit their rents, especially when high current rents are most likely to impact their ability to collect future rents. Because farm bills are negotiated periodically by Congress, we hypothesize that millers may be more likely to limit their rents during these negotiation periods. In particular, during our sample period millers would have been most likely to limit their rents from the policy during negotiation periods when target prices in the previous farm bill were high relative to market prices. We test this hypothesis using a structural model of the wheat milling industry. For the purpose of the analysis we assumed that target prices were "high" over the time period 1980-1995, when the policy was binding for a relatively large share of years under each farm bill, and "low" elsewhere.

The SIR-NW analysis suggested that there may be a break in collusion during binding years associated with relatively low realizations of the supply DRS. As noted by Bresnahan (1989) and Corts (1999), a time-varying pattern of collusion may lead to biased estimation in structural model, if ignored. In our structural analysis, we control for this effect with a dummy variable. Given that we are interested in the interaction between government intervention and strategic behavior, our structural analysis allows for a simple interaction between the price margin and whether or not the policy is binding.

We modify the regression model in Russo, Goodhue and Sexton (2009) to incorporate the results of the SIR-NW analysis, and estimate the following equation:

$$P_f = \beta_1 MC + \beta_2 P_w + \beta_3 BIN + \beta_4 (BIN \cdot P_w) + \beta_5 (BIN \cdot MC) + \beta_6 BREAK + \beta_7 TALK + \varepsilon$$

where P_f is the price of flour, *MC* is the processing marginal cost DRS, P_w is the cost of wheat to produce 1 cwt of flour and *BIN* is a dummy variable identifying the years when the policy is binding. *BREAK* is a dummy variable identifying the low-supply years when the policy is binding and *TALK* is a dummy variable identifying the years 1984, 1989, and 1995. These years are the three years associated with periods of extremely high target prices and immediately preceding negotiations over three farm bills (Westcott and Price 2001). We conduct three tests. First, we test for the existence of market power. Second, we test whether the price margin is significantly lower during binding years with low supply. If collusion breaks down during those years, then the coefficient β_7 should be negative and significant. Finally, we test whether the price margin is lower during farm bill negotiation years than over the rest of the period. This hypothesis is consistent with millers altering their behavior strategically in order to avoid exceptionally large margins when Congress is discussing a farm bill. This hypothesis would be supported by a negative and statistically significant coefficient β_8. Since P_w and BIN*P_w are endogenous variables we used the demand and farm supply DRS as instruments in the estimation. We assumed that BIN is exogenous, based on the results of the logit estimation.

We estimate an unconstrained and a constrained model. The imposed restrictions are $\beta_2+\beta_4=1$ and $\beta_1+\beta_5=0$. Table 6 reports the results of the two models. Consistent with Russo, Goodhue and Sexton (2009), the estimation results support a small amount of

oligopsony power in the milling industry, assuming constant marginal costs (θ=0.053). The estimates of the coefficients of BREAK and TALK support the hypotheses of collusion breaks for low-supply binding years and of millers' strategic behavior. Note that the estimates for the coefficients of TALK and BREAK are close to our non-parametric estimate of the additional mark-down during binding years. This implies that in these situations millers sacrifice all policy rents. By identifying the possibility of a break in collusion using our non-parametric analysis and including it explicitly in the estimation, we have controlled for a source of bias identified by Corts.

Summary and Conclusions

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 have ranged between 9 and 13 billion dollars, depending on economic conditions. Given the magnitude of these expenditures, there is an obvious public interest in efficient policy measures. In this paper we show that market power might redistribute the benefits of government intervention.

Using the example of the wheat market, we provide empirical evidence that millers were able to extract 30.6 cents per cwt of wheat flour as a rent from deficiency and loan deficiency programs alone, by increasing their marketing margin when the policy is binding. The figure is approximately equal to 3.5% of the average price for years when the policy is binding. Our analysis suggests that the 3.5% increase in rent due to the policy is the net result of two off-setting factors. On the one hand, the policy

reduces the elasticity of farmer supply, allowing millers to increase the price-cost margin. On the other hand, the threat of losing future policy rents if public expenditure is too high reduces rent extraction. These figures are non-negligible and yet they are the result of only a small amount of millers' oligopsony power. In a market with inelastic supply and demand, such as the wheat market, even a moderate amount of market power may have an important distributional effect. Many agricultural markets are characterized by inelastic demand and/or supply. Thus, the general assumption that competitive models may be a good approximation for imperfectly competitive agricultural markets does not necessarily hold.

