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Beyond inflation: The impact of energy prices on non-performing loans in the EU

Poza inflacją: wpływ cen energii na poziom kredytów zagrożonych w UE

Keywords:
Non-Performing Loans, NPL, energy prices, renewable energy, ARDL panel model

Abstract: This article analyses the level of non-performing loans (NPLs) in the European Union (EU) countries between 2014 and 2022, taking into account both standard and new proposals for variables such as energy prices. Using the econometric ARDL panel model, the traditionally used inflation indicators were replaced with a proposed energy price indicator, including normalised oil, natural gas, coal and CO_2 emission allowance (ETS) prices. The model results suggest that the energy price index can provide more valuable information about the level of NPLs than traditional inflation measures such as the HICP. In addition, a preliminary study of the impact of the share of renewable energy on the level of NPLs has shown that countries with a higher share of renewable energy are less susceptible to fluctuations in energy prices, which ultimately positively impacts financial stability. The results indicate that an in-depth energy market analysis can significantly enrich the understanding of financial stability in the context of the level of non-performing loans (NPLs).

Słowa kluczowe:
kredyty zagrożone, NPL, ceny energii, energia odnawialna, model panelowy ARDL

Streszczenie: Niniejszy artykuł analizuje poziom kredytów zagrożonych (Non-Performing Loans, NPL) w krajach Unii Europejskiej (UE) w latach 2014–2022, uwzględniając zarówno standardowe, jak nowe propozycje zmiennych, takich jak ceny energii. Wykorzystując ekonometryczny panelowy model ARDL, tradycyjnie stosowane wskaźniki inflacji zastąpiono propozycją wskaźnika cen energii, obejmującym znormalizowane ceny ropy naftowej, gazu ziemnego, węgla oraz uprawnień do emisji CO_2 (ETS). Wyniki modelu sugerują, że objaśniając poziom NPL wskaźnik cen energii może dostarczać bardziej wartościowych informacji niż klasyczne miary inflacji, takie jak HICP. Dodatkowo wstępne badanie wpływu udziału energii odnawialnej na poziom NPL wskazało, że państwa o wyższym udziale energii odnawialnej są mniej podatne na wahania cen energii, co ostatecznie pozytywnie wpływa na stabilność finansową. Wyniki wskazują, że dogłębna analiza rynku energii może istotnie wzbogacić rozumienie stabilności finansowej w kontekście poziomu kredytów zagrożonych (NPL).

JEL:
C3, C33, G21, E66, Q43

Introduction

Importance of NPLs in the context of financial stability

Bank non-performing loans are commonly considered an essential financial stability determinant or even financial stability measure [Morgan, Pontines, 2018; Zhang et al., 2018; Węgrzyn, Topczewska, 2023]. These problematic loans – sometimes called "financial pollution" [Manz, 2019] – have profound implications on microeconomic and macroeconomic levels, affecting individual banks and the broader financial system. From a microeconomic perspective, the decline of non-performing loans reduces risk and enhances banks' profitability. Moreover, an upsurge in NPLs forces banks to make provisions to cover potential losses, reducing the funds available for profitable lending and detreating particular banks' capital ratios [Arnaboldi, 2020]. This reduction can stifle economic growth as companies find it more challenging to obtain necessary financing for investment. When loans given out are not recovered together with interest, it implies that more resources will need to be committed towards provision for non-performing loans, and additional costs have to be used in financing recovery efforts. These costs and provisions consume a considerable portion of financial institutions' profits, thereby deteriorating their economic performance [Ntoiti, Jagongo, 2021].

Furthermore, from a macroeconomic perspective, high NPLs can pose a systemic risk to the financial system. If one bank fails due to high NPLs, it can lead to a domino effect, causing other banks to fall and potentially leading to a financial crisis. Nkusu [2011] points out that NPL growth can lead to an adverse spiral, with negative effects on the macroeconomic dynamics, followed by a further deterioration in the banking system. High NPLs can also negatively affect economic growth by reducing lending and undermining confidence (for banks and non-financial companies). They can make financial crises more likely and severe, impacting the world economy. According to Reinhart and Rogoff [2010], NPLs can be used to mark the beginning of banking and macroeconomy crises. The investigation of NPLs' determinants is of primary interest for quantitative financial stability analysis and macro-prudential policy design [Vouldis, Louzis 2018].

