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An Assessment of the Inflationary Impact of the European Electricity Market

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Abstract

This thesis investigates the inflationary impact of the European Electricity Market on its member countries, including the EU28, Norway, and Switzerland, from 2003 to 2019. The research question particularly focuses on whether this market impacts the level of inflation in its net exporting member countries. Utilising two panel data regression models, we explore the market's impact on the rate of inflation, through the primary variables net export, price comparison and an interaction variable between these two and exchange rate. Our findings reveal a significant influence of these variables on energy price inflation, but not a direct impact on overall inflation. This distinction suggests that the primary variables more accurately explain changes in energy price inflation rather than overall inflation. The study underlines the importance of considering both direct and indirect economic impacts when assessing the influence of the European Electricity Market. Such research is essential for understanding the market's role in the energy landscape of European countries and serves valuable insight into future energy policy decisions.

Keywords: European Electricity Market, Inflation, Energy Price Inflation, Net Export

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1. Introduction

In the last few years, the public debate around Europe has focused on record-high electricity prices (Eurostat, 2023a) and energy-driven inflation due to dependency between European countries (Euronews, 2023). During the 1990s, the progression towards market liberalisation positioned Europe as a leader in the global trend of cross-border electricity markets. Since 2003, the European Electricity Market has operated as a single-integrated entity (Bolton, 2021). In the context of this market, previous research (De Cian et al., 2013; Kriström, 2016) suggests a potential link between a country's net exporting status within this market and higher rates of inflation.

In times when electricity and inflation are widely discussed, it is important to investigate factors that may lead to higher levels of inflation. This study aims to investigate the European Electricity Market's impact on inflation, particularly among net electricity exporting countries. While existing research on this market's direct impact on inflation is limited, it is known that asynchronous demand between seasons drives the need for electricity trade (De Cian et al., 2013; Nordpool, n.d.). Furthermore, the empirical analysis of Kilian et al. (2023) highlights that indirect effects on total inflation can be tracked to the cumulative impact of various energy price shocks, including those from the electricity sector. This linkage between market-driven price changes and broader economic impacts forms the basis of our analysis and intends to provide insights that can contribute to future policymaking within the European Union. Our research question is: *Does the European single-integrated Electricity Market impact the level of inflation in its net exporting member countries?*

To answer the research question, this study employs two panel data regression models on the EU28 countries, including Norway and Switzerland. Model 1 examines factors influencing overall inflation, while model 2 specifically focuses on energy price inflation. The primary variables are net export, price comparison between the domestic price and the EU average, and an interaction variable based on the belief that being a net exporting country combined with having a domestic price relatively lower than the EU average, can further impact inflation. To thoroughly answer the research question, two hypotheses have been tested: 1. there is a positive relationship between a country's net exporting status within the market and a higher level of inflation and 2. there is a negative relationship between a country's electricity price relative to the EU average, and a higher level of inflation. These two hypotheses are interesting for further investigation, given their direct relevance to the structure of the European Electricity Market.

Looking at the results, the effects of the European Electricity Market do not show a significant impact on the overall inflation rate in its net exporting member countries. In contrast with hypothesis 1, net exporting countries do not significantly influence the level of overall inflation. Similarly, the comparison between domestic prices and the EU average shows an insignificant impact on the overall inflation rate. However, when focusing specifically on energy price inflation, both factors demonstrate a significant effect on the dependent variable. In accordance with the hypotheses, a country's net exporting status positively correlates with energy price inflation, while the relative price comparison shows a negative correlation. In summary, the European Electricity Market does not directly contribute to higher levels of overall inflation in its net exporting member countries. With that being said, there is an indirect impact, through energy price inflation.

The analysis covers the period from 2003 to 2019, deliberately chosen to exclude the impact of exogenous shocks with direct effects on the European Electricity Market, such as the Russian invasion of Ukraine. However, exogenous shocks are part of the macroeconomic landscape and are important to analyse in a larger context. A limitation of the research is therefore the short period included. However, given the purpose of the thesis followed by the fact that the observed data includes every year available since the market's opening, the limitation is considered legitimate. To verify these results, a proposition for future studies is nonetheless to explore a different or extended period.

2. Theory

2.1 The European Electricity Market

The European Electricity Market is based on several fundamental functions, including the price mechanism, common energy rules, and cross-border electricity infrastructure (The Swedish Riksbank, 2022a). The impact of the European Electricity Market is an important area to study, especially considering its role in the European countries' energy landscape. Since the opening of the market, through the adoption of the Second Energy Package in 2003, it has been functioning as a single-integrated entity that aims to ensure a secure, affordable, and sustainable electricity supply across the European Union (European Commission, 2023a).

The integration of the market into the EU marked a significant transformation in the energy sector, offering customers a wider choice of gas and electricity suppliers (European Commission, 2023a). In this market, prices are determined by the marginal cost of the most expensive production type that meets the electricity demand. Since the prices are based on production costs, renewable energy with zero production cost is the cheapest option. The bidding process starts with the cheapest and progresses to more expensive energy sources until total demand is satisfied. The price set by the last source therefore becomes the price paid by all (European Commission, 2022). This mechanism encourages competition among suppliers, aiming to keep electricity prices low (The Swedish Riksbank, 2022a). However, it is important to note that this process is influenced by the transmission capacity. In situations where the transmission capacity is insufficient, prices may not converge, resulting in varying electricity prices across different regions (Nordpool, n.d).

The broad and complex structure of the European Electricity Market highlights a potential area for further research. Central to the market's structure, the capacity of the equalising price mechanism plays a key role in balancing energy costs across different countries (Nordpool, n.d.). It equalises the prices of each energy source such that it falls between the individual countries' market prices that would exist without trade (Kriström, 2016). Consequently, this leads to an increase in prices in net exporting countries and a decrease in net importing countries (van Marrewijk, 2017). However, De Cian et al. (2013) and Kriström (2016) indicate a positive relationship between a country's status as a net electricity exporter within this market, and a higher level of inflation. Therefore, one of the purposes of this study is to provide insights into this complex relationship.

