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PRICE TRANSMISSION IN MILK SUPPLY CHAIN IN UKRAINE

Purpose. *The purpose of the study, which results are submitted in the article, is to analyze the vertical price transmission along the milk supply chain in Ukraine and identify whether this price transmission is symmetric or asymmetric in terms of direction, magnitude, speed.*

Methodology / approach. *To achieve the purpose of the study, we used the following research methods: logical operations (analysis, synthesis, induction, deduction) – to determine the structure of the milk supply chain, to make conclusions about main findings; the correlation analysis – to identify the tightness of links between farm', processors' and retailers' prices, the trend modelling – to build the functions of the trend of prices of different levels of the milk supply chain, the regression modelling – to construct the regression functions of prices of downstream sectors of the milk supply chain, graphic – for visual presentation of main tendencies, pricing and price dynamics in the milk supply chain. The research was performed on the basis of the statistical data of the State Statistics Service of Ukraine for 2013–2020.*

Results. *This paper presents the empirical evidence of asymmetric price transmission along the milk supply chain in Ukraine. The results of modelling proved asymmetric magnitudes of price growth at the organizational and technological stages of the milk supply chain: in the case of the farm prices of raw milk increase the processors' and retailers' prices grow up by a much bigger magnitude. There is no leg in price transmission in the milk supply chain, the price shocks at the farm level instantly pass to processors' and retailers' prices. The evidence of asymmetry of price transmission testifies the weaknesses of the market positions of farmers and consumers in the milk supply chain in Ukraine, points out the threats for the food security and sustainable development of all agents of this chain.*

Originality / scientific novelty. *For the first time, the quantitative assessments of the magnitude and speed of the price changes in the process of price transmission in the milk supply chain in Ukraine were obtained. The asymmetry of the magnitudes of the vertical price transmission in the milk supply chain in Ukraine was identified. The hostage position of farmers in the case of price shocks was further proved.*

Practical value / implications. *This paper provides a better understanding of arrangements of market forces in the milk supply chain, the consequences of price chocks in the upstream sector of the milk supply chain. The practical value is the methodological and empirical support for the development of regulative measures to improve the milk supply chain's functioning and sustain food security. Assessment and analysis of the mechanism of price transmission reveals the weak parts of the food supply chain, contributing to the scientific foundation of elaborating the necessary policy actions for harmonization of relations between producers of different stages of the milk chain.*

Key words: *price transmission, milk supply chain, symmetric and asymmetric price transmission, market power, food security, Ukraine.*

Introduction and review of literature. The prices of the agricultural and food products directly influence on food security, operation, and development of all agents of the agri-food chain. That's why the process of agricultural and food products' pricing is in the focus of attention of consumers, producers, traders, politicians, governments.

The E.U. households devoted, on average, 13.0 % of their total consumption expenditures to food and beverages in 2019 (Eurostat, 2020). This share is much higher for Ukrainian households (46.9 % in 2019) due to estimates of the State Statistical Service of Ukraine (2020). In such economic circumstances, the wellbeing and good nutrition of the population, the achievements of sustainable development goals (specifically, the goals "Zero hungry", "Good health and well-being") is very dependent on the agri-food prices.

An analysis of the price transmission links the agricultural prices with processors', retailers' (consumers') prices, showing how the shocks in one block of the chain cause the prices changes in the other ones. The price transmission is a process of changing the prices of some goods as the consequence of the price change of the other goods due to transferring impulses of prices shocks. Revealing the mechanisms of price transmission and its consequences at different stages of the food chain, estimating direction, speed, and magnitude of price changes help to find answers to the questions, what market agent is able to adjust to the shocks fluently and what market agent is the main shock absorber in the supply chain, who gets gains and has economic power in this chain (farmers, food producers, traders, consumers) or who is in a weak position and under the threats for the future operation and development.

The experts of the European Commission (2009) stressed: "The assessment of price transmission along the food supply chain, i.e. how much and how fast price changes are passed through between the different stages of the chain, is often used as an indicator of the effectiveness and efficiency of the chain as well as of the degree of competition in food processing and distribution". Also, as the results of price transmission, the distribution of added value between farm producers, food processors, wholesalers, and retailers is crucial for the sustainable development of the whole chain. The analysis of price transmission builds the foundation for policy actions elaboration for the benefits of all stakeholders of the chain, economic accessibility of food, and all other components of food security.

The price transmission is studied in the vertical, horizontal, cross-commodity aspects (Kravchenko, 2020). The vertical price transmission occurs with pricing along the technological stages of agricultural and food production, deliveries of the raw and food products from farms, processors, traders to consumers. The horizontal or geographical price transmission takes place in interregional or international trade. Cross-commodity price transmission is related to the price changes of substitute goods in the supply chain.

The agri-food supply chain includes the producers, traders, and consumers united by consecutive processes from agricultural production to food processing, distribution, and consumption. The agri-food supply chain includes three main sectors: the agrarian, the food processing, and the distribution representing of wholesale and retail (Bukeviciute et al., 2009). All blocks of a supply chain are tightly interdependent. The gains of some agents of the chain at the losses of others lead to the inefficient redistribution of income, which causes of the destruction of some blocks, and then – the destruction of the entire chain.

The milk supply chain is a part of the agri-food supply chain and provides the valuable and necessary food products for human life. The upstream operations of the milk supply chain refer to all processes needed to produce the raw milk, to deliver the raw materials to processors plants. Another part of the milk supply chain covers the downstream operations from processors and traders to customers. This part of the chain includes logistics, processing, wholesale, retailing and consumption.

