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Market regulations targeting emissions from the European Union's milk industry

An Environmental Economic Thesis

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Abstract

The objective of the thesis is to investigate how two different emission tax levels can change the greenhouse gas emissions from the European Union’s milk industry. The two different tax levels are an EU ETS price of 25.85 euros per tonne of emissions and a Pigouvian tax of 42 euros per tonne of emissions.

The results indicate that an implementation of an EU ETS price level would reduce the emissions from milk production by 11.7 million tonnes of CO_2eq., representing 0.26 percent of the European Union's total greenhouse gas emissions. Under a Pigouvian tax, the reduction would be 19 million tonnes of CO_2eq. emissions, representing 0.43 percent of the European Union’s total emissions. The decrease in the demanded quantity of milk was assumed to be replaced with a substitute, in this case, oat drink. The total emissions reduction would then be 8.36 million tonnes CO_2eq. under an EU ETS price and 13.58 million tonnes of CO_2eq. emissions under a Pigouvian tax.

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1. Introduction

Global warming and climate change are potential threats to humans, animals and the environment. The world's population and food production have increased rapidly within the last two centuries, mainly due to industrial and agricultural revolutions. These revolutions have simplified processes through the increase in technological knowledge and efficiency (Roser, Richie & Ortiz-Ospina 2019).

The agricultural sector produces different goods such as wheat, fruits, meat, milk and dairy. The consumer and producer price for agricultural products are typically not representative of the true cost, resulting in uncompensated costs, also known as externalities. In the agricultural sector, negative externalities can be pesticide use, biodiversity loss and greenhouse gas[1] (GHG) emissions. In the European Union, GHG emissions from the agricultural sector represented 10 percent of the total GHG emitted in 2012 (EEA 2016).

In the framework of the Paris agreement, it is stated that global warming should be kept below two degrees Celsius (IPCC 2018). The European Union has taken actions to limit its GHG emissions, for example, by implementing a cap-and-trade system and other directives regarding environmental issues. A long-term emission goal in the European Union is to reduce the emissions with 80-95 percent by the year 2050 compared to 1990's level (EC 2018a). In 1990, the total GHG emissions from the European Union were 5 720 million tonnes of CO_2 equivalent (CO_2eq.)[2]. Agriculture represented 14 percent of these emissions (EEA 2018). In 2017, the European Union emitted 4 466 million tonnes CO_2eq. emissions from all sectors, representing 12 percent of the global CO_2eq. emissions (IPCC 2018).

Milk is considered to be a normal good, indicating that when the average income rises, the demand for milk increases (FAO 2010). Issues regarding milk production are externalities in terms of emissions that are released to the atmosphere. With an increasing demand of milk, the externalities will follow a similar trend (Hedenus, Wirsenius & Johansson 2014). Emissions such as carbon dioxide, methane and nitrous oxides contribute to global warming, resulting in a negative feedback loop. Global warming contributes to habitat losses, drought, floods and extreme weather, which are factors that could limit agricultural production in the future (UNDP 2019).

This thesis wants to investigate the emissions from the agricultural sector in the European Union, specifically the milk/dairy industry. The terms *milk* and *dairy* will be used

[1] See definition in Appendix I *Definitions*
[2] See definition in Appendix I *Definitions*

interchangeably in this thesis, unless a specific differentiation is stated. Milk is the main component of dairy product; therefore, the production of dairy products is dependent on milk supply. The thesis also wants to examine how market regulations in the form of taxes could affect the supply and demand for milk. Economic theory is applied to examine changes in demand and supply in order to internalize the costs from the European Union's milk production and investigate how these costs could affect the production and total emissions.

Studies regarding milk production and emissions have been published, however, a study regarding the possible change in CO_2eq. emission with the chosen tax levels on milk production has not been encountered. Studies have found that the consumer behaviour can change due to social demands such as environmental reasons and animal welfare (Jongeneel, Burrell & Kavallari 2011).

The researched question is thus; If a tax level was implemented to compensate for the carbon dioxide equivalent emissions generated from milk production, how would production of milk, consumption of a substitute and the total GHG emissions change?

2. Theoretical background

In this section, the theoretical background that is utilized in this thesis is presented, including elasticities, market regulations, marginal costs and economies of scale.

2.1. Elasticities

Elasticities describe how one variable responds to a change in another variable (Perloff 2014), for example, how the demand for dairy products changes when the price of milk changes. Different types of elasticities can be estimated, for the sake of this thesis the price elasticity of demand (demand elasticity) is examined.

Demand elasticity is the percentage change in the demanded quantity in response to a change in price. A demand elasticity has a value between -1 and 0. A demand curve is perfectly inelastic if the demand elasticity is 0, indicating that demand does not change if the price changes. If the demand elasticity is between 0 and -1 it is inelastic (Perloff 2014). Dairy products are considered to have an inelastic demand, which is supported by Bouamra-Mechemache, Réquillart, Soregaroli and Trévisiol's (2008) findings that states that the demand elasticity for dairy in the European Union is -0.57. This indicates that a one percent increase in price results in a 0.57 percent drop in quantity demanded.

Supply elasticity is the percentage change in the quantity supplied in response to a given percentage change in the price. When a supply elasticity has a value between 0 and 1 it is inelastic, a supply elasticity of 0 indicates perfect inelasticity (Perloff 2014). Jongeneel and Tonini (2009) found, by reviewing previous research, that the supply elasticity for dairy in Europe is 0.434. This indicates that a 1 percent increase in price results in a 0.434 percent increase in the quantity supplied.

2.2. Market regulations

Market regulations, such as taxes or subsidies, are utilized if a government or a public body wants to regulate the mechanisms of supply and demand. Implementation of market regulations deals with market failures or externalities that could arise in certain market situations (Le Grand 1991). In a market, the optimal level of production and price is set by the intersection of the demand and supply curve, also knowns as the equilibrium (Jaeger 2012). According to the first theorem of welfare economics, the equilibrium is Pareto optimal in a competitive market. The second theorem of welfare economics states that a governance body can help an economy to reach the Pareto optimum allocation using market regulations (Blaug 2007). Market regulators can either focus on a certain quantity or a certain price to regulate the market. While this thesis focuses on price regulation, Weitzman (1974) mentions that it is insignificant which variable to focus on since both price and quantity are dependent on the same information in order to find the optimal value.

If externalities occur on a market, the equilibrium level is insufficient, which results in market failure (Jaeger 2012). Externalities occur when the true cost is not reflected by the price of the product. Externalities can be positive or negative, depending on whether it is the true cost or the true benefit that is greater than the price. Negative externalities imply that the producer does not bear all costs for production. An example of a negative externality is the emissions that occur during the production of milk, which is often emitted without compensations, contributing to GHG emissions, resulting in climate change. If a market is ineffective it implies that Pareto efficiency[3] is not reached. However, the market can strive to make Pareto improvements in order to reach the Pareto optimal allocation (Blaug 2007, Kolstad 2011).

In order to handle externalities a price on emissions can be set, for example, by implementing a Pigouvian tax on the origin of the externality (Kolstad 2011). A Pigouvian tax

[3] A Pareto efficient allocation indicates that one individual cannot be better off without making at least one individual worse off (Kolstad 2011).

is defined as "*an emission fee exactly equal to the aggregated marginal damage caused by the emissions when evaluated at the efficient level of pollution*" (Kolstad 2011 pg. 236), shifting the production cost upwards, which is illustrated in Graph 1 *Pigouvian tax*. With an addition of a tax that represent the damage cost, together with the production cost, a new equilibrium is reached. This equilibrium is called the social (or environmental) optimum, illustrated with a black dot in the graph. The price at the social optimum (*p (social)*) is higher than before the implementation of the tax. A tax that is added per produced unit, combined with the production cost, creates the social cost function. Under the assumption that a Pigouvian tax is implemented, the shaded area in Graph 1 is the welfare gain, indicating that the damage cost is included in the price. Without the Pigouvian tax, the shaded area would be considered a welfare loss, also known as the deadweight loss (Hallwood 2014).