Further discussing transmission capacity between countries, Switzerland is a good example. Although Switzerland is not part of the EU, it has been functionally integrated into the European Electricity Market since 1958, featuring 41 cross-border power lines. Additionally, it hosts Europe's largest power network within its borders (Swiss Federal Office for Energy, 2023). Similarly, Norway with the world's first multinational electricity market Nordpool, is well integrated. Nordpool has played an important role in the liberalisation of cross-border electricity systems in Europe (Bolton, 2021). Even though these two countries are not official members of the EU, their extensive integration into the European Electricity Market makes them important to include in the research for more accurate estimates and correct analysis.

2.2 Inflation

Inflation is the rate at which the general level of prices for goods and services rises, leading to a corresponding fall in purchasing power (Burda & Wyplosz, 2017; The Swedish Riksbank, 2023). Due to its widespread effects on economic distribution and welfare (The Swedish Riksbank, 2022b), we consider further analysis of the area important. Notably, inflation reflects a consumer basket comprising a variety of products, including energy prices (The Swedish Riksbank, 2022b; Kilian et al., 2023). In the context of the European Electricity Market, understanding the direct and indirect impact of electricity is essential for effective policymaking, since it leads to broader inflationary pressure throughout the economy (The Swedish Riksbank, 2022a). Energy prices are more volatile as they respond to different shifts in specific economic variables, such as electricity (The Swedish Riksbank, 2022c). Therefore, it is found to be interesting to further investigate the specific effects on energy price inflation.

The complexity of the inflation rate's relationship with the European Electricity Market can be further investigated in the broader context of international trade and currency fluctuations. For instance, a depreciating currency can make a country’s exports more competitive, boosting export volumes and potentially leading to a higher rate of inflation by stimulating economic growth. Conversely, countries that rely on exporting commodities might experience a higher level of inflation if commodity prices rise, increasing the money supply domestically (Burda & Wyplosz, 2017). This concept also applies to imports, where a weaker currency can raise import costs, further driving up consumer prices (The Swedish Riksbank, 2016). Understanding these relationships is important for comprehending the full spectrum of inflationary dynamics within the context of the European Electricity Market.

Furthermore, sustained increases in electricity prices are believed to play a significant role in shaping the overall inflationary landscape. One reason is that companies increase their pricing in anticipation of continued high electricity costs, which affect consumers' and businesses' inflation predictions (The Swedish Riksbank, 2022c). As a result, workers demand higher wages to cover their rising living expenses, thereby fostering inflation (Burda & Wyplosz, 2017).

Focusing on labour market dynamics, particularly unemployment plays an essential role in influencing the rate of inflation. The theoretical relationship between inflation and unemployment can be explained by the Phillips Curve. This economic theory suggests that there is an inverse relationship between inflation and unemployment (Phillips, 1958 cited in Burda & Wyplosz, 2017). When unemployment is high, inflation tends to be lower, and vice versa. This is because high unemployment often leads to decreased consumer spending, which can reduce demand for goods and services, thereby lowering inflation. On the contrary, when unemployment is low, there is more consumer spending, potentially leading to higher demand and increased prices, thus driving inflation up. Related to the European Electricity Market, rises in electricity prices can have a significant effect on employment in energy-intensive industries (The Swedish Riksbank, 2022c). However, Reinbold et al. (2020) conclude that unemployment and inflation correlate differently over different periods. Their results show that in the very short run, no correlation is observed. This suggests complexities in the relationship between inflation and unemployment.

3. Literature Review

Our study aims to assess whether the European Electricity Market contributes to a higher level of inflation in its member countries. While existing research on this market's direct impact on inflation is limited, asynchronous demand is known to drive the need for electricity trade, influencing market prices and dynamics (De Cian et al., 2013; Nordpool, n.d.). Additionally, the empirical analysis conducted by Kilian et al. (2023) highlights that indirect effects on overall inflation can be assigned to the cumulative effect of various energy price shocks, including those from the electricity sector. This connection between market-driven price changes and broader economic impacts forms the basis of our analysis. Consequently, our study posits two hypotheses: 1. there is a positive relationship between a country's net exporting status within the market and a higher level of inflation and 2. there is a negative relationship between a country's electricity price relative to the EU average, and a higher level of inflation.

The belief that being a net exporter of electricity leads to a higher level of inflation is supported by Geske et al.'s (2019) study. The study analyses the implications of a Hard Elecxit, representing the United Kingdom's complete withdrawal from the European Electricity Market. Their results show that an exit would likely lead to an increase in electricity prices in the net importing country, the United Kingdom, and a decrease in the net exporting country, France. Given the fact that no other member country has ever withdrawn from the market before (Sveriges Riksdag, 2023), our analysis excludes the perspective of such an event's effect on inflation in other member countries. However, the results of Geske et al. (2019) strengthen hypothesis 1 that net exporting countries within the market face a higher level of inflation due to increased electricity prices.

Viewing the situation from the opposite viewpoint, Fiorio et al. (2007) and Bacchiocchi et al. (2015) all find that entering the European Electricity Market raises domestic electricity prices. Their studies both focus on the EU15 countries before and after the entrance. Their results can be backed up by del-Rio et al. (2019), who examine the effects of regulatory reforms on industrial and household electricity prices, between 2003 and 2013. From the results of their panel data regression model, del-Rio et al. (2019) also conclude significant increases in price levels as a consequence of entering the European Electricity Market during this period. The objective of our study is to broaden the research on this particular market, by focusing on the trade patterns since the entry.

Another reason for believing that net exporting countries face higher levels of inflation is based on Kilian et al.'s (2023) study, implying that an increase in the cost of energy contributes to inflationary pressure. Their results show that the direct impact of energy price shocks on overall inflation is limited, due to their proportion in the consumer basket. As an example, they consider the cost share of crude oil in retail gasoline prices, where a 1% increase in the price of oil corresponds to only a 0.6% increase in gasoline prices. However, the study reports indirect effects on overall inflation due to the cumulative impact of different energy price shocks, including electricity. The study's result gives reason for further investigation into how different levels of net export affect the level of inflation, through energy price inflation.

