Market power: Modeling issues and identification problems. An investigation of selected Hungarian food chains

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Abstract. In recent years increasing number of contractual arrangements in food chains are observed. There are several reasons for this phenomenon. Improving food quality often requires significant specific investments. Given high asset specificity, investors find it difficult to appropriate the returns on investment and thus have incentives to integrate. However, besides this transaction costs related argument, the ongoing vertical integration can result form structural developments in food chains which at different stages of the value chains, might hamper the proper functioning of markets. Using a unique, firm level dataset, in this paper we will focus on the latter issue. Due to its importance among various Hungarian value chains, we have selected the milk market. The objective is to conduct an analysis of market structure and pricing behaviour, with the main research question being the existence and significance of market power, its impact of factor allocation and the induced incentives for forward and backward integration. Several theoretical and empirical approaches including structural model estimation are applied in order to investigate whether market power is exploited or not. The empirical results are discussed against the background of several issues associated with the functioning of markets and a better understanding of institutional choice. Moreover, policy recommendation will be discussed.

Keywords: Market power, Hungarian food chains.

1. Introduction

After the fall of socialist political and economic system, and entering the transition period, the restructuring process in the Hungarian dairy sector has begun. One of the most notable phenomena was an exceptional decrease in number of dairy farms. In the 1995-2007 periods, the number of dairy farms decreased to 59% leaving approximately 7,500 dairy farms in the sector. Secondly, there could be observed a continuous decrease in number of dairy cows in Hungary from almost 500 thousands in 1992 to 323 thousands in 2007. Thirdly, the processing sector consolidated in the transition period with a decrease in number of dairy processor companies from roughly 170 in 1996 to 58 in 2007, leading to higher industry concentration ratios. In 2001 the CR_5 index already amounted to roughly 60%., remaining around this level ever since.

With regard to production level, raw milk in Hungary is predominantly produced by agricultural enterprises. In 2005 their share in number of dairy cows accounted for 67%, whereas family farms share was 33%, with a total production of roughly 1.8 billion litres (around 180 litres *per capita*). The average herd size in agricultural enterprises was 295 within the individual farms 6.2. As far as the FDIs are concerned, in the Hungarian dairy sector, foreign direct investments' share in owners' equity exceeded 80 per cent already in 2000 (figure 1.).

In the recent past agricultural economists pay great attention to the analysis of market structure and pricing on the market for raw milk in the CEER countries, including Hungary. There are several papers focusing on the dairy market organisation and functioning in Hungary. Bakucs et al. (2009) discuss the effect of farm and processing industry structure upon the milk price transmission in Hungary and Poland. Szabó and Popovics (2008) discuss vertical transmission as well as coordination and integration mechanisms in the Hungarian dairy sector. Bakucs and Fertő (2008) assess the horizontal price integration between three regions within Hungary. Finally, Hockmann and Vöneki (2008) analyse the possibility of tacit collusion in the Hungarian market for raw milk using a structural market model.

Since 1980s, there have been numerous studies of New Empirical Industrial Organization (NEIO) that pays special attention to measuring market power in agricultural and food markets. Most of these studies are based upon structural oligopoly or oligopsony models and find evidence of buyer or seller market power. Contrary to the majority of studies measuring the degree of market power, Muth and Wohlgenant (1999) failed to find any evidence of oligopsony power in the beef packing industry. Perekhozhuk et al. (2008) use a production function framework for the estimation of production technology and test of market power in the Ukrainian milk processing industry. However, using the regional level data, Perekhozhuk et al. (2009) found oligopsony power in four out of twenty two regions of Ukraine.