Graph 1 Pigouvian tax

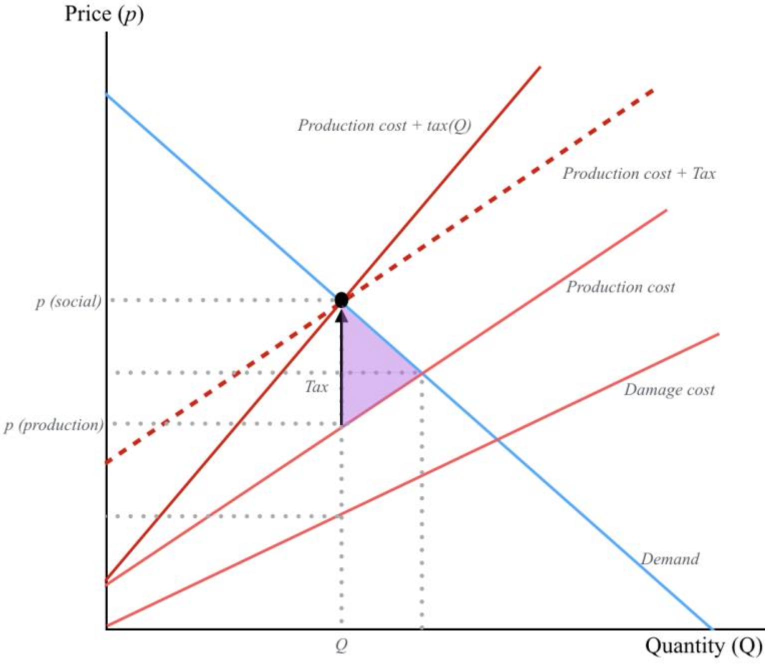


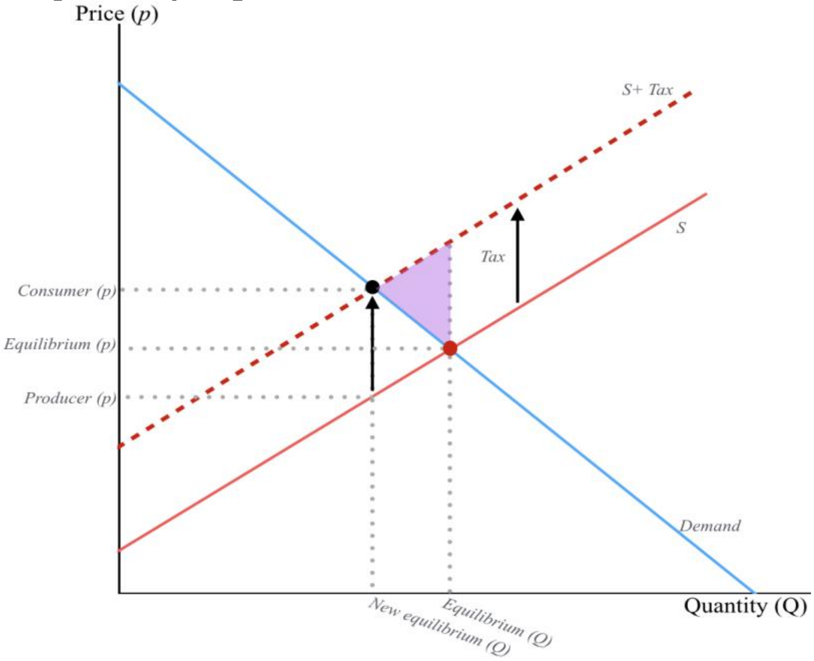
Illustration of a market change when a Pigouvian tax is added. The diagram is based of Perloff's figure 17.3 *Taxes to Control pollution* pg. 628 (2014).

The cost of reducing negative environmental effects is called the abatement cost, in this thesis it is considered to be the damage cost for emissions. The Marginal Abatement Cost is the cost of reducing one additional unit of negative effects. De Cara and Jayet (2011) found that the damage cost in the dairy industry is 42 euros per tonne of CO_2eq. emissions. In this thesis it is assumed that the damage cost of 42 euros is constant and will be the Pigouvian tax level.

It is also assumed that the Pigouvian tax is implemented to internalize externalities in a fair way.

A Pigouvian tax is valid in theory. However, in practice, it can be demanding to find the correct level of a tax and implement it fairly across producers. A criticism towards Pigouvian tax is that the tax does not guarantee efficient allocations (Coase 1960). A further problem with implementing an incorrect tax level is market inefficiency, which results in welfare losses. The welfare is a measurement of the sum of consumer and producer surplus. The consumer surplus is the area between the demand function and the price level. When the price level increases the consumer surplus decreases. The producer surplus is the area above the supply function and below the price (Hausman 1981). The welfare gain from a tax is illustrated in Graph 2 *Welfare gain.* If the tax regards all social costs, the triangle represents the welfare gain. If an incorrect tax level would be implemented, an area the same size as the shaded triangle in Graph 2, but under the demand function, would be the deadweight loss (Hallwood 2014), also illustrated in Graph 1.

Graph 2 *Welfare gain*



Graph 2 is based of Fig 19.1 *The deadweight loss of excessive corn output* on pg. 219 (Hallwood 2014).

Another approach to market regulations is subsidies. A subsidy is usually offered as a payment, either directly or indirectly, and is a compensation or a tax reduction for the producer. Subsidies are commonly provided for an activity or a product that is within the public's interest, either as a promotion or as a part of a policy (Kolstad 2011). In the year 1964, the European

Union created the Common Agricultural Policy (CAP) subsidies to assist farmers in the agricultural sector. The aim of the CAP is to support farmers and improve their productivity, ensuring a stable supply of agricultural goods at low prices for consumers. CAP-subsidies provided to farmers by the European Union are an important part of the farmer's income and is a method to bridge the gap between the consumers demand for a low price and the farmers production cost. The agricultural subsidies in the European Union accounted for approximately 36 percent of the European Union's budget in 2018 (EC 2019a).

A criticism towards subsidies is the risk that they can prevent efficient outcomes. According to economic theory, the market strives towards the equilibrium, resulting in less efficient producers being eliminated from the market. However, with market regulations the less efficient producers can still operate through economic support, such as subsidies, resulting in inefficiency (Myers 2001).

A market regulation in the European Union regarding emissions, is the European Union's Emission Trading System (EU ETS) which has adapted a Cap-and-Trade system. The cap indicates a ceiling on the maximum amount of emissions that can be emitted from certain sectors (EC 2019b). Each producer receives a set amount of permits/allowances per period, the allowances are either allocated for free or auctioned out. The total amount of emissions that are emitted will be converted into CO_2eq. at the end of the period. One allowance represents one tonne of CO_2eq. emissions. The producers can trade or sell these allowances at a set price, the EU ETS price. Producers that have higher levels of emissions have incentives to buy permits, while those who emit less, and do not utilize all their permits, are more prone to selling theirs (Bagchi & Velten 2014). Participation in EU ETS is mandatory for producers in energy-intensive industries such as oil refineries, iron production, cement production and commercial aviation. EU ETS does not regard emissions from agriculture, nuclear facilities or forestry activities (EC 2019b). In this thesis, an EU ETS emissions trading system that includes agricultural practices is assumed. The EU ETS price for emitting one tonne of CO_2eq. is 25.85 euros (Markets Insider 2019) and will be utilized as a price/tax level for emissions.

A disadvantage with pricing emissions is the interaction with other taxes. A tax increases the production price, which results in reduced real wages and thus the labour supply in the long run, as well as consumer prices (Hepburn, Grubb, Neuhoff, Matthes & Tse 2006).

2.3. Marginal costs and economies of scale

Marginal cost is the cost for producers (farmers) to produce one additional unit. Under the assumption that milk and dairy farmers are price takers under perfect competition, they will maximize their profit. The quantity produced will be where the marginal revenue (milk price) is equal to the marginal cost. If the marginal cost of milk is greater than the milk price the farm will be unprofitable (Roche, n.d.).

The marginal cost is the derivation of the total cost. The total cost consists of two parts, the fixed costs and the variable costs. The fixed costs are fixed in the short run, and is therefore set at a certain level, while the variable costs will change with output and vary over time. The variable costs in milk production is dependent on herd size, feed costs and labour, while fixed costs are costs such as farmland (Hanrahan et al. 2018). If a tax is aimed towards production, it would affect the variable cost and, in turn, the marginal cost.

The cost of producing, and thereby the marginal cost, varies between different member states and types of milk farms in the European Union (Jongeneel, Burrell & Kavallari 2011). The marginal production cost for each farm provides information regarding the amount produced at each given price. The marginal cost curve presents the cost as a function of the quantity, whereas the supply curve generates the quantity as a function of the price, therefore, the supply curve can be interpreted as the inverse of the marginal cost curve. By aggregating the information regarding the supply curves, that the marginal cost provides, it discloses information regarding the market supply. If the market price is below the average variable cost of producing, the firm will not offer any supply, the supply curve follows the marginal cost above the average variable cost curve (Jongeneel, Burrell & Kavallari 2011; Perloff 2014).

Wieck and Heckelei (2007) have found that the degree of specialization on a farm can affect the marginal cost, the more specialized a farm is in milk production, the lower marginal cost. The reasoning behind this is the fact that specialized farms often get a larger share of their income from milk production, along with greater opportunity and access to new technology. Jongeneel, Burrell and Kavallari (2011) found a similar result, their study found that farms with higher milk output and a larger herd had a lower marginal cost, which is evidence that economies of scale exist in the European Union's milk market. However, it can differ, depending on which member state that is investigated.

The milk farms that have economies of scale first experience a lower marginal cost, later on the marginal cost drops at a slower pace, and then become constant (Jongeneel, Burrell & Kavallari 2011). Within the European Union's member states the marginal cost varies, the cost varies between 152.06 euros per tonne of milk and 303.67 euros per tonne of milk (Wieck & Heckelei 2007).

When the marginal cost is lower than the average cost of producing milk, the farm experience economies of scale. Among the producer on the European dairy market the trend shows that the average farm size increases and the number of smaller farms decrease (Eurostat 2018). The large-scale producers will continue to increase their output until the point where the profit of increasing the output is 0, where the marginal cost curve will flatten out, since they have maximized their output at that point.

Economies of scale is the cost advantages that occur for large-scale producers. The larger farms have a competitive advantage compared to smaller ones. Competitive advantages generate lower cost per produced unit when the total production quantity increases, decreasing the marginal cost. When a producer increases the output, and thereby the scale, the fixed and variable costs are distributed over all the produced units, decreasing the average cost per unit (Porter 1985).