Recent research has confirmed more complex aspects of price transmission and efficient pricing (Kravchenko et al., 2020; Onegina, 2012). The symmetric price transmission is an important condition of harmonization of economic relations between the market agents, sustainable development of all the agri-food chain elements. The asymmetric transmission causes distortions of market equilibrium and potentially has important welfare and policy issues. The asymmetric price transmission is defined as a difference in adjustment to a price shock at the different supply chain stages (farm, processing, wholesale or retail) (Vavra and Goodwin, 2005). The asymmetry may be in the direction, speed, and magnitude of adjustment. The evidence of asymmetric price transmission in the supply chain might be a consequence of the market structures, a growing concentration of processing and retail sectors, some agents' market power, and considered as a sign of market failures.

This study focuses on the vertical price transmission along the milk supply chain in Ukraine.

The existing studies of vertical price transmission are concentrated on its different issues. Lloyd (2017) overviewed of challenges and prospects of almost forty years of price transmission research. Tweeten and Quance (1969), Wolffram (1971) made an important contribution to the methodological foundation of asymmetric price analysis. They proposed and adjusted a dummy variable-splitting technique to reveal asymmetric or symmetric price transmission is. The methodology of price transmission econometric analysis was developed in the works of Von Cramon-Taubadel et al. (2004, 2006), Frey and Manera (2007).

Different empirical investigations described the price transmission process in the specific sectors within the food supply chain. Boyd and Brorsen (1988) paid attention to the price asymmetry in the U.S. pork marketing channel. Von Cramon-Taubadel and Loy (1996) studied price transmission in the international wheat market. McCorriston et al. (1998) proved that increases in farm-gate prices are passed to consumers more fully than an opposite process of decreasing farms' prices. Peltzmen (2000) analysed downstream and upstream prices adjustments to the positive and negative shocks and concluded that downstream prices tended to respond faster to input increases than to decreases, the asymmetric response to cost shocks was substantial.

Von Cramon-Taubadel et al. (2006) studied vertical price transmission relating to the German pork prices. Abdulai (2002) proved that the increase of farm-gate pork prices in Switzerland was passed to retail prices faster than reductions in farm-gate pork prices. Bakucs and Ferto (2005) did not prove that the price transmission was asymmetric in the pork supply chain in Hungary. Vavra and Goodwin (2005) estimated asymmetric price transmission in farm, wholesale, and retail markets in the U.S. for beef, chicken, and eggs. Their findings are as follows: variability in prices is much higher for egg prices compared to chicken and beef prices; the retail prices of beef appear to drift apart from those at wholesale and farm level; beef prices appear to be non-stationary while the price series for chicken and eggs are largely stationary; the modelling retail, wholesale, and farm prices in the U.S. beef, chicken, and egg markets indicates the asymmetries in responses to negative and positive price shocks. Reziti and Panagoplos (2008) showed the asymmetric price transmission from producers to retailers in vegetable markets in Greece. The European Commission experts (2009) evaluated and analysed price transmission in the dairy and pig meat sectors of Austria, Czech Republic, Denmark, France, Germany, Lithuania, Slovenia and the United Kingdom for 2000–2009. Their statistical analysis of price transmission showed wide differences of results between similar products across countries and products in each country due to the diversity in the competitive structure and the operation of the chain in each country (European Commission, 2009). Their findings indicate that some price transmission took place after a given number of months, the asymmetric behaviour along the dairy chain, fast increase of dairy consumer prices, and their slow reduction. Pocricak and Rajcaniova (2014) analyzed a relationship between prices of farms and retails levels in the chain of milk, beef, pork, chicken, potatoes, and apples in Slovakia and found evidence of asymmetry in the vertical price transmission. Chaudhry and Miranda (2020) tested price transmission in Pakistan's poultry supply chain. They identified asymmetric price transmission in the egg supply chain.

Bakucs et al. (2012) overviewed the papers focused on the European agricultural sector and investigated price transmission mechanism for 69 cases. These authors made up a comprehensive list of studies investigating price behaviour along the European agri-food chain. They used meta-analysis and detected price transmission asymmetry in 28 cases, whereas in 41 cases, the symmetric price behaviour was detected. Most of their investigated cases (43) dealt with livestock products, and the asymmetry of price transmission was revealed in 82 % of cases; 57 observations were made for Western Europe, and 12 observations were made for the Central and East European countries.

The influence of different factors on price transmission patterns was studied in the recent research. The dependence of price transmission schemes on product perishability were considered by Ahn and Lee (2015), the effects of uncertainties in farm level on price transmission were investigated by Simioni et al. (2013). Frey and Manera (2007) pointed out the adjustment costs (advertising and relabelling costs or "menu" costs that make prices "sticky") as an explanation for asymmetric price transmission. Bakucs et al. (2014) analysed the influence of market structure on the price transmission. The experts of the Commission of the European Communities (Report of E.C., 2009) summarized the explanations for asymmetric price transmission: information asymmetries, inventory management methods, “menu” costs, government interventions; internalization of price variation; the number of vertical stages along the chain; spatial location and dispersion of food chain.

Subsequent research on vertical price transmission tested the increasing market power of food retailers (Lloyd, 2017). But some research could not prove asymmetric price transmission from upstream to downstream markets in many cases. Serra and Goodwin (2003) did not find evidence of asymmetric price transmission in the milk supply chain of Spain, Tekgüç (2013) did not confirm asymmetric price transmission along the milk supply chain of Turkey.

Meyer and von Cramon-Taubadel (2004), Assefa et al. (2014) have explained the causality between the market power of agents in a supply chain and asymmetric price transmission and proved that the agents with market power could delay price adjustments. Bakucs et al. (2014) pointed out that the institutional settings and socio-economic characteristics of the agri-food chain influence the asymmetries of price transmission. Their findings include the following explanations: the asymmetry of farm-retail price transmission occurs more seldom when food producers’ turnover is higher than retailers’ turnover; the limited price competition between the retailers tends to more asymmetric price transmission; positive influence of government regulation on price transmission asymmetry.