Further examining how exports affect inflation, Dexter et al.'s (2005) study states that trade volumes have a significant impact on overall inflation. The study focuses on international trade's effect on the relationship between excess demand and inflation in the United States, between 1967 and 1991. The results of their study demonstrate that by incorporating international trade data into the analysis, trade volumes themselves significantly impact inflation. Their study reveals that while an increase in export quantities could potentially raise inflation by reducing domestic availability, export prices do not directly affect a country's inflation rate. These findings indicate that all else being equal, an increase in real exports positively influences the inflation rate significantly at the 1% level. Having said that, their research supports the belief that quantities of exports, rather than imports, are the primary drivers of higher inflation rates. The results of Dexter et al. (2005) support our choice of focusing on exports rather than imports and quantities instead of prices. Furthermore, hypothesis 1 is strengthened by Dexter et al.'s (2005) results, stating a positive relationship between a country's net exporting status and a higher level of inflation.

Turning to country-specific effects of the European Electricity Market, Nordpool (n.d.) highlights how insufficient transmission capacity can create price disparities across regions. This leads to unbalanced inflationary pressure between countries. Due to a lack of data on transmission capacity, no data-driven research has been done on this topic. However, in a forecasting analysis of Italy, Armillei et al. (2022) propose upgrading existing transmission infrastructure, suggesting this could integrate renewable energy sources more efficiently and stabilise electricity prices in the EU. Considering our research question of whether the European Electricity Market has an impact on the level of inflation in its member countries, it is reasonable to believe that different prices may result in various levels of inflation.

As for hypothesis 2, it suggests that countries with a low electricity price relative to the EU average experience a higher level of inflation. This belief is partially based on Kravis & Lipsey's (1977) study on the trading manufacturing sectors of the United States, United Kingdom, Japan, and Germany, spanning between 1953 and 1984. The research emphasises how competitive advantage is affected by the relative increase in export prices, especially during periods of high foreign inflation or domestic currency depreciation. The result further underscores the importance of analysing the changing relationship between export and domestic prices when understanding the economic impacts of varying inflation rates and exchange rate fluctuations. These findings support hypothesis 2 as it suggests a potential negative relationship between countries' domestic electricity prices and inflation when compared to the EU average.

The belief that countries with a low electricity price relative to the EU average encounter a higher rate of inflation is also supported by The Swedish Riksbank's (2016) report focusing on the Swedish krona's depreciation since 2014. The report assesses the correlation between exchange rate fluctuations and inflation, highlighting that countries heavily dependent on exporting commodities may face inflation when commodity prices rise, thereby increasing the domestic money supply. Likewise applies to imports, where a weaker currency can raise import costs, further driving up consumer prices (The Swedish Riksbank, 2016). Considering asynchronous demand (De Cian et al., 2013), the market's uniform pricing structure leads to increased import costs for net exporting countries during demand spikes (European Commission, 2023a). This may be particularly evident in net exporting countries like those in the Nordic region and France, where demand changes between seasons (De Cian et al., 2013). Related to hypothesis 2, The Swedish Riksbank (2016), De Cian et al. (2013) and the European Commission (2023a) all conclude that the price differences are correlated with countries' trading status within the market.

In further exploring the relationship between inflation and exchange rate, an additional factor to consider is a country's membership in the Economic and Monetary Union (EMU). EMU member countries are not subject to exchange rate fluctuations to the same extent (European Commission, 2023b), indicating their domestic electricity prices are more competitive. This advantage could be interpreted as causing EMU countries to function similarly to net exporters of electricity, consequently experiencing higher levels of inflation.

Upon closer examination, Ghosh et al. (1997) conducted an empirical analysis for the International Monetary Fund, including 145 countries over a 30-year timespan. They state that countries with fixed exchange rate regimes experience less price volatility than those with flexible exchange rates. The conclusions drawn by Ghosh et al. (1997) are relevant to understanding the impact of exchange rate fluctuations on inflation, as they show evidence that having a fixed exchange rate can effectively lower inflation. To understand the conclusions in the context of hypothesis 2, countries that are members of EMU do not experience exchange rate fluctuations to the same extent. Thus, making their domestic electricity prices more stable and relatively higher in times of other currencies' depreciation, generating a lower inflationary pressure.

4. Method

The European Electricity Market's effect on the level of inflation is captured in two separate panel data regression models. A panel data regression model combines cross-sectional data across different entities with time-series data for each entity, providing a dataset that captures both inter-entity variations and intra-entity dynamics over time (Baltagi & Songs, 2004). The choice of econometric model has been decided on with support from previous literature (del-Rio et al., 2019). Model 1 (2) captures the effects on the inflation rate (CPI) and model 2 (6) focuses on energy price inflation (CPI Energy).

$$Y_{i,t} = \beta_0 + \sum_{j=1}^{3} \beta_j \, z_{j,i,t} + \sum_{k=1}^{4} \beta_k \, x_{k,i,t} + \beta_l d_{l,i,t} + \alpha_i + \varepsilon_{i,t} \tag{1}$$

In model 1 (2), Y represents the inflation rate, while in model 2 (6), Y denotes energy price inflation. Z represents the primary variables, including net export, price comparison, and the interaction variable. X contains the control variables. The control variables included in model 1 are last year's inflation rate, real GDP per capita growth, unemployment rate, and exchange rate. In model 2, the included control variables are real GDP per capita growth, unemployment rate, exchange rate, and oil price. Both models include the dummy variable, d, which represents whether a country is a member of the EMU. True for both models is also that is the error term for the fixed effect estimator and represents the error term. Furthermore, the notation *i* stands for country, *t* for time, *j* for the primary variables, *k* for the control variables and *l* for the dummy variable.