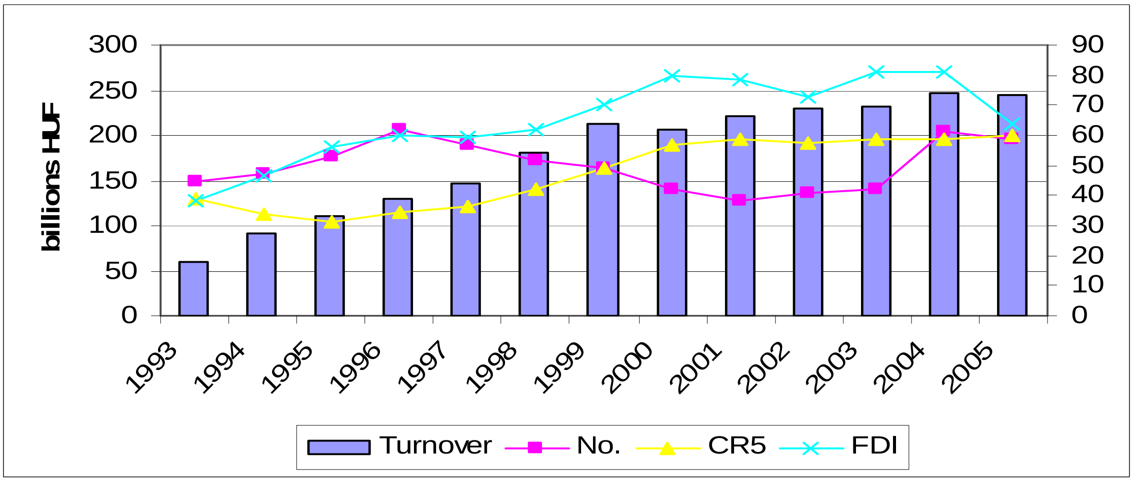

Figure 1. Turnover, number of companies, industry concentration and FDI (share in owners equity)

Source: Own calculations based on data from the Agricultural Economics Research Institute (AKI), Hungary.

Here it is necessary to underline that all this studies rooted in the New Empirical Industrial Organization theory (NEIO), use the market level data to estimate a degree of market power at a national level, which are really limiting. As far as we know, only Wann and Sexton (1992), Weliwita and Azzam (1996), as well as Koontz and Garcia (1997), have estimated the degree of market power in a regional market level and found evidence of market power in the pear and meat packing industries, respectively.

To our best knowledge, up to now there have been rather little of publication of empirical studies analyzing market power exertion at the firm-level. Only Morrison Paul (2001), using a plant-level data for the U.S. beef packing plants and found a presence of market power based on estimation of input demand equations derived from the Generalized-Leontief-Quadratic cost function. Moreover, she specifies the parameter of market power as a function of the number of cattle buyers, the expenditures of cattle procurement, the payment for overtime workers and the others variables. Using the binary dummy variable Hockmann and Vöneki (2009) to implicate the effects resulting from the ending of export subsidies at the beginning 2004 and estimated the parameter of oligopsony power over time. In contrast to the large and still rapidly expanding empirical studies the objective of this paper is to provide an analysis of market power at the firm level and to find firm specific effects that can be have influence on market structure and pricing in the Hungarian milk supply chain.

Our paper is organized as follows: The next section presents the theoretical model of oligopsony power followed by description of firm-level data of the Hungarian milk processing plants in Section 3. The estimation results and specification tests are discussed in Section 4. The final section consists of the results and conclusions.

2. Econometric specification of the market structure model

In contrast to Morrison Paul (2001) that Generalized-Leontief-Quadratic cost approach we use a production approach based on the transcendental logarithmic (translog) production function (Christensen, Jorgenson and Lau, 1973). Using the firm-level data for the Hungarian Milk Processing Industry we assume that the milk processing plants use only three factors, namely, raw milk (M), capital (C) and labor (L), thus the production function of the *i*th dairy plant can be written as:

$$\begin{aligned} \ln Y = {} & \ln\alpha_0 + \alpha_M \ln M_{it} + \alpha_K \ln C_{it} + \alpha_L \ln L_{it} + \alpha_T T_{it} \\ & + \frac{1}{2}\left[\alpha_{MM}(\ln M_{it})^2 + \alpha_{CC}(\ln C_{it})^2 + \alpha_{LL}(\ln L_{it})^2 + \alpha_{TT}(T_{it})^2\right] \\ & + \alpha_{MC}\ln M_{it}\ln C_{it} + \alpha_{ML}\ln M_{it}\ln L_{it} + \alpha_{MT}\ln M_{it} T \\ & + \alpha_{CL}\ln C_{it}\ln L_{it} + \alpha_{CT}\ln C_{it} T + \alpha_{LT}\ln L_{it} T, \end{aligned} \tag{1}$$

where the variable T is a proxy for technical change in the dairy industry. The use of panel data means that is possible to estimate the parameter of market power over time t, as well as, to compare market power across the *i*th dairy plant.

The first-order condition for profit maximization with respect to raw milk that allows for imperfect competition on the raw milk market is determined as follows:

$$W_M = P\frac{Y}{M}\left(\alpha_M + \alpha_{MM}\ln M_{it} + \alpha_{MC}\ln C_{it} + \alpha_{ML}\ln L_{it} + \alpha_{MT} T\right) \Big/ \left(1 + \frac{\Theta}{\varepsilon}\right), \tag{2}$$

where W_M is the price of raw milk.

Using the price elasticity of raw milk supply as exogenous constant point[1] the parameter of oligopsony power Θ can be tested econometrically based on the estimation of the production function (1) and the first order condition for profit maximization that allows for imperfect competition (2). For the econometric specification additive disturbance terms were added which were assumed to have zero mean, constant variance, and to be independently and normally distributed.

A number of other aspects concerning the estimation and interpretation of the parameter of Θ can be found in the empirical studies. Based on the plant-level data, Morrison Paul (2001) assumes that the parameter of market power is a function of the specific variable as the number of cattle buyers, the expenditures of cattle procurement, the payment for overtime workers and other variables. Hockmann and Vöneki (2009) used the binary dummy variable to implicate the effects resulting from the ending of export subsidies at the beginning 2004 and estimated the parameter of oligopsony power Θ over time.

Using the firm-level data for Hungarian dairy plants we will estimate the parameter of market power as constant parameter and used the dummy variables to specify the parameter of oligopsony power as function of variables for politic change (*PC*), Scale of Enterprise (*SE*) and the legal form of enterprise as the Private Enterprise *(PrE)*, the Foreign Enterprise *(FoE)* and the Public Enterprise *(PuE).*

3. Description of statistical data source

In order to test for the existence of oligopsony power of the Hungarian milk processing industry, we use the firm level data obtained from the Institute of Economics Tarifa PM database. The data set includes 432 firm-level observations of the Hungarian milk processing industry in the investigation period from 1993 to 2006[2].

A database contains individual data of enterprise net revenue (Y), material (M), capital (C) and labour (L) input. The data for the farm price of raw milk (W_M) and the retail price of milk (P) provided by the Institut of Economics of Hungarian Academy of Science. All variables in price and monetary terms were deflated by CPI.

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[1] Similar assumptions may be found in works of Morrison Paul (2001), Schroeter (1988), Azzam and Pagoulatos (1990).

[2] A detailed description of the data sources is available from the authors upon request.

Table 1. Description of statistics of the firm-level data

Variable	Description	Mean	Std. Dev.	Minimum	Maximum
Y	Production output (net revenue, Mio. HUF)	1466.7	1981.7	3.717	12234.700
M	Material input (material cost, Mio. HUF)	1258.7	1713.5	1.859	11024.200
C	Capital input (tangible assets, Mio. HUF)	232.6	320.6	0.536	1778.380
L	Labour input (number of employees)	298.7	333.4	10	1874
T	Time $(T = 1993,..,2006)$	1998.6	3.8	1993	2006
W_M	Farm price of raw milk (100 HUF pro kg)	18.3	1.7	13.993	20.447
P	Retail price of milk (100 HUF)	35.1	2.7	31.521	41.001

Source: Own calculation based on the firm data provided by the Institut of Economics of Hungarian Academy of Science.

Evidently from Table 2, the number of dairy enterprises (N) decreased from 35 to 21 between 1993 and 2006. According to Hockmann and Vöneki (2009) the number of milk processor in Hungarian milk processing industry was reduced from 104 to 93 between 1997 and 2004. That means that we do not have all the firm data. However, based on a calculation of concentration of Hungarian milk processing we have estimated approximately the same results at least for concentration ratio (CR_1) by the largest dairy enterprises as indicated by Hockmann and Vöneki (2009).

Table 2. The Concentration Ratio (CR) and the Herfindahl-Hirschman Index (HHI)

Year	N	CR_1	CR_4	CR_{10}	*HHI*1000*	*1/n*1000*
1993	35	10.65	33.67	66.47	54.99	28.57
1994	36	11.35	34.01	66.07	54.65	27.78
1995	40	9.95	31.26	63.06	49.66	25.00
1996	40	9.99	33.71	63.26	50.71	25.00
1997	36	11.53	38.18	66.23	57.54	27.78
1998	40	13.10	38.50	70.00	61.61	25.00
1999	35	21.76	51.69	82.75	96.51	28.57
2000	35	23.00	56.89	84.63	107.94	28.57
2001	32	20.02	55.92	83.78	104.86	31.25
2002	24	21.43	61.30	90.11	124.17	41.67
2003	19	31.60	70.77	92.63	167.05	52.63
2004	19	27.28	68.50	92.63	145.14	52.63
2005	20	24.32	65.59	90.65	130.61	50.00
2006	21	36.16	65.64	87.52	172.14	47.62

Source: Own calculations based on the firm data provided by Institut of Economics of Hungarian Academy of Science.

Using the net revenue of dairy enterprises we calculated the four-firm and ten-firm concentration ratio (CR) and the Herfindahl-Hirschman Index (HHI) for Hungarian dairy industry. Between 1993 and 2006, the market share of the four largest dairy enterprises in the industry (the four-firm concentration ratio) has double from approximately 33.6% to more than 65.6%. In 2006, the ten-firm concentration ratio (CR_{10})

makes up almost 90% of total output of dairy industry. Between 1993 and 2006, the market share of the largest dairy enterprise increased from 10.7% to 36.1%, thus three times as many. These results indicate a high degree of concentration in the Hungarian dairy industry.

Compared to the milk processing industry in Germany or the United States, the Hungarian dairy industry is relatively highly concentrated. In 2004, the market share of the six and ten largest dairy enterprises in milk processing industry in Germany was 25.2% and 37.4%. In 2002, the four and eight firm concentration ratio in the USA was 29.6% and 42.5% respectively.

4. Estimation results and specification testing

The model is based on the estimation of the translog production function (1) and the first-order condition for profit maximization (2). Hence, the price of raw milk (W_M) and the output of milk processing industry (Y) are endogenous. Since equation (2) is intrinsically nonlinear in its parameters, the market structure model represents a nonlinear simultaneous equation system. Therefore, the model was estimated using nonlinear three-stage least squares (cf. Amemiya, 1977). All the exogenous variables in the system were used as instruments. Estimation was carried out using the statistical software STATA. For the estimation of the market structure model we use the price elasticity of raw milk supply $(\varepsilon = 0.1)$ that was previously estimated in the other empirical studies, for example, by Suzuki et al. (1993), Lopez et al. (1994), Perekhozhuk (2007). Tables 3 preset the estimation result of the four estimated models.

Table 3. Estimated parameters of NLS estimation

Parameter	Model 1: Competition			Model 2			Model 3			Model 4		
	Coef.	Std. Err.	z-Ratio	Coef.	Std. Err.	z-Ratio	Coef.	Std. Err.	z-Ratio	Coef.	Std. Err.	z-Ratio
α_0	-0.0651	0.0093	-6.99	-0.0602	0.0092	-6.56	-0.0617	0.0085	-7.22	-0.0616	0.0085	-7.28
α_M	0.9738	0.0059	166.08	0.9359	0.0103	90.55	0.9553	0.0102	93.65	0.9519	0.0097	98.02
α_C	0.0197	0.0079	2.48	0.0262	0.0079	3.31	0.0131	0.0075	1.74	0.0124	0.0074	1.67
α_L	0.0231	0.0122	1.90	0.0600	0.0146	4.11	0.0447	0.0138	3.24	0.0488	0.0135	3.61
α_T	-0.0031	0.0016	-2.01	-0.0028	0.0015	-1.84	-0.0021	0.0014	-1.46	-0.0020	0.0014	-1.42
α_{MM}	0.1523	0.0054	28.00	0.1460	0.0054	27.21	0.1461	0.0050	29.36	0.1484	0.0049	30.08
α_{CC}	0.0203	0.0086	2.36	0.0240	0.0084	2.85	0.0126	0.0079	1.59	0.0084	0.0079	1.06
α_{LL}	0.0358	0.0227	1.58	0.0517	0.0223	2.31	0.0343	0.0218	1.58	0.0505	0.0207	2.44
α_{TT}	0.0036	0.0008	4.50	0.0031	0.0008	3.93	0.0038	0.0007	5.20	0.0038	0.0007	5.26
α_{MC}	-0.0478	0.0060	-8.00	-0.0431	0.0058	-7.40	-0.0271	0.0057	-4.78	-0.0219	0.0058	-3.76
α_{ML}	-0.1197	0.0099	-12.10	-0.1242	0.0096	-13.00	-0.1204	0.0094	-12.80	-0.1319	0.0090	-14.65
α_{MT}	-0.0157	0.0015	-10.68	-0.0158	0.0014	-11.31	0.0028	0.0024	1.17	0.0027	0.0024	1.15
α_{CL}	0.0678	0.0109	6.22	0.0601	0.0108	5.56	0.0499	0.0102	4.90	0.0498	0.0100	4.98
α_{CT}	-0.0006	0.0020	-0.29	-0.0003	0.0019	-0.14	-0.0035	0.0018	-1.89	-0.0032	0.0018	-1.80
α_{LT}	0.0189	0.0029	6.47	0.0199	0.0028	6.98	0.0006	0.0033	0.18	0.0006	0.0033	0.19
Θ_C	-	-	-	-0.0055	0.0012	-4.44	-0.0722	0.0118	-6.12	-0.0961	0.0392	-2.45
Θ_T	-	-	-	-	-	-	0.0144	0.0031	4.66	0.0136	0.0032	4.30
Θ_{PC}	-	-	-	-	-	-	0.2749	0.0348	7.91	0.2822	0.0347	8.12
Θ_{SE}	-	-	-	-	-	-	0.0048	0.0019	2.52	-	-	-
$\Theta_{\Pr E}$	-	-	-	-	-	-	-	-	-	0.0123	0.0390	0.31
Θ_{FoE}	-	-	-	-	-	-	-	-	-	0.0859	0.0418	2.05
Θ_{PuE}	-	-	-	-	-	-	-	-	-	0.0037	0.0040	0.92

Source: Own estimation based on the firm-level data provided by the Institut of Economics of Hungarian Academy of Science.

In the first model the parameter Θ was restricted to zero (Model 1). In this case, the market structure model represents competitive market conditions. In the second model, the parameter Θ_C was estimated as a constant parameter (Model 2). In the Model 3 we use dummy variables to capture various effects from the policy change *(PC)* over time (T) and the scale of enterprise *(SE)*. In comparison to the third model, instead of the effects of scale of enterprise, the Model 4 presents effects of legal form of enterprise as the Private Enterprise *(PrE)*, the Foreign Enterprise *(FoE)* and the Public Enterprise *(PuE)*.

The asymptotic z-ratio indicates that most parameters are significant at least at 5 % level. For the purpose of simplification of interpretation of estimated parameter values, all model variables were transformed into deviations from their geometric mean. Therefore of the estimated parameter of the translog function, namely, α_M, α_C and α_L indicate a production elasticity of raw milk, capital and labour input, respectively. Moreover the parameter γ_T is the rate of technical change in the milk processing plants over time. The production elasticity of raw milk was estimated to be between 0.97 (Model 1) and 0.95 (Model 4). The estimated production elasticity of capital and labour is very robust and changes itself starting with the second decimal point. However, not all estimated parameters of capital and labour elasticities are statistically significant. In addition, we test the hypothesis of constant returns to scale based on test linear hypotheses for the parameters of production function, such $\sum_j \alpha_j = 1,\ j = M, C, L$. The hypothesis of constant returns to scale could be rejected even at the 1% level. Thus, we estimated the increasing returns to scale in the Hungarian milk processing industry. The scale elasticity is very similar and approximately amounts from 1.02 for first and second models to 1.01 for the third and fours model in all estimated models, respectively. Finally, the estimated rate of technical change (γ_T) is negative, but not statistically significant at least at the 10 % level of statistical significance.

Here, the estimated parameters of the first-order condition for profit maximization measuring the degree of oligopsony power of milk processing plants is of great interest to us. The results of model 1 indicate that the parameter of oligopsony power estimated as constant is close to zero.

However, in Model 3 and 4 we use a dummy variable to account for policy change and other firm specific effects. The Model 3 present results for the effects of policy change *(PC)*, over time *(T)*, as well as, of the scale of enterprise (*SE*). The asymptotic z-ratio indicates that all this effect is significant at least at the 1 % level of statistical significance. In additional Model 4 also has other firm specific effect such as legal form of enterprise. While, the parameter Θ_{PrE} (Private Enterprise) and Θ_{PuE} (Public Enterprise) is not statistically significant, the parameter Θ_{FoE} (Foreign Enterprise) is statistically significant at least at 5 % level. In addition, we test the null hypothesis pertaining to the parameter Θ_C (Model 2), to the subset $\Theta_C + \Theta_T + \Theta_{PC} + \Theta_{SE}$ (Model 3) and to the following subset of firm specific effects $\Theta_C + \Theta_T + \Theta_{PC} + \Theta_{PrE} + \Theta_{FoE} + \Theta_{PuE}$ (Model 4).