Shyian and Kolosha (2020) made an assessment of trends in milk prices in Ukraine in comparison with other countries, identified the patterns in their change, and estimated the level of its variation in time series. Shyian et al. (2021) substantiated the methodological approach for forecasting milk prices and dairy products, taking into account the time lag and the correlation between prices for certain types of dairy products, the share of milk prices in the selling price of dairy products. But the identification of characteristics of price transmission in the Ukrainian milk supply chain was not in the focus of the previous research.

The purpose of the article. The goal of this study is to analyse the vertical price transmission in the milk supply chain in Ukraine and to identify whether symmetric or asymmetric the price transmission is.

Methodology and data. The important contribution in the development of the methodology of the price transmission study based on the econometric analysis was made by Meyer and Cramon-Taubadel (2004), Vavra and Goodwin (2005), Frey and Manera (2007). The methodology applied in this study of price transmission is based on their approaches and includes the following stages:

- the collection of statistical data to build up the time series of prices of different levels of the milk supply chain;
- the identification of properties of time series of variables (prices) by checking for stationarity each time price series applying the Dickey-Fuller test (1979) for the existence of unit root;
- findings the relationships between dynamic price rows of different supply chain levels and estimation of correlations between them;
- testing on cointegration of dynamic price series to confirm a long-term

relationship between them, which leads to some joint, interrelated change despite the random changes of the economic variables of every time series;

- the construction of the trend and regression models to assess the magnitude of price changes during the adjustment and the speed of price adjustment, i. e. the lag of price transmission;
- the test of statistical significance of obtained results of modelling;
- interpretation of obtained models and check of their results on the condition of price symmetry; the identification of the characteristics of price transmission in the milk supply chain in Ukraine.

Monthly farm-gate prices, processors' and retail prices of milk in Ukraine in 2013–2020 were retrieved from the database of the State Statistical Service of Ukraine for this study.

Results and discussion. The overview of the food supply chain improves the understanding of pricing processes along this chain, how changes of input costs are passed on, and where the regulations are necessary.

The participants of the agri-food price chain of livestock products include the following economic agents: agricultural producers of livestock products (farmers); food processing enterprises for meat and dairy products (processors); the wholesale and retail traders of food products (traders). The number of business entities and the number of employees in the above-mentioned types of economic activity in Ukraine in 2019 are shown in Fig. 1. The statistical reports do not separate meat and milk production data due to peculiarities of production technology.

The number of business entities producing agricultural livestock products is 4.5 thousand (farms) in Ukraine. The primary producers of meat and dairy products also include 2.7 million households that have farm animals. But households are not registered as business entities, as they carry out agricultural activities mainly for the self-sufficiency in the food provision.

The number of food processing industry producers amounts to 1726 meat processors and 730 milk processors. The number of trade entities is impressive: wholesale trade – 29.3 thousand units (7.8 thousand representatives of wholesale trade in agricultural raw materials and live animals and 21.5 thousand – in trade of food products), food retail sector includes almost 35 thousand (data of State Statistical Service of Ukraine, 2020).

Regarding the number of employees, the following facts and tendencies are observed: 73.4 thousand persons are employed in the farms; 117.3 thousand persons are employed in the processing of meat and dairy products; 174.2 thousand persons are involved in wholesale trade in agricultural raw materials and food and 97.1 thousand persons are involved in retail trade. There are more employees in the sector of traders than in all sectors of this chain. The comparison of the number of employees in mentioned sectors since 2010 shows a two times decrease in the number of employees in the farm production of livestock products and a decrease by 5–10 % in other blocks of this supply chain.