Besides explanatory variables, both models also include a constant which represents the value of the dependent variable when all independent variables are equal to zero. In practical terms, if the constant is significantly different from zero, it indicates that the dependent variable has a baseline value that is not explained solely by the independent variables included in the model.

The study encompasses all 28 EU member countries during the specified period, along with Norway and Switzerland. Both Norway and Switzerland are well integrated into this system (Bolton, 2021; Swiss Federal Office for Energy, 2023), making their inclusion crucial for the analysis. While all selected countries are small open economies on a global scale, Bolton (2021) argues that France and Germany are considered large economies in the context of electricity trade. However, due to historical differences in trade patterns (International Energy Agency, 2020), this is not something that has been taken into further consideration in the analysis.

The analysis covers the period from 2003 to 2019, deliberately chosen to exclude the impact of exogenous shocks with direct effects on the European Electricity Market. The start of this period, 2003, is significant as it marks the adoption of the Second Energy Package, initiating the legal framework of the European Electricity Market (European Commission, 2023a). The end year, 2019, was selected to intentionally avoid the inclusion of the years following 2020, marked by a global pandemic and the Russian invasion of Ukraine. Including these years could undermine the consistency and accuracy of the analysis due to the events' atypical and exogenous impacts, which are not representative of standard market dynamics.

Due to the interplay between different factors in the macroeconomic landscape, it can be difficult to pursue econometric analysis. This can be explained by the complex relationship between a country's inflation rate and all its explanatory factors depending on time, what shock caused the pressure and where the inflation stuck in the first place (Burda & Wyplosz, 2017). Throughout the process, all econometric decisions have therefore been discussed and balanced with economic arguments.

In total, five regressions have been performed across the two different models, three in model 1 (2) focusing on overall inflation and two in model 2 (6) focusing on energy price inflation. Model 1 includes one primary regression and two additional regressions focusing on specific variables' explanatory power over the dependent variable. Model 2 includes one primary regression and one additional regression to investigate the interaction variable's specific effect on the model fit. The models further test two hypotheses: 1. there is a positive relationship between a country's net exporting status within the market and a higher level of inflation and 2. there is a negative relationship between a country's electricity price relative to the EU average, and a higher level of inflation.

4.1 Data and Variable Specification

4.1.1 Model 1

In model 1 (2), the inflation rate is the dependent variable. The model intends to answer the research question of whether the European Electricity Market affects the level of inflation in its member countries. The data on inflation rate is captured as the annual percentage level in the Consumer Price Index (CPI). It is retrieved from the World Development Indicators (The World Bank, 2023). It is further divided by 100 for a more straightforward interpretation of the coefficient.

$$CPI_{i,t} = \beta_0 + \beta_1 Net\ exp_{i,t-1} + \beta_2 Price\ c_{i,t-1} + \beta_3 ln\Delta GDPperCapita_{i,t-1} + \beta_4 \Delta Unempl_{i,t-1} + \beta_5 \Delta Exrate_{i,t} + \beta_6 CPI_{i,t-1} + \beta_7 Interaction_{i,t-1} + \beta_8 EMU_i + \alpha_i + \varepsilon_{i,t} \quad (2)$$

Looking at the explanatory variables, the model includes three primary variables. These are net export, price comparison and an interaction variable which is viewed as the product of net export, price comparison and exchange rate. The initial objective of the regression analysis is to determine whether these three variables significantly affect inflation. It is further important to understand the variables' specific influences on the level of inflation in relation to the macroeconomic control variables included in the analysis.

The first variable, net export, treats the first hypothesis that a net exporting country suffer from a higher level of inflation. The variable is derived by subtracting a country's electricity imports from its exports.

$$Net\ export = Export\ of\ Electricity - Import\ of\ Electricity \quad (3)$$

The data for net export is sourced annually from the International Energy Agency and is measured in terajoule (International Energy Agency, 2023). To convert terajoules to terawatt-hours (tWh), each observation is multiplied by the conversion factor of 0.000278 (Hainke, 2024). It is then scaled up by 1 000 000 000 to express the data in kilowatt-hours (kWh). This is done for logical reasons, as kWh is broadly used in the public debate. The data on net export is missing for Cyprus for all years and between 2003 and 2014 for Malta. In both regressions, net export is lagged one year due to a belief of a delayed effect on inflation.

The second variable, price comparison, handles the second hypothesis that a country with a low electricity price relative to the EU average faces a higher level of inflation. The variable is calculated by subtracting the EU average price from the country-specific price, resulting in a relative price difference between countries.

$$Price\ Comparison = Domestic\ Electricity\ Price - EU\ Average\ Electricity\ Price \tag{4}$$

The purpose of including this variable is to capture how price differences relative to other countries impact electricity exports and imports, and consequently inflation in these countries. The data is gathered bi-annually for all domestic prices from Eurostat, originally measured in Euro per kWh. The conversion to get the data on an annual basis is calculated as the arithmetic mean of each year's two values (Eurostat, 2023b; Eurostat, 2021). For consistency between the variables, the data is converted to USD per kWh. There is no missing data for the variable. However, this variable is lagged one year due to a belief of a delayed effect on inflation.

The third variable is an interaction variable, based on the belief that there is a multiplicative effect between three variables, causing a higher level of inflation. It is constructed to cover both hypotheses and is calculated by multiplying net export with the negative value of price comparison and exchange rate.

$$Interaction\ Variable = Net\ Export * Price\ Comparion * Exchange\ Rate \tag{5}$$

The negative value of price comparison is used to ensure that the coefficients of all variables can be interpreted consistently, especially since they are expected to influence inflation in contrasting directions. Essentially, this variable aims to capture the multiplicative effect between the export volume and relative price competitiveness in the European Electricity Market. Exchange rate is further included to account for currency fluctuations affecting the broad economy. This is a critical factor, as the strength of countries' different currencies affects import and export prices, thereby influencing inflation. The data missing for the variable is the same as for net export; Cyprus for all years, and Malta between 2003 and 2014. Similar to net export and price comparison, the interaction variable is lagged one year in both models. Both price comparison and the interaction variable are measured in US dollars. Using a common currency benchmark like the US dollar standardises these measurements, enabling a more straightforward comparison across different economies.