The model concludes that pricing behavior is the results of the strategic interaction among four groups: millers, consumers, farmers and the government. Active players are aware of the policy and react strategically to government intervention. Failure to recognize this point may result in undesirable policy outcomes. In the case of wheat market, millers' strategic behavior resulted in the appropriation of parts of the public expenditure aiming at supporting farmers' income.

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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.

Variables		**mean**	**min**	**max**	**std. dev.**
Cost of fertilizer (real $/acre)	FRT	16.0	9.3	23.0	3.0
Cost of agr. fuel (real $/acre)	FUEL	8.4	5.1	14.3	2.1
Cost of hired labor (real $/hour)	HLB	3.1	1.9	5.3	0.9
Land rental rate (real $/acre)	LND	34.5	20.5	47.5	6.3
Wheat weight (pounds/bushel)	WGHT	60.4	58.4	61.6	0.7
Wheat protein content (%)	PRTN	12.1	11.2	13.4	0.6
Industry wages (real $/hour)	RHW	15.3	14.7	16.3	0.5
Gas price (real $)	GAS	112.2	76.4	193.7	25.9
Transportation price index	TPI	114.3	45.8	173.9	35.5
Per capita income (real $)	PCI	18,146.6	7,373.4	31,121.2	7,353.2
Population (millions)	POP	251.9	213.3	293.9	25.3
Bank prime loan rate (%)	IR	9.0	4.1	18.9	3.2
Caucasian share of population (%)	CAUC	0.8	0.8	0.9	0.0

Table 3: Correlation Matrix: Explanatory Variables

	FRT	FUEL	HLB	LND	WGHT	PRTN	RHW	GAS	TPI	PCI	POP	IR	CAUC	Price Spread
FRT	1.00													
FUEL	0.51	1.00												
HLB	-0.32	-0.08	1.00											
LND	0.07	-0.07	0.43	1.00										
WGHT	-0.02	-0.07	-0.39	-0.19	1.00									
PRTN	-0.01	0.16	0.25	0.07	-0.37	1.00								
RHW	0.34	0.18	-0.73	-0.05	0.31	-0.03	1.00							
GAS	0.72	0.85	-0.32	0.02	-0.06	0.14	0.50	1.00						
TPI	0.68	0.48	0.02	0.36	-0.34	0.26	0.23	0.72	1.00					
PCI	0.66	0.29	-0.13	0.38	-0.28	0.17	0.40	0.66	0.94	1.00				
POP	0.68	0.36	-0.09	0.37	-0.26	0.23	0.39	0.69	0.97	0.98	1.00			
IR	-0.21	0.24	-0.01	-0.20	0.15	0.04	-0.26	-0.11	-0.45	-0.58	-0.56	1.00		
CAUC	-0.66	-0.32	0.09	-0.44	0.21	-0.16	-0.35	-0.62	-0.85	-0.86	-0.88	0.51	1.00	
Price Spread	-0.04	-0.03	-0.11	-0.29	-0.04	-0.26	-0.13	-0.08	-0.17	-0.12	-0.21	0.03	0.26	1.00

Table 4: 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
POP	-0.5912	-125.2	0	-	0	-
PCI	0.0010161	12.94	0	-		
WGHT	1.5485	8.6357	0	-	-0.68559	-5.1194
PRTN	0.1185	0.53093	0	-	1.2052	7.4256
CAUC	160.23	12.634	0	-		
TIME	1.0686	5.9226	-0.086379	-1.7142	-0.85777	-5.4915
HLB	0	-	0.55362	2.6384	0	-
FERT	0	-	0.35834	4.093	0	-
LAND	0	-	-0.35134	-2.3763	0	-
FUEL	0	-	0.017412	0.27851	0	-
GAS	0	-	0	-	0.1484	2.1731
RHW	0	-	0	-	2.6217	4.2417
TPI	0	-	0	-	3.2527	7.1682
Kansas	-0.34707	-1.4666	1.2763	4.4509	1.0316	4.6415
IR	0	-	0.025414	0.1743	-1.4904	-5.7199

Table 5: Logit Regression of the Policy Regime on DRSs and Policy Variables

Variable		Coefficient	Asymptotic t-ratio	
Demand DRS	(DS)	3.61	1.90	*
Supply DRS	(SS)	-0.03	-0.05	
Marg. Cost DRS	(MC)	-0.04	-1.11	
Policy price	(POL)	8.57	2.13	**
Post 1996 dummy	(D96)	9.30	1.07	
Constant		-520.63	-1.98	
Percentage correct predictions: 98.44% Likelihood ratio test: 74.60 with 5 d.f. p<0.0001				