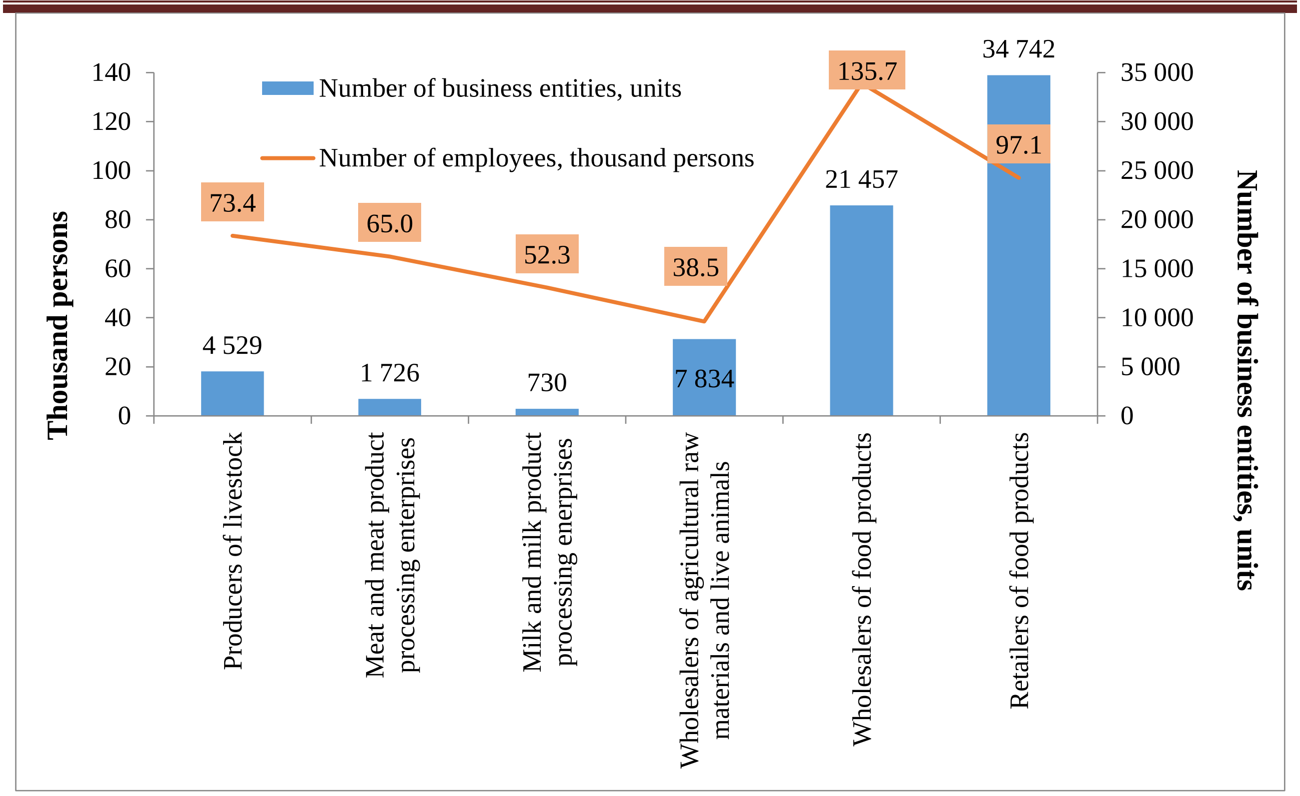

Fig. 1. Number of business entities and employees by type of economic activity in the Ukrainian meat and milk supply chain

Source: generated by the authors using the data of the State Statistics Service of Ukraine.

In Ukraine, since 2010, the structure and the results of livestock production and the number of participants in the agri-food chain have changed. The situation in the milk market is no exception. There is a dual structure of raw milk production. According to the estimates of the State Statistical Service of Ukraine, 72 % of milk was produced by households and only 28 % by enterprises in 2019; 3.1 million cattle were counted in Ukraine (January 1, 2020), including 1.8 million cows, which is 32 % less than in 2010, or 2.8 times less than the number of cows compared to 2000. There are 24.5 % of cows in agricultural enterprises, 75.5 % – in households. The volume of milk production in 2019 in Ukraine was 9.7 million tons, or 86 % of the level of 2010 and 76 % of the level of 2000. The consumption volume of milk and dairy products in the country per capita per year is 201 kg in 2019 (206 kg – in 2010), which is only 53 % of the scientifically recommended 380 kg (State Statistical Service of Ukraine, 2020). It should also be noted that only 38 % of milk produced by all categories of farms is sold to food processing enterprises. The food processing enterprises purchased almost 70 % of milk from agricultural enterprises and 30 % from households (46 % to 54 % in 2010).

The next stage of the study was the analysis of average milk sales prices in 2020, including prices of agricultural enterprises or farm-gate prices, industrial producer prices at the stage of processing, and consumer prices at the trade stage.

The consumer's price (the price that consumers pay for milk) includes the parts that each market participant receives at a particular stage of the food chain (agricultural production, processing, and trade). The structure of milk price (final product) (Fig. 2) is as follows: the producer of raw milk received 35 % of the final product price or consumer's price; food processing enterprises – up to 33 %; the share of wholesale and retail trade was 32 % of the consumer's price of milk. In the E.U., the costs of the agricultural products make up approximately 20 % of the final consumer prices of food (European Commission, 2009).

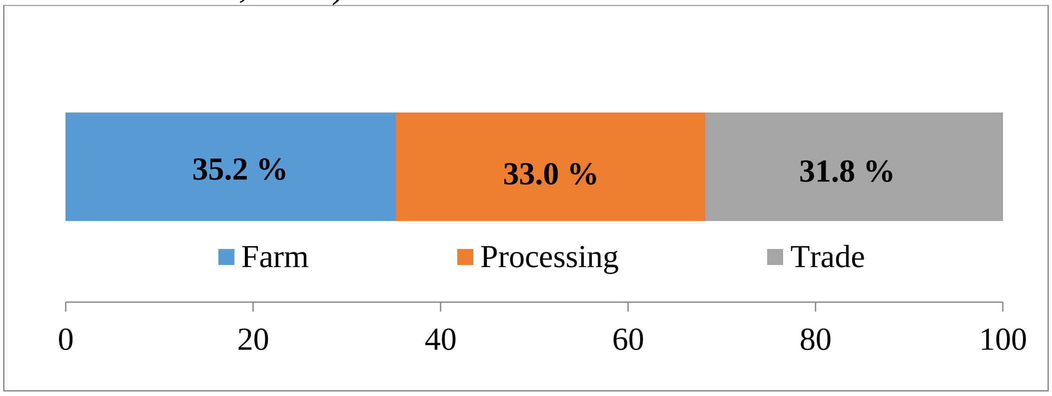

Fig. 2. The structure of final price of milk in Ukraine in 2020, %

Source: calculated by authors using the data of State Statistical Service of Ukraine.

The indices of milk prices of agricultural producers (farmers), food processors, and consumer prices are submitted in Fig. 3. The presented data confirm fluctuations of prices and profitability in milk production and even very low correlation between them. The significant growth of farmers' milk prices in 2010 and 2017 (price index 155.5 % and 131.0 %, respectively) did not lead to the significant increasing efficiency of agricultural producers in the mentioned periods due to the costs price shocks. At the same time, in 2018, the relatively low change of the price of raw milk from farmers, compared with the increase in milk prices from other participants in the price chain, did not become a factor of a significant deterioration of the efficiency of agricultural enterprises (farmers).