Besides the primary variables, the model also includes four control variables to capture fundamental macroeconomic effects on the level of inflation. These variables are last year's inflation rate, unemployment rate, exchange rate and real GDP per capita growth. These variables are included to account for factors that might influence the relationship between the primary variables and the dependent variable. For example, last year's inflation rate is added to account for the self-correcting nature (Burda & Wyplosz, 2017) and expectation-driven dynamics of inflation (Fisher, 1930 cited in Rötheli, 2020; Adrian, 2023). Real GDP per capita growth is incorporated to reflect economic fluctuations (Reserve Bank of Australia, 2023), and unemployment rate is used to capture unemployment rates' effect on inflation through wage levels (Reinbold et al., 2020). Moreover, exchange rate is included to explain trade patterns between countries, possibly fostering inflation (Burda & Wyplosz, 2017).

Last year's inflation rate is calculated as the dependent variable, adding one lag. The data for real GDP per capita growth and unemployment rate are both collected from the World Development Indicators (The World Bank, 2023). Unemployment rate is included in first difference, as the regression is based on the belief that it is the change in the unemployment rate that affects the inflation rate. Furthermore, it is included with one lag due to the belief that its effect on inflation shows after one year. Real GDP per capita growth is calculated as the countries' real GDP in constant US dollars in 2015, divided by their population. The variable is further transformed into first difference with one log to capture percentage growth. The data on exchange rate is also retrieved from the World Development Indicators and is expressed as local currency per USD, period average (The World Bank, 2023). It is reported in first difference.

In addition to the two group of variables, a dummy variable is included to indicate if a country is a member of the Economic and Monetary Union (EMU). The reason for including the dummy variable is to ensure that the country-specific effects of being a member of the monetary union are captured, which the exchange rate can not capture. It is an important factor to consider since members of the monetary union face an increased price transparency and therefore are not affected as much by trade partners' exchange rate depreciation/appreciation (European Commission, 2023b). Also, the fact that EMU members have the same central bank makes the currency more stable, as all member countries share the same monetary policies (European Central Bank, 2024). In the panel data, EMU countries are assigned a value of one, meanwhile non-members are given the number zero. The data is collected from the European Central Bank (2023). The data set is complete. However, not all EMU countries have been members since the beginning of the data set. The regression therefore captures the effects of entry into the monetary union for some countries.

4.1.2 Model 2

Model 2 (6) concentrates on energy price inflation and therefore has CPI energy as the dependent variable. The reason for analysing this model is to look further into the effects of trading with electricity, on energy price inflation. The volatility in energy price inflation is greater (Kilian et al., 2023), suggesting that there are other variables important to include in the analysis. This model provides an understanding of the specific aspect of inflation related to energy prices, offering a detailed view of this particular part of the consumer basket. Energy price inflation is measured as the annual growth rate in CPI energy, retrieved from the OECD (2023a). It is further divided by 100 for easier interpretation of the coefficient. The variable is missing data from Bulgaria, Croatia, Cyprus, Malta and Romania all years, 2003-2019.

$$\begin{aligned} CPI\ Energy_{i,t} = {} & \beta_0 + \beta_1 Net\ exp_{i,t-1} + \beta_2 Price\ c_{i,t-1} + \beta_3 ln\Delta GDPperCapita_{i,t-1} \\ & + \beta_4 \Delta Unempl_{i,t-1} + \beta_5 \Delta Exrate_{i,t} + \beta_6 \Delta Oil\ price_{i,t} + \beta_7 Interaction_{i,t-1} \\ & + \beta_8 EMU_{i,t} + \alpha_i + \varepsilon_{i,t} \end{aligned} \tag{6}$$

In comparison to model 1 (2), model 2 (6) includes oil price as an explanatory variable. Oil price is included due to the belief that it has an important impact on energy price inflation. Kilian et al.

(2023) state that energy price shocks have a limited direct impact on overall inflation due to their proportion in the consumer basket. Focusing on model 2, excluding oil price as an explanatory variable would risk misleading the results through omitted variable bias, making the other independent variables unreliable. The data on oil prices is retrieved as crude oil import prices from the OECD (2023b). It is measured in US dollars/barrel and analysed in first difference. A possible measurement error in model 1 is excluding oil price. By excluding this variable, its entire impact on overall inflation will show through net export and price comparison. It is therefore a risk of inaccurate significance in those variables.

Lastly, model 2 (6) excludes last year's inflation rate as an explanatory variable. Given the greater volatility in energy price inflation (Kilian et al., 2023), last year's inflation rate is not believed to have a direct impact on energy price inflation. Including a variable without explanatory power risks misleading the result and is therefore excluded.

4.2 Econometric specification tests

In the analysis of the European Electricity Market, an unbalanced panel has been chosen to maximise the number of countries included, despite the trade-off with missing data. This approach is necessary to ensure a broad representation of countries affected by the system. For the regressions to yield consistent results, some assumptions about the least squares estimation method must hold (Baltagi, 2021). These include stationarity of the data, homoscedastic standard errors, absence of autocorrelation in the residuals and lack of multicollinearity among the independent variables. Furthermore, the null of random effects explaining the correlation between error terms and their regressor is being tested.

The first assumption is stationarity. Stationarity is a stochastic process where the mean and variance are constant over time. To test for stationarity, the Augmented Dickey-Fuller test is being used to test for individual unit roots (Baltagi, 2021). The results reported on the regressors show stationarity through all variables during the chosen period.

The second assumption is about homoscedastic standard errors. This is tested through White's test. Given the null of homoscedasticity, the null can be rejected for all variables, as they show heteroscedasticity. To correct for heteroscedasticity, robust standard errors are being used. Robust standard errors are designed to provide consistent standard error estimates in the presence of heteroscedasticity since they are "robust" to violations of this assumption (Wooldridge, 2012).

