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Multiple-regime price transmission between wheat and wheat flour prices in Korea

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Abstract: In order to derive the evidence of the asymmetric price transmission, we employed the threshold estimation for the price relationship between the imported wheat and the wheat flour prices. We estimated the exact level of threshold points of the imported wheat price that have different impacts on the Korean wheat flour price. Our empirical estimations proved the main hypothesis of this study, namely, that the impact of input price on output price is stronger at higher levels of the input price. In the sub-sample, which includes data from January 1993 to January 2008, the price transmission effect from the imported wheat to the domestic wheat flour in the Regime 3, in which wheat prices are the highest among our three regimes, is larger than that in the Regime 2. In the whole sample, which includes data from January 1993 to March 2014, the price transmission effect in the Regime 3 is larger than that in the Regime 2, and that of the Regime 2 is larger than that of the Regime 1.

Key words: asymmetric price transmission, price equation, reduced form, threshold estimation

Prices are the main connection among markets, and therefore, the analysis of the price transmission from one market to another enables us to derive information regarding the extent of market linkages, how price adjustment occurs, and how efficiently the markets work. Previous studies that investigated the price transmission can be classified according to the specific market linkage or product under investigation. Examples of the main issues regarding market linkages are price relationships in input and output markets, different layers of supply chains, or spatially disperse markets. Meanwhile, a variety of products, from agricultural commodities to forest products, has been analysed empirically in the context of the price transmission.

The other criterion for classifying studies on the price transmission is the type of the transmission itself. While numerous studies have presumed the symmetric price transmission from one market to another, a significant number of studies have investigated the transmission structure that captures the difference in the responses of the output price to the negative and positive shocks in input prices. If the change in the output price to the rise in the input price is different from the change to the fall in the input price, it has been regarded as an evidence of the asymmetric price transmission (APT). Notable examples for this line of investigation of the APT include studies in the crude oil and gasoline industries (Borenstein et al. 1997; Kaufmann and Laskowski 2005; Kilian and Vigfusson 2011), pork prices in marketing stages (Boyd and Brorsen 1988; von Cramon-Taubadel 1998; Abdulai 2002; Čechura and Šobrová 2008), beef prices (Goodwin and Holt 1999; Luoma et al. 2004; Hassouneh et al. 2010), the prices retail level (Peltzman 2000; Carman and Sexton 2005), the producer and consumer prices of agricultural commodities (Ward 1982; Herry and Forker 1987; Azzam 1999; Bettendorf and Verboven 2000; Ahn and Kim 2008) and the price transmission among spatially separated markets (Bailey and Brorsen 1989; Abdulai 2000).

These previous studies, however, are limited to reflect the more interesting nature of the APT, since the regimes in which prices are transmitted are only separated into two: price-rising regime and price-falling regime. However, the patterns of prices being transmitted can be differentiated by the price levels.

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In other words, if the price of interest is below a reference point, then the price transmission appears differently from the one when the price is above the reference level. This implies the number of regimes that have different price-transmitting patterns is not only two as in the above studies but it depends on the number of the reference points which are proven to be statistically meaningful. Building on this line of study that allows multiple regimes, the present study investigates the APT by differentiating the regimes of price transmission using the threshold regression for the relationship between the imported wheat price in Korea and the wheat flour price.

Wheat consumption in Korea has continuously increased during the last several decades and wheat products have become second most important food after rice. With this background, the wheat flour price has received much attention from the consumers and the government since it significantly influences the food expenditure of households. Wheat flour is a primary product processed from wheat, therefore, the wheat price is the major determinant of the wheat flour price. In Korea, most of wheat is imported, thus the fluctuation of the international wheat price is directly transmitted to the prices of domestic wheat flour and the related wheat products. In this regard, a number of studies have attempted to investigate the relationship between the prices of wheat and the wheat flour prices in Korea. Kim and Kim (2009) estimated the lead-lag relationship between domestic wheat flour and price of the imported wheat. Hwang et al. (2012) analysed the price transmission effects from wheat to the wheat flour prices. Kim et al. (2012) estimated the APT effects between wheat and the wheat flour prices. Lee et al. (2011) analysed the effects of increase in the wheat price on the wheat products such as the wheat flour, bread and noodles. However, none of these studies have investigated the APT in the framework of multiple regimes. The research question that the present study investigates is whether there exist specific reference levels of the international wheat price (i.e., the threshold points) by which the price transmission from wheat to wheat flour are differentiated. If there exist the reference prices, how the price transmission effects differ by the regimes is the other issue that the present study intends to explore. If we have different transmission patterns at different levels of international wheat prices, the implications of wheat price to the domestic market and the associated policy considerations would differ by each regime.

Most previous studies on the APT focused on the relationship between the input and output prices only, whether they followed the traditional approach that differentiates the price-rising regime from the price-falling regime or the methodology that allows several regimes by which different price transmission patterns appear. The current paper contributes to the literature by reflecting the influences of the demand and supply shifters on the input–output price relationship. When the input and output markets are faced with common factors that influence both prices, a simple setting that focuses on the price transmission from input to output would be sufficient for the empirical implementation. However, for the relationship between wheat and wheat flour prices, the factors that affects the wheat flour price are not the same as those which affect the wheat price since wheat the price is determined at the international market whereas the wheat flour price is formed at the domestic market. In selecting the demand and supply shifters for the wheat flour price equation, the current study includes a theoretical framework of the input demand and the final demand and also uses the industrial background. In the empirical analysis, the redundant variable tests are performed and the endogeneity problem is controlled for estimating a reasonable price equation.

EMPIRICAL MODEL

A large number of previous studies on the APT analysed the asymmetric price transmission by differentiating the regimes based on the criteria of the increase or decrease in the input price. Thus, these approaches can test only the asymmetry of the response of output price to the increased and decreased input price. However, if we depend on the threshold regression, the criteria that differentiate the regimes for different APT results can be endogenously determined (Goodwin and Holt 1999l; Ghoshray 2002; Myers and Jayne 2011; Simioni et al. 2013).