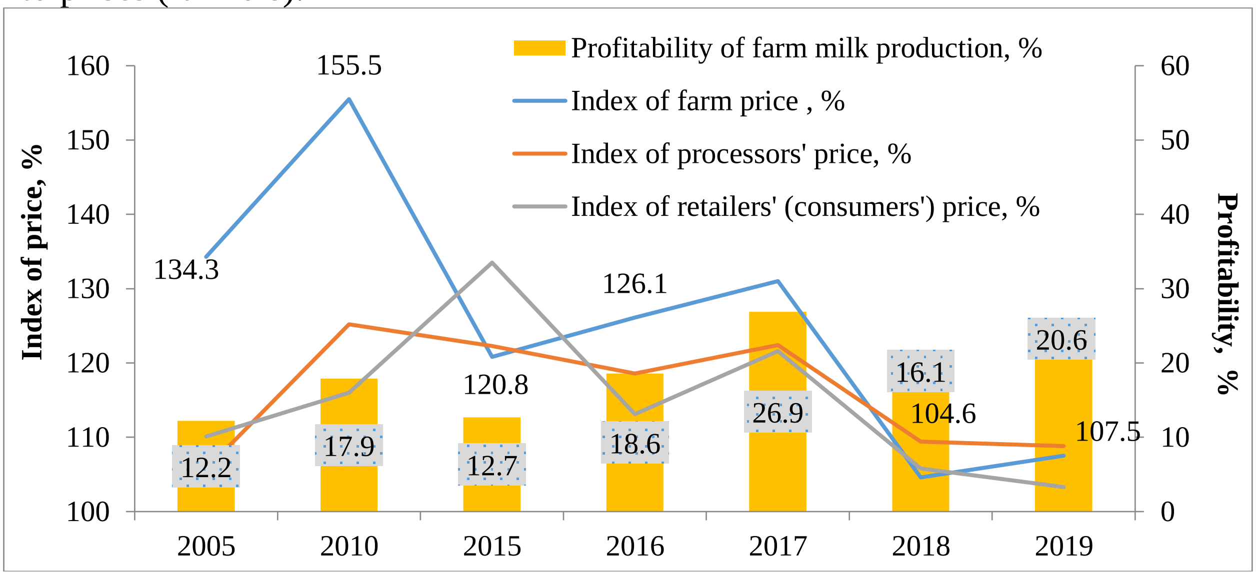

Fig. 3. Price indices and profitability of milk production in agricultural enterprises in Ukraine in 2005–2019, %

Source: calculated by authors using the data of State Statistical Service of Ukraine.

The dynamics of prices in the milk chain "production-processing-trade" in 2020 are shown in Fig. 4. The average prices of raw milk of agricultural producers (enterprises and households), the average prices of sold milk by processors, and the average milk prices of retailers (or prices that consumers pay for milk) in Ukraine for 12 months of 2020 were submitted in this Fig. 4.

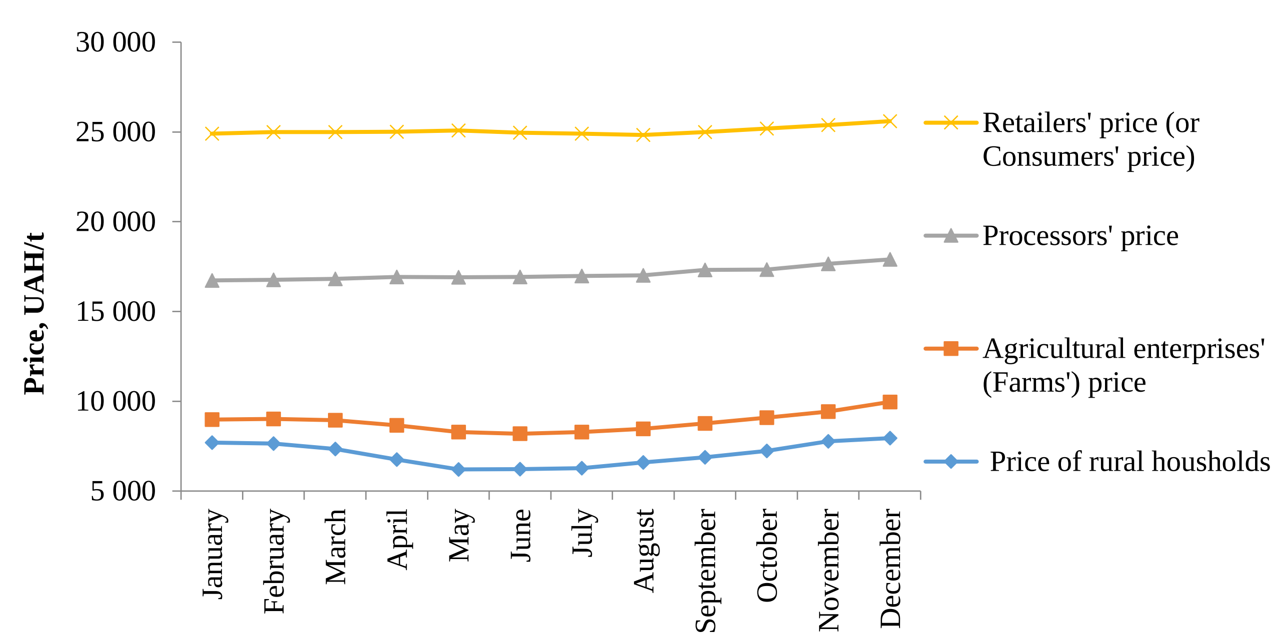

Fig. 4. Prices in the milk supply chain in Ukraine in 2020, UAH/t

Source: data of State Statistical Service of Ukraine.

According to the data of 2020, milk from households was sold at 7.05 UAH per kg on average; milk from enterprises was more expensive by 20–25 % and was sold at 8.84 UAH per kg. The households sold raw milk with higher bactericidal and bacterial contamination; that's why their price was lower. The processing enterprises sold milk at 17.11 UAH. Wholesalers and retailers got more than 20 UAH per kg of milk. For the consumers, the average price of milk was 25.07 UAH, including VAT, or at least three times higher than the farmers received.

The main pricing factor in milk markets is the monopoly status of the producers of certain blocks of the supply chain, which set the "game rules". Paradoxically, the prices of milk and dairy products in Ukraine have reached the level of the world's leading countries, but agricultural producers continue to reduce livestock. According to the conclusions of many scientists (Burka et al., 2017), traders of the milk supply chain are the main player, and retailers are dictators of the "game rules" in the milk supply chain in Ukraine.

Currently, in Ukraine, there is a situation where agricultural milk producers, representatives of the upstream sector, do not have leverages of commercial influence on other participants, and they are price takers. The received prices by farmers do not allow them to get cost-effective returns on investments.