Table 4. Wald test and estimates of the parameter of market power

Model	Oligopsony power and impacts of effects	H_0-Test		Test of market power		
		χ^2	p-value	Coef.	Std. Err.	z-Ratio
Model 2	Θ_C	19.75	0.0000	-0.0055	0.0012	-4.40
Model 3	$\Theta_C + \Theta_T + \Theta_{PC} + \Theta_{SE}$	39.81	0.0000	0.2219	0.0352	6.30
Model 4	$\Theta_C + \Theta_T + \Theta_{PC} + \Theta_{PrE} + \Theta_{FoE} + \Theta_{PuE}$	25.43	0.0000	0.3015	.0598	5.04

Source: Own estimation based on the firm-level data provided by Institut of Economics of Hungarian Academy of Science.

As the test results indicate, the null hypothesis could be rejected even at the 1% significance level in all models. Moreover, on the basis of the test of market power there is an extensive evidence of the existence of oligopsony market power of Hungarian milk processing enterprises. Our estimation results confirm the findings of previous studies by Hockmann and Vöneki (2009). The test results of Model 3 and 4 indicate that the parameter oligopsony market power is 0.22 and 0.30 in the evaluation period from 1993 to 2006, respectively. The asymptotic z-ratio indicates that estimated results are significant even at 1 % level. This empirical result is consistent with a relatively highly concentration in the Hungarian milk processing industry. In the course of the last seven years, the Herfindahl-Hirschman Index *(HHI)* for Hungarian dairy industry has immensely increased and lies between 0.1 and 0.2. Moreover, based on the obtained firm-level data, the econometric results confirm the test characteristics of effects reported by Hockmann and Vöneki (2009), who have used monthly time series data from January 1998 to October 2006 at the national level.

For a general comparison of the estimated models Table 5 lists some coefficients of statistical inference. The fit of the estimated models is quite good.

Table 5. Statistical inference of NLS estimation

Equation	Model 1			Model 2			Model 3			Model 4		
	Parms.	RMSE	R-sq	Parms.	RMSE	R-sq	Parms.	RMSE	R-sq	Parms.	RMSE	R-sq
$\ln Y$	15	0.1033	0.9944	15	0.1016	0.9945	15	0.0957	0.9952	15	0.0953	0.9952
W_M	5	0.1489	0.9783	6	0.1480	0.9785	9	0.1357	0.9819	11	0.1346	0.9822

Source: Own estimation based on the firm-level data provided by the Institut of Economics of Hungarian Academy of Science.

The lowest and largest R-square between observed and predicted values obtained for the equations of the production function are very similar and amount from 0.9944 in the competition model (Model 1) to 0.9952 for the Model 3 and 4, respectively. The lowest and the largest R-square values for the first-order condition are 0.9783 in the Model 1 (competition model) and 0.9822 in the model 4. Thus, statistical results show a slightly better performance of the Model 4.

5. Summary and conclusions

The objective of this paper was to measure the degree of oligopsony power in the Hungarian milk processing industry. For this purpose, four econometric models were estimated. In this study, the production technology in Hungarian milk processing industry is represented by a translog production function, which imposes much less a priori restrictions on the technology than neoclassical functions. The estimated production elasticities of capital and labour are positively, but not highly statistically significant. The hypothesis of constant returns to scale is rejected. The econometric results show increasing returns to scale in the Hungarian milk processing industry.

Using the firm-level data, we estimated the parameter of oligopsony market power in the Hungarian Milk Processing Industry. The null hypothesis test for perfect competition in Hungarian milk processing industry is rejected. Furthermore, the various effects have to be considered. The statistical results show that the effects from the policy change over time, the firm specific effects from the scale of enterprise, the legal form of enterprise as the Private Enterprise, the Foreign Enterprise and the Public Enterprise are statistically significant and produce evidence suggesting the exercise of market power by the Hungarian milk processing plats. The statistical results show that all these effects are statistically significant and indicate that the estimated parameter oligopsony market power is 0.22 and 0.30 in the estimated period since 1993 until 2006, respectively. This econometric result is consistent with a relatively highly concentration in the Hungarian milk processing industry and confirm the findings of earlier analysis of collusion in the Hungarian market for raw milk.

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