The critical role of the level of NPLs from the perspective of individual banking institutions and the financial system as a whole or even the development of the economy makes research in this area valuable. Such research can cover the channels of influence of NPLs on the level of financial stability or economic growth, as well as the factors that shape the level of NPLs. In this article, we have addressed the topic of research into the factors influencing the NPLS by identifying a new variable (or rather a group of variables from the energy area) that may affect the amount of non-performing loans and, thus, the financial stability in the analysed UE countries.

Macroeconomic factors influencing the NPLs – a literature review

The level of NPLs can be affected by both bank-specific as well as macroeconomic variables [Amuakwa-Mensah, Boakye-Adjei, 2014]. According to bank-specific variables, Klein [2013] shows that equity-to-asset ratio and return on equity (REO) negatively correlate with NPLs, while excessive lending leads to higher NPLs. However, Messai and Jouini [2013] find no relationship between bank lending and NPLs. Koju et al. [2018] show that bank-specific variables such as asset size and capital adequacy can have a significant relationship with the NPLs.

Although researchers often use both categories of explanatory variables in empirical studies, greater weight is given to macroeconomic variables. As Louzis et al. [2012] dynamic panel data methods show, for all loan categories (e.g. consumer loans, business loans and mortgages) NPLs can be explained mainly by macroeconomic variables (such as GDP change, unemployment, interest rates and public debt). Charalambakis et al. [2017] find that bank-specific variables associated with bank capitalisation and liquidity risk determine NPLs only under normal economic conditions. Thus, NPLs can be mainly attributed to macroeconomic deterioration. As a systematic literature review conducted by Manz [2019] shows, the macroeconomic environment is still the most significant determinant of loan performance and thus, macroeconomic variables can also be considered crucial.

Most studies highlight the relevance of the macroeconomic environment and lending standards in explaining the quality of banking loans for both developed and emerging economies. Even though the impact seems to differ in amplitude, the results point in the same direction: decreasing or slower economic growth, high unemployment, a depreciation of the local currency or an increase in costs can lead to higher NPLs [Tatarci et al., 2020]. The relationship between NPLs and macroeconomic factors was extensively studied in the literature, starting from the underlying assumption of the pro-cyclicality of the financial system. Beck et al. [2013] econometric analysis across 75 countries suggests that real GDP is the primary driver of NPLs. Also, Kuzucu and Kuzucu [2019] research shows that real GDP growth is the primary determinant affecting the NPL ratio (in the pre- and post-crisis period). Therefore, a drop in global economic activity remains the most critical risk for banks' asset quality, and the level of NPL is influenced by macroeconomic factors such as the rate of economic growth (measured by the change in GDP) or the level of unemployment. An increase in GDP influences a decrease in NPL levels, and an increase in unemployment levels affects an increase in NPL levels [Ghosh, 2015]. Espinoza and Prasad [2010] investigated the determinants of NPLs for 80 countries from 1995–2008. They found that slow economic growth, high interest rates and risk aversion, and previous credit dynamics contribute to increases in NPL ratios. Also, Klein [2013] evaluated the NPL dynamics for the top 10 banks in 16 countries in CESEE Central, Eastern and Southeastern Europe) from 1998 to 2011. He showed that the higher unemployment rate, currency depreciation and inflation increase the NPL ratios.

Several studies attempted to identify the existence of a causality effect between inflation and NPLs. Nevertheless, no consensus has been achieved [Naili, Lahrichi, 2022; Amuakwa-Mensah et al., 2017]. For example, some quantitative studies prove that an increase in inflation influences an increase in NPL levels [Ghosh, 2015; Gulati et al., 2019], while other studies show that this influence is the opposite and the relationship between inflation and NPLs is negative [Makri et al., 2014; Nkusu, 2011]. The negative relationship between inflation and NPLs is explained that higher inflation decreases the value of outstanding debts, which improves the repayment capacity of households and firms [Nkusu, 2011]. Moreover, inflation is also connected with increased labour wages, which allows the sustainability of repayments [Naili, Lahrichi, 2022]. Some other studies show that borrowers are more challenged to repay their debts under inflationary conditions, especially with variable interest rates loans [Jabbouri, Naili, 2019]. On the other hand, authors such as Tanasković and Jandrić [2015] and Peric and Konjusak [2017], in research conducted on selected EU countries, investigated the absence of a significant relationship between inflation and NPLs. Also, research by Kartal et al. [2023] shows that inflation is not statistically significant in explaining the NPL level. As Naili and Lahrichi [2022] indicated, these opposing results require further profound research.