On another side, the consumer price paid by retailers is too high and does not allow to achieve and keep the sound standards of consumption of dairy products. Therefore, the analysis of the transmission mechanism of food prices between the participants in the milk supply chain is vitally important for the harmonization of economic relations and sustainable development of all agents of this chain.

The analysis of price transmission in this study is based on the clarification of the condition for its symmetry. The price of the commodity of downstream sectors via prices of upstream sectors can be expressed as:

$$P_j = \sum_{1=n}^{n} P_i\, v_i + \pi, \quad (1)$$

where P_j – the price of *j* product of downstream sector;

P_i – the price of *i* product from the upstream sector;

v_i – a technological coefficient of a quantity of *i* product as a resource used for the manufacture of *j* product;

π – profit.

We assume that ΔP_{it} is the absolute change of product price from upstream sector of the agri-food chain over the period *t*.

$$\Delta P_{it} = P_{it} - P_{i(t-1)} \quad (2)$$

If $\Delta P_{j(t+l)}$ is an absolute change of product price from downstream sector over the period t+l, and *l* is a lag of transmission, then:

$$\Delta P_{(j+l)} = P_{j(t+l)} - P_{jt} \quad (3)$$

Respectively, an absolute change in the price of *j* product as the consequence of price change of *i* product in case of symmetric transmission (for the magnitude) is equal to:

$$\Delta P_{j(t+l)} = \Delta P_{it} \cdot v_i \quad (4)$$

where v_i – a technological coefficient of *j* product manufacture.

So, equation (4) is the condition of symmetric transmission expressed for absolute price changes. For the case of relative price changes, the condition of symmetric price transmission is:

$$\Delta p_{j(t+l)} = \Delta p_{it} \cdot s_{it} \quad (5)$$

where $\Delta\, p_{j(t+l)}$ is a relative change (coefficient of change) of the product price from the downstream sector over the period t+l, Δp_{it} is the relative change of product price from the upstream sector, s_{it} –the share of costs of *i* product in the price of *j* product.

$$\Delta p_{it} = \frac{P_{it} - P_{i(t-1)}}{P_{i(t-1)}} \quad (6)$$

The consequence from equation (5) allows concluding that the bigger added value at the next stage of the chain and less share of raw materials (in our case – raw milk) in the price of *j* product, the smaller relative change of price of *j* product in comparison with the relative change of *i* product price. The direct evidence of price magnitude asymmetry is the bigger relative price changes of *j* product than the relative price changes of *i* product, i. e.:

$$\Delta p_{j(t+l)} \geq \Delta p_{it} \quad (7)$$

The tight correlation between dynamic rows of prices testifies strong links between the prices of supply chain blocks. For the case of a liner regression model, the dependence of processors' or retailers' prices on farms' prices might be expressed as:

$$P_{j(t+l)} = \alpha + \beta \cdot P_{it} + \varepsilon \quad (8)$$

where $P_{j(t+l)}$ – the price of *j* product of downstream sector in the period (t+l);

α – the *y*-intercept;

β – the slope of the line;

P_{it} – the price of *i* product of upstream sector;

ε – random error or the variable explained by other factors.

The condition of the symmetric price transmission (in the part of magnitude) for the rows of absolute prices is as follows:

$$\frac{\partial P_{j(t+l)}}{\partial P_{it}} = 1 \qquad (9)$$

or β=1.

So, the symmetry/asymmetry of price transmission might be identified on the basis of the regression model and the deviation of its coefficient β from 1.

The trend is a common tendency of changes of time series variables. The trend models describing the magnitude of price changes during the periods in the different blocks of the supply chain might also be informative for identifying symmetry/asymmetry of price transmission. The sign of magnitude asymmetry of price transmission for these type of models (the bigger relative price changes of *j* product then the relative price changes of *i* product) ensues from equations 5 and 6.

We apply the Augmented Dicky Fuller (ADF) and the Dicky Fuller-Generalized Least Squares (DF-GLS) tests to check for unit roots and find the order of integration of monthly prices for every price time series. The results of t-statics (96 observations, 95 % – the confidence level) are -0.113 for time series of farm prices, -0.145 – for time series of processors' prices and -0.635 – for time series of retailers' prices. These results are less negative than the critical value of ADF t-distribution, which confirms the null hypothesis of the existence of unit root (in contrast to the classical case of this test, the critical values of the ADF statistics are larger in absolute value). The results of unit root tests reveal that each price series is not stationary, has a unit root, and is integrated into order 1.

The correlation coefficients were calculated to evaluate how strong the relationship between the two variables. The results of calculations of coefficient of correlation between prices of different levels of the Ukrainian milk supply chain (2013–2020) are submitted in Table 1.

The meanings of the coefficients of correlation between farmers' and processors' prices, between farmers' and retailers' prices, between processors' and retailers' prices are very close to 1 and confirm very tight dependence of volatility of these prices and their changes in one direction.

Table 1

Coefficients of correlation between prices in the milk supply chain in Ukraine (2013–2020)

Correlation coefficient	Lag = 0	Lag = 1 month
Farms' – processors' prices	0.985498987	0.984250855
Farms' – retailers prices	0.983087010	0.982531157
Processors' – retailers' prices	0.995754337	0.995425378

Source: authors' calculations.

The calculation of these correlation coefficients for the one-month lag gave results of the slight reduction of the degree of tightness of the relationship between prices of different supply chain stages. This fact is evidence of the symmetry of price transmission in the speed in the milk supply chain during the investigated period.

Cointegration is a property of the economic time series of variables. Despite the random changes of the economic variables of every time series, there is a long-term relationship between them, which leads to some joint, interrelated change. Cointegration of several non-stationary (integrated) time series means the existence of some stationary linear combination of them. The dynamic price rows of the milk supply chain were tested for cointegration.