In the European Union, the agricultural sector is moving towards large-scale farming. There is not a clear definition what defines a small or large farm, however, there are general definitions that can help to define the size of a farm (Eurostat 2018);

1) classification of farms based on their standard output

2) classification based on the utilised agricultural area

Between the years 2005 and 2013, dairy farms in the European Union decreased by 26.2 percent, while the total utilised agricultural area remained the same, indicating that the farms that are still operating have increased in size. In the same period, the standard output increased by approximately 56 percent (EC 2018b). The change indicates that there has been a productivity shift in farming, the average herd sizes have increased along with the average milk yields per cow. Farms in the European Union are shifting towards large-scale farming (Eurostat 2018). Considering this trend, small-scale farms can be more vulnerable to changes in production cost, compared to large-scale farms. Many small-scale farmers are struggling to make a living and are dependent on subsidies from the CAP (Eurostat 2018). Farms with economies of scale, also known as large-scale farms, are more resistant to increased production costs while smaller farms risks being eliminated from the market (Porter 1985).

3. Background

The anthropogenic influence on global warming has been noticeable since the 1950's. As temperature increases, the occurrence of droughts, floods and other extreme weather has become more frequent (Allen et al. 2018). The global carbon dioxide concentration has increased by 20 parts per million per decade since the year 2000, which is ten times faster than the sustained increase in carbon dioxide during the past 800 000 years. A global ambition is to keep the global temperature rise below 2 degrees Celsius as stated in the Paris agreement (UNCC 2019). The European Union has taken multiple actions to reduce its GHG emissions. One of their objectives is to reduce the total amount of GHG emissions by 80-95 percent compared to the 1990's emissions level by 2050 (EC 2018a).

Agricultural practices are both affected by climate change and a contributor to it. According to the European Environmental Agency (EEA) it is a challenge to reduce the emissions from the agricultural sector. However, with new technological advances in production methods, it could be possible (EEA 2016). In 2012, the agricultural sector represented 10 percent of the total GHG emissions in the European Union (EEA 2016). An approach to lower emissions from enteric fermentation is to change the feed that the cows are provided, for example feeding them with algae. Algae's protein helps the cow's digestive system to break down the food faster, which results in a reduction of methane emissions (Panjaitan et al. 2015). The emissions per cow might be able to decrease even further if changes in breeding are made according to New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC 2019).

Milk production in the European Union has become more efficient as technology and research develops. The total production of milk in the year 2000 was 149.4 million tonnes and in 2016 the total amount was 161 million tonnes (FAOstat)[4]. The number of cows in the European Union has decreased with 5 million between the years 2000 and 2016, while the average milk yield per cow has increased by 1500 litres per cow between the years 2000 and 2017 (EC 2017). This indicates an increased efficiency per cow and an increase in production. The top milk producing countries in the European Union are Belgium, Denmark, France, Germany, Luxembourg and the Netherlands. In total they produce 50 percent of the milk supplied throughout Europe. The European milk board (2017) carried out a survey which found that the average herd size in these countries was between 59 and 165 cows on areas ranging

[4] Appendix II Data, Table 2 *Variables from 2016*

from 51 to 156 hectares. Danish dairy farms had the highest average farm size (156 hectares), the highest average herd size (165 cows) and the highest annual milk yield (9462 kilograms per cow).

This thesis focuses on conventional farming in the European Union, another alternative is organic farming. However, organic farming plays a minor role in milk production compared to conventional farming, representing approximately 3 percent of dairy farms in the European Union in 2016 (Augère-Granier 2018). The organic dairy farms average kilogram of CO_2eq. emissions per kilograms of milk is 1.04 with large deviations according to Hietala, Kurppa and Hermanssen (2014). This is less than conventional farming emissions of 1.4 kilograms of CO_2eq. per kilogram of milk (Leip et al. 2010). However, organic dairy farms have approximately 30 percent lower yield per cow than conventional farms, resulting in the average total emissions of organic milk to be approximately equal to conventional milk (Augère-Granier 2018).

4. Previous research

Previous research regarding milk and dairy production and its CO_2eq. emissions per produced amount, along with elasticities for dairy have been conducted. In Table 1 *Key findings* the relevant researchers and their findings are summarized.

Svenster and de Jong's (2008) literature review, investigated the climate impacts of dairy in industrialized countries. Their literature review focuses on three GHG emissions; carbon dioxide, methane and nitrous oxide. The two latter ones are the most prominent since they have the highest global warming potential in the dairy industry. The cradle-to-farm gate emissions from dairy production contribute to 3 percent of the global GHG emissions where enteric fermentation[5] is the largest share contributor in dairy production. The emissions from the birth of the cow to its production of milk are estimated to be 0.8-1.4 kilograms of CO_2eq. per kilogram of milk. With the addition of post-farm emissions, the CO_2eq. emissions per kilogram of milk will increase with 10-20 percent, resulting in 0.9-1.8 kilograms of CO_2eq. emissions per kilogram of milk for the entire life cycle of production.

According to Leip et al. (2010), the European Union's estimated GHG emissions from the dairy industry is 1.4 kilograms of CO_2eq. per kilogram of milk, with variances between 1.0 to 2.8 kilograms of CO_2eq. emissions. Leip et al. (2010) utilized the method of a Life Cycle

[5] See definition in Appendix I *Definitions*

Assessment (LCA) to estimate the emissions from milk production, the emissions arising from enteric fermentation, manure management and transports. Variances within the European Union is explained by differences in production, member states that have high production and high efficiency emits less CO_2eq. per kilogram of milk compared to lower producing ones (Leip et al. 2010).

Leip et al. (2010) and Svenster and de Jong (2008)'s results indicate that emissions from milk emit as low as 0.9 kilograms of CO_2eq. emissions per kilogram of milk and as high as 2.8 kilograms of CO_2eq. emissions per kilogram of milk. In Leip et al. (2010) study, the average emission level within the European Union is 1.4 CO_2eq. emissions per kilogram of milk and will be the value that this thesis will base its research on.

Röös, Patel and Spångberg (2015) calculated the kilogram of CO_2eq. per kilogram of oat drink in Sweden and they found that the average emissions from oat drink were 0.4. The calculations are based on an LCA scenario where the production of milk on a Swedish farm was replaced by the production of oat drink.

To find the optimal emission price for reducing emissions from the European Union's dairy industry, De Cara and Jayet (2011) conducted a quantitative assessment of the marginal abatement costs of GHG emissions in the agricultural sector by using data on the output. The equilibrium emission price was estimated to be 32 or 42 euros per tonne of CO_2eq. emissions. The different price levels depended on whether a business-as-usual approach (32 euros) or an emissions-reducing-price level approach (42 euros) was assumed.

In order to summarize the demand elasticity for dairy in the European Union, Bouamra-Mechemache et al. (2008) investigated several studies, where two different method was the most prominent ones[6], to study consumer behaviour. They found that the average demand elasticity of all dairy products from the studies was -0.57 in the European Union.

Jongeneel and Tonini (2009) evaluated the impact of quota rent and supply elasticity estimates for the European Union dairy policy. Quotas in milk production are an income generating asset for the person who holds the quota. Milk quotas was used by the European Union's CAP system between the years 1984 to 2015 in order to regulate the milk market. In order to evaluate the impact of different estimates of quota rent and supply elasticity, the method that was used included different data programs for each member state in order to find an average supply elasticity. The average supply elasticity for dairy products in the European Union was estimated to be 0.434.

[6] The prominent methods use was an Almost Ideal demand system or a Quadratic Almost Ideal demand system

Table 1. ***Key findings***

Unit	Value	Researchers
Emission coefficient in kilogram of CO_2eq. per kilogram of milk	1.4	Leip et al. (2010)
Emission coefficient in kilogram of CO_2eq. per kilogram of oat-drink	0.4	Röös et al. (2015)
Emission reducing price in euros per tonne of CO_2eq. emissions	25.85	EU ETS (Markets Insider 2019)
Emission reducing price in euros per tonne of CO_2eq. emissions	42	De Cara & Jayet (2011)
Demand elasticity	-0.57	Bouamra-Mechemache et al. (2008)

Key units from previous research. The emission coefficients can be converted from kilogram of CO_2eq. per kilogram of milk to tonnes of CO_2eq. per tonnes of milk.

Although a supply elasticity was estimated by Jongeneel and Tonini (2009), their value for the supply elasticity will not be used in this thesis since it was estimated during a period when the European Union's dairy industry was subject to milk quotas that affected the produces supply. The milk quotas are no longer in practise and will therefore be excluded from this thesis.

5. Method

The aim of this thesis is to investigate the effects that taxes can have on production and GHG emissions from the milk industry in the European Union. Since GHG emissions can be converted to CO_2eq., the measurement used is a tax on CO_2eq. emissions. It is assumed that the milk market is a competitive market which indicates that there are many producers and consumer, it also assumes that the a single producers exiting or entering the market will not change the supply curve. In this thesis the European Union is assumed to be a large closed economy, therefore import and export of milk from the European Union are excluded. The import and export of milk/dairy products in the European Union is a relatively small part of the total consumption and supports the assumption of excluding the import and export (OECDstat n.d.). It is also assumed that all the produced quantity is consumed, in other words, the quantity supplied equals the quantity demanded. A simplification of the supply to the consumer has been assumed, indicating that the milk produced by farms goes directly to the consumers. The demand for milk is assumed to be the final consumption of the product.

To estimate the effects of different emission price levels, values regarding quantity, production cost and average weighted price for raw milk from the year 2016 was used as references to represent present values.

An increase in production cost is assumed to increase the price of dairy products, which in turn could decreases the demand of milk while increasing the demand for close substitutes. A substitute product for milk could be a plant-based “milk” option, in this thesis the substitute will be oat drink. Oat drink also generates emissions, according to Röös et al. (2015), the CO_2eq. emissions per kilogram of oat drink are 0.4. It is assumed that the reduction in the demanded quantity of milk, when a tax is added, is replaced with oat drink. The assumption that consumers will choose oat drink as a substitute was made due to availability of an LCA and simplification of the prediction. The amount of oat drink consumed will be presented as the change in demanded quantity of milk. If milk demand decreases with 1 unit then oat drink consumption will increase with 1 unit.