Furthermore, considering the strong correlation between inflation and interest rates, some quantitative models can not include both variables. This is because econometrics models assume that the explanatory variables should not be significantly correlated. Due to the clear positive relationship between interest rates and NPLs, interest rates become a more appropriate variable to explain NPLs level. Another solution to address the strong correlation between inflation and interest rates issue is to calculate and use in the model real interest rates (i.e. market interest rates minus inflation).

In the literature, have NPL been widely discussed in recent years, especially in the field of non-performing loans determinants, where many authors have obtained similar results [Cucinelli, 2015; Azeem et al., 2017; Vouldis, Louzis, 2018; Kuzucu, Kuzucu, 2019]. Nevertheless, according to Manz [2019], the literature still needs interdisciplinary research, especially in economics and law. In response, we propose an interdisciplinary approach to studying NPL levels. This approach, however, combines not the areas of economics and law (as suggested by Manz) but economics and environmental science.

The importance of energy and its impact on NPLs

Energy is the basis for the development of modern economies. Energy is still a factor determining the scope and pace of changes in the structure of national economies [Sharma, 2010]. Access to primary energy sources still significantly determines the shape of the energy mix and, above all, the cost of producing secondary energy: electricity, heat/cold or mechanical energy. Energy availability and prices are critical economic development stimuli along different development stages [Toman, Jemelkova, 2003; Kecek, 2023]. This is ultimately reflected not only in the quality of life and functioning in a specific geographical space but also determines the possibility of introducing qualitative and quantitative changes in the sectors of the economy [Mróz et al., 2022].

Since most EU countries do not have significant natural resources, it is necessary to import them [European Commission, 2022]. In particular, this applies to fossil fuels, such as crude oil, natural gas and coal, which are still crucial for EU economies[1]. The cost of obtaining these fossil fuels, as well as the not very diverse type structure of the hydrocarbons used, together with the low (sometimes even marginal) share of other energy sources, determine the environment that allows the formation of the so-called cost inflation [ECB, 2022]. The essence of this type of inflation consists of a general price increase due to an increase in raw materials, particularly fossil fuels. An increase in the prices of primary energy carriers, such as crude oil or natural gas, quite often causes a very violent reaction in the economies of energy importers, like UE countries. This is a consequence of the impact of secondary energy prices on the production of every good and service today and the critical role of transport costs. The level of sensitivity of the economy to price changes is, therefore, a function of the degree of dependence on a given hydrocarbon, the import of a given energy resource, and the structure of the energy mix. Therefore, the issue of vulnerability of the EU economies to changes in the volume of primary/secondary energy supplied/produced and the reaction to price

[1] For countries lacking natural resources, there is a growing dependence of economic development on access to energy. Moreover, these countries have a significant vulnerability to the negative effects of the increase in the prices of imported energy resources.

fluctuations causing the inflationary process to require not only an assessment but also finding an answer to the question of how to prevent such phenomena.

Energy is a fundamental development factor in nearly all sectors of the economy [Mróz, 2021]. As energy prices rise, business production costs increase, potentially reducing profitability and the ability to repay debts, thereby increasing NPLs. Also, for households, higher energy prices mean an increased cost of living, including food prices [Irz et al., 2013]. This can reduce the ability of consumers to service their debts and contribute to higher NPLs. As Breitenfellner [et al., 2015] results show, rising energy prices increase the probability of house price corrections, which reduces the value of banks' collateral for the financing provided. Through these channels, energy prices have a direct impact on the NPL levels for enterprises and households. Unlike inflation indicators, such as the Consumer Price Index (CPI) or Harmonised Index of Consumer Prices (HICP), which covers a broad spectrum of goods and services, the energy price could provide a clearer perspective on default risk.

