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Tobit regression to estimate impact of EU market intervention in dairy sector

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Abstract

This study examines the effect of European intervention politics in the European butter market in the context of market liberalization using the example of Germany. A heteroscedastic Tobit model is estimated using German butter market data from 1973-2010. There is evidence that price support has reduced price instability in the butter market. Simulation indicates that enhancing intervention price causes an increase in the expected butter price in the long-run, even though if market price is higher than intervention level. We find changing effects of stockpiling. If difference between market and intervention price is small and stock quantity is high, it significantly contributes to reducing price volatility. On the contrary if price difference is large and stock quantity low, the effect of reducing price volatility decreases.

Keywords: Censored regression, market liberalization, butter market.

JEL classification: C5, D4, Q11.

1. INTRODUCTION

Common Agricultural Policy (CAP) was implemented to achieve the objectives of price stabilization, farm income support, and food security in the European Community. (European Court of Auditors, 2009:12) In CAP different support mechanisms have been developed. One of the main instruments is intervention agency purchasing for various agricultural commodities, e.g. grains, sugar, butter, and skimmed milk powder (SMP). These purchases prevent market prices from falling below specified intervention prices. (Bureau of Agricultural Economics, 1985:31) The dairy sector was unconcerned by the radical change in CAP by MacSherry reform in 1992. With Agenda 2000 (Benjamin et al., 1999) and Mid-Term Review 2003 the reform process towards market liberalization continues and decreases intervention prices for butter and SMP. Because for other agricultural commodities support reduction already took place in the 1990s, European dairy market reform is still in progress. Reform's impact is not yet fully conceivable.

Basing on the work of Chavas and Kim (2006) analysing the U.S. butter market, this study examines price dynamics while lowering intervention prices using the example of the German butter market. The results of the study indicate how recent CAP reform influences butter prices. Understanding the effects of intervention politics helps to make efficient use of this instrument to manage price volatility in future. This is needed due to EU Commission's decision to retain intervention purchases and public stock holding as safety net after health check. (European Court of Auditors, 2009:42)

The paper is organized as follows. Section 2 contains a short description of the data from the German butter market. In section 3 we propose a Tobit model to analyse the butter price.

Section 4 briefly describes the maximum likelihood estimation method. Section 5 presents the results of the maximum likelihood estimation including some numeric simulations. Implications are discussed in the proximate section. The paper ends with a conclusion.

2. GERMAN BUTTER MARKET

The development of the German butter market price (EUR/100 kg) from Oct 1973 through Dec 2010 can be seen in Figure 1. From the beginning until 1991, intervention agencies in each member state bought in butter at intervention price without restrictions. In 1991 intervention is linked to market price. If market price falls below 92% of intervention price for two weeks, agencies buy butter into intervention at 90% of intervention price. (Regulation (EEC) No 1634/91) For analysis monthly purchase prices (EUR/100 kg) are used, which consist of intervention prices and from 1991 onwards of 90% of intervention prices. For explanation the monthly intervention butter stock (1000 t) is used. The prices and butter stock are accessed via the monthly reports from the German Federal Ministry of Food, Agriculture and Consumer Protection (1973-2011). Purchase price and public butter stock are displayed in Figure 1 as well. It reveals two different regimes: one with high stock quantities and high purchase price (*government regime*), and the other with low stock quantities and low purchase price (*market regime*).

Figure 1: Market price, purchase price, and public butter stock in German butter market Oct 1973 - Dec 2010.
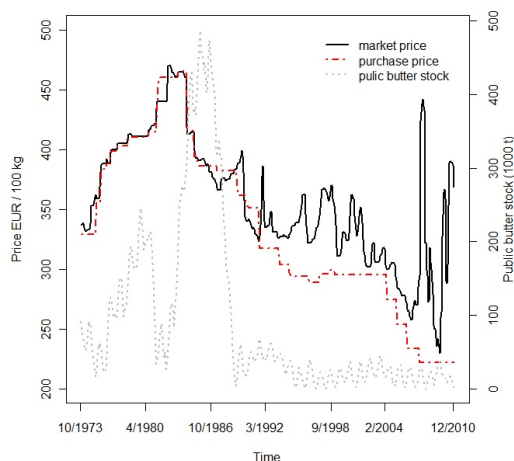
Source: own elaboration

3. TOBIT MODEL

To analyse the butter price a model is required which takes account of the fact that the dependent variable of the model is limited by intervention prices. Using Ordinary Least Squares (OLS) estimation yields biased estimates due to violation of the linearity assumption.