5.1. Total emissions and total emissions cost

The emissions prices/tax per tonne of CO_2eq. used in this thesis are the EU ETS price for emitting one tonne of CO_2eq. which is 25.85 euros[7] (Markets Insider 2019) and the marginal abatement cost of 42 euros per tonne of CO_2eq. emissions (De Cara & Jayet 2011).

The *total emissions from the dairy industry* per year ($TE_{dairy\ in\ kilograms\ per\ year}$) is calculated using Formula (1). *TP* is the total production[8] of dairy in the European Union times the emission coefficient (*ec)*. The coefficient can also be applied as tonnes of CO_2eq. emissions per tonne of milk.

(1) $$TE_{dairy\ in\ kilograms\ per\ year} = TP * ec$$

The result from $TE_{dairy\ in\ kilograms\ per\ year}$ is converted to million tonnes of CO_2eq., in order to receive a more manageable result, generating $TE_{dairy\ in\ million\ tonnes}$.

In Formula (2) the *Total emissions costs* (TEC_{dairy}) is calculated by taking $TE_{dairy\ in\ million\ tonnes\ per\ year}$ times the *price level* in euros per tonne providing the researcher with the *total emissions cost* in million euros. The *total emissions cost* is the price that the milk producers must pay for emitting CO_2eq. each year.

(2) $$TEC_{dairy} = TE_{dairy\ in\ million\ tonnes} * price\ level$$

5.2. Demand and changes on the market

The demand is assumed to be linear, therefore the *demand function* is given by Q^d=a-(b*p), where *a* is the intercept, *b* is the slope and *p* is the consumer price[9]. Due to restraints in being able to access data on the true demanded quantity, the demanded quantity is assumed to be equal to the produced quantity.

By using the *demand elasticity,* the *inverse demand curve slope* (*b*) for milk for a certain year can be estimated by using the *change in quantity* ($\triangle Q$) and the *change in price* ($\triangle p$) (see Formula (4). The *demand elasticity* (ε) has been derived from Bouamra-Mechemache et al. (2008) research and is estimated to -0.57. Although the dairy production was subjected to milk quotas during the period when the demand elasticity was estimated, it is assumed that the

[7] The closing permit price from EU ETS varies over time, the price of 25.85 euros was valid on 30th of April 2019.
[8] See Appendix II, Table 2 *Variables from 2016,* Produced quantity in thousand tonnes
[9] Represented by the *Average Weighted Raw Milk Price* found in Appendix II, Table 2 *Variables from 2016.*

demand elasticity was not affected by this. This is due to the assumption that milk quotas targeted the producers rather than the consumers. Formula (3) displays the demand elasticity function.

(3) $$\varepsilon = \frac{\Delta Q}{\Delta p} * \frac{p}{Q} = -0.57$$

(4) $$\textit{Inverse demand slope (b)}: \frac{\Delta Q}{\Delta p} = \varepsilon(\frac{Q}{P})$$

When the *inverse demand slope (b)* is known an *intercept (a)* on the price axis can be calculated. Knowing the *demanded quantity (*Q^d*)* and the *demanded price (p)* for a certain year Formula (5), which is derived from the *demand function*, can be utilized.

(5) $$a = Q^d + (b * p)$$

Formula (6) will be utilized in order to find the change in *demanded quantity (ΔQ)* when an *emission price* (tax) is added to the market, represented by the *change in price (Δp).* The formula was derived from Formula (3).

(3) $$\varepsilon = \frac{\Delta Q}{\Delta o} * \frac{P}{Q}$$

→ $$\Delta Q = \Delta p * (\varepsilon / \frac{p}{Q})$$

→ $$\Delta Q = \Delta p * (\varepsilon * \frac{Q}{p})$$

(6) $$\Delta Q = \Delta p * (b)$$

To illustrate the change on the market when an *emission price (tax)* per emitted tonne of CO2eq. is added, it is necessary to find the *emissions cost* by using Formula (7). *ec* represents the chosen *emission coefficient*. In order to get the *total production cost* Formula (8) is used.

(7) Emissions cost = ec * emission price level

(8) Total production cost = emissions cost + production cost

In order to find the intercept on the demand curve, where the market equilibrium is, the change in quantity and change in production cost is used. Under the assumption that the demanded quantity is equal to the supplied quantity, the changes will reveal a new intercept. The change in production cost will be known after calculating Formula (8) and represents the change in the production cost on the market. The term production cost is used to represent the price for the supplier, while production price is used in order to represent the price/tax the producer must pay in order to emit.

5.3. Substitutes

In this thesis it is assumed that the reduction in demanded/supplied quantity of milk will migrate to an increase in the demand for a substitute, in this thesis, oat drink. The change in demanded/supplied quantity of milk is thus multiplied with the *emission coefficient*[10] for oat drink. In order to find the *total emissions reduction* on the market Formula (9) is used.

(9) *Total emissions reduction in the EU= Total reduction in quantity + (reduced quantity * emission coefficient)*

6. Data collection

Data have been collected from FAOstat and OECD.stat, a detailed description on how to acquire the data is found in Appendix II *Data*, Table 2 *Variables from 2016*. The relevant component from the collected data has been conducted to construct new variables. The variables of interest from the data was; *production quantity of milk, average weighted market price* and *production cost in euros*.

The coefficients from previous research are; *prices per tonne of* CO_2*eq. emissions in euros, emissions of* CO_2*eq. per kilogram of milk* and *emissions of* CO_2*eq. per kilogram of oat drink.* Based on the variables from datasets and the coefficients from previous research, new variables were created. The new variables are; *total emissions from dairy per year, total emissions from oat drink per year* and *total emissions costs* for each price level. The data collected can be found in Appendix II *Data.*

The *average weighted market price for raw milk per year* is derived from data by the European Commission which is presented for each month. The monthly data is summarized to derive the yearly total amount and then divided by 12 to retrieve an average raw milk price per year. The price was presented as euro per 100 kilograms, which was converted to euros per tonne for it to coincide with the rest of the data which is expressed in tonnes.

[10] This coefficient is interpreted in tonnes of CO_2eq. emissions per tonne of oat drink.

6.1. Uncertainty in the data

Uncertainty from investigating the averages in production, market price and production cost between the member states in the European Union, for each year, is the fact that there are large variations within the European Union. The accuracy of the measurements from FAO is not possible to assess. According to the organization itself, it is because data is collected by each member country in FAO. The sampling error for member states in the European Union cannot be more than 3 percent according to regulations in the European Union (FAO 2019a). In the thesis, it is assumed that the data collected from the databases is as accurate as it can be at the time of the data collection.

6.2. Assumptions

In this section the assumption that have been made for the conduction of this thesis is presented.

- The quantity demanded is equal to the quantity supplied, all the produced quantity of milk will be consumed.
- The demand function is assumed to be linear in order to simplify the analysis, and the illustrations in this thesis. The statement is supported by Jongeneel, Burrell and Kavallari (2011).
- The European Union's milk market is a large market, indicating that a single farm entering or exiting the market will not change the supply nor the demand curve. If a producer exits the market, another producer will produce more, since the demand has not changed. The statement is supported by Jongeneel, Burrell & Kavallari (2011).
- The Europeans Union's milk market experience perfect competition and the producers are profit maximizing. Therefore, the marginal cost will be equal to the market price in order to maximize profit.
- The supply curve is not illustrated since the shape of the curve is unknown. However, the supply curve will be represented by the marginal costs, which has been found to decrease and later become constant, within the interval relevant to this thesis (Jongeneel, Burrell & Kavallari 2011).
- The European Union's dairy market is considered to be closed, thereby the import and export of dairy products can be excluded.
- The reduced consumption of milk products will be replaced entirely with substitute products, in this thesis, oat drink.

7. Results

In order to estimate the change in emissions that the different price/tax levels could generate, it is necessary to calculate the demand function. The results from each section are summarized in Table 4 *Consumed quantity and emissions*, Table 5 *Production of milk with market regulations* and Table 6 *Total change on the market* on page 29-30. The calculations are presented in Appendix III *Calculations.*

7.1. Demand

In this section the method to derive the demand function for the European Union's milk market presented in section 5.2 *Demand and changes on the market* is applied, some variables have already been collected from previous research or datasets. The *elasticity of demand* is -0.57. The *weighted average price for raw milk (p)* is 284.3 euros per tonne and the *produced quantity* (*Q)* is 161261.6 thousand tonnes.

The *inverse demand slope* (*b)* is -323.317 and have been calculated using Formula (4), indicating that the demanded quantity for milk will decreases with 323.317 units for every euro that price increases. The calculation can be found in Appendix III *Calculations*.

When the *demand slope* is known and the *demanded quantity* (Q^d) on the market is equal to 161 261.6 thousand tonnes at the *price* (*p)* 284.3 euros per tonne, the *demand function intercept* (*a*) is calculated using Formula (5).

The *demand function intercept* is 253 180.7 thousand tonnes, and the *demanded quantity* can be calculated using the demand function $Q^d=a-b*p$ and is presented below.

$$Q^d = 253180.7 - 323.317p$$

In order to illustrate the *demand function* in a graph, the *inverse demand function* is computed, the price is a function of the demanded quantity, $p(Q^d)$.

$$p = 783.07-0.0031Q^d$$

The results are presented in Table 2 *Demand*.