Increases in energy prices affect the various sectors of the economy in specific ways, causing an increase in costs for most sectors (incredibly energy-intensive ones). On the other hand, higher energy prices imply an increase in revenues for commodity players. This distinction makes it possible to examine NPLs more accurately on a per-sector basis (in terms of business loans). Furthermore, energy prices are often more volatile than general inflation, meaning that rapid increases could lead to sudden strains on borrowers, potentially leading to increases in NPLs. This could help in the timely identification of potential risks of possible growth in NPL levels and, in a better, more flexible way, explain this financial variable. In the context of geopolitical developments, this was confirmed by the war in Ukraine, which started in 2022 and resulted in a sharp increase in the price of energy raw materials and, thus, an increase in energy prices in EU countries.

Moreover, we see another significant argument that supports the inclusion of the energy price, rather than inflation, in studies concerning the level of Non-Performing Loans (NPLs). The confirmation of a significant impact of energy prices, particularly electricity, on the level of NPLs in the banking sector provides a foundation to assert that influencing (e.g., by governments) energy prices can affect the financial stability of a country. The Emissions Trading Scheme (ETS) could execute this energy price intervention. In the case of inflation, such government intervention may not yield the anticipated results. This is primarily because, as other empirical research outcomes indicate, the impact of inflation on the level of NPLs is not unambiguous. Secondly, the primary tool influencing its status is monetary policy (including the regulation of interest rates), whose increase has a decidedly negative impact on the level of loan repayment by raising the financing costs for households and businesses (especially in countries where loans are primarily based on a variable interest rate, e.g. in Poland).

The Nugroho and Endri [2022] study included oil prices as a determinant for NPLs in Indonesia. However, the reason for the oil prices in the model was that Indonesia is an oil-exporting country. Thus, price increases will directly increase rea national income through an increase in the export value. Nevertheless, this study has shown that oil prices positively and significantly affected NPLs. Interestingly, in this same study, inflation had a negative and insignificant effect on NPLs. Breitenfellner [et al., 2015] results convince us that energy price should be a leading indicator for analysing macro-financial risk.

Based on that, we assume energy prices can be used in NPL quantitative models as alternative price levels instead of HICP or other inflation rates. A systematic literature review shows this approach was uncommon in NPL studies [Manz, 2019; Naili, Lahrichi, 2022].

Data and methods

Data and sample

The main objective of this study is to analyse the relationship between the NPLs (Non-Performing Loans as % of total gross loans and advances)[2] and energy index including fossil fuels like crude oil, natural gas and coal (all of these in current USD) and ETS (current EUR per ton of CO_2 emission), as well as relationship between the NPLs and share of energy from renewable sources. Control variables such as unemployment (as a percentage of the labour force) and GDP growth (percentage change compared to the same period in the previous year) were chosen due to investigate the strong influence on NPLs in EU countries [Louzis et al., 2012; Dimitrios et al., 2016].

In the first step, the normalisation procedure was applied to the prices of oil, natural gas, coal and ETS to calculate the energy index, transforming their values to fall within the [0,1] range. This transformation, also known as min-max normalisation, re-scales the values of the variables, bringing them into a standard range without distorting differences in the range of values or losing information. Normalisation was computed as below:

$$normalized\ \ value = \frac{current\ \ value - \min value}{\max value - \min value} \tag{1}$$

where:
Current value refers to the specific data point of variable in particular period,

2 We define non-performing loans as those loans in the portfolio that are over 90 days overdue on interest or principal repayments.

min *value* correspond to the minimum observed values of variable,
max *value* correspond to the maximum observed values of variable.

In the next step, an energy price index was calculated using a weighted average approach. The Normalised indices were assigned equal weights (0.25). This procedure allows for a relative comparison of the four variables, taking into account their Normalised values. This energy price index, therefore, gives an averaged view of the energy prices, allowing for comparability over time and providing a unified measure of the changes in the prices of these commodities and ETS. The energy price index was computed as:

$$\begin{aligned} &Energy\ price\ index = \\ &= 0.25(Normalized\ Oil\ Price) + 0.25(Normalized\ Gas\ Price) \\ &+ 0.25(Normalized\ Coal\ Price) + 0.25(Normalized\ ETS\ Price) \end{aligned} \tag{2}$$

The structure of the energy mix varies significantly across countries in the region, making it difficult to apply a differentiated approach. Some countries remain heavily dependent on fossil fuels, while others have made significant progress in transitioning toward renewable energy sources. Given this heterogeneity, equal weights (0.25) were assigned to three primary energy carriers – crude oil, natural gas, and coal – along with the price of CO_2 emission allowances (ETS) to ensure a neutral and balanced representation of energy-related costs in the EU.