* significant at 90% confidence level
** significant at 95% confidence level

Table 6. Results of the Parametric Estimation

	Unconstrained			**p-**	**Constrained**			**p-**
Variable	**Coefficient**	**s.e.**	**t-stat**	**value**	**Coefficient**	**s.e.**	**t-stat**	**value**
PW	1.161	0.018	66.340	0.000	1.161	0.017	69.210	0.000
BIN*PW	-0.208	0.120	-1.733	0.089	-0.161	0.017	-9.574	0.000
MC	0.001	0.000	3.034	0.004	0.001	0.000	3.127	0.003
BIN	2.602	1.139	2.285	0.026	2.373	0.090	26.240	0.000
BIN*MC	-0.001	0.001	-0.551	0.584	-0.001	0.000	-3.127	0.003
TALK	-0.313	0.182	-1.720	0.091	-0.316	0.177	-1.788	0.079
BREAK	-0.367	0.160	-2.298	0.025	-0.328	0.144	-2.278	0.026

Figure 1: Real prices of wheat and wheat products by location: 1974-2005

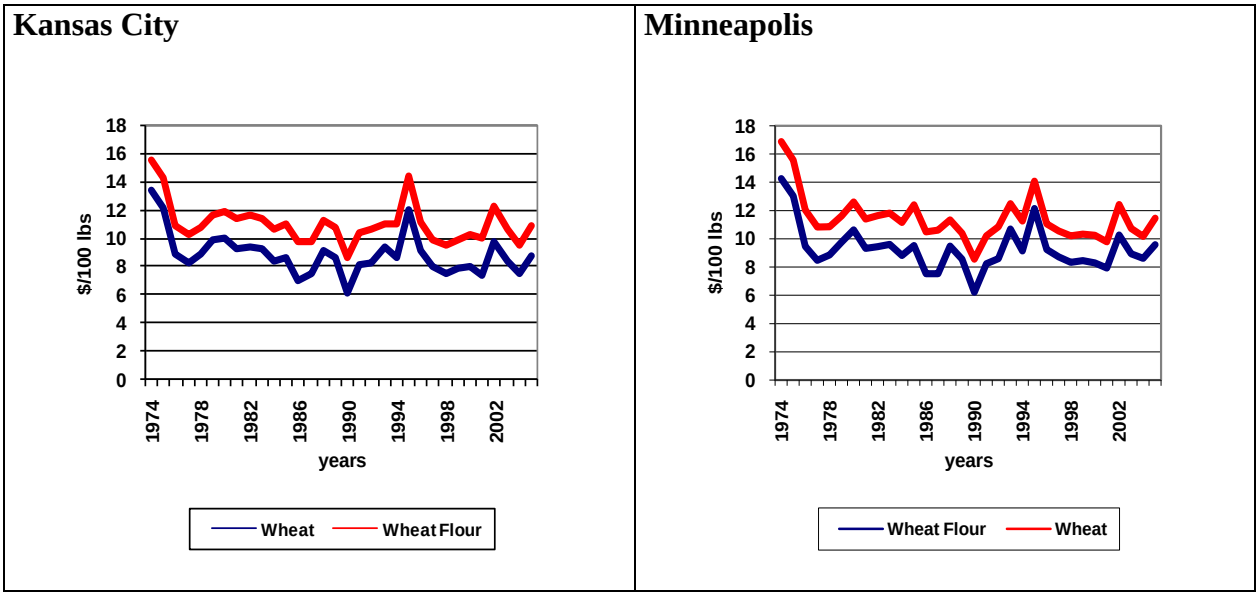


Figure 2: Market and policy prices, binding and non-binding policy years: 1974-2005, Kansas City