Table 2 ***Demand***

Inverse demand slope (b)	-323.317
Intercept (a)	253 180.7
Demand function $Q^d(p)$	$Q^d = 253180.7-323.317p$
Inverse demand function $p(Q^d)$	$p = 783.07-0.0031Q^d$

The *demand function* indicates that when the price is 0 the total quantity demanded is 253 180.7 thousand tonnes, which is illustrated in Graph 3 and Graph 4 on page 23 and 25 respectively. It is assumed that the demand is linear.

7.2. Shifts on the market

In order to find the new *production cost* in euro per tonne of milk if an *emission price* is added, Formula (7) is used for the EU ETS price and the Pigouvian tax. The *emission coefficient* (1.4) for dairy is multiplied with the *emission price* levels per tonne of CO_2eq. emissions, that have been stated previously. The calculations are found in Appendix III *Calculations.*

The result from Formula (7) is added to Formula (8) with addition of the original *production cost* (282.8 euro per tonne of milk[11]), the results are presented in Table 3 *Cost in euros per tonne of milk*.

The added *production cost*, i.e. the *emissions cost,* is calculated using Formula (7), and results in 36.19 euros per tonne of milk under an EU ETS price. This change in production cost corresponds to an upwards shift in the price and therefore the production cost. The new production cost under an EU ETS price will be 318.97 euros per tonne of milk, calculated in Appendix III *Calculations,* and illustrated in Graph 3 on page 23.

Under a Pigouvian tax, the added *production cost* i.e. the *emissions cost* is calculated using Formula (7), and results in 58.8 euros per tonne of milk. The change in *production cost* corresponds to a upwards shift in the price, and increases the total production cost. The new *production cost* under a Pigouvian tax price will be 341.58 euros per tonne of milk, calculated in Appendix III *Calculations,* and illustrated in Graph 4 on page 25.

[11] The original production cost can be found in Appendix II *Data*, Table 2 *Variables from 2016*. The value of the production cost is within the marginal cost interval found by Wieck and Heckelei (2007).

Table 3 ***Costs in euro per tonne of milk***

	No change	**EU ETS**	**Pigouvian tax**
Emissions cost (Euros/tonne milk)	0	36.2	58.8
Production cost (Euros/tonne milk)	282.8	319.0	341.6

Costs in euro per tonne of milk (rounded to closest decimal). The production cost without a tax added would be 282.8 euros per tonne of milk.

The change in *demanded quantity* when an EU ETS tax is added, can be calculated using Formula (6), where the added tax (25.85 euros) equals the change in price. The reduced quantity is equal to 8 357.75 thousand tonnes, illustrated in Graph 3 on page 23. The reduced quantity indicates a shift to the left in the graph, together with the change in production cost, this illustrates the change on the market. The supplier will face a higher price for production under a tax, indicating a higher marginal cost.

The change in *demanded quantity* when a Pigouvian tax is added, can be calculated using Formula (6), the change in price is represented by the tax level (42 euros). The reduced quantity is equal to 13 579.32 thousand tonnes, illustrated in Graph 4 on page 25. The reduced quantity indicates a shift to the left in the graph, with the change in production cost this represents the change on the market. The supplier will face a higher price for production under a tax, indicating a higher marginal cost.

7.2.1. The market under an EU ETS tax level

The shift on the market under an EU ETS tax level was calculated in the section above using the change in demanded quantity and the added emissions cost.

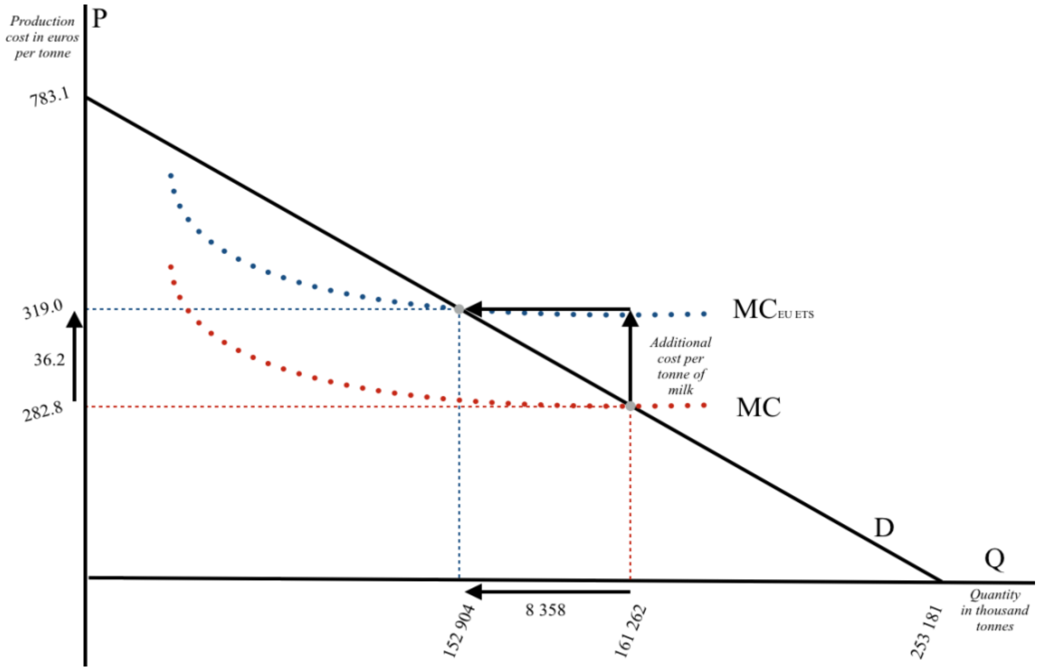
The marginal cost curve (MC), that represent all producers' marginal costs on the market, is illustrated in Graph 3 on page 23. The (MC) curve is considered to be the supply curve when no emissions cost per tonne of milk is present on the market. The reasoning behind the statement can be found in section 2.3 *Marginal costs and economies of scale*.

The marginal cost curve under an EU ETS price is ($MC_{EU\ ETS}$) and represent the supply curve when an EU ETS emissions cost per tonne of milk is added. The added cost shifts the curve upwards from its original position due to changes in the variable price. The dashed lines represent the produced quantities and the price levels. The produced quantities decrease and the price levels increases when the tax is implemented. The quantities on the horizontal axis are presented in thousand tonnes and the prices are in euros per tonne of milk. The arrows in the graph represent the changes in production cost and produced quantity.

In the long run, the market will adapt to the increased *production cost* that the *emission price* level causes. This indicates that the *supplied quantity* will reach a permanent change, towards a new equilibrium quantity.

The difference between the new quantity and the original quantity is utilized together with the *emissions cost* per tonne of milk, in order to calculate the deadweight loss that would occur if the EU ETS *price level* would be considered an inefficient allocation of market resources. The deadweight loss can be estimated, if the curves are linear, by using the change in quantity multiplied by the change in cost and divide it by two (Hallwood 2014). Due to the insufficient knowledge regarding the true shape of the MC curves, the calculations of the deadweight loss will deviate from the true value. However, if the MC curves have a similar shape to the ones in the graph the deadweight loss would be approximately 151 million euros per year. This is calculated by using the method described in Hallwood (2014). The possible deadweight loss is equal to the welfare gain when a tax of the EU ETS price level is implemented, given that this is the correct tax level.

Graph 3 ***Market equilibrium and the welfare gain under EU ETS emission price***



The graph is not to scale. The shape of the marginal cost curves is not known but are estimated to have a slope that flattens out as the quantity increases, within the relevant interval in this thesis, this is supported by Jongeneel, Burrell and Kavallari (2011). The MC curve represents the marginal cost for all producers and can therefore represent the supply on the market.

7.2.2. The market under a Pigouvian tax level

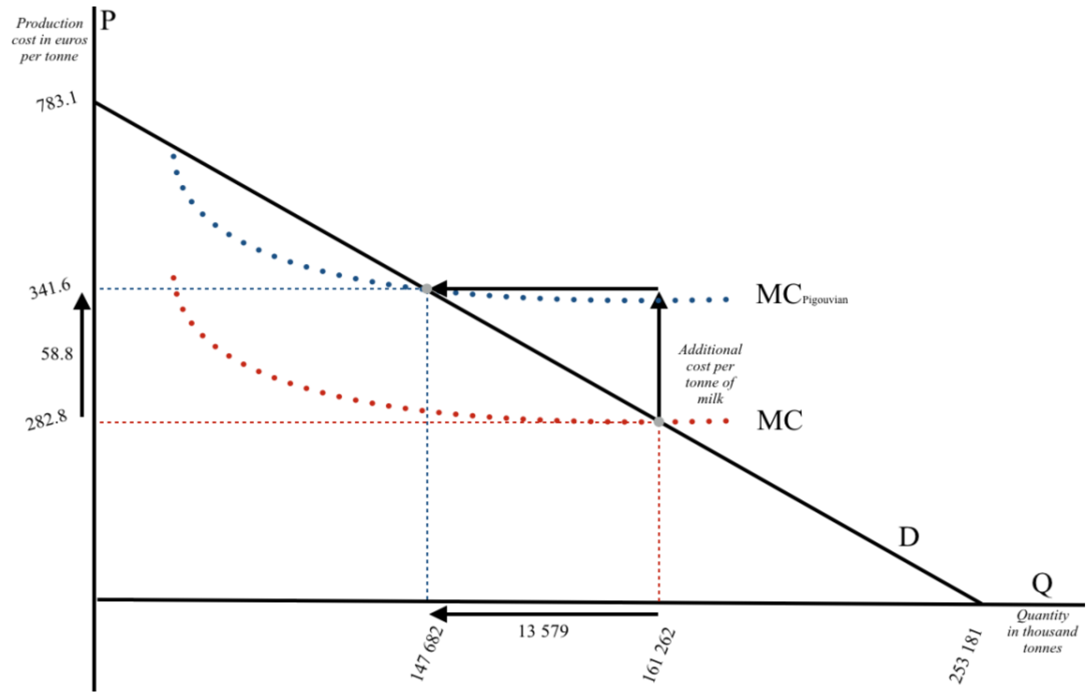
The shift on the market under a Pigouvian tax level was calculated in section 7.2, using the change in demanded quantity and the added emissions cost.