For the application of the threshold regression model, first we set up the reduced form price equation based on the demand and supply of wheat flour. Wheat flour is consumed partially by final consumers for the household purposes. However, it is demanded generally by the industry users or restaurant owners as an input for making wheat products, such as bread and noodles. Thus, we have to consider several aspects in deriving the wheat flour price equation. Equation (1) indicates demand for wheat flour when it is con-

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sumed as a final good by consumers. Equation (2) shows demand for wheat flour when it is demanded as an intermediate good or an input.

$$Q_{DD} = f_{dd}\,(P_f,\, Inc,\, P_m) \quad (1)$$

$$Q_{ID} = f_{ID}\,(P_{fI},\, P_{rm}) \quad (2)$$

where P_f is the wheat flour price faced by consumers, *Inc* is the consumers' income, P_m is the demand shifter (e.g., the prices of substitutes and complementary goods) when it is demanded as a final good, P_{fI}, is the wheat flour price faced by the industry users or restaurant owners and P_{rm} is the demand shifter of wheat flour demand when it is demanded as an intermediate good. From the production theory, we can derive the input demand, which is a function of its own price, other input prices, and output prices. Thus, the demand shifter P_{rm} in Equation (2) may include the prices of wheat products (e.g., bread, noodles, and ramen) and the prices of inputs that can substitute wheat flour in wheat products. By aggregating Equations (1) and (2), we can represent the total demand for wheat flour as $Q_D = f_d\,(P_f,\, P_{fI},\, P_{rm},\, Inc,\, P_m)$. For the simplicity, we assume the price (P_{fI}) faced by the industry users or restaurant owners is lower than the price of P_f by δ percent since the industry users or restaurant owners are likely to purchase the wheat flour in a large volume thus would purchase at a lower (or discounted) price. Under this assumption, the aggregate demand can be expressed as the Equation (3), reflecting the share (θ) of consumption by the consumers within the total consumption of wheat flour. The composite price P_{fC} in Equation (3) is the share-weighted average prices of P_f and P_{fI}

$$\begin{aligned} Q_D &= f_d\big(P_f, (1-\delta)P_f, P_{rm}, Inc, P_m\big) \\ &= f_d\big([(\theta + (1-\theta)(1-\delta))P_f, P_{rm}, Inc, P_m\big) \\ &= f_d\big(P_{fC}, P_{rm}, Inc, P_m\big) \end{aligned} \quad (3)$$

On the other hand, the supply of wheat flour includes several cost-side factors. The most important raw material for producing wheat flour is wheat while other input costs for making wheat flour can influence the supply of wheat flour. Therefore, the supply function of wheat flour can be represented as the Equation (4), assuming the effective price that is paid by the wheat flour producers is the composite price of P_{fC}.

$$Q_S = f_s(P_{fc}, P_w, W) \quad (4)$$

where P_w is the price of wheat and W is the supply shifter for wheat flour, such as the prices of inputs for making wheat flour. Under the equilibrium of wheat flour supply and demand, we can derive the reduced-form price equation as the Equation (5).

$$P_{fc} = f(P_w, P_{rm}, Inc, P_m, W) \quad (5)$$

Equation (6) shows how to specify the threshold with which we differentiate the regimes of the price transmission between the input and output prices, if there are two threshold points (i.e., c_1 and c_2) in the input price.

$$\begin{aligned} P_t^{output} &= \\ &= \alpha_1 + \phi_1 P_t^{input} + \beta_1 DS_t + \gamma_1 SS_t + \varepsilon_t \;\; if\; P_t^{input} < c_1 \\ &= \alpha_2 + \phi_2 P_t^{input} + \beta_2 DS_t + \gamma_2 SS_t + \varepsilon_t \;\; if\; c_1 \le P_t^{input} < c_2 \\ &= \alpha_3 + \phi_3 P_t^{input} + \beta_3 DS_t + \gamma_{31} SS_t + \varepsilon_t \;\; if\; P_t^{input} > c_2 \end{aligned} \quad (6)$$

where P_t^{output} is the output price, P_t^{input} is the input price, DS_t is the demand shifter and SS_t is the supply shifter. The wheat flour price is the output price in the relationship between the wheat price and wheat flour price. In comparison with the Equation (6), the variables P_{rm}, *Inc* and P_m in the Equation (5) are the demand shifter *DS* and the variable *W* in the Equation (5) is the supply shifter *SS*. For empirical implementation, we considered demand shifters of wheat flower to be prices of ramen, bread, meat, and rice as well as the personal income, and the supply shifters of wheat flour to be the prices of electricity, intermediate goods, and wage. We identified the threshold points and estimated the price equations in the different regimes by the following econometric procedures in Hansen (2000).

DATA

The data used in the empirical estimation are explained in Table 1. We depend on the monthly data from January 1993 to December 2013. The wheat flour price, the dependent variable, is the consumer price index for the domestic flour market and the base year is 2010 (i.e., the average of monthly prices in 2010 is set to be 100). The imported wheat price, the variable for threshold points, is calculated by dividing the total value of the imported wheat by the total quantity of the imported wheat.

As discussed in Section 2, we included demand and supply shifters for the wheat flour price equation. *Elec, Wage, and Inter* are the variables for the supply shifters. *Elec* is the producer price index of electricity. *Wage* in Table 1 is the wage index in the processing industry. *Inter* is the price index for the intermediate goods in the manufacturing indus-

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Table 1. Variable explanation

Variable	Explanation of variable
Flour	Consumer price index of wheat flour (average of monthly prices in 2010 = 100)
Wheat	Imported wheat price per kg (Won, nominal)
Elec	Producer price index of electricity (average of monthly prices in 2010 = 100)
Wage	Wage index in processing industry (average of monthly prices in 2010 = 100)
Inter	Index of intermediate goods in industry (average of monthly prices in 2010 = 100)
Ramen	Consumer price index of ramen (average of monthly prices in 2010 = 100)
Bread	Consumer price index of bread (average of monthly prices in 2010 = 100)
Meat	Consumer price index of meat (average of monthly prices in 2010 = 100)
Rice	Consumer price index of rice (average of monthly prices in 2010 = 100)
Income	Growth rate of nominal income (%)
Soybean oil	Consumer price index of soybean oil (average of monthly prices in 2010 = 100)
Dummy1	Period of IMF financial crisis (IMF period = 1, 0 otherwise)
Dummy2	Period of international financial crisis (crisis period = 1, 0 otherwise)

try. On the other hand, *Ramen, Bread, Meat, Rice, Income*, and *Soybeanoil* are the variables included as the demand shifters. *Ramen* in Table 1 indicates the consumer price index of ramen. *Bread* in Table 1 is the consumer price index of bread. *Meat, Rice* and *Soybeanoil* in Table 1 are the consumer price indexes of meat, rice, and soybean oil. As an income variable, we used the growth rate of the nominal income. All the data other than the wheat price were collected from the Korean Statistical Information Service (KOSIS). Wheat prices are based on data from the Korean Agricultural Trade Information (KATI) and the Economic Statistics System (ECOS). In order to reflect the impacts of the financial crises in 1998 and 2008, we included dummy variables (*Dummy 1* and *Dummy 2*).

Table 2 presents the summary statistics of the data. The wheat flour price index is between 30.80 and 147.44. The threshold variable, the imported wheat price, is between 131.28 and 636.52 won/kg. Since *Flour, Elec, Wage, Inter, Ramen, Bread, Meat, Rice*, and *Soybeanoil* are price indexes, the range of the imported wheat prices in Table 2 is broader than these variables. *Income* is the growth rate of nominal income, thus, it has a minimum value of the negative number, –6.8.

Table 2. Data summary statistics

Variable	Max	Min	Mean	S.D
Flour	147.44	30.80	70.51	30.73
Wheat	636.52	131.28	262.93	114.61
Elec	136.53	56.46	80.74	20.49
Wage	124.81	27.83	71.43	26.96
Inter	110.62	53.64	79.34	17.05
Ramen	107.91	40.96	74.91	21.48
Bread	126.64	44.34	80.23	20.40
Meat	115.10	44.19	71.74	22.98
Rice	129.99	67.27	102.25	14.86
Income	6.5	–6.8	1.75	1.93
Soybean oil	112.10	40.57	70.88	22.79

As mentioned, wheat is the second largest grain consumed in Korea after rice; the country's per capita annual consumption of wheat is 33.9 kg. Currently, the ratio of the domestic production to the total consumption of wheat is only 0.7% and most is imported from other countries, such as the US and Canada. Therefore, from the perspective of Korea, the wheat price is determined exogenously and the domestic wheat flour price is influenced mainly by the imported wheat price. Meanwhile, Korea does not import wheat flour, thus the price of wheat flour is purely determined at the domestic market. As Figure 1 shows, wheat and wheat flour prices in Korea move in a similar fashion but show different transmission patterns by the period.

The movements in wheat and wheat flour prices are very similar before a big spike in the international prices of grain, including wheat, in 2008. However, after 2008, the relationship between wheat and wheat flour prices changes. While the wheat prices in 2009 and 2010 fell significantly after the rapid increase in 2008, they remained at a relatively high level, albeit lower than in 2008. This suggests a threshold point around the time of the big spike in 2008. Another observable characteristic in Figure 1 is the pattern of the price gap between the wheat and wheat flour prices. The differences are large at the wheat price of around 350 won/kg or 430 won/kg, which implies

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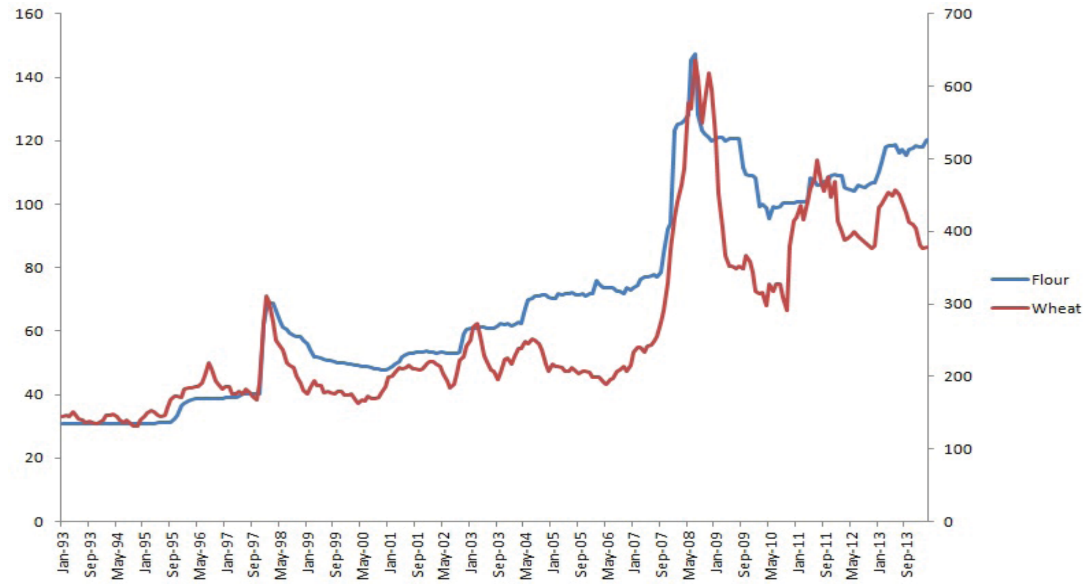

Figure 1. Prices of domestic flour and imported wheat

Note: Since there is no announced data for the wheat flour price, we illustrate the price index of wheat flour. The left vertical axis indicates the price index of wheat flour (2010 = 100) and the right vertical axis indicates the price of imported wheat (Korean won/kg).

that these price levels are other candidates for the threshold points.

ESTIMATION RESULTS

It is widely known that there was a strong spike in the world grain prices in 2008.[1] To investigate how big this shock was on the price transmission structure, we first estimated the wheat flour price equation using the sub-sample that does not include the impact in 2008, and then, we estimated the price equation including the shock in 2008. For this, we divided the data into samples. The first sample (sub-sample) covers January 1993–January 2008 and the second sample, which is the whole sample, covers January 1993–March 2014.

In estimating the reduced-form price equation, we followed several steps. First, we estimated the base model, which includes all candidate variables of the demand and supply shifters that can affect the domestic wheat flour price. Next, we found redundant variables whose influences are trivial. Some unnecessary variables are excluded based on the result of the redundant variable test. Third, we tested the existence of threshold points. If the test results indicated a significant threshold point, we conducted the threshold test again for each regime which is differentiated by the threshold point identified by the prior test. Finally, we estimated the price equations for each regime.

Estimation results of base equation

Table 3 represents the estimation results of the base price equation. In conducting the empirical implementation, the initial price equation that includes all the variables, *Wheat, Wage, Inter, Elec, Ramen, Soybeanoil, Bread, Income, Rice, Meat, Dummy1* and *AR(1)* was estimated (as in table 1 and 3 in appendix) first. In this initial equation, *Dummy1* is the dummy variable that represents the period of the Asian financial crisis in 1997–1998 while *Dummy2* represents the period of the international financial crisis in 2008~2009. After estimating the initial equation, the redundant variable test was performed. For

[1]Regarding the reasons for the price shock in 2008, there have been alternative explanations such as increase in the feed use due to meat consumption rises in Indian and China, decrease in production due to drought and fire, speculative bubbles, rise in energy and fertilizer costs, dollar depreciation and increase in biofuel demand etc. Among these reasons, change in demand shifter such as the policy that surge in demand for biofuel is proven to have a significant effect (Wright 2014).

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Table 3. Estimation results of price equation

Variables	Estimation result using sub-sample (Jan. 1993–Jan. 2008)		Estimation results using whole sample (Jan. 1993–Mar.2014)	
Constant	–52.8999***	(7.3157)	–15.1568	(17.9340)
Wheat	0.1278***	(0.0152)	0.0267***	(0.0085)
Inter	0.8981***	(0.1465)	0.8174***	(0.1751)
Soybean oil	0.2986***	(0.0967)	0.2340***	(0.0659)
Income	0.3833	(0.2655)	0.1878	(0.2307)
Dummy1	0.5817	(1.7477)	6.1252***	(1.8447)
Dummy2			17.9899***	(1.6880)
AR(1)	0.8326***	(0.0546)	0.9761***	(0.0190)
Adjusted *R*-squared	0.981752		0.994214	

( ) indicates standard error; *, **, and *** are significant at 90%, 95%, and 99% levels

this test, we preselected key variables from the direct and indirect demand shifters as well as the supply shifters. Of the demand shifters for the direct demand for wheat flour, we chose *Income* as the preselection variable because income is an important factor for the consumer decisions. Of the demand shifters for the indirect demand (i.e., the input demand for wheat flour), we chose the price of *Ramen* as the preselection variable because the production quantity of *Ramen* is the largest among the foods processed from wheat flour. Of the supply shifters, we chose the price of the intermediate good (*Inter*) as the preselection variable because the intermediate goods include all the most important inputs for making wheat flour, other than wheat.

The redundant variable test indicated that *Wage, Elec, Bread, Rice*, and *Meat* are unnecessary variables (as in Table 2 and 4 in appendix). Therefore, we estimated the final form of the empirical equation as in Table 3 after excluding these redundant variables. The price of ramen influences the price of wheat flour because it is an output price that is one of the most important explanatory variables in the input demand function of wheat flour. However, at the same time, the price of wheat flour is an input price for making ramen, and thus, it influences the ramen price. Therefore, there arises a simultaneity issue that is a type of the endogeneity problem. In order to handle this problem, we used an instrumental variable. A reasonable instrumental variable has to be related closely with the price of ramen, but it must not affect the wheat flour price. We chose the price of the soybean oil because this product is one of the most important materials to make ramen but is not related with the price of wheat flour.

In the results from the sub-sample period, the estimated coefficient of *Wheat* is significantly positive. The coefficient on *Inter* is estimated to be a significantly positive number. The coefficient on the instrument variable, *Soybeanoil*, is estimated to be 0.2986 and is significantly positive. For the whole sample period, the estimated coefficients of *Wheat, Inter*, and *Soybeanoil* are 0.0267, 0.8174, and 0.2340, respectively. We used the empirical equation that yields the results in table 3 as the final form of the price equation for testing the existence of thresholds and estimating the transmission equation by each regime.[2]

Test results for the existence of threshold points

Table 4 reports the results of the test for the existence of the threshold points based on the sub-

Table 4. Threshold estimation results based on the sub-sample

Null hypothesis	Whole data range: no threshold in whole data range	Regime A: no threshold in regime A (under the wheat price of 208.8435 won/kg)	Regime B: no threshold in regime B (upper the wheat price of 208.8435 won/kg)
Number of bootstrap Replication	1000	1000	1000
Trimming %	0.01	0.01	0.01
Threshold estimate	208.8435 won/kg	194.6068 won/kg	232.9253 won/kg
Bootstrap *P*-value	0.023	0.119	0.050

[2]We checked whether seasonality should be controlled in the price equation since monthly data is used in the analysis. The *F*-test statistics for the null hypothesis that seasonal dummies are jointly zeros were 0.2364 (2, 170) and 0.9818 (3, 243) with *p*-values of 0.8709 and 0.4019 for the sub- and whole sample estimations, respectively. Therefore, we did not include seasonal dummy variables in the final form of price equation.

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Table 5. Threshold estimation results of whole sample (Jan. 1993–Mar. 2014)

Null hypothesis	Whole data range	Regime A
	no threshold in whole data range	no threshold in regime A (under a wheat price of 464.0359 won/kg)
Number of bootstrap replication	1000	1000
Trimming %	0.01	0.01
Threshold estimate	464.0359 won/kg	344.2669 won/kg
Bootstrap P-value	0.001	0.077

sample from January 1993 to January 2008. First, we checked the existence of the threshold under the null hypothesis of no threshold. The number of the bootstrap replications was set as 1000 and the trimming percentage was set by 0.01, following the econometric procedures in Hansen (2000). The threshold point is identified as 208.8435 won/kg and the test results indicate that the existence of a threshold at this point is significant.

We then divided the sample into two regimes based on the estimated threshold point of 208.8435 won per kg. Regime A is the data range in which the wheat price is lower than the 208.8435 won/kg and Regime B is the data range in which the wheat price is higher than the 208.8435 won/kg. We estimated the threshold point again using the data in Regime A and the null hypothesis of no threshold cannot be rejected. Thus, we concluded that there is no threshold point in Regime A. In addition, we tested for the existence of a threshold in Regime B. The estimated threshold is 232.9253 won/kg. Based on this, we finally divided the data from the sub-sample covering January 1993–January 2008 into three regimes. Regime 1 represents the period when the imported wheat price was less than 208.8435 won/kg. Regime 2 is the period when the imported wheat price was between 208.8435 won/kg and 232.9253 won/kg. Lastly, Regime 3 is the period when the imported wheat price was more than 232.9253 won/kg.

The same procedure was applied to the whole sample from January 1993 to March 2014. Table 5 presents the threshold estimation results. For the whole data range, the estimated threshold is identified as 464.0359 won/kg. The estimated threshold wheat price of 464.0359 won/kg is at a relatively very high level. Thus, only 15 observations are included in the regime above this threshold, which suggests that the estimation and test results would be devoid of the firm statistical grounds. Therefore, we checked only the existence of threshold in the regime (Regime A in Table 5) under the wheat price of 464.0359 won per kg. The estimated threshold point in this regime is identified as 344.2669 won/kg. Based on these results, we finally divided the whole sample period into three regimes. Regime 1 is the period when the imported wheat price was less than 344.2669 won/kg. Regime 2 represents the period when the imported wheat price was between 344.2669 won/kg and 464.0359 won/kg. Regime 3 is the period when the imported wheat price was more than 464.0359 won/kg.

Table 6. Price equation of each regime using sub-sample

Variables	Regime 1 (P_w < 208.84)		Regime 2 (208.84 < P_w < 232.92)		Regime 3 (P_w > 232.92)	
Constant	31.4372*	(15.9581)	65.0170	(68.9396)	–10.4986	(34.2843)
Wheat	–0.0008	(0.0113)	0.1351*	(0.0718)	0.2078***	0.0175)
Income	0.0811	(0.0990)	–0.3922	(0.3717)	–1.6849	(1.7928)
Inter	0.1396	(0.1660)	–0.2227	(0.4969)	–0.7355	(0.7769)
Soybean oil	0.1156***	(0.0545)	0.0322	(0.2439)	1.2890***	0.3994)
AR(1)	0.9926***	(0.0056)	0.9805***	(0.0397)	–0.0345	(0.2644)
Adjusted *R*-squared	0.9976		0.9662		0.9428	
Elasticity of wheat flour price with respect to wheat price at the mean values for each prices	–		0.4972		0.7374	

( ) indicates standard error; *, **, and *** are significant under 90%, 95%, and 99% confidence intervals

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Table 7. Price equation of each regime using the whole sample

Variables	Regime 1 (P_w < 344.26)		Regime 2 (344.26 < P_w < 464.03)		Regime 3 (P_w > 464.03)	
Constant	−45.0704***	(4.8917)	204.6912***	(21.7893)	61.1925	(50.9954)
Wheat	0.0616***	(0.0115)	0.0850***	(0.0242)	0.1852***	(0.0527)
Income	0.1295	(0.1789)	−0.5601	(0.3389)	6.1926	(1.9709)
Inter	1.0668	(0.1009)	−1.4695***	(0.1843)	0.7435	(0.5031)
Soybean oil	0.1859***	(0.0692)	0.2303	(0.1512)	−1.2489***	(0.4051)
AR(1)	0.8479***	(0.0406)	0.4420***	(0.0963)	−0.3613	(0.4374)
Adjusted R-squared	0.9925		0.8177		0.5960	
Elasticity of wheat flour price with respect to wheat price at the mean values for each prices	0.2262		0.3085		0.8191	

( ) indicates standard error; *, **, and *** are significant under 90%, 95%, and 99% confidence intervals

Estimation results of threshold equations

We estimated the price equations in three regimes based on the results of the threshold estimations. Table 6 shows the estimation results of the price equation using the sub-sample. In Regime 1, in which the imported wheat price is lower than 208.84 won per kg, the price of the imported wheat is estimated to have no influence on the domestic wheat flour price. The price of soybean oil and *AR(1)* term are the only factors that have significant impacts on the wheat flour price.

Estimation results using the data in Regime 2, in which the imported wheat price is between 208.84 won per kg and 232.92 won/kg, differ from those for Regime 1. In Regime 2, the estimated coefficient on the wheat price is 0.1351 and statically significant at the 10% level. The coefficient of *AR(1)* is estimated to be significantly positive. In Regime 3, in which the wheat price is more than the second threshold of 232.92 won per kg, the coefficient on the wheat price is estimated as 0.2078, which is statistically significant at the 1% level. In addition, the soybean oil price is estimated to be significant.

These estimation results imply that each regime has different price transmission effects between the imported wheat and domestic wheat flour prices. The transmission effect is more powerful in Regime 3 than in Regime 2 and there is no price transmission effect between the input price of wheat and the output price of wheat flour in Regime 1.

The estimation results based on the whole sample are similar to those of the subsample. Table 7 reports the estimation results on the data from January 1993 to March 2014. In Regime 1, in which the imported wheat price is lower than 344.26 won/kg, the estimated coefficient on the wheat price is estimated to be 0.0616, which is significant at the 1% level. In addition, the soybean oil price and the *AR(1)* term are estimated to be significant. In Regime 2, in which the price of the imported wheat is between 344.26 won/kg and 464.03 won/kg, the coefficient on the wheat price is estimated be 0.0850 and is statistically significant. The coefficient on the wheat price is estimated to be 0.1852 and is significant in Regime 3, which is the highest level of wheat price. The coefficients on the wheat price across each regime imply that the price transmission effect between the imported wheat and domestic wheat flour become stronger when the imported wheat price rises.

Across the estimation results based on the sub- and whole sample, wheat price is found to be more transmitted to the wheat flour price at the regimes where the wheat prices are higher. This result implies that the wheat flour producers may consider the specific levels of wheat price as reference points and charge higher price if the wheat price becomes higher than each specified reference point. We calculated the elasticity of wheat flour price with respect to the price of wheat at the mean values as indicated in the last rows in tables 6 and 7, since the units of the prices of wheat flour and wheat are different one each other and thus the estimated coefficient on wheat price does not deliver the explicit meaning directly. As illustrated, the elasticities become greater at the regimes of higher wheat prices. For example, the elasticities based on the estimation results from the whole sample are derived as 0.2262, 0.3075 and 0.8191 for regime 1, 2 and 3, respectively. In other words, one percent increase in wheat price results

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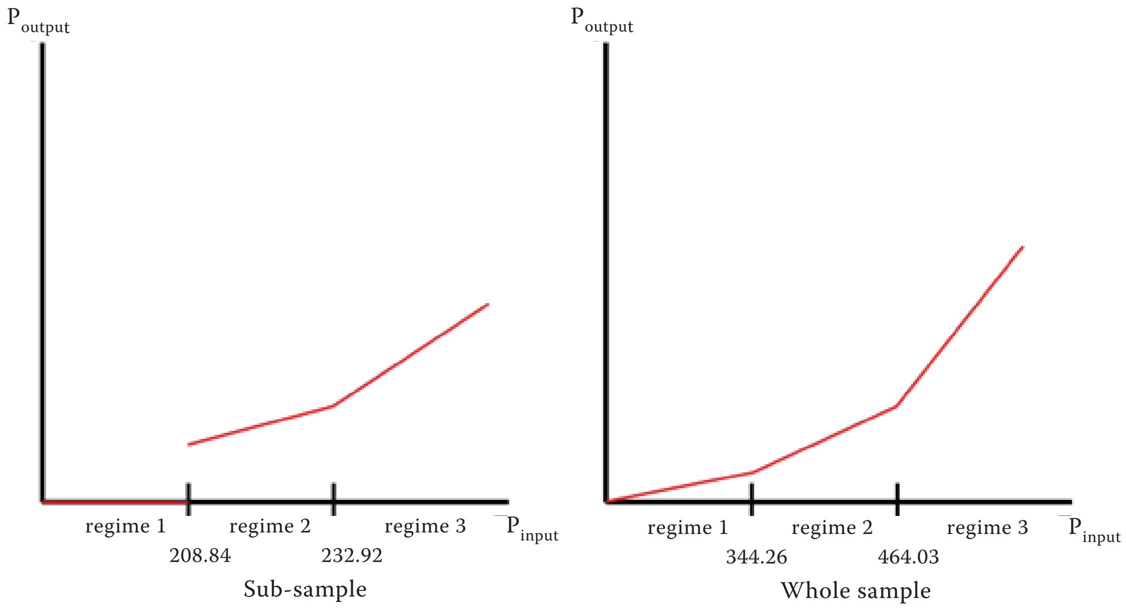

Figure 2. Price transmission in each regime

in 0.2262 percent increase in wheat flour price when the wheat price is below 344.26 kg/won. However, one percent increase in the wheat price results in 0.3075 and 0.8191 percent increases in the wheat flour price when wheat price is between 344.26 kg/won and 464.03 won/kg, and greater than 464.03 won/kg.

Different price transmission effects in each regime can be expressed by Figure 2. In the figure, the x-axis represents the input price of the imported wheat and the y-axis represents the output price of the domestic wheat flour. The x-axis is divided by three regimes based on the estimated threshold points. In the left graph, which indicates the results of the subsample, there is no significant relationship between the prices of input and output in Regime 1, which has the lowest level of input price. There are positive relationships between the input and output prices in Regimes 2 and 3, and the relationship is stronger in Regime 3 than in Regime 2. In the right graph, which indicates the results for the whole sample, there are significant positive relationships in all three regimes and the relationship grows stronger when the level of input price rises.

A comparison of the right and left graphs in Figure 2 provides some information about the impacts of the price spike in 2008 and the associated price-setting behaviour of the wheat flour processers. First, wheat prices above the upper threshold point of 464.03 won per kg (i.e., wheat prices in Regime 3 in the right graph) are observed only in the period after 2008; in addition, the prices of wheat in the range of 344.26 won/kg to 464 won/kg (i.e., wheat prices in Regime 2 in the right graph) are also observed only in the period after 2008. These results imply that the price transmission effects from wheat to wheat flour have become stronger in the recent years than in the past periods. Second, the threshold points of wheat prices 208.84 won/kg and 232.92 won/kg are no longer statistically significant in the whole sample period, and therefore, do not appear in the right graph in Figure 2. This suggests that the structure of price transmission has changed, and thus, the critical points of the wheat price that previously determined the APT have become meaningless as a result of the impacts of the recent increase in the international wheat price.

SUMMARY AND CONCLUSIONS

In order to derive the evidence of the asymmetric price transmission of which the perspective is different from prior studies, we employed the threshold estimation for the price relationship between the imported wheat and the wheat flour prices. We estimated the exact level of threshold points of the imported wheat that have different impacts on the Korean wheat flour price. In constructing our price equation for the wheat flour, we identified both the demand and supply shifters that can significantly influence the wheat flour price and we controlled for the endogeneity problem.

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Because there was a big spike in the world grain prices in 2008, we used two sample periods for the threshold estimation in order to evaluate the influence of the 2008 price shock. The sub-sample includes data from January 1993 to January 2008 and the whole sample includes data from January 1993 to March 2014. Our empirical estimations proved the main hypothesis of this study, namely, that the impact of the input price on output price is stronger at higher levels of the input price. In the sub-sample, the price transmission effect from the imported wheat to the domestic wheat flour in Regime 3, in which the wheat prices are highest among the three regimes, is larger than that in Regime 2. In the whole sample, the price transmission effect in Regime 3 is larger than that in Regime 2, and that of Regime 2 is larger than that in Regime 1.

Some studies point out that the existence of the APT is a natural phenomenon in the food industry because of the transaction and marketing costs. However, the APT can be caused by different reasons, such as the market failure, the existence of the monopoly power, menu costs, or asymmetric inventory costs. In Korea, wheat flour is processed by three major companies. This suggests that the market power hypothesis would be a plausible explanation for the ATP in the wheat flour price. However, the analysis of this issue needs a more elaborate modelling, and thus, the relevant empirical estimation has to be pursued in future studies.

There are some policy implications resulting from the existence of threshold points in the wheat price and the APT in the price relationship between wheat and wheat flour. As discussed, the wheat products are among the most important staple foods in Korea, thus, the Korean government has monitored the prices of wheat flour, bread, ramen, and so on, in order to evaluate the impacts of changes in these prices on the food expenditure of households. The present study indicates that the price of wheat flour is affected by the wheat price differently, based on the level of the wheat price. This implies that monitoring the wheat price is very important for evaluating the consumer expenditure on food. If the government wants to implement a policy that influences the prices of wheat products, the threshold points identified in this study may be an important reference level.

Generally the output price is mostly influenced by the input price as in the previous studies and the present analysis, however, there could be the factors that significantly impact the output price other than the input price. By reflecting these other influencing factors in the wheat flour price equation, the present study extends the applications of the APT analysis. However, the output price is asymmetrically transmitted not only from the input price but also from the influencing factors such as the demand and supply shifters. This suggests that there exist more room for differentiating multiple regimes based on the input price as well as the demand and supply shifters. This would be one of the future research directions in developing more general model of APT.

Appendix I. Estimation results of price quations and the redundant variable test

Table 1A. Estimation results of the initial and second (equation excluding redundant variables) price equations using the sub-sample (Jan. 1993–Jan. 2008)

Variables	Model 1	Model 2
Constant	−40.9502*** (9.3057)	−46.4145*** (7.6497)
Wheat	0.1384*** (0.0146)	0.1393*** (0.0149)
Wage	−0.0516 (0.1064)	
Inter	0.7143*** (0.2262)	0.6009*** (0.2186)
Elec	−0.0987 (0.2092)	
Ramen	0.4833** (0.1862)	0.4635*** (0.1509)
Bread	−0.0537 (0.1799)	
Income	0.3096 (0.2675)	0.2622 (0.2653)
Rice	−0.0908 (0.2092)	
Meat	0.1301 (0.1218)	
Dummy1	3.2431* (1.9317)	3.2508** (1.8652)
AR(1)	0.7480*** (0.0675)	0.8139*** (0.0571)
R-squared	0.982809	0.982321
Adjusted R-squared	0.981684	0.981708
Akaike info criterion	4.529317	4.501769

( ) indicates standard error; *, **, and *** are significant at 90%, 95%, and 99% levels

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Table 2A. Redundant variable test using the sub-sample

Redundant variables: *Bread, Wage, Meat, Rice, Elec*			
	Value	Df	Probability
F-statistic	0.954350	(5.168)	0.4475
Likelihood ratio	5.041330	5	0.4109

The null hypothesis is *that Bread, Wage, Meat, Rice,* and *Elec* are redundant variables. This hypothesis is not rejected, as indicated by *F*-test and Likelihood ratio test.

Table 3A. Estimation results of the initial and second (equation excluding redundant variables) price equations using the sub-sample (Jan. 1993–Mar. 2014)

Variables	Model 1	Model 2
Constant	–42.8752*** (10.2790)	–43.7698*** (8.1177)
Wheat	0.0301*** (0.0008)	0.0297*** (0.0087)
Wage	–0.1161 (0.0819	
Inter	0.8170*** (0.1620)	1.0007*** (0.1530)
Elec	0.1697 (0.1085)	
Ramen	0.1851 (0.1862)	0.3339*** (0.1175)
Bread	0.0290 (0.1590)	
Income	0.1593 (0.2367)	0.1734 (0.1530)
Rice	–0.0248 (0.1192)	
Meat	0.0416 (0.0889)	
Dummy1	7.2285*** (1.8805)	6.1939*** (1.8645)
Dummy2	19.5963*** (1.7639)	18.7704*** (1.7424)
AR(1)	0.8893*** (0.0343)	0.9148*** (0.0307)
Adjusted *R*-squared	0.994025	0.993931

( ) indicates standard error; *, **, and *** are significant under 90%, 95%, and 99% confidence intervals

Table 4A. Redundant variable test using the whole sample

Redundant variables: *Bread, Wage, Meat, Rice, Elec*			
	Value	Df	Probability
F-statistic	1.770350	(5,241)	0.1196
Likelihood ratio	9.161987	5	0.1028

Appendix II. Threshold regression model and estimation procedure

The threshold regression model in Hansen (2000) takes the form of $y_i = \theta' x_i + \delta'_n x_i(\gamma) + e_i$, where the dummy variable is $d_i(\gamma) = \{q_i \le \gamma\}$. To express this equation in matrix notation, we can define the $n \times 1$ vectors Y and e by stacking the variables Y_i and e_i, and the $n \times m$ matrices X and X_γ by stacking the vectors X_i' and $X_i(\gamma)'$. Then we can obtain $Y = X\theta + X_\gamma\delta_n + e$. When we let the following be the sum of squared errors function, then by definition the LS estimators $\hat\theta, \hat\delta, \hat\gamma$ jointly minimize the following equation.

$$S_n(\theta,\delta,\gamma) = (Y - X\theta - X_\gamma\delta)'(Y - X\theta - X_\gamma\delta)$$

The concentrated sum of squared errors function can be expressed by

$$S_n(\gamma) = S_n\big(\hat\theta(\gamma), \hat\delta(\gamma), \gamma\big) = Y'Y - Y'X_\gamma^*(X_\gamma^{*\prime}X_\gamma^*)^{-1}X_\gamma^{*\prime}Y.$$

Finally, the significant threshold $\hat\gamma$ can be derived by finding out the level that minimizes the abovementioned equation. It can be expressed by $\hat\gamma = argminS_n(\gamma)$.

REFERENCES

Abdulai A. (2000): Spatial price transmission and asymmetry in the Ghanaian maize market. Journal of Development Economics, 63: 327–349.

Abdulai A. (2002): Using threshold cointegration to estimate asymmetric price transmission in the Swiss pork market. Applied Economics, 34: 327–349.

Ahn B., Kim T.H. (2008): Test for asymmetric price transmission between producer and consumer prices of major agricultural products. Korean Journal of Agricultural Economics, 49: 77–95.

Azzam A.M. (1999): Asymmetry and rigidity in farm-retail price transmission. American Journal of Agricultural Economics, 81: 525–533.

Bailey D.Y., Brorsen B.W. (1989): Price asymmetric in spatial fed cattle markets. Western Journal of Agricultural Economics, 14: 246–252

Bettendorf L., Verboven F. (2000): Incomplete transmission of coffee bean prices: evidence from the Dutch coffee market. European Review of Agricultural Economics, 27: 1–16.

Borenstein S., Cameron C., Gilbert R. (1997): Do gasoline prices respond asymmetrically to crude oil prices? Quarterly Journal of Economics, 112: 305–339.

Boyd M.S., Brorsen B.W. (1988): Price asymmetry in the US pork marketing channel. North Central Journal of Agricultural Economics, 10: 103–109.

doi: 10.17221/47/2015-AGRICECON

Carman H.F., Sexton R.J. (2005): Supermarket fluid milk pricing practices in the Western United States. Agribusiness, 21: 509–530.

Čechura L., Šobrová L. (2008): The price transmission in pork meat agri-food chain. Agricultural Economics – Czech, 54: 77–84.

Ghoshray A. (2002): Asymmetric price adjustment and the world wheat market. Journal of Agricultural Economics, 53: 299–317.

Goodwin B.K., Holt M. T. (1999): Price transmission and asymmetric adjustment in the US beef sector. American Journal of Agricultural Economics, 81: 630–637.

Hansen B.E. (2000): Sample splitting threshold estimation. Econometrica, 60: 575–603.

Hassouneh I., Serra T., Gil J.M. (2010): Price transmission in the Spanish bovine sector: the BSE effect. Agricultural Economics, 41: 33–42.

Herry W.K., Forker O.D. (1987): Asymmetry in farm-retail price transmission for major dairy products. American Journal of Agricultural Economics, 69: 285–292.

Hwang E.K., Hwang Y.J., Kim T.E. (2012): A Study on Short and Long Term Fluctuation Factors of Processed Food Price and Countermeasures. Research Report R659, Korea Rural Economic Institute.

Kaufmann R.K., Laskowski C.(2005): Causes for an asymmetric relation between the price of crude oil and refined petroleum products. Energy Policy, 33: 1587–1596.

Kilian L., Vigfusson R. (2011): Are the responses of the US economy asymmetric in energy price increases and decreases?. Quantitative Economics, 2: 419–453.

Kim K.S., Im J.B., An D.H., Kim K.H., Lee S.J., Cho J.S., Yang C.Y., Kim Y.J. (2012): Influences of Rises in Material Prices in the International Market on the Prices of Domestically Processed Foods. Seoul National University.

Kim T.H., Kim B.S. (2009): Analysis on the lead-lag relationship of the prices of grain products. Journal of Rural Development, 32: 21–40.

Lee Y.S., Sung M.H., Jung H.K., Jeon H.M. (2011): Effect of Rising Prices of Imported Agricultural Products on Food Prices and Countermeasures. Research Report P147, Korea Rural Economic Institute.

Myers J., Jayne J.S. (2011): Multiple-regime spatial price transmission with an application to maize markets in southern Africa. American Journal of Agricultural Economics, 94: 174–188.

Petzman S. (2000): Price rise faster than they fall. Journal of Political Economy, 108: 466–502.

Simioni M., Gonzales F., Guillotreau P., Le Grel L. (2013): Detecting asymmetric price transmission with consistent threshold along the fish supply chain. Canadian Journal of Agricultural Economics, 61: 37–60.

von Cramon-Taubadel S., Loy J.P. (1996): Price asymmetry in the international wheat market: comment. Canadian Journal of Agricultural Economics, 44: 311–317.

Ward R.W. (1982): Asymmetry in retail, wholesale and shipping point pricing for fresh vegetables. American Journal of Agricultural Economics, 62: 205–212.

Wright B. (2014): Global biofuels: key to the puzzle of grain market behavior. Journal of Economic Perspectives, 28: 73–98.

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