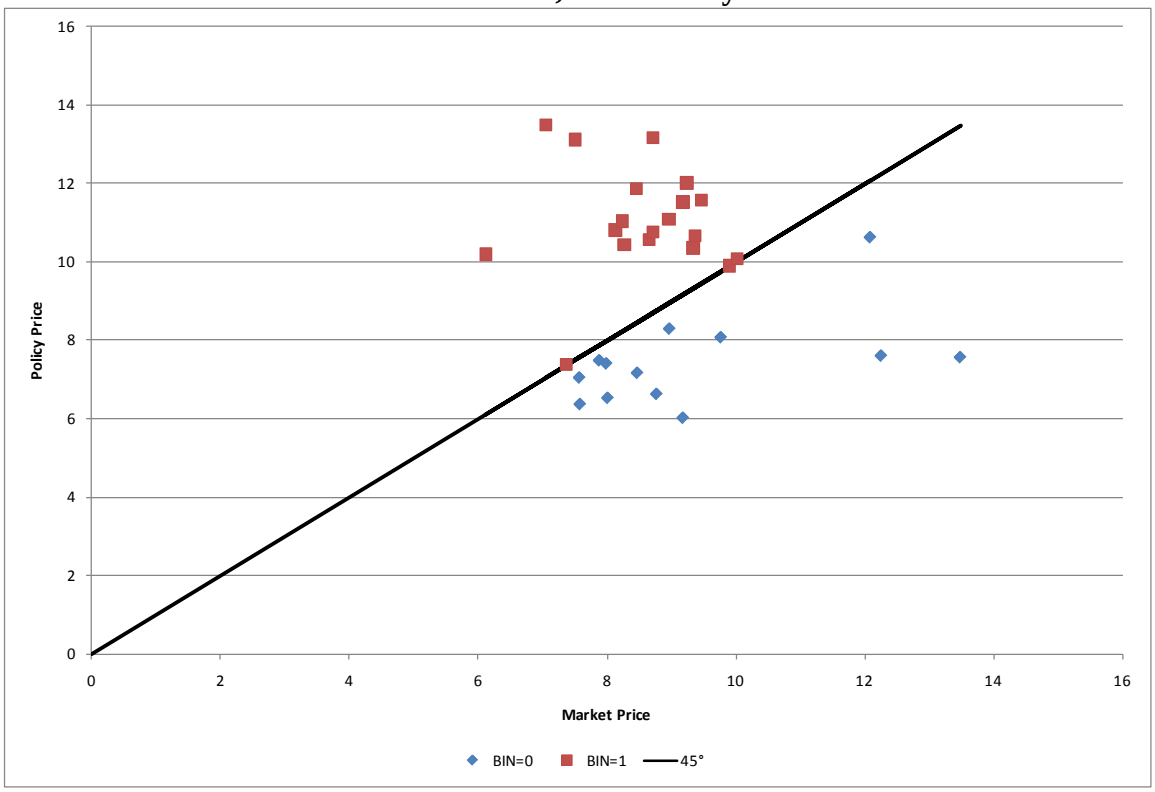


Figure 3: Market and policy prices, binding and non-binding policy years: 1974-2005, Minneapolis.