(Amemiya, 1984) The Tobit model (1), suggested by Tobin (1958) accounts for left censoring at s_t. In the model p_t^* is a latent variable representing market outcome without censoring, whereas dependent variable p_t and regression vector $\boldsymbol{X}_t$ are observed for each t. Tobin (1958) assumed disturbances u_t to be normal distributed $N(0, \sigma_t^2)$.

$$p_t^* = f(\boldsymbol{X}_t, \beta) + u_t \qquad p_t = \begin{cases} p_t^*, if\ p_t^* > s_t, \\ s_t, if\ p_t^* \le s_t, \end{cases} t = 1, \dots, T. \qquad (1)$$

To control for long-term and seasonality effects, $\boldsymbol{X}_t$ includes time-trend (TT) and quarterly dummy variables ($Q1, Q2, Q3$). In theory, high (low) public butter stock at time $t-1$ (ST_{t-1}) lowers (raises) market price and price volatility at t. Therefore, $\boldsymbol{X}_t$ contains ST_{t-1} as well. (Chavas and Kim, 2006, Wright and Williams, 1982) Since Mid-Term Review 2003, intervention on butter market is limited to the period 1st March until 31th August. This agreement becomes effective in 2005. A dummy-variable ($D03$ equal 1, if intervention is limited in time) controls for impact of time limitation on seasonality.

Chavas and Kim (2006) detected heteroscedasticity in their data. To account for potentially heteroscedasticity in our data, standard deviation σ_t is changing over time. Variables affecting σ_t are investigated to answer the question whether variance increase is due to lowering intervention prices or other factors. Following Chavas and Kim (2006), used standard deviation specification is $\sigma_t = exp\,(\gamma' \boldsymbol{Z}_t)$. Beside time trend TT to control for long-term changes in σ_t the difference of price to intervention level ($p_{t-1} - s_{t-1}$) is included in $\boldsymbol{Z}_t$. If the difference is low, it is likely to correspond to the *government regime*. If the difference is high, it is likely to correspond to the *market regime*. Similar to Chavas and Kim (2006) it detects changes in market instability not captured by censoring. Also, the effect of the difference on standard deviation should vary with stock level. Therefore an interaction term (($p_{t-1} - s_{t-1})ST_{t-1}$) is introduced to reflect latent volatility shifters. Finally, the lagged stock variable ST_{t-1} is part of $\boldsymbol{Z}_t$. The model is specified as follows

Model I:
$$p_t^* = \beta_0 + \beta_1 TT + \beta_2 D03 + \beta_3 Q1 + \beta_4 Q2 + \beta_5 Q3 + \beta_6 D03 \cdot Q1 + \beta_7 D03 \cdot Q2 \qquad (2)$$
$$+ \beta_8 D03 \cdot Q3 + \beta_9 p_{t-1} + \beta_{10} p_{t-2} + \beta_{10} ST_{t-1} + u_t$$
$$\sigma_t = exp\,(\gamma_0 + \gamma_1 ST_{t-1} + \gamma_2(p_{t-1} - s_{t-1}) + \gamma_3(p_{t-1} - s_{t-1}) \cdot ST_{t-1} + \gamma_4 TT) \qquad (3)$$

To assess the impact of intervention limitation in time a second model is specified. It reuses model I without the dummy variable $D03$. Standard deviation specification (3) retains unmodified.