Thirdly, the Durbin-Watson statistic is being observed to check for autocorrelation. It ranges from 0 to 4. A value close to 2 indicates no autocorrelation in the residuals of a regression model. Values approaching 0 suggest positive autocorrelation and values closer to 4 indicate negative autocorrelation. The exact interpretation of the DW statistic depends on the number of predictors and observations in the model (Durbin & Watson, 1971). Given values around 2 when using robust standard errors, no autocorrelation is found in the residuals.

The final test to check that the assumptions hold is for multicollinearity. Multicollinearity is caused by correlation between the independent variables, undermining the statistical significance because one independent variable can be linearly predicted from the others with a high degree of accuracy (Ferré, 2009). To test for multicollinearity, VIF is used to measure how much the variance of an estimated regression coefficient increases due to multicollinearity. Ferré (2009) and O'Brien (2007) both consider a VIF value below 4 to be good. Testing our variables, no VIF shows a value above 2, indicating that the assumption of no multicollinearity holds.

Lastly, the data has been analysed by performing a Hausman test. The null hypothesis of the test is no correlation between a unique error term and its regressor, indicating that random effects explain the potential correlation, instead of cross-sectional or period-specific factors (Hausman, 1978). The null can not be rejected. In econometric terms, this indicates that there is no statistically significant difference between using the fixed effects model and the random effects model. Therefore, the choice between fixed and random effects is not clear-cut based on statistical significance alone (Hausman, 1978 cited in Baltagi, 2021). However, previous research suggests that there are country-specific effects across countries (Bolton, 2021; Fiorio et al., 2007; Ghosh et al., 1997; Kriström, 2016), leading to the choice of using a fixed effects model with cross-sectional effects.

5. Results

The findings of this study are presented through two different models, each reported in separate tables for clarity and thorough analysis. The results of model 1 (2) are reported in Table 1 to show the estimated relationship between overall inflation and its explanatory factors. The results of model 2 (6) are stated in Table 2 to show the estimated relationship between energy price inflation and its explanatory factors. The models are analysed separately, allowing a more comprehensive comparison in the discussion.

Table 1: Regression Results of Model 1

Dependent Variable: Inflation Rate (CPI)	(1)	(2)	(3)
Net Export *1000 kWh*	0,0000591 (0,3077)	0,0000865* (0,0928)	0,0000904 (0,1920)
Price Comparison *0,1 USD*	-0,0045077 (0,2270)	-0,0060347* (0,0682)	-0,0032445 (0,3560)
Interaction Variable *1000 kWh*	0,000112* (0,0616)	0,000188*** (0,0011)	
EMU Member *Dummy Variable*	-0,008352 (0,1552)	-0,018550** (0,0194)	-0,007187 (0,1869)
Real GDP per Capita Growth	0,23172** (0,0388)	0,248145** (0,0203)	0,228041** (0,0426)
Unemployment Rate	0,238651* (0,0516)	0,263624** (0,0370)	0,244075* (0,0531)
Exchange Rate	-9.3E-05** (0,0115)	-0,000120*** (0,0079)	-0,000101** (0,0175)
Last Year's Inflation Rate (CPI)	0,333287 (0,1477)		0,359334 (0,1167)
Constant	0,013585** (0,0426)	0,025912*** (0,0001)	0,012285* (0,0503)
R^2	0,446908	0,365108	0,437393
Adjusted R^2	0,394075	0,306532	0,385485
Durbin Watson	2,101275	1,436609	2,106659

Note, P-values in parenthesis, significant levels: p*<0,1 p**<0,05 p*** < 0,01

Table 1 represents model 1 (2), with the inflation rate (CPI) as the dependent variable. The results are captured in three different regressions. Regression (1) is the primary regression for model 1, conducted to answer the hypotheses stated about the market. Regression (2) excludes last year's inflation rate as an explanatory variable, and regression (3) excludes the interaction variable. In line with hypothesis 1, the coefficient of net export is positive. Similarly, the direction of price comparison is in line with hypothesis 2. However, they do not show significance. It is therefore difficult to argue that there are significant relationships between the primary variables and inflation independently.

However, the interaction variable is significant. This means that there is a multiplicative effect between net export, price comparison, and exchange rate. Combining the hypotheses, a net exporting country with a low electricity price relative to the EU average will face a higher level of inflation. Also, by comparing the results in regression (1) with the ones in regression (3), it can be concluded that excluding the interaction variable leads to a worsening of the model fit in terms of the significance of the constant and R^2. R^2 and adjusted R^2 are both higher in regression (1) where the interaction variable is included, indicating that it does have explanatory power in the model.

When looking further into explanatory reasons for inflation through the model's control variables, the effect of last year's inflation rate is assessed. Regression (1) includes last year's inflation rate as an explanatory variable, while regression (2) excludes it. Although the variable does not show significance in regression (1), the fit of the model becomes worse in regression (2). In addition, the constant's impact on inflation grows bigger in regression (2), indicating that there are variables outside of the model explaining more of the change in inflation. Also, net export, price comparison and the dummy variable are all significant in regression (2), even though the overall fit reported as R^2 is worse. This indicates omitted variable bias, making the other independent variables less reliable. Looking at R^2 and adjusted R^2, the overall fit of the model is higher in regression (1) compared to regression (2), proving that last year's inflation rate does affect inflation. This aligns with the belief that last year's inflation rate should be included in the model since it is supposed to capture expectations and cycles within inflation.

Focusing on model 1 (2), regression (1) reports an R^2 of 44,6% and 39,4% adjusted for the number of variables. When focusing on one specific sector such as electricity, 39,4% explanatory power over the overall inflation rate is considered high. However, net export and price comparison which are directly connected to the electricity market, are both insignificant. Instead, the control variables included in the model are responsible for a large part of the high value of R^2. With that being said, there are factors outside of the model explaining the level of inflation which is further strengthened by the significance of the constant. As reported in Table 1, the constant is significant at a 5% level.