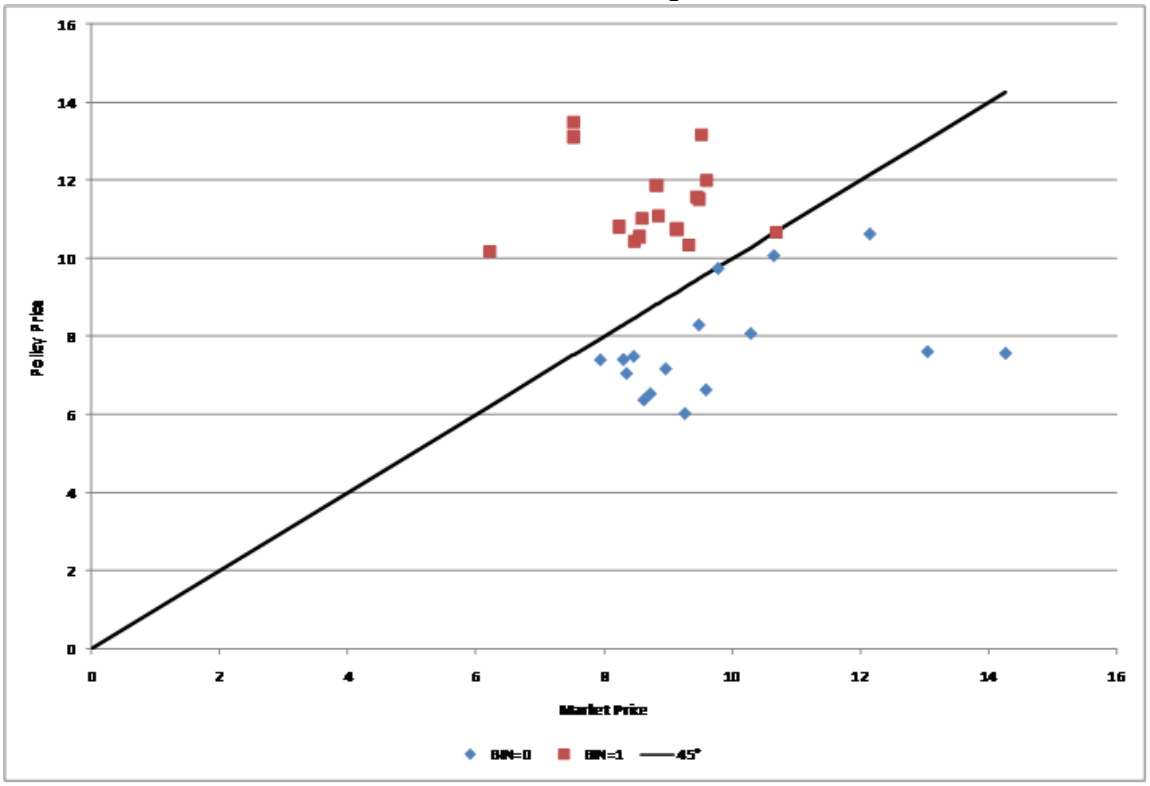


Figure 4: Distribution of the demand dimension-reduced shifter: 1974-2005

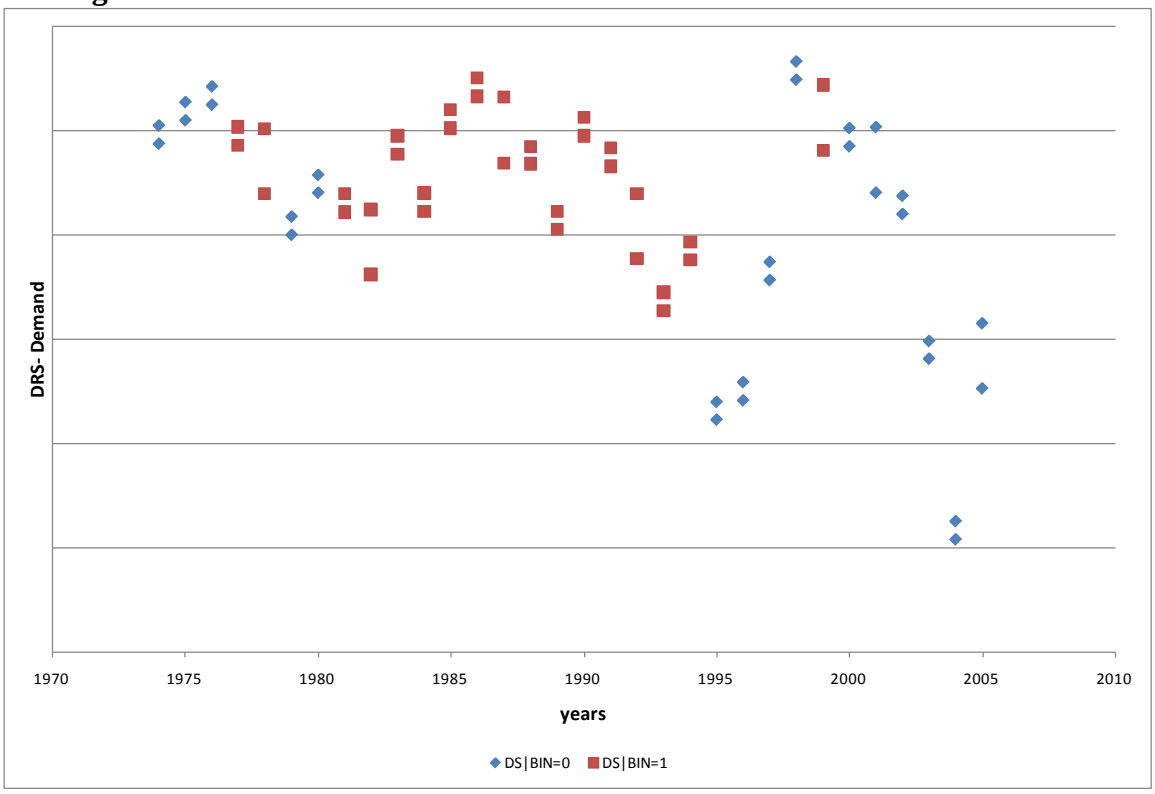


Figure 5: Distribution of the