In the long run, the market will adapt to the added *production cost* that is caused by the added *emission price* level. This indicates that the supplied quantity will have changed to the new equilibrium. A deadweight loss would occur if the Pigouvian tax level is inefficient, and if the curves are linear the deadweight loss is derived by calculating the difference between the new equilibrium quantity and the original equilibrium quantity and multiplied with the *emissions cost* per tonne of milk and divide the answer by two (Hallwood 2014). Since the curves are not linear an approximate answer has been calculated using the assumption that the MC curves are linear in the interval.

In Graph 4 the marginal cost curve (MC) illustrates the supply on the market when there is no emissions cost per tonne of milk. The marginal cost curve ($MC_{Pigouvian}$) is the new supply curve after the Pigouvian emissions tax is added, this curve has shifted upwards from the original. The dashed lines represent the price levels and the produced quantities. The amount of milk supplied is highest for the no-emissions-cost scenario and lowest for the Pigouvian tax scenario. The quantities on the horizontal axis are presented in thousand tonnes and arrows in the graph represent the changes in production cost and produced quantity, in the long run.

Since the shape of the MC curves are not know the calculations of the welfare gain (or deadweight loss) will deviate from the true value. However, if the MC curves have a similar shape to the ones in the graph the welfare gain would be approximately 399 million euros per year with a Pigouvian tax. The possible deadweight loss is equal to the welfare gain when a tax of 42 euros per tonne of CO_2eq. emissions is implemented. Despite the uncertainties the welfare gain under a Pigouvian tax is significantly higher than the welfare gain under an EU ETS emissions price level.

Graph 4 ***Market equilibrium and welfare gain under Pigouvian tax***



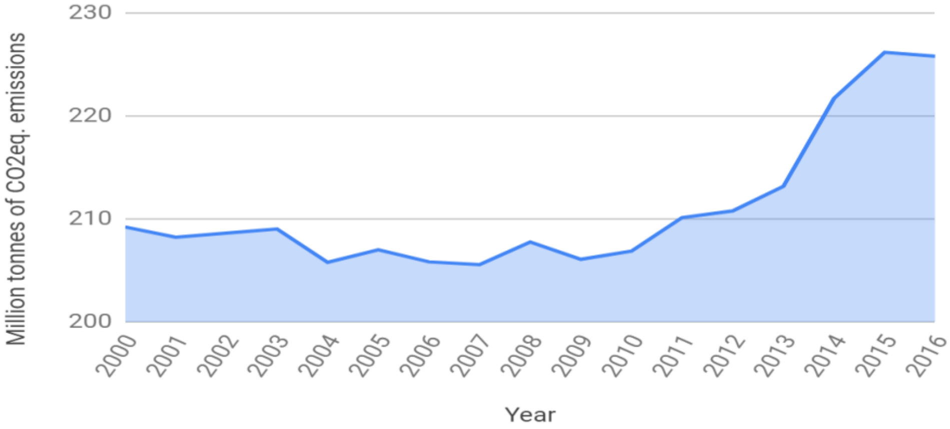
The graph is not to scale. The shape of the marginal cost curves is not known but are estimated to have a slope that flattens out as the quantity increases, within the relevant interval in this thesis, which is supported by Jongeneel, Burrell and Kavallari (2011). The MC curve represents the marginal cost for all producers and can therefore represent the supply on the market.

7.3. Greenhouse gas emissions from the European Union's milk industry

The *total emissions* from the European Union's dairy sector are calculated using Formula (1), by taking the *total production quantity* each year and multiplying it with the *emission coefficient* 1.4 from the LCA of dairy (Leip et al. 2010). This provides the *total emissions* in kilograms of CO_2eq. per kilogram of dairy between 2000 and 2016. The results from *total emissions* (Formula 1) are converted into million tonnes of CO_2eq. emissions per year in order to get a more manageable value. The results are presented in Appendix III *Calculations.*

The results of the *total emissions* can be found in Appendix II *Data*, Table 1 *Total amount of emissions from the European Union's dairy sector (2000-2016)* and are presented in Graph 5 *Million tonnes CO_2eq. emissions in the European Union's milk industry*. The *production quantity* and *emissions* have the same trend since the emission coefficient per produced amount of milk is constant at 1.4. The total emissions in the European Union from dairy production have increased in the last couple of years, which is also mentioned in section 1. *Introduction*. The total emissions were approximately 209 million tonnes of CO_2eq. emissions in 2000 and in 2016 they were approximately 226 million tonnes of CO_2eq. emissions.

Graph 5 ***Million tonnes CO_2eq. emissions in the European Union's milk industry***



Results from Formula (1), see Appendix II *Data*

7.3.1. EU ETS emission price and total emissions reduction

In the year 2016[12] the *total emissions cost* would be 5 836 million euros if an EU ETS price/tax level was added, and has been calculated using Formula (2), calculations are found in Appendix III *Calculations.*

A reduction in produced quantity indicates reduced emissions. In order to retrieve the change in quantity, Formula (6) that calculates the reduction in demanded quantity, which was also calculated in section 7.2 *Shifts on the market.*

The *change in price* (Δp) is the *emission price* the EU ETS price level of 25.85 euros, the *demand slope* (b) is -323.317, which was calculated in section 7.1 *Demand*. The *emissions reduction* is estimated by taking the *decrease in production*, which is 8.36 million tonnes and multiplying it with the *emission coefficient* (1.4), which equals to 11.7 million tonnes CO_2eq. emissions, using an adaptation of Formula (1).

The reduction represents 5.18 percent of the total GHG emissions from the dairy industry in the base year, which can be found in Appendix II, Table 1 *Total amount of emissions from the European Union's dairy sector (2000-2016).*

If the total *quantity reduction* of dairy is replaced with an equal amount of oat drink, which emits 0.4 kilograms of CO_2eq. per kilogram of product, the total emissions from oat drink in this scenario are 3.3 million tonnes CO_2eq. emissions, calculated by an adaptation of Formula (1).

[12] As mentioned previously, 2016 is the base year that the thesis bases its research on.

In the scenario when the emission price is 25.85 euros per tonne of CO_2eq. emissions, the total emissions reduction is calculated by taking the emissions reduction from dairy production and weighing in the emissions from oat drink, using Formula (9).

To calculate the total emission reduction in the European Union under an EU ETS price, Formula (9) is used provides a total reduction of emissions of 8.36 million tonnes CO_2eq. emissions. Converted into percent of total emissions before the reduction, it equals to approximately 3.7 percent[13]. The results are presented in Table 6 *Total change on the market*, on page 30.

After the implementation of an EU ETS price level, the consumed quantity of milk is the produced quantity before implementation of the tax subtracted with the quantity calculated using Formula (6). The consumed quantity of milk would be 152 903.8 thousand tonnes after implementation of an EU ETS tax on milk production.

The total CO_2eq. emissions from the market under an EU ETS price in millions of tonnes are calculated by deriving the total emission from the base year[14] and subtracting the reduction from Formula (9) times the emission coefficient for milk (1.4), subtracted by the quantity reduction times the emission coefficient for oat drink (0.4). Which is equal to 217.41 million tonnes CO2eq. emissions, also presented in Table 4 *Consumed quantity and emissions*.

7.3.2. Pigouvian tax on emission and total emissions reduction

Under a Pigouvian tax the change in produced quantity, when the emission price level is set to 42 euros per tonne of CO_2eq. emissions, is calculated using Formula (2), yielding the total emissions cost to be 9 482.18 million euros.

The change in price (Δp) is 42 euros per tonne and the slope coefficient from section 7.1 *Demand* (-323.317) is used in order to calculate the change in quantity (ΔQ) from Formula (6) and results in a reduction of 13.6 million tonnes.

A reduction in produced quantity indicates reduced emissions. The emissions reduction is estimated by taking the decrease in production and multiplying it with the *emission coefficient* (1.4), which equals to 19.0 million tonnes of CO_2eq. emissions, using an adaptation of Formula

[13] Total emission reduction in millions of tonnes divided by total emissions from the European Union's dairy industry.

[14] Found in Appendix II, Table 1 *Total amount of emissions from the European Union's dairy sector (2000-2016) for the year 2016*

(1). This represents 8.42 percent of the total GHG emissions from the dairy industry in the European Union, also presented in Table 5 *Production of milk with market regulation.*

Assuming that the total *quantity reduction* of dairy is replaced with the equal amount of oat drink, with an *emission coefficient* of 0.4 (Röös et al. 2015) the total emissions from oat drink in this scenario is calculated to be 5.4 million tonnes of CO_2eq. emissions, using an adaptation of Formula (1). By using Formula (9) the total reduction of emissions is calculated to 13.58 million tonnes, which is shown in Appendix III *Calculations.* Converted into percent of total emissions in the European Union's dairy market without a regulation, the reduction is equal to approximately 6.0 percent.

After an implementation of a Pigouvian tax level, the consumed quantity of milk is the produced quantity before implementation of the tax subtracted with the quantity calculated using Formula (6). The consumed quantity of milk would be 147 682.2 thousand tonnes after implementation of a Pigouvian tax on milk production.

The total CO_2eq. emissions from the market under a Pigouvian emissions price in millions of tonnes is calculated by deriving the total emission from the base year and subtracting the reduction from Formula (9) times the emission coefficient for milk (1.4), subtracted by the quantity reduction times the emission coefficient for oat drink (0.4). The result indicates that the total emission from the dairy market under a Pigouvian tax would be 212.19 million tonnes.

7.4. Conclusions

This section presents results from the calculations in previous sections, which is summarized in Table 4 *Consumed quantity and emissions,* Table 5 *Production of milk with market regulation* and Table 6 *Total change on the market.*

Under the assumption that the European Union would apply an EU ETS emission price level in the agricultural sector, the demand for oat drink is assumed to increase with 8.36 million tonnes, which corresponds to the reduction in demand for milk. The consumption of milk after an implementation of the EU ETS price would be 152 903.8 thousand tonnes, which represents a total emissions reduction of 5.18 percent in the European Union's milk industry.

If a Pigouvian tax would be implemented the demand for oat drink would increase with 13.58 million tonnes, which corresponds to the reduction in the demanded quantity of milk. The consumed quantity of milk after the tax would be 147 682.2 thousand tonnes. The changes in consumption represent a total emissions reduction of 8.42 percent in the European Union's milk industry. The total emissions cost in euros per tonne is displayed in Table 3 *Costs in euro per tonne of milk.*

Table 4 ***Consumed quantity and emissions***

	No emission price	**EU ETS**	**Pigouvian tax**
Consumed quantity of milk	161 261.6 thousand tonnes	152 903.8 thousand tonnes	147 682.2 thousand tonnes
Increased quantity of consumed oat drink.	0 thousand tonnes	8 357.8 thousand tonnes	13 579.32 thousand tonnes
Total CO_2eq. emissions from the market	225.77 million tonnes CO_2eq.	217.41 million tonnes CO_2eq.	212.19 million tonnes CO_2eq.

Oat drink consumption is assumed to be 0 with no emission price, since consumers have not changed their preferences.

The total emissions reduction from the dairy industry under an EU ETS price level would be 11.7 million tonnes of CO_2eq. emissions, representing a total reduction in the sector of 5.18 percent or 0.26 percent of the European Union's total GHG emissions in all sectors. The consumers on the market will consume both oat drink and cow milk. This is due to the change in preferences when the price of milk increases as the cost of producing milk increases. The reduction of CO_2eq. emissions under an EU ETS price would be 3.7 percent in the European Union's' dairy market, representing a reduction of 0.19 percent of the total GHG emissions.

Under a Pigouvian tax, which is 14.15 euros higher than the EU ETS price, the reduced production of milk would represent a decrease of 8.42 percent of the CO_2eq. emissions in the dairy sector, which is 0.43 percent of the total emissions from all sectors in the European Union. The reduction in the demanded quantity of cow milk is assumed to be replaced with oat drink. Under a Pigouvian tax, the total reduction would be 6 percent of the dairy sectors total CO_2eq. emissions in the European Union. The percentage reduction out of the total European Union's GHG emissions is 0.3 percent.

The results indicate that the definitive effect on emission in the market, including the change in consumption toward oat drink, is larger with a higher emission price level.

Table 5 ***Production of milk with market regulation***

Production	EU ETS	Pigouvian tax	Differences between Pigouvian tax and EU ETS
Reduced emissions from dairy industry	11.7 million tonnes CO_2eq.	19.0 million tonnes CO_2eq.	7.3 million tonnes CO_2eq.
Portion of total emissions from EU dairy industry	5.18 %	8.42 %	3.24 percent units
Portion of emissions reduction compared to the total EU emissions	0.26 %	0.43 %	0.17 percent units

The table is based on the values from the base year, that can be found in Appendix II, Table 2 *Variables from 2016*, and the European Union's total emissions in 2016 which was 4466 million tonnes CO_2eq. (IPCC 2018).

Table 6 ***Total change on the market***

Total change on the market	EU ETS	Pigouvian tax	Differences between Pigouvian tax and EU ETS
Reduced emissions from consumption	8.36 million tonnes CO_2eq.	13.58 million tonnes CO_2eq.	5.22 million tonnes CO_2eq.
Total emissions reduction from consumption compared to the dairy market emissions	3.7 %	6.0 %	2.3 percent units
Portion of emissions reduction from consumption compared to the total EU emissions	0.19 %	0.3 %	0.11 percent units

The table is based on the numbers from 2016 that can be found in Appendix II *Data*, Table 2 *Variables from 2016*, and the European Union's total emissions in 2016 which was 4466 million tonnes CO_2eq. emissions (IPCC 2018).

8. Discussion

The thesis based its estimations of the effects of implementing a market regulation in present time using data from the year 2016 and it is assumed that the data is equal to present day values. This assumption limits the results since the market structures might have changed from the base year. The market structures regarding the milk industry might have shifted since 2016 due to possible expansion of substitute products and consumer awareness. The consumers might have acquired more information, as mentioned in the introduction, which can shift the demanded quantity by differentiating between the products. A shift in demand for other substitutes would, in the case of this thesis, shift consumption towards oat drink, which could lower emissions without government interference.

Restrictions were present during the conduction of this thesis. One restriction was the lack of available data concerning the demanded quantity of milk in the European Union. The demanded quantity was not specified in the datasets available, after discussion with the supervisor, an assumption that the quantity supplied was equal to quantity demanded was made. Further restrictions were that data regarding each member states production, consumption and supply elasticities was not available. The European Union's averages had to be used, which is discussed in section 6.1 *Uncertainty in the data.* If these variables had been available, the result from the research might have differed. If more data and time was available, it would be possible to conduct an in-depth econometric analysis. For example, a regression on the significant effect of taxes and subsidies on emission from the milk industry, along with additional coefficient from the LCA-analysis.

Demand elasticities and supply elasticities allow researchers to find how sensitive the supply and demand are towards changes in price and quantity. It is, therefore, important to know the correct elasticity when researching a change in supply and demand. The thesis was limited in time, which meant that it was not possible to carry out an in-depth method study in order to find the best prediction for elasticities. Therefore, only the demand elasticity from previous research and prices based on existing data were used. Further research within the subject of price elasticity of demand and supply for dairy would be necessary in order to find the true changes on the market given market regulations, without CAP interference on demand and supply.

The results are dependent on the emission coefficient, which was assumed to be 1.4. However, the value can differ between member states. If an analysis of specific countries was conducted, the results might differ. If data was available for consumption and production for each member state, it would be possible to conduct a larger study that investigates the emission reduction in each member state, as well as using different emission price levels depending on the member states emission costs.

As the results indicate, a market regulation will affect the production cost, which affects the consumer, producer and their total contribution to GHG emissions in the European Union. The total emissions reduction in production due to less demand, is a prediction, some consumers will not change their consumption behaviour, spending more of their budget on milk products, while other consumers might not be able to do so. A higher tax level indicates a higher price per litre for consumers, depending on the objective of the tax it can have positive or negative effects. If the objective of the tax is to decrease consumption, a tax that increases the price has a positive effect on normal good. There might be individuals that cannot respond to a higher milk price due to a smaller budget, steering them to relatively cheaper substitutes, which could be oat drink. Other substitutes are also available on the market and further research on specific substitutes and their emissions, elasticities and demand could be conducted along with change in indirect land use.

The marginal cost will differ between countries, studies regarding the marginal cost in individual member countries have been conducted. The reports regarding individual member states production have been able to estimate a marginal cost for its producers, however due to large variation between member countries, such estimation have not been pursued in this thesis. The marginal cost curves that are presented in the graphs is only estimations of how the MC curves will appear on the market based on previous studies and the state of the dairy market. Emissions cost has a direct effect on production and farmers, which could limit the number of farms on the market in the European Union and labour demand. Higher emission cost results in higher variable cost, and therefore, higher marginal cost. As mentioned in section 2.3 *Marginal costs and economies of scale* the large-scale farmer has a higher resilience to increased production cost due to a lower marginal production cost in comparison to small-scale farmers. A considerable part of the dairy farmers is in a vulnerable state, increasing the chances of being excluded from the market if the production cost rises due to a regulation. If a smaller farm exits the market, their production would be taken over by a larger farm to satisfy the demand. Organic dairy farms might be more sensitive than conventional farms due to their small-scale structure. From an economic point of view, large-scale farms are more efficient. However, they could also contribute to larger negative externalities for the environment such as large monocultures that are a threat to biodiversity. Organic dairy farming has less impact on the surrounding environment due to regulations, which reduces the risk of biodiversity and habitat losses. Aside from contributing to a similar amount of CO_2eq. emissions as conventional farm, organic farms can have other positive effects that are not brought up in this thesis, such as less fertilization and pesticide use.

Critics towards market regulations mention that taxes might not result in efficient allocations and the optimal price is difficult to find. If the tax is set higher than the optimal level it generates deadweight loss. If the original equilibrium is the optimal one, the new price-level would generate a deadweight loss. However, this is not the case since the original equilibrium generates externalities and is therefore not Pareto optimal.