Furthermore, all other control variables are reported to impact inflation significantly. Exchange rate has a significant effect on a 1% level. Its coefficient suggests a negative relationship between the change in exchange rate and inflation. The model also captures that real GDP per capita growth and unemployment rate are significant at a 5% level. The relationship to inflation is positive for both variables, indicating that an increase in a variable leads to a higher rate of inflation. Looking at the dummy variable on the other hand, the results show that being a member of the EMU does not have a significant effect on a country's overall inflation rate.

Table 2: Regression Results of Model 2

Dependent Variable: Energy Price Inflation (CPI Energy)	(1)	(2)
Net Export *1000 kWh*	0,000692** (0,0241)	0,00079*** (0,0098)
Price Comparison *0,1 USD*	-0,024741* (0,0548)	-0,0211591* (0,0820)
Interaction Variable *1000 kWh*	0,000288** (0,0102)	
EMU Member *Dummy Variable*	-0,39736** (0,0254)	-0,039411** (0,0248)
Real GDP per Capita Growth	0,126844 (0,3146)	0,116369 (0,3430)
Unemployment Rate	0,396328** (0,0327)	0,404338** (0,0379)
Exchange Rate	0,00018 (0,2310)	0,00016 (0,2412)
Oil Price	0,002432*** (0,0000)	0,002448*** (0,0000)
Constant	0,051793*** (0,0005)	0,051406*** (0,0005)
R^2	0,643834	0,639
Adjusted R^2	0,608439	0,604352
Durbin Watson	2,411609	2,376354

Note, P-values in parenthesis, significant levels: p*<0,1 p**<0,05 p*** < 0,01

Table 2 represents model 2 (6), with energy price inflation as the dependent variable. The results are captured in two different regressions. Regression (1) is conducted to answer the hypotheses stated about the system. Regression (2) excludes the interaction variable, to evaluate its impact on energy price inflation. As the table presents, the three primary variables are significant at 10% respectively 5% levels and thus have a direct influence over energy price inflation.

The difference between the two regressions in model 2 (6) is the inclusion of the interaction variable. Since the interaction variable is significant at a 5% level in regression (1), excluding it from the model will mislead the results. It is therefore only excluded in regression (2) to allow for different interpretations regarding its effects on the model. In regression (2), the significance of net export increases from a 5% to a 1% level. In contrast, the primary variable price comparison is not similarly affected. Its significance level stays at 10% even after removing the interaction variable. However, its coefficient becomes smaller, and the variable has less influence on the results of regression (2).

Contrary to model 1 (2), where the removal of the interaction variable notably impacts the model fit, the change in model 2 (6) is relatively smaller. The removal of the interaction variable in model 2 (6) induces a less significant change in the constant. This suggests that the interaction variable has less explanatory power in model 2. This can also be observed in the R^2 value. When the interaction variable is removed in model 2, the change in R^2 is smaller.

Looking closer at the dummy variable in model 2 (6), the results report a negative relationship between an EMU membership to energy price inflation. It is significant on a 5% level in each regression. If a country within the European Electricity Market is a member of the EMU, energy price inflation will decrease, assuming all other factors remain constant. The results of model 2 in comparison to model 1 (2) indicate that the effect of being part of EMU has a greater influence on energy price inflation than on overall inflation in a country.

In contrast, real GDP per capita growth and exchange rate do not exhibit statistical significance in explaining energy price inflation. This suggests no linear relationship between these variables and energy price inflation. However, unemployment rate is significant at the 5% level. Similar to the results in model 1 (2), the sign of the coefficient is positive.

By comparing the models, model 1 (2) reports an R^2 of 44.6%, and model 2 (6) exhibits an R^2 of 64.3%. Both models demonstrate a high overall fit, indicating explanatory power. While the primary variables net export and price comparison only show significance in model 2, the interaction variable is significant in both models. Furthermore, being a member of the EMU shows a significant impact on energy price inflation. Nevertheless, exchange rate and real GDP per capita growth only exhibit significance in model 1, suggesting their greater relevance in explaining overall inflation rather than energy price inflation.

6. Discussion

Our findings indicate that while the hypotheses are supported in the context of energy price inflation, they do not hold for overall inflation. Regarding the research question *Does the European single-integrated Electricity Market impact the level of inflation in its net exporting member countries?*, the results on net export and price comparison are insignificant when looking at model 1 (2). In other words, no clear relationship is declared between either of these primary variables and a higher rate of inflation. However, the interaction variable is significant in both models, confirming the belief that there is a multiplicative effect of the variables in interplay. Also, both net export and price comparison are reported to have a significant impact on energy price inflation, as viewed in model 2 (6). From this, it can be concluded that the primary variables are more efficient in explaining the inflation in energy prices than in explaining overall.

The results for the primary variable net export differ between the two models. In model 1 (2), net export is not reported to have a significant impact on the level of inflation. This aligns with Kilian et al.'s (2023) conclusion that direct effects on overall inflation are limited due to electricity's small proportion in the consumer basket. However, it is significant in model 2 (6), which focuses on energy price inflation. The results of model 2 support hypothesis 1 in line with previous research (Dexter et al., 2005), that larger export quantities result in a higher level of energy price inflation. Therefore, being a net exporting country within the market does indirectly impact the overall inflation as energy price inflation is part of the consumer basket.

Similar to the results on net export, the results on price comparison also differ between the models. Hypothesis 2 stands true for price comparison and is significant in model 2 (6). This is due to its greater influence on energy price inflation. Expanding upon this, there is a multiplicative effect between these two primary variables and exchange rate. This effect is shown through the interaction variable, which holds significance in both models.

Table 3: Inflationary Effects of the Interaction Variable

Trading Status	Price Comparison	Exchange Rate	Effect on Inflation
Net Exporter +	(Low Relative Price -) -	Exchange Rate +	+
Net Exporter +	(High Relative Price +) -	Exchange Rate +	-
Net Importer -	(High Relative Price +) -	Exchange Rate +	+
Net Importer -	(Low Relative Price -) -	Exchange Rate +	-

Note, trading status is defined as whether a country is a net exporter or net importer in the European Electricity Market. The signs reflect the inflationary effect of the variables. The additional negative sign of Price Comparison variable is used to ensure that the coefficients are interpreted consistently.