wheat supply dimension-reduced shifter: 1974-2005

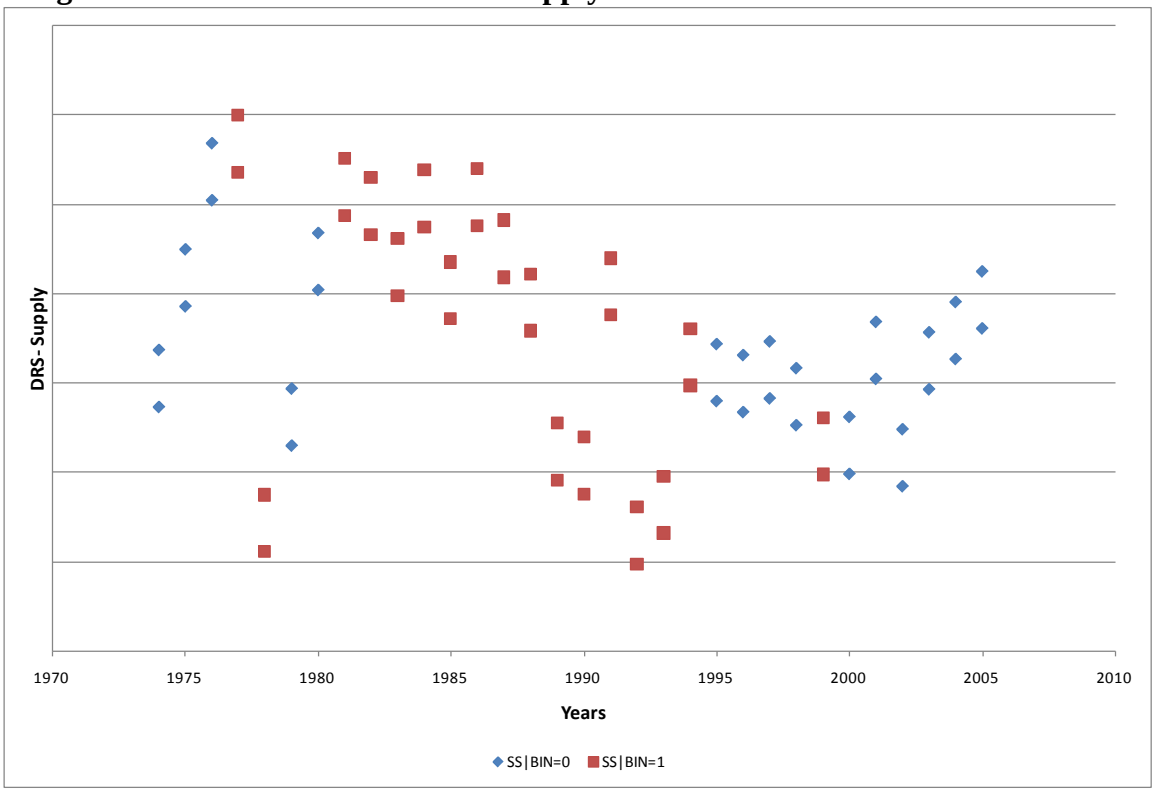


Figure 6: Distribution of the processor non-wheat marginal cost dimension-reduced shifter: 1974-2005