The total emissions reductions calculated in this thesis might not seem significant in comparison with the total emissions from the European Union. The European Union's long-term goal is to decrease its total GHG emissions with 80-95 percent by 2050. Nonetheless, the emissions from the agricultural sector will not be able to reach zero since agriculture is a necessity in order to feed the population and animals will always have a certain contribution to the emissions. However, agriculture can reduce their emissions with different methods such as changing the feed or developing further emission efficient technology, resulting in reduced emissions from the animals. The technical development and other changes to the production chain can also reduce the average cost and thereby shift the marginal cost. Investing in environmentally friendly technology could contribute to reducing the total GHG emissions. Depending on which GHG the technology aims to reduce, the reduction could have varied results. If technology is focused on reducing methane then a reduction of one kilogram will have a higher impact than a reduction of one kilogram of carbon dioxide, since the global warming potential is 25 for methane. The consumer can contribute to the reduction of GHG emissions by implementing dietary changes, choosing products with lower CO_2eq. emissions, such as oat drink instead of milk.

Further research within the subject of the true emissions cost can be conducted, as well as the marginal cost function. For example, by setting a specific emission reduction goal for the milk industry, the emission price could be calculated using a similar formula as presented in this thesis, with reverse calculations. Instead of using the *production level* times the *emission price level* to find the *emissions reduction*, the *emissions reduction* quantity/percentage is known and the wanted *emission price level* is estimated. This approach is useful for policymakers who are interested in finding the optimal emission price level. Weitzman (1974) states that it is irrelevant if a policy maker focuses on price or quantity since they both require the same information, indicating that the reverse approach to the calculations in this thesis is possible. Policymakers might also be interested in looking at positive externalities from milk production.

In order to reduce global emissions, it is necessary to cooperate. Producers, consumers and policymakers must act together in order to reduce emissions and keep the global temperature rise below two degrees Celsius. Implementations of different market regulation, more environmentally friendly technology and information towards consumers could be steps towards reaching the goal of reducing emissions that causes climate change.

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Appendix I Definitions

Carbon Dioxide equivalents

Carbon dioxide equivalents (CO_2eq.) are defined as *"a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential. /.../ The carbon dioxide equivalent for a gas is derived by multiplying the tonnes of the gas by the associated GWP" (*Eurostat 2017). Methane has a CO_2eq. of 25, which means that 1 tonne of methane has the same GWP as 25 tonne of CO_2 Nitrous Oxide has a CO_2eq. of 298, which indicates that 1 tonne of Nitrous Oxide has the same GWP as 298 tonne of CO_2 (Brander & Davis 2012).

Enteric fermentation

Enteric fermentation is defined as *"fermentation that takes place in the digestive systems of animals. /.../ Methane is produced /.../ by bacteria as a by-product of the fermentation process."* (EPA n.d.).

Greenhouse gases

"A greenhouse gas (or GHG for short) is any gas in the atmosphere which absorbs and re-emits heat, and thereby keeps the planet's atmosphere warmer than it otherwise would be. The main GHGs in the Earth's atmosphere are water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone." (Brander & Davis 2012 pg.1). Greenhouse gases contribute to climate change.

The Food and Agriculture Organisation (FAO) and Organisation for Economic Co-operation and development

The Food and Agriculture Organisation (FAO) is "*A specialized agency of the United Nations that leads international efforts to defeat hunger."* and *"has 194 Member Nations, two associate members and one member organization, the European Union*." (FAO 2019b). Organisation for Economic Co-operation and development (OECD) is an intergovernmental economic organisation and has 36 member countries around the world (OECDwatch n.d.).

Appendix II Data

Table 1 ***Total amount of emissions from the European Union's dairy sector (2000-2016)***

Year	Kilograms of CO_2eq. emissions	Millions of tonnes of CO_2eq. emissions
2000	209210152200	209.21
2001	208220017600	208.22
2002	208617019800	208.62
2003	209009931200	20901
2004	205782763200	205.78
2005	207003599600	207.00
2006	205825778200	205.83
2007	205549443400	205.55
2008	207752428800	207.75
2009	206073868000	206.07
2010	206870197800	206.87
2011	210121655800	210.12
2012	210765380000	210.77
2013	213146514000	213.15
2014	221667096000	221.67
2015	226134451200	226.13
2016	225766188200	225.77

The table is based of production quantity data from FAO and the emissions coefficient (1.4) from Leip et al. (2010).

Production quantity data is collected from: FAOstat > Time Range: 2000-2016 > Groups: Production > Domain: Livestock primary > Country/Region: European Union + (Total) > Element: Production quantity > Item: Milk, whole fresh cow > Compare data

Table 2 ***Variables from 2016***

2016 variables	**Value**	**Gathered from**
Produced quantity in thousand tonnes	161261.6	**Milk production, quantity:** FAOstat > Compare data > Time Range: 2000-2016 > Groups: Production > Domain: Livestock primary > Country/Region: European Union + (Total) > Element: Production quantity > Item: Milk, whole fresh cow > Compare data
Average weighted price for raw milk in euros per tonne of milk	284.3	**The average weighted price for raw milk:** European commission > EU milk market observatory > EU historical series > EU historical prices. https://ec.europa.eu/agriculture/market-observatory/milk_en [Accessed 2019-04-26]
Production cost in euros per tonne of milk	282.8	**Production cost:** OECD.stat > Agricultural Outlook > OECD-FAO Agricultural Outlook 2018-2027 > OECD-FAO Agricultural Outlook 1990-2028, by commodity > Country: European Union-28, Variable > Producer price > Commodity: Milk

The *producer price* is referred to as the *production cost*, since it is the closest available estimation of this measurement.

Appendix III Calculations

The calculations in this Appendix have been divided into sections corresponding with the sections in 7. Results.

Section 7.1 Demand

Inverse demand slope

(4) $\textit{Inverse demand slope (b):} \frac{\Delta Q}{\Delta p} = \varepsilon(\frac{Q}{P})$

$\textit{Inverse demand slope (b):} \frac{\Delta Q}{\Delta p} = -0.57(\frac{161261.6}{284.3})$

$\textit{Inverse demand slope (b)} = -323.317$

Demand function intercept

(5) $161\ 261.6 + (323.203 * 284.3) = 253\ 180.7\ \textit{thousand tonnes}$

Price as a function of the demanded quantity

$Q^d = 253180.7 - 323.317p$

$323.317p = 253180.7 - Q^d$

$p = \frac{253180.7}{323.317} - \frac{Q^d}{323.317}$

$p = 783.07 - 0.0031Q^d$

Section 7.2 Shifts on the market

Emission and production cost under an EU ETS price

(7) $\textit{Emissions cost}_{EU\ ETS} = 1.4 * 25.85 = 36.19$ *euros per tonne of mi*

(8) $\textit{Production cost}_{EU\ ETS} = 36.19 + 282.8 = 318.97$ *euros per tonne of milk*

Emission and production cost under a Pigouvian tax

(7) $\textit{Emissions cost}_{Pigouvian} = 1.4 * 42 = 58.8$ *euros per tonne of milk*

(8) $\textit{Production cost}_{Pigouvian} = 58.8 + 282.8 = 341.58$ *euros per tonne of milk*

Changes in quantity under an EU ETS tax

(6) $$\Delta Q = \Delta p * (b)$$

$$\Delta Q = -323.317 * 25.85$$

$$\Delta Q = -8357.75\ thousand\ tonnes$$

Change in quantity under a Pigouvian tax

(6) $$\Delta Q = \Delta p * (slope)$$

$$-323.317 * 42 = \Delta Q$$

$$\Delta Q = -13579.32\ thousand\ tonnes$$

7.3.1 EU ETS emission price and total emissions reduction

Total emission cost of dairy

(2) $$TEC_{dairy} = (161261.6 * 1.4) * 25.85 = 5\ 836\ 056\ euros$$

Total emissions from dairy, adaptation of Formula (1).

(1) $$TE_{dairy\ in\ kilograms\ per\ year} = 8\ 357\ 750\ 616 * 1.4 = 11\ 700\ 850\ 862$$

Total emissions from oat drink, adaptation of Formula (1)

(1) $TE = 8\ 357\ 750\ 616 * 0.4 = 3\ 343\ 100\ 246$ kilograms of CO_2eq. emissions

Total emission reduction in the whole market

(13) Total emissions reduction= -11 700 850 862 + 3 343 100 246=

-8 357 750 616 Kilogram CO_2 eq. emissions.

Consumed quantity of milk after implementation of a EU ETS price

161 261.6 - 8 957.8 ≈ 152 903.8 thousand tonnes

Total CO_2eq. emissions from the market under an EU ETS price in millions of tonnes

225.766 - *((8.358 * 1.4) - (8. 358 *0.4)) = 217.408*

7.3.2 Pigouvian tax on emissions and total emissions reduction

Total emission cost of dairy

(2) $TEC_{dairy} = (161261.6 * 1.4) * 42 = 9\,482\,180\ thousand\ euros$

Total emissions from dairy, in kilograms

(1) $TE = 13\,579\,324\,018 * 1.4 = 19\,011\,053\,625$

Total emission from oat drink, in kilograms

(1) $TE = 13\,579\,324\,018 * 0.4 = 5\,431\,729\,607$

Total emission reduction under a Pigouvian tax

(9) Total emissions reduction=-19 011 053 625 + 5 431 729 607=-13 579 324 018 kilogram of CO_2eq. emissions

Consumed quantity of milk after implementation of a Pigouvian tax

161 261.6 - 135 79.32 ≈ 147 682.2 thousand tonnes

Total emissions from the dairy market under a Pigouvian tax in millions of tonnes

225.766 - *((13.579 * 1.4) - (13.579 *0.4)) = 212.187 million tonnes*