The famous cointegration tests of variables' time series are the Johansen (1995) cointegration test and Engle and Granger (1987) test. Also, one of the used tests of cointegration is a unit root test. It is based on the assumption that if the model's residuals are nonstationary (have a unit root), then there is no cointegration of the time series of price variables. In fact, the cointegration equation of non-stationary series is an analogue of the regression model of stationary series. The null hypothesis means the absence of cointegration, that is, the presence of a unit root in the model's errors (cointegration equation).

To test the existence of the unit root or null hypothesis for our cointegration equations of the time series of price variables, the statistics of the ADF test were applied to the residuals of the regression model. The ADF test assumes that the more negative results of statics, the stronger the rejection of the null hypothesis (there is a unit root at some level of confidence).

Our models were estimated using a sample of 96 observations and yields of D.F. statics of -3.64 for time series of farm-gate and processors' prices, -3.03 – for farm-gate and retailers' prices. These results are more negative than the tabulated critical value of – 2.89 at the 95 % confidence level of rejecting the null hypothesis of a unit root. So, these prices time series are cointegrated.

Modelling the trend functions of prices gives an understanding of the reaction of processors' and traders' to the changes in farms' prices. We developed the trend models using the least squares method (LSM) as the most universal way to align empirical series in correlation-regression analysis. The task of the method is to define the patterns on the basis of the observed random fluctuations and use them to identify the tendencies and their forecasting.

Fig. 5 shows the monthly milk prices trends at farm production, processing, and trade stages of the milk supply chain in Ukraine for 2013–2020.

This linear trend models allow us to estimate and compare the coefficient of price changes per period (month) for every price time series. The adequacy (reliability) of trend models was assessed using the calculation of coefficients of correlation (R) (Table 2) and approximation (R^2).

The economic meaning of the obtained results relating to the price change is: the famers', processors' and traders' prices changed in one direction; in average, the producers of raw milk increased prices by 72.38 UAH per ton every period (in our calculations – month), or at a rate of +1.200 % of the price in the previous period, the processors increased prices by 145.03 UAH (+1.259 %), the traders – by 234.91 UAH

(+1.397 %) (Table 2), whereas the magnitude symmetry condition of price transmission for these type of models is the smaller relative price changes of downstream sector prices in comparison to upstream sector prices (equations 5, 6).

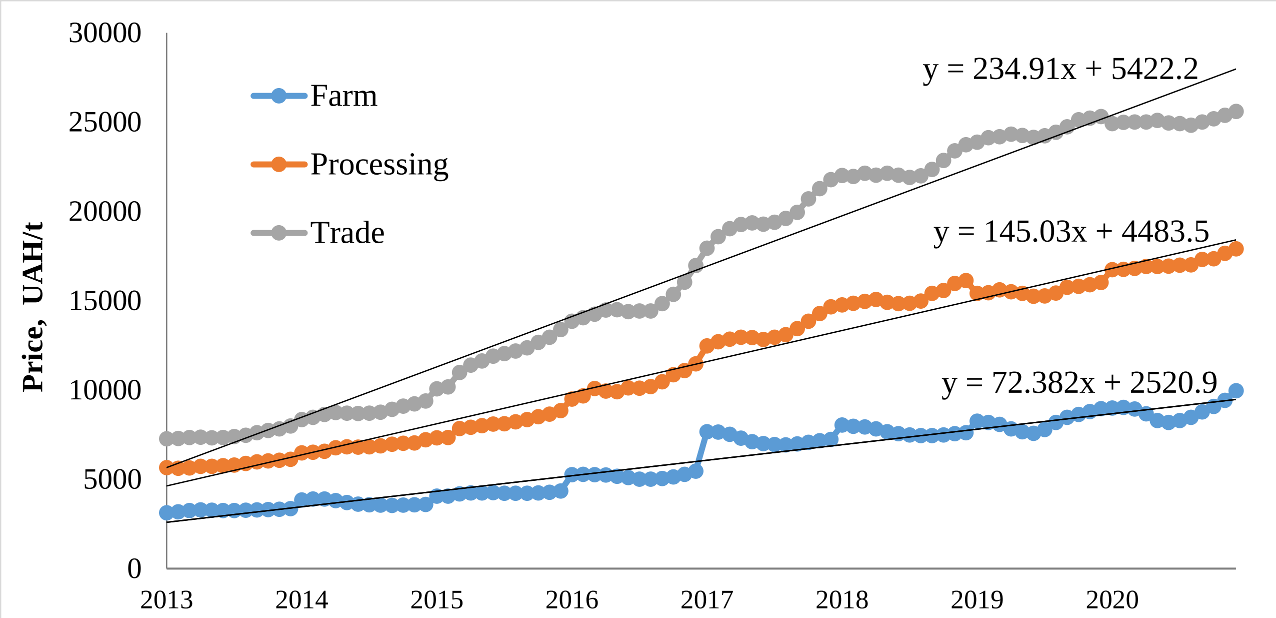

Fig. 5. Trend models of farms', processors' and traders' milk prices (UAH/t) in Ukraine in 2013–2020

Source: authors' calculations using the data of State Statistical Service of Ukraine.

The regression analyses were employed to identify the magnitude of price adjustment to the shocks in the upstream sector. In the regressions, the processor's prices and retail prices of milk are the dependent variables, while farm-gate milk prices are the explanatory variables. The obtained equations of the regression models are as follows:

$$P_{pt} = -163.01 + 1.94p_{ft}$$

where P_{pt} – the processor's price in the period t;

p_{ft} – the farmer's price in the period t.

$$P_{rt} = -2079.78 + 3.13\,p_{ft}$$

where P_{rt} – the retailer's price in the period t;

p_{ft} – the farmer's price in the period t.

The results of modelling of price transmission along the milk supply chain in Ukraine in 2013–2020 are submitted in Table 2.