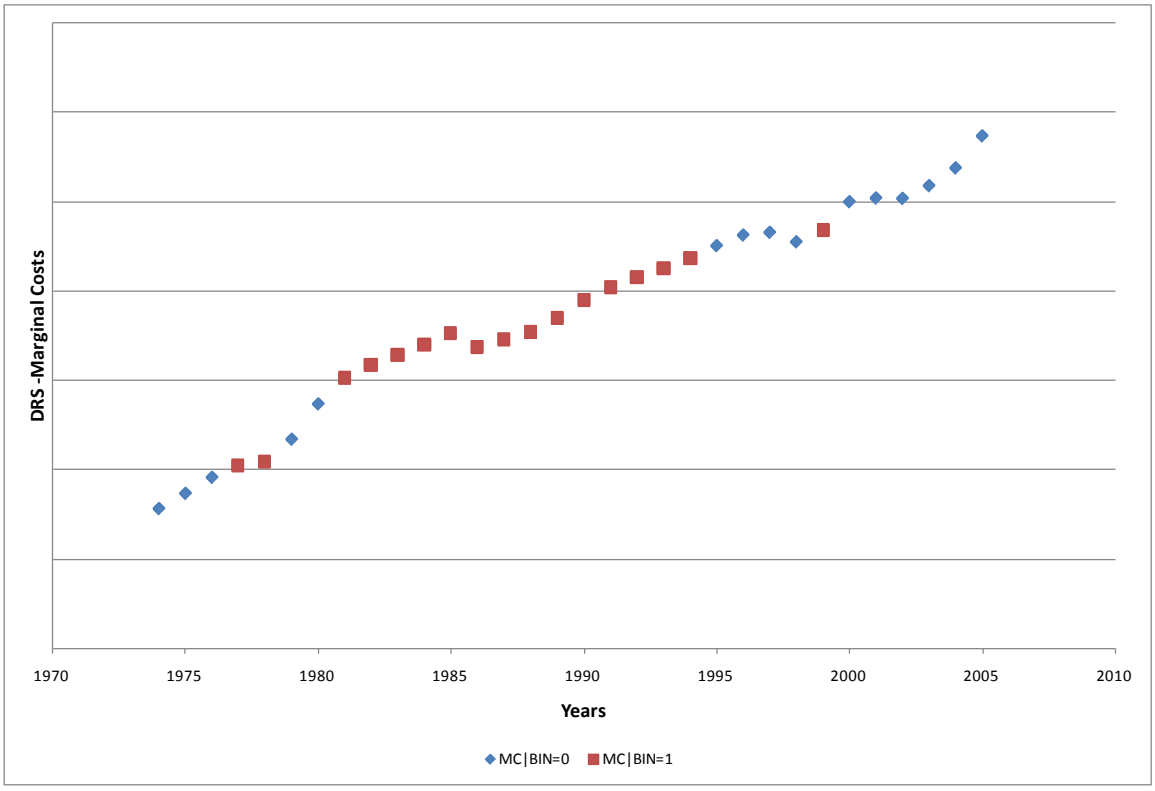


Figure 7: Policy regime and demand and supply DRS.

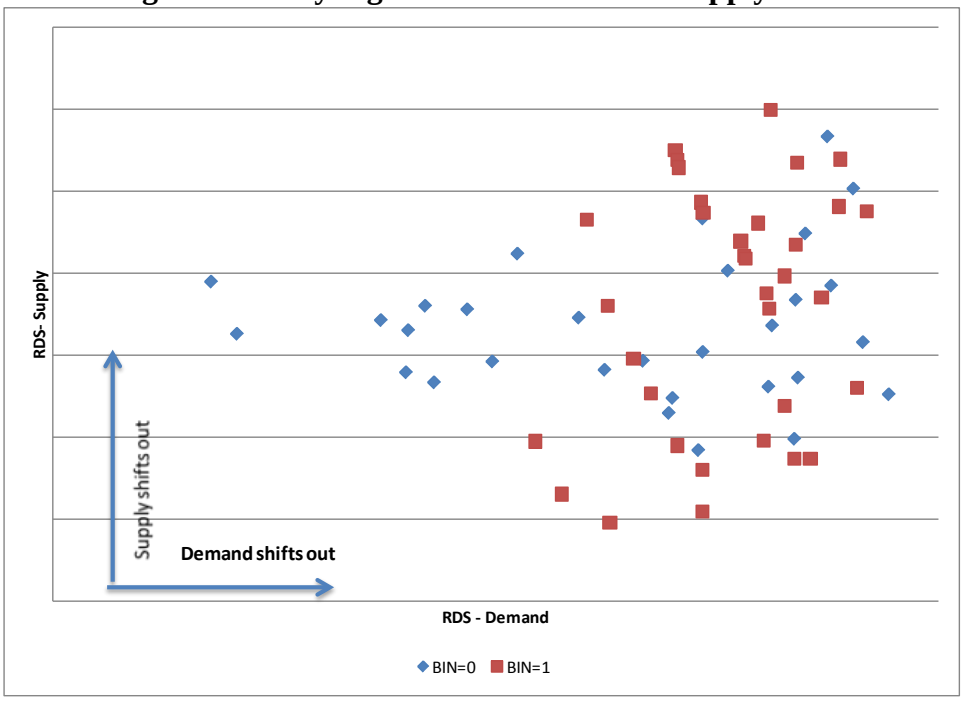


Figure 8. N-W Non-parametric estimation of the relationship between the flour price-wheat price margin (PM) and the DRS for demand

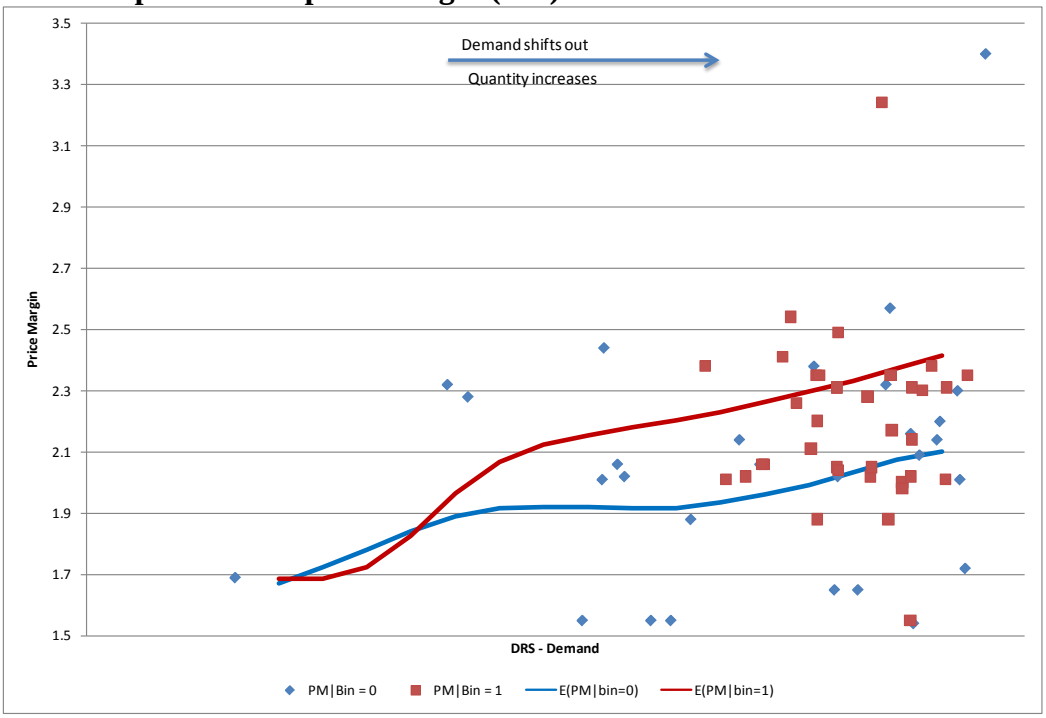


Figure 9. N-W non-parametric estimation of the relationship between the flour - wheat price margin and the DRS for processor marginal cost

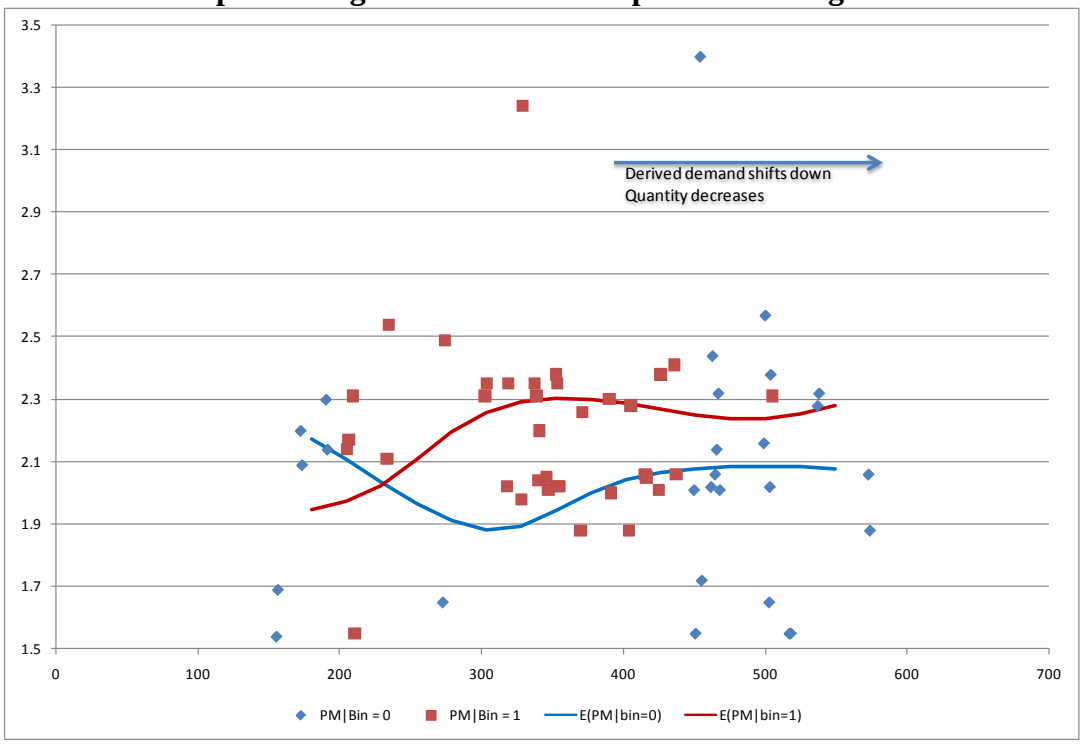


Figure 10. N-W non-parametric estimation of the relationship between the flour price-wheat price margin and the DRS for wheat supply