Model II:
$$p_t^* = \beta_0 + \beta_1 TT + \beta_2 Q1 + \beta_3 Q2 + \beta_4 Q3 + \beta_5 p_{t-1} + \beta_6 p_{t-2} + \beta_7 ST_{t-1} + u_t \qquad (4)$$
$$\sigma_t = exp\,(\gamma_0 + \gamma_1 ST_{t-1} + \gamma_2(p_{t-1} - s_{t-1}) + \gamma_3(p_{t-1} - s_{t-1}) \cdot ST_{t-1} + \gamma_4 TT) \qquad (3)$$

Define the indicator variable $D_t = 1$ if $p_t^* > s_t$. The expected value and variance of p_t are

$$E(p_t) = Prob(D_t = 1)\big[f(\boldsymbol{X_t}, \beta) + E\big(u_t | u_t > s_t - f(\boldsymbol{X_t}, \beta)\big)\big] + Prob(D_t = 0)s_t \quad (5)$$
$$= [1 - \Phi(h_t)] \cdot f(\boldsymbol{X_t}, \beta) + \sigma_t \cdot \phi(h_t) + \Phi(h_t) \cdot s_t$$

$$Var(p_t) = \sigma_t^2 \cdot [1 - \Phi(h_t) + h_t \cdot \phi(h_t) + h_t^2 \cdot \Phi(h_t) - [h_t \cdot \Phi(h_t) + \phi(h_t)]^2] \quad (6)$$

where $h_t = \frac{s_t - f(\boldsymbol{X_t}, \beta)}{\sigma_t}$, and ϕ and Φ are standard normal density and cumulative distribution function. (Chavas and Kim, 2006, Amemiya, 1984, Maddala, 1983, Tobin, 1958)

4. MAXIMUM LIKELIHOOD METHOD

We are using maximum likelihood estimation method for the model. First step in maximum likelihood estimation is to define the likelihood function, which represents the likelihood as a function of parameters given the observed data. Desired parameters are the one that maximizes the likelihood function in order to find the probability distribution that makes the observations most likely. For simplicity, logarithm of the likelihood (log likelihood) is maximized. The log likelihood of the Tobit model is

$$\log L = \sum_{t=1}^{T}\left[D_t \log\left(\frac{1}{\sigma_t}\phi\left(\frac{p_t - \beta' X_t}{\sigma_t}\right)\right) + (1 - D_t)\log\left(1 - \Phi\left(\frac{\beta' X_t - s_t}{\sigma_t}\right)\right)\right] \quad (7)$$

$$\sigma_t = exp(\gamma_t' Z_t). \quad (8)$$

Necessary condition for maximum is that first derivatives (so called score function) of the log likelihood (6) are zero in the optimum. The score function of the heteroscedastic Tobit model is (Maddala, 1983: 149 and 180)

$$\frac{\partial \log L}{\partial \beta} = \sum_{t=1}^{T}\left(D_t \frac{(p_t - \beta' X_t)X_t}{\sigma_t^2} + (1 - D_t)(-1)\frac{\phi\left(\frac{\beta' X_t - s_t}{\sigma_t}\right)X_t}{\left[1 - \Phi\left(\frac{\beta' X_t - s_t}{\sigma_t}\right)\right]\sigma_t}\right) = 0 \quad (9)$$

$$\frac{\partial \log L}{\partial \gamma} = \sum_{t=1}^{T}\left(D_t \frac{\big((p_t - \beta' X_t)^2 - \sigma_t^2\big)Z_t}{\sigma_t^2} + (1 - D_t)(-1)\frac{\phi\left(\frac{\beta' X_t - s_t}{\sigma_t}\right)(\beta' X_t - s_t)Z_t}{\left[1 - \Phi\left(\frac{\beta' X_t - s_t}{\sigma_t}\right)\right]\sigma_t}\right) = 0 \quad (10)$$

The ML estimator is strongly consistent and asymptotically normal if the standard assumptions hold. Disregarded heteroskedasticity and an incorrect normal assumption imply inconsistency for the ML estimator. (Arabmazar and Schmidt, 1981, Arabmazar and Schmidt, 1982, Hurd, 1979) Serial correlation appears not to be a major problem. (Amemiya, 1984)

Although the specified model accounts for heteroscedasticity, there is no warranty of correct specification.