Table 2

Results of modelling of milk price transmission in Ukraine in 2013–2020

Indicators	Price					
	Farmers'		Processors'		Retailers' (consumers' price)	
	UAH/t, (%)	R	UAH/t, (%)	R	UAH/t, (%)	R
1. Monthly price change (trend model)	+72.38 (+1.200%)	0.966	+145.03 (+1.259%)	0.985	+234.91 (+1.397%)	0.984
2. Price change due to the farmers' price change (regression model)	+1.00	1.000	+1.94	0.985	+3.13	0.983

Source: authors' calculation.

The coefficients of correlation (R) and approximation (R^2) testify the great dependence of variation of processors' and retailers' prices on farm prices changes. The F-statistics tests confirm the statistical significance of obtained results. The values of Fisher coefficients in the tables of dispersion analysis (3170.8 and 2708.6 – for the first and the second regression equation) are much higher than its critical value (3.94 for the false-rejection probability 0.05). So, $F > F_v$, and null hypnosis is rejected.

The following results using the development of the linear regression models were obtained: with the increase in the raw milk price at farmers' stage by 1.00 UAH, the processors increased the price of processed milk by 1.94 UAH, and the retail price for the consumers, respectively, is increased by 3.13 UAH. The shocks in upstream sector (farm price increase) immediately transfer to the downstream sector.

The technological peculiarities cannot explain this process of the growing "shakes" of the prices because both the capital intensity and the term of turnover of current assets of the food processing industry and trade, especially wholesale, are much smaller than the size of these indicators of agricultural milk producers. But such "price fluctuation" with the growing amplitude in the upstream sector leads to the reduction of milk and dairy products consumption.

The results of modelling show that the increase of the price of raw milk instantly transfers from agricultural enterprises to the rise of the price of processed milk and the consumer price of milk in trade. In Ukrainian conditions, there is no time lag. The rate of price increase for primary producers is lower than the rate of price change for processing and trade. This is direct evidence of asymmetric price transmission in the milk supply chain during the investigated period.

Summing up the results of price transmission modelling along the agri-food chain of milk production and supply in Ukraine gives grounds for the conclusion about the imperfection of price transferring from the agricultural producer to the consumers. Agricultural enterprises – producers of raw milk have got from 30 to 35 % of the final milk price. They cannot respond in kind to market shocks because even their small price increase leads to significant consumer price growth. These imperfects of price transmission cause limitations for the expanded reproduction of milk in the farms' sector, threats for sustainable development of agricultural enterprises – milk producers.

Conclusions. The vertical price transmission as the price changes along the supply chain relative to the initial market shock is characterized by speed, direction, and magnitude. This study has clarified the condition of symmetric price transmission and developed trend and regression models to identify price transmission characteristics in the milk supply chain in Ukraine. The database for the modelling included the monthly prices of farmers, processors, and retailers in Ukraine in 2013–2020. The econometric analysis confirmed that each price time series is not stationary and is integrated of order 1. The price time series of farm and processors' levels, farms' and traders' levels are cointegrated. The modelling has shown that the prices changes at the farm, processing and retail sectors of the milk supply chain were in the same directions. The correlation coefficients and modifications of the models have not confirmed the existence of lags between the price changes. The initial shocks at farm-gate immediately transform into price changes at processors' and retailors' levels. But the modelling results have testified the asymmetry in the part of the magnitude of price transmission in the milk supply chain in Ukraine.

The following results were obtained on the basis of regression models: the increase of the farm price of raw milk by 1.00 UAH was accompanied by the price growth of the processed milk by 1.94 UAH, and the retail price for the final consumers by 3.13 UAH, when the condition of magnitude symmetry of price transmission for regression model has the same absolute changes at all levels of supply chain. Using the trend models, we also found evidence of asymmetric price transmission. When the farm prices of raw milk increase by 0.727 %, the processors' prices grow up by 0.810 %, and the retailers – by 0.918 %, but the condition of symmetry of price transmission for these models is smaller relative changes of prices at the processors' and retailors' levels in comparison with the prices of farm level.

This evidence of asymmetry of price transmission in the milk supply chain in Ukraine points out the violation of economic relations harmonization between the agents of milk supply chain, weaknesses in the market position of farmers and consumers, the threats for the food security and sustainable development.

This paper on parameters of price transmission in the Ukrainian milk supply chain contributes several aspects to the existing studies. This price transmission research evaluates empirical evidence of agricultural markets operation in emerging countries and proves the asymmetry in the price transmission along the milk supply chain in Ukraine. The heterogeneous structure of milk production and supply with the domination of the small producers in the farm sector and large-scale commercial operators in the processing and retail sectors generates the risks of inefficient and unfair redistribution of market power. This study testifies the farm sector does not have vulnerable leverages of pricing. More specifically, our research investigated the directions, magnitudes, and speed of price transmission in the milk supply chain in Ukraine and has found the signs of asymmetric price transmission and distribution of the market power in this supply chain.

Assessment and analysis of the mechanism of price transmission allow to determine the necessary policy actions for harmonization of relations between producers of different stages of milk chain, on the one hand, and support the consumers of this vitally important product, on the other. The practice of the European Union gives examples of policy actions to strengthen the market position of farmers in the case of price transmission asymmetry (Report of Agricultural Market Task Force, 2016). These actions are targeted to ensuring market transparency, elimination of unfair trading practices, improving contract practice and competition law, updating risk management technologies, support payments, cooperation among agricultural producers, promotion of farm products, facilitation of the access to finance, and innovation for farmers.

In our modelling, other potential explanatory variables like costs of labour, energy have not been included. We assumed that the rate of changes of these costs are the same for the producers of all stages of the milk supply chain because they operate under the same macroeconomic conditions. Still, the costs structures are different in agricultural production, processing, and trade, and this fact should be considered in future studies. Also, the causes of asymmetric price transmission need to be investigated in future research and the characteristics of price transmission in the supply chain of other products.

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