The interaction variable covers both hypothesis 1 and 2, showing four different results depending on the country's trading status and electricity price relative to the EU average. The first case aligns with the hypotheses, as it describes a country which is a net exporter of electricity with a low price relative to the EU average. Consequently, it faces a higher rate of inflation. The low relative price can be traced to competitiveness and is common for net exporting countries within the European Electricity Market. Thus, it can be concluded that net exporting countries with low electricity prices relative to the EU average face a higher rate of inflation.

In the second case, the analysis focuses on a country that is a net exporter with a high relative electricity price. This country experiences a lower rate of inflation. This result can be explained by a greater demand abroad than domestically. Due to a high relative price on the domestic market, trade of electricity will curb inflation. Furthermore, Dexter et al. (2005) support that export prices do not directly affect a country's inflation rate. Consequently, a net exporting country with a high relative price will face a lower rate of inflation.

The third case contradicts hypothesis 2, which proposes that a net importer with high relative prices will face a lower rate of inflation. This turns out to be incorrect as the results indicate that a country which is a net importer of electricity and has a high relative price experiences a higher level of inflation. One possible explanation is that such a country might rely on imports due to inefficient or non-competitive domestic production, creating a higher level of inflation when its electricity demand exceeds local supply. This results in the need to import energy. Depending on the local currency's strength, this might lead to imported inflation.

The last case concerns a country which is a net importer of electricity, with a low relative price. This means that the country can produce at a low cost domestically, assuming high competitiveness. However, it is a net importer. A reason for this could be asynchronous demand. In accordance with De Cian et al. (2013), some countries experience seasonal variations in electricity demand. Therefore, even if a country can produce electricity cost-effectively, it may still rely on imports to meet domestic demand during periods when local supply falls short.

Linking these interactions to a broader economic framework, one important aspect to include is the Economic and Monetary Union and its expected impact on the level of inflation. In this light, examining the effect of an EMU membership through the dummy variable in our two models reveals different results. Model 1 (2), examining overall inflation, encompasses a wider range of global trade factors. Consequently, the results of this model indicate that an EMU membership does not significantly affect overall inflation. In contrast, model 2 (6) which focused on energy price inflation, demonstrates a notable impact of an EMU membership. The significance of model 2 is consistent with hypothesis 2, that countries tend to face a lower rate of inflation when electricity prices are relatively higher. This is assumed to be a consequence of a more stable and competitive currency over time.

Moving beyond the specific impact of EMU, there is a significance in the control variables which lies in their ability to capture broader economic changes. In opposition to the primary variables that are specific to the European Electricity Market, the control variables reflect the impact of the overall economy. In model 1 (2), the control variables exchange rate, real GDP per capita growth and unemployment rate are all significant, showing their role in explaining overall. However, neither exchange rate nor real GDP per capita growth show significant effects in model 2 (6). This suggests that electricity demand is relatively inelastic; consumers and businesses tend to purchase electricity even at higher prices, indicating that broader economic conditions are less influential in determining electricity demand. Hence, the variables are better at explaining the changes in overall inflation than energy price inflation.

Furthermore, unemployment rate is reported to have a positive relationship with inflation, in both models. The results contradict our expectations and deviate from the macroeconomic theory on the Phillips curve (Phillips 1958 cited in Burda & Wyplosz, 2017). This can be explained by the specific time interval studied, marked by low inflation and overall favourable economic conditions. Another reasonable alternative can be tracked to the choice of lags in the data. Since unemployment is strongly dependent on wages decided on in contracts, they change at a slower pace than prices (Burda & Wyplosz, 2017; Reinbold et al., 2020). Unemployment is therefore expected to impact inflation after a longer period.

Contrary to the unemployment rate, oil prices are expected to affect energy price inflation immediately. When looking at overall inflation, the production through different energy sources is assumed to show through the primary variables of net export and price comparison. Nevertheless, the inclusion of oil prices in model 2 (6) is necessary, given its immediate impact on energy price inflation. In model 2, it is significant at a 1% level. It is therefore important to acknowledge that there could be other variables not included in the model that also explain energy price inflation. For instance, the differences in energy sources. This is particularly relevant in current discussions about electricity and inflation, where understanding the causative factors is key to formulating effective policies.

Lastly, the chosen period for the study represents a relatively stable phase in terms of inflation. This limitation, while acknowledged, is considered appropriate given the comprehensive coverage of available data from the market's opening. Future research could explore extended periods to further validate the findings. For example, the EU's work for energy independence has notably intensified after the Russian invasion of Ukraine in 2022 (World Economic Forum, 2023). This recent development underscores the potential impact of geopolitical events on energy markets. Therefore, by incorporating different periods, further research can examine the implications of such significant events on the electricity market.

7. Conclusion

In conclusion, this study sheds light on the European single-integrated Electricity Market. More specifically, the impact of the market's inflationary effects on its member countries is being assessed. In times when electricity and inflation are widely discussed, it is essential to investigate factors that may lead to higher levels of inflation. We have identified a gap in research, and besides answering our research question, also come up with potential areas of study for the near future.

Through a panel data regression model with fixed effects estimators, we have found an answer to the research question *Does the European single-integrated Electricity Market impact the level of inflation in its net exporting member countries?*. Model 1 (2) examines factors influencing overall inflation, while model 2 (6) specifically focuses on energy price inflation. The primary variables included are net export, price comparison and an interaction variable. Gaining a nuanced understanding of the direct and indirect impact of the market is essential for effective policymaking. Our findings indicate that while the hypotheses are supported in the context of energy price inflation, they do not hold for overall inflation. Answering the research question, the European Electricity Market has an indirect effect on overall inflation, through energy price inflation.

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Appendix

Countries included in the study:

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom.