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Changes in the Milk Market in the United States on the Background of the European Union and the World

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Abstract:

Purpose: *The aim of the article was to learn and evaluate the development of the U.S. milk market.*
Design/Approach/Methodology: *The study analyzed the number of dairy cows, milk yield of cows, milk production, import, export and consumption of milk and milk products in the USA. In the analysis of the research results, tabular, graphic and descriptive methods were used.*
Findings: *United States (U.S.) dairy farms used to be most efficient in the world. The average herd of dairy cow is 115 head in the United States of America (USA) and 22 in the European Union (EU). The vast majority of cow's milk production (85%) comes from dairy herds having more than 100 head. The analysis shows that the milk yield of cows and milk production in the USA increased, with a slight increase in the number of cows.*
Practical Implications: *During the analyzed period, the USA increased the consumption of dairy products, while the consumption of liquid milk has decreased.*
Originality/Value: *In 2009-2018, the trade balance was positive Data Envelopment Analysis (DEA) method – CCR, BCC and NIRS model focused on input-oriented minimization were used.*

Keywords: *Milk production, dairy products trade, milk consumption, the USA.*

JEL codes: *D22, D24, O13, Q12, Q13.*

Paper type: *Research study[7].*

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1. Introduction

According to Zalewski (2000), milk and milk products are important products in human nutrition, supplying the body with protein and main vitamins A, B, D, and calcium. Moreover, milk consists of water, fat, casein, lactose, organic acids, mineral substances, and other ingredients (Xu and Flapper, 2009). Milk can be transformed into a variety of products, for example: yogurt, fluid milk, dry milk powder, cheese, dry whey powder, and butter (Briam *at el.,* 2015). An important part of the agricultural economy of many countries in the world is the production of milk on farms specializing in dairy cattle breeding, thanks to which many jobs are created in rural areas, mainly in food processing (Borawski and Dunn, 2014). Milk production is mainly influenced by elements such as the level of investment, resources, prices, and costs (Śmigla, 2014). The functioning of dairy farms determines their spatial distribution in different regions, economic value, and the efficiency of milk production. Dairy farms, due to the growing costs of production and increasing labor costs, have increased their production (Adamski, 2014). The development of dairy farms shapes sustainable development and the level of investment (Borawski and Pawlewicz, 2006; Sass, 2009).

Agriculture in the USA is a leader in large-scale production. Since 1940, the USA has experienced a decline in farm numbers and an increase in the size of the average farm (Stokes *et al.,* 2007). From 1992 to 2017 the number of dairy farms decreased by 74,1% from 155,339 to 40,219 (ERS 2020). In the U.S., the average herd of dairy cows is 115 head, and 75 percent of all U.S. dairy farms have fewer than 100 cows. Eighty five percent of cow's milk production in the U.S. comes from farms with dairy herds of more than 100 head. There are also small farms in the USA, some of which are organic producers (Mayen *et al.,* 2009).

The consolidation of dairy farms in the U.S. has led to a decline in the price of milk and milk products. The fall in the prices of U.S. dairy products made them more competitive on international markets, which had a positive impact on the exports of dairy products. In the U.S. today, nearly 200 farms have 5,000 or more cows, and the largest farms have more than 25,000 cows. Also, a decline in the number of smaller dairy farms - especially those with fewer than 200 cows - will continue in the coming years (MacDonald *et al.,* 2020).

Wisconsin has been the leader in milk production in the U.S. for much of the 20th century, but in 1993 California gained first place in milk production. In the years 1980–2009, the five states that led in dairy product production were Wisconsin, California, Minnesota, New York, and Pennsylvania. The states of Idaho and New Mexico have joined the top ten states with the largest dairy production. The states of California and Wisconsin have different dairy farm characteristics. The state of Wisconsin has the largest number of family farms with herds of 80 to 120 dairy cows, while California is dominated by larger herds of more than 1000 cows. Further increases in milk production are expected in the U.S., New Zealand, and EU

(Parzonko and Runowski, 2015). A very wide range of external factors that directly affect the efficiency and productivity of farms was the stimulus for this paper. This is very important in the context of well-targeted and effective development of the U.S. economy. Little research was found comparing the milk market development in the USA to other countries. Moreover, the analysis including the technical efficiency using DEA method of milk market is limited.

The analysis of farms using the DEA method has been studied in Poland by Świtłyk (2011). Rusielik (2012) presents a comparative analysis of the technical efficiency of dairy farms in Europe for the needs of the European Milk Producers Association using the alternative methods of the DEA and SFA. The analysis of dairy farms mainly in Pennsylvania was studied by Stokes *et al.* (2007). They found that 29% of the farms studied were DEA efficient. Siewert *et al.* (2018) measured factors associated with productivity on automatic milking system dairy farms in the Upper Midwest United States. They found that more frequent feed push-up and good stall comfort appeared to be important farm level factors to achieving high milk yield on AMS farms. Bell *et al.* (2013) analyzed the effect of changing cow production and fitness traits on net income and greenhouse gas emissions from Australian dairy systems. They found that reducing milk volume, live weight, and poor fertility in Australian dairy systems across breeds can improve the net income and reduce the GHG emissions per cow and per unit product. Skevas *et al.* (2012) measured technical efficiency in the presence of pesticide spills and production uncertainty in Dutch arable farms. They found that Dutch farmers have noticeable output inefficiency scores and high EI (both input and output) inefficiencies that reveal a considerable scope for decreasing pesticides' environmental spillovers.

The DEA model is mostly used to evaluate the technical efficiency for different kinds of farms. Our intention was to fill in the gap in the literature including the milk market efficiency in the USA. This approach was also done by Wysokiński *et al.* (2020) who measured the technical and energy efficiency of the EU countries. The authors used the following variables to elaborate the efficiency.: gross value added as output and utilized area, number of employees, and greenhouse gas emissions in agriculture as inputs.

The main aim of the research was to understand and evaluate the development of the U.S. milk market. The detailed objectives include:

- identification of the dairy cow population in the USA,
- evaluation of milk production in the USA,
- analysis of the consumption of milk and dairy products in the USA,
- evaluation of technical efficiency of the milk market in the USA.

We wanted to answer the following questions:

1. What is the milk production in the USA and how has it changed in the years 2009-2018?

2. What is the per capita consumption in the USA?
3. How did the exports and imports change?
4. What is the technical efficiency of the milk market in the USA?
5.

2. Literature Review

Milk production is an important issue and is shaped by various factors and systems. First, milk production can be organized using conventional or organic systems of production. The eco-efficiency can be measured by a Life Cycle Assessment (LCA) of farm systems (Basset-Mens *et al.,* 2009, Van der Werf and Petit, 2002). The National Organic Program (NOP) is a federal set of requirements in the USA under which organic dairy cows should spend at least 120 days per year on pasture and receive at least 30 percent of dry matter from pasture (Walsh *et al.,* 2020). The use of synthetic inputs and antibiotics are also restricted. Such requirements cause reduced yields from organic farms.

The most important changes in the milk market took place in the supply chain and most notably for the concentration processes. The number of dairy farms in the world and the number of processing enterprises both decreased. Moreover, the milk yield increased (USDA, 2020). Milk production depends to a large extent on feed and feed costs, which are major expenses in dairy production (Mäntysaari *et al.,* 2012). Farmers may achieve greater conversion of feed to milk that can improve economic performance (Ferraretto *et al.,* 2011). Another important issue in milk production is lactation performance by dairy cows. New animals give more milk, but do not live as long. This means that after a few lactations dairy cows are eliminated from the herd because it is more difficult for them to become pregnant and give birth to calves. Crossbreeding can be used to improve fertility health and longevity traits (Xue *et al.,* 2011).

Milk production varies in the EU. According to Parzonko *et al.* (2019), the milk production is characterized by the large variation in the scale of production (cow population and milk production level). This is the result of the different production technology and assets involved. The technology of production and machinery used relates to various energy needs (Parzonko, 2013). The demand for energy is increasing not only in agriculture but in other sectors of the EU economy. It is a challenge for policy makers to cover consumption increasing needs (IEA, 2018). There are many factors that shape milk production. The main issue in the development dairy farms is milk yield per cow, which leads to higher profitability. Moreover, the production per cow can be increased by genetic selection (Harrison *et al.,* 1990).

The EU is also an important milk producer in the world. The EU milk market has undergone major changes in recent years. These include the liberalization of milk trade, the elimination of the milk quota system, and investments aimed at increasing the efficiency of farms specializing in dairy cattle breeding. Liberalization on the milk market was aimed at removing trade barriers within the EU market. Therefore, the EU dairy industry was subjected to strong competition. The new member states that joined the European Union in 2004 and 2007 (EU13) faced strong market competition. As a result, many small dairy farms went out of business. The strong competition in the EU and elsewhere pushed farmers to reduce production costs and to improve efficiency. All these changes resulted in lower milk prices (Jiří *et al.*, 2017). The observed tendency resulted also in the increase of dairy processing (Špička, 2015).

As in other U.S. agricultural sectors, the dairy industry has undergone significant structural changes. The number of farms in 2000 was half of its level in 1990, while milk production continued to grow, reflecting a higher average herd size (Dairy Report, 2004; 2005; 2006; Parzonko, 2009; 2013). In South America milk production of is forecast to grow. For example, Argentina expects an average annual increase of 3% in milk production between 2011 and 2020 (Seremak-Bulge, 2012; Parzonko, 2013).

Today milk production has a global character, which means that changes in the biggest producers have an impact on smaller countries. The global milk prices are the effect of milk production in the biggest producers and consumers (Parzonko, 2016). The global demand for milk will continue to grow in the world because of increasing population. However, often only big dairy farms can compete effectively. In 2018 the milk production increased in the European Union (0.8%), New Zealand (3.2%) and United States (1.1%) (OECD-FAO, 2019). From the literature, we have inferred the research hypotheses as:

H1. The milk market in the USA had high technical efficiency.
H2. The increase of American dairy exports is the result of the efficiency of the farms.

3. Materials and Methods

The study compared data for 2009-18. The data of the United States Department of Agriculture (USDA) were used for the analysis. The article analyzes the supply (production and imports) and demand (consumption and exports) for milk and its products in the USA. In the analysis, tabular, graphical, and descriptive methods as well as trend analysis were used. To analyze the milk market in the USA, we have prepared the DEA models. This is a non- parametric method that measures efficiency as the maximum ratio of a weighted sum of outputs to a weighted sum of inputs. The ratio is calculated by means of linear programming (Bórawski and Dunn, 2012, Lenort *et al.,* 2019).

The CCR model assumes constant returns to scale (CRS) (Mecit and Alp, 2013). The BCC estimates the pure technical efficiency with reference to the efficient frontier (Banker *et al.,* 1984). The only difference between the BCC model and the

CCR model is adding the variable of output to the input-oriented model (Banker *et al.,* 1984). This method has both advantages and disadvantages. The most important advantages include:

- the possibility of multiple inputs and outputs,
- no need to specify the form of the production function,
- we analyze the inefficiency of evaluated units,
- and we can use any input-output measurement.

The most important disadvantages include:

- the efficiency can be achieved by niche combinations of inputs/outputs,
- the increase of the number of inputs and outputs increases the number of efficient units,
- the selection of inputs and outputs has an impact on the results,
- a DMU's efficiency scores may be obtained by using non-unique combinations of weights on the input and/or output factors.

In the classic DEA models are developed with the assumption that all inputs and outputs are non-negative (Allahyar and Rostamy-Malkhalifeh, 2015). The DEA aims to identify the top performing units in a particular sector and develop ways to improve the DMU’s performances, if it is not considered one of those top performing units (Liang *et al.,* 2008). The DEA method allows the study of the relationship between the level of many inputs and many effects (Wysokiński *et al.*, 2020).

In linear programming, this indicator is a function of the target. In the DEA method, two variants of the objective function can be distinguished: maximization of effects at a given level of inputs or minimization of inputs at given effects (Cooper *et al.*, 2007). Our DMU was the milk market in the USA. We have checked the changes in output and inputs in the years 2009-2018. Based on the literature review, the following variables were adopted for the model:
– Effect Y1 – milk production (thousand tons);
– Input X1 – trade balance of dairy products (thousand tons);
– Input X2 – number of dairy cows (thousand head);
– Input X3 – milk yield (kg/head);
– Input X4 – consumption of dairy products (kg / person).

Charnes, Cooper, and Rhodes (1978) in their basic model (CCR) define the objective function to find efficiency as:

$$\max \quad \theta_j = \frac{\sum_{m=1}^{M} y_m^j u_m^j}{\sum_{n=1}^{N} x_n^j v_n^j},$$

where the $DMU'_j s$ known *M* outputs $y_1^j, \ldots, y_m^j$ are multiplied by their respective weights $u_1^j, \ldots, u_m^j$ and divided by the *N* inputs $x_1^j, \ldots, x_n^j$ multiplied by their respective weights $v_1^j, \ldots, v_n^j$.
The efficiency score θ_j is sought to be maximized, under the constraints that use those weights on each $DMU_k \quad k = 1, \ldots, K$, no efficiency score exceeds one:

$$\frac{\sum_{m=1}^{M} y_m^k u_m^j}{\sum_{n=1}^{N} x_n^k v_n^j} \leq 1 \qquad k = 1, \ldots, K,$$

and all inputs, outputs and weights must be non-negative.

4. Empirical Results

4.1 Milk Production in the USA in the Context of the World

Table 1 shows a comparison of the number of dairy cows in the world, in the USA, and in the EU-27/28 in 2009-2018. The analysis shows that the number of dairy cows in the USA in the analyzed period was from 3.37 to 3.56% of the world's number of dairy cows, and the number of dairy cows in the EU-27/28 countries ranged from 8.40% to 9.36% of the world's dairy cow population. In the analyzed period, the lowest number of dairy cows in the USA was in 2010 (9,123) and the highest in 2018 (9,432). For comparison, the lowest number of dairy cows in the EU-27/28 was in 2018 (23,013) and the highest in 2009 (24,274). In the years 2009 - 2018 in the world the lowest number of dairy cows was in 2009 (259,237) and the highest in 2016 (276,574).

Worldwide milk production is constantly increasing. Over the past 10 years, world milk production has increased by more than 20%. The leading countries in the growth were China, India, New Zealand, and Turkey (Kołoszyc, 2016). The highest increase in the years 2000-2016 was recorded in China by almost four times. According to the International Comparison Farms Network (ICFN), in 2013, global milk production included 122 million producers. Globally, 363 million dairy cows and buffaloes were bred, producing milk with an average yield of about 2,100 kg.

The European Union is a significant player in the world milk production. In 2017 the production of raw milk in the EU amounted to approximately 172 million tons (Eurostat, 2020), which accounted for approximately 20.4% of global milk production. The average yield of dairy cows in the European Union countries was about 6,200 kg of milk per cow (Olszewska, 2015). Before 2015, EU farms involved in milk production were limited in their ability to compete by milk quotas (Judzińska and Łopaciuk, 2011). On April 1, 2015, the European Commission abolished the milk production quota system, which led to an increase in milk production, facilitating the expansion of farms and improving the competitiveness of European farmers against the global milk producers (Sadowski and Michalczak, 2015). The largest EU milk producers are Germany, France, Great Britain, the Netherlands, Poland, and the smallest is Malta (Eurostat, 2020).

Table 1. *The number of cows in the world, in the US and EU-27/28 in 2009-2018.*

Years	Number of cows				
	World thousand head	USA thousand head	% share of US dairy cows in the world	EU-27/28 thousand head	% share of the number of dairy cows EU-27/28 in the world's dairy cow population
2009	259 237	9 202	3,55	24 274	9,36
2010	261 374	9 123	3,49	23 907	9,15
2011	263 992	9 199	3,48	23 345	8,84
2012	268 213	9 237	3,44	23 333	8,70
2013	269 645	9 224	3,42	23 350	8,66
2014	272 951	9 257	3,39	23 486	8,60
2015	275 545	9 307	3,38	23 597	8,56
2016	276 574	9 313	3,37	23 458	8,48
2017	275 384	9 369	3,40	23 130	8,40
2018	265 099	9 432	3,56	23 013	8,68

Source: *Authors' calculations based on FAO 2020 data.*

The performance level of dairy cows in the studied period in the USA was higher than the level of cows elsewhere in the world and ranged from 406% to 430% relative to the world productivity of dairy cows. For comparison, the level of milk yield of dairy cows in the EU-27/28 countries ranged from 266% to 289% of the milk yield of cows in the world (Table 2). The increase of the milk yield is the effect of different factors. First, the genetics has improved. This means that the more productive animals can deliver more milk per cow.

However, the cows live shorter lives and have problems with their legs and breast. Normally, the cows give birth to 3-4 calves. Previously the cows could give birth to 10 and more calves but gave less milk. Another reason for the increase of milk yield per cow is better feed, which is more concentrated. Also, the health of animals is important in milk yield. Early identification of clinical lameness is important in prevention of the illness (Green *et al.,* 2002). Moreover, housing, and grazing conditions have an impact on animal health, lameness, and milk yield. Milking parlors where cows are pushing each other or turning sharply near the parlor entrance or exit also can worsen the condition of animal health and finally the yield (Main *et al.,* 2012). The world dairy industry faced changes in production, milk yield, relocation, and agricultural systems (Cooper *et al.,* 2007). In 2009-2018, the production of cow's milk in the USA accounted for from 14.26% to 14.54% of world production, while in the EU-27/28 countries, the production of cow's milk was at the level from 23.87% to 24.93% of world production. In the analyzed period, there is a clearly visible increase in the production of cow's milk from year to year in the USA, as in the EU-27/28 and in the world. The exception is milk production in 2018 in the EU-27/28, which is lower than in 2017 (Table 3).

Table 2. *Milk yield of cows in the world, in the USA and EU-27/28 in 2009-2018.*

Years	Milk yield of cows				
	World kg/cow	USA kg/cow	Milk yield of cows in the USA to milk yield of cows in the world in%	EU-27/28 kg/head	Milk yield of cows in the EU-27/28 to milk yield of cows in the world in%
2009	2 278	9 326	409	6 064	266
2010	2 303	9 590	416	6 181	268
2011	2 334	9 677	415	6 429	275
2012	2 350	9 853	419	6 452	275
2013	2 356	9 896	420	6 520	277
2014	2 401	10 097	421	6 742	281
2015	2 400	10 167	424	6 845	285
2016	2 407	10 348	430	6 922	288
2017	2 461	10 435	424	7 111	289
2018	2 577	10 463	406	7 088	275

Source: *Authors' calculations based on FAO 2020 data.*

In the EU dairy sector has also experienced changes. The huge impact in the milk production in the EU have few countries which have decisive impact on the market (Poczta *et al.*, 2020). In this respect, Poland ranked fifth in the European Union, just behind Germany producing 33.109 million tones, France 26.012 million tons, Great Britain 15.488 million tons and the Netherlands 14.426 million tons. Poland overtook Italy (13.131 million tons) and Spain (8.417 million tons of raw cow's milk produced) (Eurostat, 2020). The total production of milk in the European Union amounted to over 172 million tons, of which over 8% was produced in Poland.

World milk production in 2019 was 852 million tons, 1.4% higher than in 2018. The increase in milk production occurred in India, Pakistan, Brazil, the European Union, the Russian Federation, and the United States of America, while a decrease in milk production was recorded in Australia, Turkey, Colombia, Argentina, and Ukraine (Dairy Market Review, 2019).

According to the United States Department of Agriculture (USDA) (US Dairy Export Council, 2014), the number of farms producing milk in the US decreased from 74,100 in 2002 to 34,187 in 2019, but despite the decline in the number of farms, milk production continued to increase. The number of dairy farms decreased by an average of 4% each year from 2002 to 2017, while in 2018 it decreased by 6.8% compared to 2017. In 2019, the number of dairy farms decreased by another 8.8% compared to 2018 (US Dairy Export Council, 2014).

Table 3. *Cow's milk production in the world, in the USA and EU-27/28 in 2009-2018.*

Specification	**Cow's milk production**				
	World (thousand tons)	**USA (thousand tons)**	**% share of US cow's milk production in world production**	**EU-27/28 (thousand tons)**	**% share of EU 27/28 cow's milk production in in world**
2009	590 471	85 821	14,53	147 196	24,93
2010	601 868	87 488	14,54	147 764	24,55
2011	616 177	89 020	14,45	150 087	24,36
2012	630 245	91 010	14,44	150 547	23,89
2013	635 379	91 277	14,37	152 248	23,96
2014	655 246	93 465	14,26	158 334	24,16
2015	661 431	94 619	14,31	161 525	24,42
2016	665 597	96 366	14,48	162 371	24,39
2017	677 671	97 762	14,43	164 472	24,27
2018	683 217	98 690	14,44	163 101	23,87

Source: *Authors' calculations based on FAO data.*

In the years 2009-2018 in the United States of America, the number of dairy cows slightly increased to 9,398,000 head in 2018 (2%) from 9,202 thousand heads in 2009, while in 2019 the number of dairy cows decreased by 62 thousand heads compared to 2018. In 2009, milk production per cow was 9,326 kg. The yield of dairy cows yearly, reaching 10,501 kg in 2018 per dairy cow (increase by 13%). In 2019, there was also an increase in milk production per cow by 109 kg (10 610 kg) compared to 2018. The total production of cow's milk in the analyzed period increased by 15%. In 2018, the total production of cow's milk in the USA was at the level of 98,687 thousand tons and increased by 12 866 thousand tons in relation to 2009, when it was 85 821 thousand tons. In 2019, the total production of cow's milk in the U.S. amounted to 99,056 thousand tons and was higher by 369 thousand tons from 2018 (Sadowski and Michalczak, 2015).

Over 95% of the U.S. dairy cow population in 2018 was in 27 U.S. states. The leaders in 2018 include such states as California (1,734,000), Wisconsin (1,274,000), New York (623,000), Idaho (609,000), Texas (537,000), Pennsylvania (519,000), Minnesota (453,000), Michigan (423,000), New Mexico (330,000), and Washington (227,000), which accounted for more than 72% of the entire U.S. dairy cow population (98,687,000). The highest increase in the dairy cow population in 2018 compared to 2009 was recorded in the states of Colorado (43%), Kansas (35%), South Dakota (29%), Texas (27%), Michigan (19%), and Utah (19%). The highest loss in the dairy cow population in 2018 compared to 2009 was recorded in the states of Kentucky (-35%), Missouri (-22%), Virginia (-14%), Illinois (-12%) (Table 4).

Table 4. *Number of dairy cows in the 25 US states with over 95% of the population in 2009-2019 (thousand heads)*

Specification	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Change 2009-2019 (%)**
California	1 796	1 754	1 769	1 782	1 780	1 780	1 776	1 762	1 749	1 734	1 726	-3
Wisconsin	1 257	1 262	1 265	1 270	1 271	1 271	1 279	1 279	1 278	1 274	1 267	1
New York	619	611	610	610	610	615	618	620	624	623	627	1
Idaho	550	564	578	580	573	575	585	595	600	609	625	11
Texas	423	413	431	436	437	463	463	477	515	537	565	27
Pennsylvania	545	541	541	536	533	530	530	529	525	519	490	-5
Minnesota	469	470	468	465	464	460	460	461	458	453	448	-3
Michigan	355	358	366	375	380	390	408	419	427	423	426	19
New Mexico	325	321	329	330	323	323	323	315	329	330	326	2
Washington	240	251	260	262	266	273	277	276	274	277	280	15
Ohio	277	271	268	270	270	267	267	265	264	259	251	-6
Iowa	214	210	204	205	208	207	211	213	218	220	218	3
Arizona	177	177	188	188	190	196	199	201	208	208	197	18
Indiana	168	170	172	175	176	178	182	184	187	183	178	9
Colorado	123	119	128	133	137	144	148	153	162	176	186	43
Kansas	118	119	123	126	134	141	143	146	152	159	163	35
Vermont	135	136	134	133	134	132	132	130	129	127	126	-6
Oregon	114	118	121	123	123	124	125	125	124	123	124	8
South Dakota	94	92	91	92	94	97	106	115	117	121	125	29
Florida	115	114	119	123	123	123	125	123	124	120	116	4
Utah	84	88	93	95	95	95	96	91	96	100	98	19
Illinois	102	100	98	98	96	94	94	94	93	90	83	-12
Missouri	107	99	95	94	92	90	88	85	85	83	78	-22
Virginia	96	95	96	96	95	93	91	90	87	83	75	-14
Georgia	77	79	79	80	80	81	83	84	84	83	82	8
Nebraska	61	59	57	56	54	54	57	60	60	60	58	-2
Kentucky	84	78	76	74	71	63	61	58	56	55	50	-35

Source: *Authors' calculations based on USDA 2020b.*

According to Ziętara (2007), the increase in the yield of dairy cows is associated with biological progress in breeding and developments in the field of animal nutrition and maintenance.

In the USA, in the years 2009-2018, the milk yield of cows increased in 2018 compared to 2009 in the states of Kentucky (29%), Nebraska (22%), Wisconsin (20%), Iowa (19%), New York (19%) and Michigan (18%). A decrease in milk production per cow in 2018 compared to 2009 was recorded in Missouri, which was -2%. The highest milk production per dairy cow in 2009 was in New Mexico (11,031 kg / head), and the lowest in Kentucky (6,436 kg / head), while in 2018 the highest milk yield of cows was recorded in Michigan (11,979 kg / head), and the lowest in Missouri (6,397 kg / head). In 2019 there was an increase in milk yield for most states of the 27 states with over 95% of the dairy cows. The states in which there was a decrease in productivity were the states of Colorado (decrease in 2019 compared to 2018 by 21 kg / head), Washington (decrease in 2019 compared to 2018 by 42 kg / head), Utah (decrease in 2019 in relation to 2018 by 62 kg / head) and Missouri (decrease in 2019 by 128 kg / head compared to 2018). In 2018, the milk yield of cows was higher than the U.S. average in the states of Michigan by 14%, Colorado by 12%, New Mexico by 8%, Idaho by 7% and in Washington by 5% (Table 5).

Table 5. *Milk yield of cows in kg / head in 27 US states with over 95% of the dairy cow population in 2009-2019 (kg/head).*

Specification	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Changes 2009-2019 (%)
Michigan	10 181	10 558	10 507	10 875	10 939	11 176	11 408	11 774	11 930	11 979	12 122	18
Colorado	10 462	10 734	10 628	10 958	11 019	11 318	11 514	11 636	11 729	11 744	11 723	12
New Mexico	11 031	11 136	11 274	11 201	11 314	11 382	10 997	11 103	11 322	11 388	11 391	3
Idaho	10 020	10 273	10 399	10 603	10 632	10 944	10 943	11 180	11 062	11 281	11 344	13
Washington	10 510	10 666	10 762	10 793	10 805	10 926	10 817	10 929	10 812	11 030	10 988	5
Wisconsin	9 108	9 358	9 344	9 723	9 840	9 920	10 295	10 678	10 766	10 887	10 955	20
Nebraska	8 908	8 980	9 334	9 607	9 786	10 038	10 401	10 576	10 917	10 886	11 019	22
Iowa	9 116	9 378	9 612	9 986	10 047	10 183	10 400	10 720	10 776	10 866	11 009	19
Texas	9 479	9 696	10 084	9 983	9 975	10 101	10 092	10 244	10 617	10 863	11 119	15
Arizona	10 461	10 638	10 647	10 877	10 717	10 886	10 793	10 916	10 976	10 845	10 981	4
New York	9 104	9 438	9 546	9 808	10 018	10 133	10 336	10 811	10 852	10 835	10 940	19
Kansas	9 564	9 518	9 533	9 835	9 928	10 018	10 074	10 342	10 442	10 578	10 627	11
California	9 979	10 444	10 631	10 640	10 513	10 789	10 445	10 418	10 321	10 569	10 660	6
Utah	9 563	9 933	10 052	10 370	10 175	10 428	10 489	10 428	10 466	10 532	10 470	10
Indiana	9 134	9 114	9 370	9 725	9 871	9 829	9 882	10 218	10 321	10 321	10 379	13
South Dakota	9 130	9 289	9 336	9 703	9 762	9 867	10 099	10 042	10 150	10 144	10 197	11
Minnesota	8 723	8 784	8 616	8 850	8 933	9 000	9 330	9 510	9 772	9 881	10 055	13
Ohio	8 502	8 821	8 706	8 996	9 153	9 216	9 350	9 589	9 654	9 688	9 804	14
Georgia	8 247	8 010	8 325	8 681	8 890	9 470	9 788	9 882	9 936	9 651	9 797	17
Vermont	8 296	8 408	8 591	8 762	8 821	9 161	9 161	9 515	9 596	9 583	9 709	16
Illinois	8 280	8 346	8 396	8 646	8 647	8 927	9 139	9 226	9 408	9 465	9 553	14
Oregon	8 944	9 222	9 293	9 267	9 271	9 328	9 257	9 409	9 251	9 334	9 481	4
Pennsylvania	8 782	9 002	8 843	8 867	8 980	9 127	9 243	9 271	9 412	9 314	9 357	6
Florida	8 204	8 487	8 649	8 629	8 788	9 249	9 373	9 205	9 130	8 996	9 173	10
Virginia	8 202	8 208	8 122	8 160	8 318	8 687	8 833	8 684	9 051	8 935	9 012	9
Kentucky	6 436	6 699	6 505	6 865	6 836	7 214	8 009	8 188	8 440	8 321	8 537	29
Missouri	6 647	6 621	6 627	6 794	6 700	7 021	6 845	6 734	6 622	6 525	6 397	-2

Source: *Authors' calculations based on USDA 2020c.*

During the analyzed period in the USA, milk production increased significantly in 2018 compared to 2009. Of the 27 states with over 95% of the dairy cows, milk production increased in Colorado (61%), Kansas (49%), Texas (45%), South Dakota (43%), and Michigan (40%). The drop in milk production in 2018 compared to 2009 took place in Missouri (-24%), Kentucky (-15%) and Virginia (-6%). The highest milk production in 2009 was in California (17,922 thousand tons), and the lowest in Kentucky (541 thousand tons), as in 2018, where also the highest milk production was in California (18,327 thousand tons), and the lowest in Kentucky (427 thousand tons). In 2019, there was an increase in milk production in 15 out of the 27 states with over 95% of dairy cows, while in the remaining twelve states there was a decrease in milk production. The states in which milk production increased in 2019 compared to 2009 were California (increase by 73 thousand tons), Idaho (increase by 220 thousand tons), New York (increase by 109 thousand tons), Texas (increase by 449 thousand tons), Michigan (increase by 97 thousand tons), Minnesota (increase by 27 thousand tons), Washington (increase by 22 thousand tons), Colorado (increase by 113 thousand tons), Kansas (increase by 50 thousand tons), South Dakota (increase by 48 thousand tons), Oregon (increase by 28 thousand tons) (Table 6).

The US dairy industry is relocating its activity to the southwest, the Plains, the Corn Belt, and the Northwest. The most important reasons for these moves are favorable climate conditions, more land available to rent and buy. In some states the farmland prices are high and the state regulations on input use force farmers to move to other less restrictive states (Murova and Chidmi, 2006). Moreover, small dairy farms in the USA are exiting because of high production costs and inefficiency. When the farm is small it is per units' costs are high and when the production is increasing the costs are decreasing (Bailey *et al.,* 1997; Blayney, 2002).

Table 6. *Milk production in 27 US states with more than 95% of the dairy cow population in 2009-2019.*

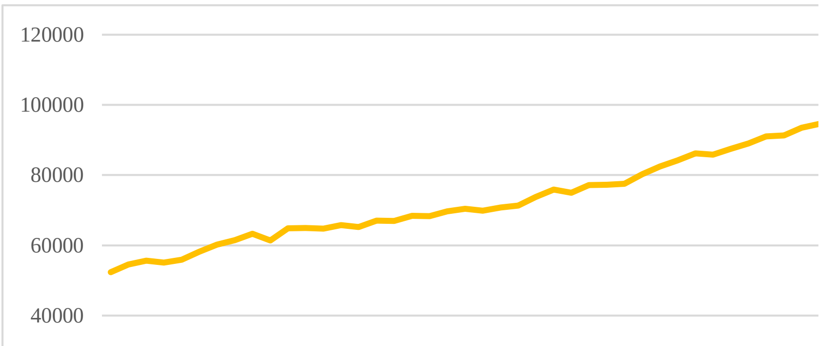
Specification	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Changes 2009-2019 (%)**
California	17 922	18 318	18 807	18 961	18 713	19 205	18 551	18 356	18 052	18 327	18 400	2
Wisconsin	11 448	11 809	11 820	12 349	12 506	12 608	13 168	13 658	13 759	13 870	13 880	21
Idaho	5 511	5 794	6 011	6 150	6 092	6 293	6 402	6 652	6 637	6 870	7 090	25
New York	5 635	5 767	5 823	5 983	6 111	6 232	6 388	6 703	6 772	6 750	6 859	20
Texas	4 010	4 004	4 346	4 353	4 359	4 677	4 672	4 887	5 468	5 833	6 282	45
Michigan	3 614	3 780	3 846	4 078	4 157	4 359	4 654	4 933	5 094	5 067	5 164	40
Pennsylvania	4 786	4 870	4 784	4 753	4 786	4 837	4 899	4 904	4 941	4 834	4 585	-1
Minnesota	4 091	4 129	4 032	4 115	4 145	4 140	4 292	4 384	4 476	4 476	4 505	9
New Mexico	3 585	3 575	3 709	3 696	3 655	3 676	3 552	3 498	3 725	3 758	3 714	5
Washington	2 522	2 677	2 798	2 828	2 874	2 983	2 996	3 016	2 962	3 055	3 077	21
Ohio	2 355	2 390	2 333	2 429	2 471	2 461	2 497	2 541	2 549	2 509	2 461	7

Iowa	1 951	1 969	1 961	2 047	2 090	2 108	2 194	2 283	2 349	2 390	2 400	23
Arizona	1 852	1 883	2 002	2 045	2 036	2 134	2 148	2 194	2 283	2 256	2 163	22
Colorado	1 287	1 277	1 360	1 457	1 510	1 630	1 704	1 780	1 900	2 067	2 180	61
Indiana	1 535	1 549	1 612	1 702	1 737	1 750	1 798	1 880	1 930	1 889	1 847	23
Kansas	1 129	1 133	1 173	1 239	1 330	1 412	1 441	1 510	1 587	1 682	1 732	49
South Dakota	858	855	850	893	918	957	1 070	1 155	1 188	1 227	1 275	43
Vermont	1 120	1 144	1 151	1 165	1 182	1 209	1 209	1 237	1 238	1 217	1 223	9
Oregon	1 020	1 088	1 124	1 140	1 140	1 157	1 157	1 176	1 147	1 148	1 176	13
Florida	943	968	1 029	1 061	1 081	1 138	1 172	1 132	1 132	1 080	1 064	14
Utah	803	874	935	985	967	991	1 007	949	1 005	1 053	1 026	31
Illinois	845	835	823	847	830	839	859	867	875	852	793	1
Georgia	635	633	658	694	711	767	812	830	835	801	803	26
Virginia	787	780	780	783	790	808	804	782	787	742	676	-6
Nebraska	543	530	532	538	528	542	593	635	655	653	639	20
Missouri	711	655	630	639	616	632	602	572	563	542	499	-24
Kentucky	541	523	494	508	485	454	489	475	473	458	427	-15

Source: *Authors' calculations based on USDA 2020c.*

As we can see the milk production in the USA is increasing since 1975. It has increased from 52343,7 thousand tons to 98687,2 thousand tons (Figure 1).

Figure 1. *US milk production in 1975-2018 (thousand tons).*



Source: *Authors' calculations based on USDA data 2020b.*

4.2 Consumption of Milk and Dairy Products in the USA

The amount of milk consumed in different regions of the world varies greatly. In highly developed countries, such as the EU countries, the USA, Australia and New Zealand, the consumption of milk and dairy products is 2.5-3 times higher than the average world consumption. Between 2005 and 2010, there was a decrease in milk consumption per capita in Australia and Oceania by 22%, while in the European Union milk consumption per capita decreased by 3%. In the US, milk consumption remained unchanged at the same time. An increase in milk consumption per capita in the above-mentioned period occurred in Asia by 17%, in Africa by more than 6%, but still milk consumption per capita in Asia and Africa is lower by 33-55% than the average milk consumption in the world (USDA, 2020a). In the USA, the consumption of dairy products expressed as milk equivalent in the years 1981-2009 was stable. In 2009, milk consumption per capita in the USA was 258 kg, which was 5 kg higher than the consumption in the early 1980s (Borawski *et al.*, 2015). In the analyzed period in the USA, there is an upward trend in the consumption of all dairy products expressed in milk equivalents. In 2009, the consumption of dairy products expressed as milk equivalent was 276 kg / person, and in 2019 it was 293 kg / person (Figure 2).

The volume and scale of production of milk and dairy products depends on the demand for these products, and this depends on their prices and quality. The increase in the prices of dairy products causes an increase in milk production, which in the long run causes a decrease in milk prices. The most important factors increasing the demand for dairy products are the number of potential consumers, their financial wealth, and individual preferences, as well as the prices of these products (Tomek and Robinson, 2001; Sznajder, 1999). The world milk market is sensitive to changes in the volume of trade in dairy products. In 2018, the global production of cow's milk amounted to approximately 843 million tones and increased by 2.2% compared to the previous year (Dairy Market Review, 2019). The largest global producer of milk in 2018 was the USA, with the production of almost 98 million tons of raw milk per year (FAOSTAT, 2020).

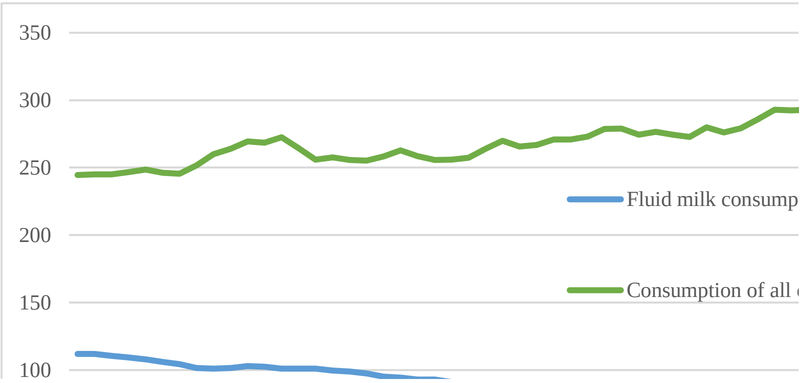
Milk is a good purchased in many households. Its consumption depends on the level of household’s income from one side and quality, quantity, and price level from the second (Kubicová *et al.*, 2014). The declining consumption of liquid milk in the USA is influenced by wider and increasing choices for plant milk. The consumption of fluid milk decresed from 112 kg per person in 1975 to 66 kg/person in 2018. Moreover, the consumption of all dairy products increased from 244 kilograms per person to 293 kilograms per person (Figure 2).

Moreover, intensive advertising and cheap flavored drinks with the increasing awareness of reducing cholesterol in the human diet contributed to the significant fall in the consumption of liquid milk (Bórawski *et al.*, 2016). The USA is a country with big milk production which means that must look for new consumers of milk and increase export (Ramirez *et al.*, 2006).

4.3 International Trade of Milk and Dairy Products in the USA

The international trade of products has an impact on the development of the country and creation of Gross Domestic Products (GDP) (Bórawski *et al.*, 2016). Milk production has a big impact on the US economy and depends on exchange rate of dollar to other currency. For example, a strong dollar has a negative impact on U.S. milk prices because the domestic market must absorb the surplus. When the dollar falls the exports recover and milk prices rise. This has an impact on the foreign trade between the U.S. and the EU. The weaker euro is making dairy exports more profitable, whereas the U.S. dairy exports suffer. For this and other reasons the USA is not exporting milk and dairy products to the EU. The other reasons include trade barriers of the EU to outside countries and self-sufficiency of this region.

Figure 2. *Consumption of liquid milk and dairy products in kilograms per person in the US in 1975-2018.*



Source: *Authors' calculations based on USDA 2020c.*

American milk production has a significant share on world production. In the years 1981-2009, exports were at the level of 3 to 8% and imports were at the level of 2 to 3% in relation to the production of milk in the USA (Ramirez *et al.*, 2006). In the USA, milk production is mainly used to meet domestic demand. The USA has been a net importer of dairy products for decades and is now a net exporter. The U.S. supplies nearly 12% of the world's milk production. Imported dairy products to the US are intended mainly for food processing. Imports of dairy products from 2005-2010 from New Zealand (23.7%), Italy (13.6%), France (7.9%), Canada (6.6%), Ireland 30 (5.2 %) and Australia (4.1%) cover only 1.3% of the domestic demand in the USA (Bórawski *et al.*, 2016).

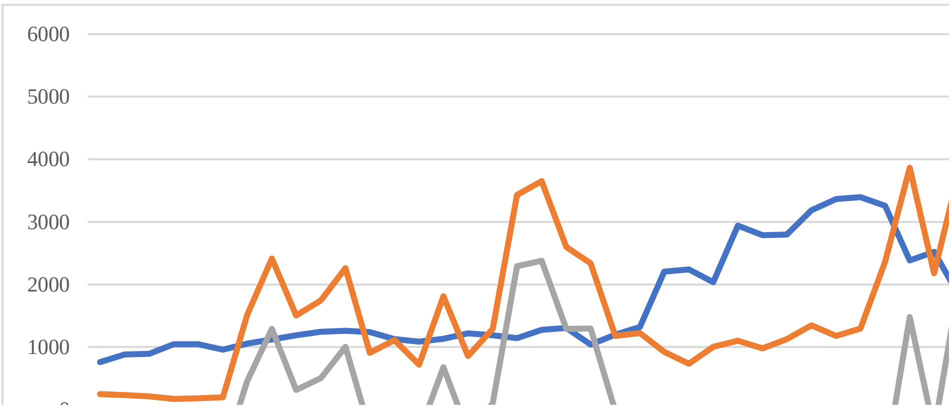
In the USA, in the analyzed period, imports of dairy products (2 522 thousand tons) were higher than exports (2 182 thousand tons) only in 2009. In 2009-2018, the export of dairy products was the highest in 2014 (5,522 thousand tons) and the lowest in 2009 (2,182 thousand tons). Imports of dairy products in the USA in the analyzed period were the highest in 2016 (2,612 thousand tons). The lowest level of imports in the USA occurred in 2011 (1,589 thousand tons). The most favorable balance (3 766 thousand tons) in the U.S. of exports (5 477 thousand tons) to imports (1 711 thousand tons) was recorded in 2013.

In the USA in 2009-2018, the imports of dairy products in relation to the level of milk production was at the level from 2.94% in 2009 to 2.56% in 2018. Imports of dairy products in relation to the production in the USA in the analyzed period show a downtrend.

The USA market is decreasing in dairy imports and increasing in exports. Mexico has been the biggest importer of the U.S. dairy products since 1990 (Ramirez and Christopher, 2008). The import of milk and dairy products will also remain high in China, mainly from the USA and New Zealand (Wang, 2010). In 2014, the USA mainly exported dairy products to Mexico, Southeast Asia, the Middle East, North Africa, China, Canada, and South Korea (USDA, 2020). The exports of dairy products by the USA in 2009-2018, compared to the level of milk production, shows an upward trend. In the analyzed period, exports ranged from 2.54% in 2009 to 4.77% in 2018 (Figure 3). One of the most important reasons why the USA is exporting milk is overproduction. The USA is a self-sufficient country in milk production and the rate is 102% what means that this country has a surplus for export (Bórawski *et al.*, 2016).

As we can see from Figure 3 the USA has improved the competitive position of milk market. However, from 1996 to 2006 the USA achieved negative trade balance of milk and dairy products. From 2010 the trade balance of milk and dairy products is positive.

Figure 3*. Exports, imports, and trade balance of dairy products from the USA in 1975-2018.*



Source: *Authors' calculations based on USDA 2020c.*

4.4 Technical Efficiency of Milk Market in the USA

In order to find changes in variables we have generated some descriptive statistics (Table 7). According to the analysis the highest standard deviation has been observed in milk production (4146.1) and trade balance of dairy products (1110.8). The US dairy farms must achieve high technical efficiency (TE) to be competitive. To measure the efficiency, we adopted DEA model which can use multiple output and inputs characterized in different units. Using this tool, we can measure the TE as a distance away from the frontier (Murova and Chidmi, 2013).

Table 7. *Descriptive statistics of milk market in the USA 1975-2018*

Variables	Mean	Standard deviation	Min	Max	Coefficient of variation	Skewedness	Cortosis
Imports	1799,4	824,8	757,1	3394,7	45,8	0,6	-1,1
Exports	2027,5	1510,0	172,4	5522,0	74,5	0,7	-0,6
Trade balance	228,1	1508,2	-2190,3	3765,7	661,3	0,4	-0,5
Milk production	73676	13090,0	52344,0	98687,0	17,8	0,3	-1,0
Fluid milk consumption	91,5	12,7	66,2	112,0	13,9	-0,2	-0,9
Consumption of all dairy products	265,5	13,4	244,5	292,9	5,0	0,2	-0,6

Source: *Authors' calculations based on USDA 2020.*

To evaluate the efficiency of dairy market we have conducted the DEA model (Table 8). The method is using the CCR and BCC model. The CCR model assesses the constant return to scale (CSR) and is describing the proportionality between the output and input values whereas the BCC model describes variable return to scale (VRS) when the outputs do not change in proportion to inputs (Rybaczewska-Błażejowska and Gierulski, 2018). In our analysis the results obtained from the BCC model are higher than CCR model. According to BCC model, the efficiency was the weakest in 2012. According to CCR model, the technical efficiency was not full in 2010, 2011, 2012, 2013, 2014 and 2015. The average technical efficiency was achieved by the milk market was 98,9% by CCR model. That is why to achieve technical efficiency, on average, the market should reduce the inputs adopted for the model by 1.8%. The technical efficiency achieved by BCC model was 99.9%. This means that the market should reduce the inputs by 0,1%.

In order to determine in which year milk market have increasing or decreasing scale effects, the efficiency was calculated at variable effects of scale and compared with the technical efficiency at non-increasing effects of scale (NIRS) for each of the researched farms. If the NIRS technical efficiency values were equal to the total technical efficiency (TE) values, the scale effects in each farm were increasing. If these values were different, then such a farm was classified to the decreasing scale effects (Szymańska, 2011).

Table 8. *DEA models of milk market in the USA.*

Year	Model CCR	Model BCC	Model NIRS	Scale character
2009	1	1	1	Increase
2010	0.967	1	0.967	Decrease
2011	0.975	1	0.975	Decrease
2012	0.979	0.999	0.979	Decrease
2013	0.982	1	0.982	Decrease
2014	0.995	1	0.995	Decrease
2015	0.994	1	0.994	Decrease

2016	1	1	1	Increase
2017	1	1	1	Increase
2018	1	1	1	Increase
Average	0,989	0,999	0,989	-

Source: *Authors' calculations based on FAO 2020.*

The milk market in the USA could achieve better efficiency in the years 2010-2015. This could be achieved by the increase of milk and dairy products consumption. Moreover, the exports in the years were very changeable. The stable exports of milk surpluses can help achieve better market efficiency. On the farm level, better efficiency can be the result of better combination of inputs in cost minimization (Hansson, 2007). The lower efficiency in the years 2010-2015 means that the market operated below the optimal scale of production. It means that the milk production and the scale of operations could be increased (Fraser and Graham, 2005).

5. Conclusions

In the USA in 2009 - 2018, despite a slight increase in the number of dairy cows (2%), the milk yield of cows (13%) and total milk production (15%) increased. The number of dairy cows in the USA in relation to the world number of dairy cows in the analyzed period remained at a comparable level, as was the number of dairy cows in the EU-27/28 countries. The milk yield of cows in the USA is at a very high level compared to the milk yield of cows in the world and in the EU-27/28 countries. The milk yield of cows in the USA in the analyzed period was more than four times higher than the world yield for dairy cows. In the EU-27/28 countries, the milk yield of cows is more than twice the world yield but is lower than that in the USA.

The production of cow's milk in the USA in 2009-2018 increased year by year, but the level of production in relation to the world production of cow's milk remained at a stable level ranging from 14.26% to 14.54%. The share of cow's milk production in the EU-27/28 countries remained in the analyzed period in relation to the world production, similarly to the USA at a stable level, ranging from 23.87% to 24.93% of world production.

In 2009-2018, the consumption of liquid milk in the USA decreased, while the consumption of all dairy products increased, indicates changes in the mix of consumer preferences for various dairy products. The conducted research confirmed the hypothesis that the increase of dairy American exports is the effect of strong efficiency of the farms. In the U.S., in the analyzed period, a positive trade balance was recorded for milk and its products, or a trade surplus.

The situation on the milk market is determined by prices which are a decisive factor. Policy makers may consider supply management programs or price support to keep high prices of milk for both conventional and organic producers (Walsh *et al.*, 2020). Price volatility in the U.S. dairy market may persist and can create disturbances in the market (Stewart *et al.*, 2011). According to IFCN (2020), the U.S., EU and Oceania are the regions with high self-sufficiency of milk and dairy products. Asia, Africa, and South America are deficit regions. This global situation has an impact on world dairy trade where 18% of milk is traded. The strong market position of the U.S. dairy sector is result of high efficiency.

The conducted research confirmed the hypothesis that the milk market in the USA had high technical efficiency. Our analysis confirmed high technical efficiency of the dairy market in the USA. The technical efficiency measured by the BCC model was higher than from the CCR model. The strength of technology in the milk market differs depending on the approach used. The technology in milk market and dairy farms is characterized by increasing economies of scale (Marzec *et al.,* 2015).

The high technical efficiency can be the effect of various programs such as the federal milk marketing program, the milk income loss program, and other regulations (Murova and Chidmi, 2013). State support plays an important role in creating the efficiency of dairy market not only in the USA, but also in the EU and world. The efficiency of dairy farms depends on various factors such as costs. Frontier costs are decreased by using milking machines. Costs increase with the age of farmers when they become less efficient. Moreover, some farmers can use new technology and technique achieving low costs, whereas other cannot. Another factor can be rotational grazing, which reduces the cost of milk production (Tauer and Mishra, 2006).

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