5. RESULTS FROM MAXIMUM LIKELIHOOD ESTIMATION

The maximization is done by using Nelder-Mead algorithm implemented in the package `maxLik` for the statistical software `R` (for details see Henningsen (2011)). Table 1 reports the ML parameter estimates of the dynamic Tobit model I and II. To choose m (order of the AR process) in (2) and (4), the Schwarz criterion is applied. For each estimated model specification $m = 2$ is selected. To assess the impact of omitting the dummy-variable $D03$ from the model a likelihood ratio test is conducted. The test of the hypothesis these four coefficients are zero yields a test statistic of $5.8624 \sim \chi^2(4)$ (p-value 0.2097). The hypothesis that the effect of intervention's limitation in time do not matter cannot be rejected. Model I does not significantly improve the likelihood. Hence, model II is used in the following. Next, we test the assumption of heteroscedasticity. The Likelihood-Ratio statistic is $129.5651 \sim \chi^2(5)$. The p-value is 0. The null hypothesis of homoscedasticity is strongly rejected.

In the mean of model II, the first and second lagged price effects are statistically significant, reflecting significant price dynamics in the butter market. The lagged stock variable has positive impact in contradiction to theoretical considerations. In contrast to private stock holding, public stock accumulation is done if price decrease is expected. The positive estimate might reflect that stock quantity increases in *government regime* with higher price and higher butter stock comparing to *market regime* (see Figure 1), whereas stock quantity decreases in *government regime*. As well as the negative impact of lagged stock the negative time trend differs from Chavas and Kim's (2006) results. The first quarter is statistically significant. On 10%-significance level the third quarterly dummy variable is statistically significant. The estimated parameters of the standard deviation equation of model II are statistical significant beside the interaction term (p-value 0.108). We find a negative effect of lagged stock meaning stocks reduce price volatility. The effect of the difference between market price and purchase price on standard deviation is positive. As the difference increases (as in the *market regime*), standard deviation is estimated to increase. In contrast to Chavas and Kim (2006) the estimator of $((p_{t-1} - s_{t-1})\ ST_{t-1})$ has positive sign. The stock effect to reduce volatility declines under *market regime*. This result provides support for structural changes in market due to different regimes. The time trend TT has negative sign.

Table 1: ML estimates for dynamic Tobit model. Asteriks indicate statistical significance.

	model I			model II		
	Value	Std.error	p-value	Value	Std.error	p-value
$(Intercept)$	27.4748	9.3397	0.004**	27.3399	8.9908	0.002**
TT	-0.0159	0.0084	0.058	-0.0155	0.0084	0.066
$D03$	3.7747	3.6058	0.296			
$Q1$	-2.3062	1.0574	0.030*	-3.8424	1.2029	0.002**
$Q2$	0.1173	1.1547	0.920	0.1169	1.1645	0.920
$Q3$	2.2895	1.4247	0.108	2.2900	1.3091	0.080
$D03\,Q1$	-12.2268	4.8130	0.012			
$D03\,Q2$	-0.3891	4.3761	0.930			
$D03\,Q3$	2.9527	4.4506	0.508			
p_{t-1}	1.1716	0.0835	0.00***	1.1709	0.0817	0.00***
p_{t-2}	-0.2414	0.0807	0.002**	-0.2421	0.0792	0.002**
ST_{t-1}	0.0023	0.0029	0.428	0.0031	0.0038	0.426
$(Intercept)$	3.0011	0.2901	0.00***	3.0016	0.3200	0.00***
ST_{t-1}	-0.0053	0.0007	0.00***	-0.0052	0.0007	0.00***
$(p_{t-1} - s_{t-1})$	0.0081	0.0020	0.00***	0.0068	0.0016	0.00***
$(p_{t-1} - s_{t-1})ST_{t-1}$	0.0001	0.0001	0.556	0.0002	0.0001	0.108
TT	-0.0021	0.0007	0.004**	-0.0023	0.0008	0.004**
Log likelihood		-1347.377			-1350.308	

Source: own estimation

Figure 2: Expected prices, market prices and purchase prices in German butter market Oct 1973 - Dec 2010.
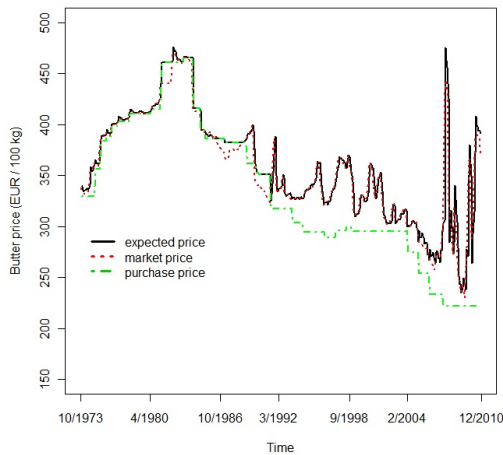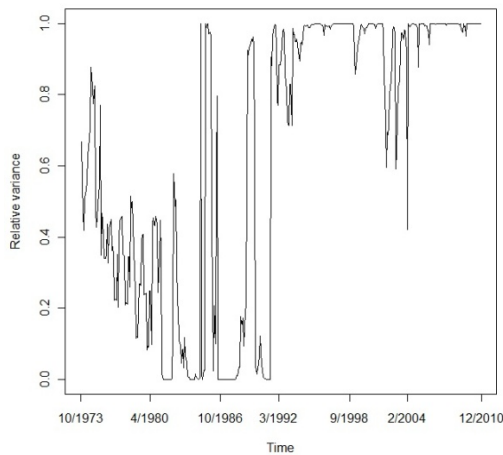

Source: own calculation

Performance evaluation of model II is done comparing expected price from (5) with observed prices (see Figure 2). From the beginning of the 1990s the estimated model has high explanatory power. To investigate the relative role of intervention politics in the estimated variance, $Var(p_t)/\sigma_t^2$ is derived from (6). In absence of censoring the relation is one, whereas it is close to zero in the presence of strong censoring effects. (Chavas and Kim, 2006) Figure 3

shows the results. Predicted standard deviation of butter price from (6) is shown in Figure 4. The smallest standard deviation is in the 1980s. This finding can be explained by Figure 3, which shows strong censoring effect in the 1980s. Also, largest standard deviation (Figure 4) comes along with moderate censoring effect (Figure 3) due to reducing support prices in 1990s until today (Figure 1).

Figure 3: Relative variance $Var(p_t)/\sigma_t^2$.

Source: own calculation

Figure 4: Estimated standard deviation $\sqrt{Var(p_t)}$.
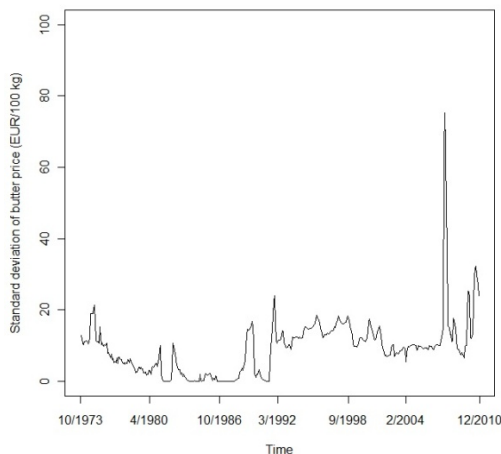
Source: own calculation

In accordance with Chavas and Kim (2006) numerical simulation is conducted. Their conclusions are broadly in line with the ones we get. Basing on Figure 3 we presume period starting in Oct 1994 to be *market regime* and period starting in Jan 1984 to be *government regime*. Using historical data for explanatory data we simulate the forward path of expected

price and standard deviation of price derived from (5) and (6) for 24 months. At first we examine the effect of a temporary shock in the price of butter in those two regimes. After this we analyse permanent changes in the purchase price. All observed dynamics depend on the initial circumstances of chosen periods. Therefore, as mentioned in Chavas and Kim (2006), results are "local" in nature.

Figure 5 shows simulation results of a temporary exogenous shock in the price of butter (+10 EUR / 100 kg). It is calculated as relative deviation of expected price level in the absence of the temporary change. In *market regime* the shock has large effect on expected butter price. Return to expected price level without shock lasts the whole simulated period. The temporary shock in butter price increases volatility for some time. In *government regime* after few months price returns to expected price level without shock. The standard deviation explodes after the shock and then quickly returns to expected level without shock. It is a coherent result as government intervention is driving force in *government regime*.

Figure 5: Simulation: Temporary price shock in Dec 1983 (government regime) and in Jul 1994 (market regime).
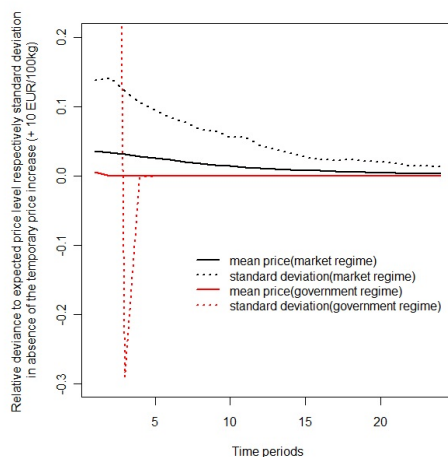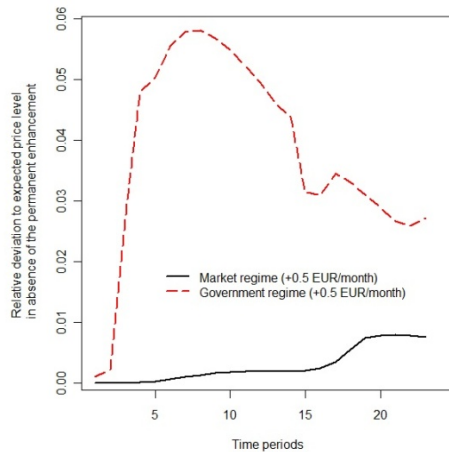

Source: own calculation

Next, we simulate a permanent increase in the purchase price. The effect can be seen in Figure 6. Again, it is calculated as relative deviation of expected price level in the absence of the permanent change. In *government regime* development is dominated by the change in purchase price (+0.5 EUR/month). All the time it is a positive effect. Interestingly, expected price also increases in *market regime*. The increase of the expected price can be explained by the way of how to calculate it (see (5)). It is a weighted average of y_t^* and s_t. The weights are given by the probability of intervention. As purchase price s_t increases the probability of intervention increases as well. We also investigate the expected standard deviation. In the *market regime* there is no significant change. Similar to Chavas and Kim (2006) in the *government regime* the initial effect is negative and large. After 4 months we can observe a positive large effect. This positive effect changes to negative effect again and starts to fluctuate

to positive. We assume it is due to the increasing price level and the estimated overshooting ($\hat{\beta}_9 > 1$).

Figure 6: Simulation: Permanent increase in purchase price.

Source: own calculation

In Addition, the elasticity of the mean and standard deviation of butter price with respect to public butter stock is calculated in both regimes. For calculation particular average values in each regime are used. Results are given in Table 2. Comparing to Chavas and Kim (2006) we find different results. The elasticity of mean price with respect to stock is positive in both regimes. In *government regime* the effect is larger. The elasticities of standard deviation with respect to butter stock do have different signs. In *government regime* stockpiling contributes to reducing price volatility. On the contrary in *market regime* stock accumulation is conducive to raise standard deviation. The different effects can follow from different stock quantities, i.e. high public butter stock (*government regime*) lowers price volatility, whereas low stock (*market regime*) raises market volatility.

Table 2: Elasticities with respect to public butter stock.

	Elasticity of $E(p_t)$ with respect to butter stock	Elasticity of $\sqrt{Var(p_t)}$ with respect to butter stock
Market regime	0.0110	0.0358
Government regime	0.2778	-2.0794

Source: own calculation

6. IMPLICATIONS

From the estimated model and numerical simulations different implications can be drawn. At first we investigate the relative effect of intervention politics on price instability. It is done by calculating relative variance $\sqrt{Var(p_t)}/\sigma_t$. It measures the impact of censoring from intervention politics on price volatility. In case of censoring, the relative variance is reduced. The reduction indicates how government intervention decreases volatility. (Chavas and Kim (2006)) The effect is largest in 1980s and weakest in the 1990s. This result is similar to findings in the U.S. butter market. It provides evidence that price support has reduced price instability in the German butter market.

Second we conduct numerical simulations. Under *government regime* the effects of a temporary shock on market price has small effect on price dynamics. After only few months expected price returns to expected level without shock. Price volatility is stronger affected, but still after strong upward and downward movements it returns to expected level without shock. In *market regime* it takes a long time to dissipate exogenous price shock. Both expected price level and volatility are higher compared to situation without exogenous price change. In absence of government intervention there are other price adjustments on the market.

Analysis of permanent enhancement in purchase price indicates that purchase price is a determining factor in price development. If difference between market and purchase price is low, a permanent increase in purchase price leads to a permanent increase in expected market price. In such situation estimated price volatility is much more affected and tends to fluctuate in both directions. If difference between market and purchase price is high, there is only little effect on price volatility. The effect on price dynamics takes place in the long run only. After 16 months expected price level significantly increases although market price is above purchase price.

Chavas and Kim (2006) observe the same impact. If intervention price is below market price the results indicate that intervention price still can affect expected price. In the long-run it can contribute to increase expected prices. We would like to point out that an increase in intervention price also rises the probability of intervention. Next to the conclusion from Chavas and Kim (2006) *"that it is possible for government policy to affect long-term market behavior at a relatively low cost to taxpayers"* (Chavas and Kim, 2006:80), it must be considered that increasing probability of intervention also rises the expected public expenditures regarding intervention $(E(Public\ expenditures) = Prob(Dt = 0) \cdot C + Prob(Dt = 1) \cdot 0$, where C is costs of government intervention). It is arguable whether this is to aspire.

Using mean data from both regimes we estimate elasticities with respect to butter stock. The elasticity of mean price with respect to stock is larger in *government regime* comparing to *market regime*. But still, the effect is very small. In *government regime* butter stock can contribute to significant reduction in price volatility. This is in contrast to findings from Chavas and Kim (2006). They concluded that effect of stock on reducing price volatility is stronger in *market regime*. Our results may follow from the impact of already existing quantities of public stock. This interaction effect has to be considered as well.

7. CONCLUSIONS

Our goal is to examine the effects of European intervention politics in the butter market. German butter market is taken to exemplify the effects. Basing on the analysis of the U.S. butter market done by Chavas and Kim (2006), we estimate a heteroscedastic Tobit model and conduct some simulations. Monthly data for the period Oct 1973 through Dec 2010 are used. The Tobit model accounts for censoring due to intervention politics on the market.

The estimated model gives some insight to the dynamics of butter prices and their changing volatility. We show how price volatility has changed. Since the 1990s the price volatility increases. It is associated with lowering support price.

Our analysis provides evidence on the price stabilization effects of intervention politics. In *government regime* exogenous price shocks dissipate in short time. Also, in *government regime* public stock has significant effect on reduction of price volatility. But, the volatility reducing effect of stock tends to change in *market regime* (where stock quantity is low). It emphasizes the need to investigate the interactions of price dynamics and storage behavior.

The simulation of permanent enhancement of intervention price documents some dynamic aspects of price adjustment in the *market regime* scenario (intervention price below market price). Although it takes some time, there is positive influence on price expectation observable due to increasing purchase price. This result is probably useable to stabilize markets in the long run. Keeping support price below market price, government intervention purchases are still possible in case of sudden low prices. As Chavas and Kim (2006) mentioned, the role of expectation formation in price dynamics need further research for efficient usage of such intervention purchases and intervention price.

Altogether, these results suggest that intervention price may play a key role in stabilizing and supporting European butter market. The ML estimates of the Tobit model including distribution assumptions provide a useful framework for analysis. Results do not deviate significantly from the analysis of the American butter market. The validity of the results requires correct specifications. Therefore, further estimation should be done using censored least absolute deviation (CLAD) estimation which is robust to heteroscedasticity and nonnormality. (Amemiya, 1984, Powell, 1984, Powell, 1986) Since its robustness CLAD method is in some way the natural benchmark. (Chay, 2001) CLAD results can be used to provide information on sources of misspecification in the log likelihood. In future work distributional specification should be tested by a Hausman Test basing on CLAD estimation. (Newey, 1987, Peters, 1991) Also, further research on world market's impact on price adjustment in the period of market liberalization is to conduct.

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