This index provides a comprehensive measure of energy commodity price fluctuations, capturing their relative changes over time. The applied normalisation and subsequent averaging serve as valuable tools for tracking energy price trends and ensuring comparability across countries with diverse energy mix structures. The inclusion of ETS is justified by its significant impact on the cost of fossil fuel-based energy production, which indirectly influences overall energy prices in the region. Additionally, we used Eurostat's data about the share of fossil fuels in gross available energy (as %) and the share of energy from renewable sources (%) to check the robustness of the results. As seen in Table 1, we used these variables, and other control variables[3], for all UE-27 countries with quarterly data for the 4Q 2014–4Q 2022 period and yearly data for the 2014–2021 period, in case of the (1) and (2) model respectively (both models presented in methods and models subsection).

Concerning the explanatory variable (NPLs), it is worth emphasizing that its level varies widely across EU countries. A feature common to all countries surveyed is a marked decline in the level of NPLs between 2014 and 2022. In 2014 economies were

[3] Due to the non-stationarity of interest rate level variables and interest rate benchmarks across EU countries (also after first- and second-stage differentiation), these relevant variables were not included in the model as a control variable.

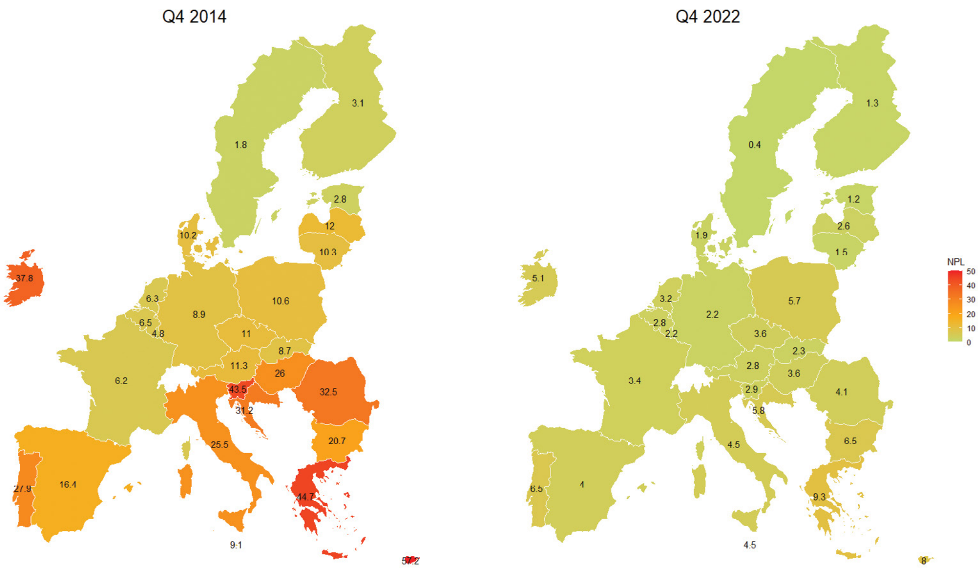
experiencing relatively high levels of NPLs through the 2007–2012 financial crisis. At the end of 2022, the level of NPLs in the EU ranged from 0.4% in Sweden to 9.3% in Greece (Graph 1).

Table 1. Data details

Description	Source	Variables	Period
Gross non-performing loans and advances [% of total gross loans and advances]	World Bank database	*NPL*	4Q 2014–4Q 2022
Unemployment [%]	Eurostat database	*UNEMP*	
Harmonised Indices of Consumer Prices [% change compared to same period in previous year]	Eurostat database	*HICP*	
Gross Domestic Product [% change compared to same period in previous year]	Eurostat database	*GDP*	
Crude oil [USD per bbl]	EIA database	*ENER*	
Natural Gas [USD per million Btu]	EIA database		
Coal [USD per ton]	EIA database		
ETS [EUR per ton of CO_2]	Reuters		
Share of fossil fuels in gross available energy [%]	Eurostat database	*Share of FF*	2014–2021
Share of energy from renewable sources [%]	Eurostat database	*Share of RE*	2014–2021

Source: own elaboration.

Graph 1. NPL ratio in EU countries in Q4 2014 and Q4 2022

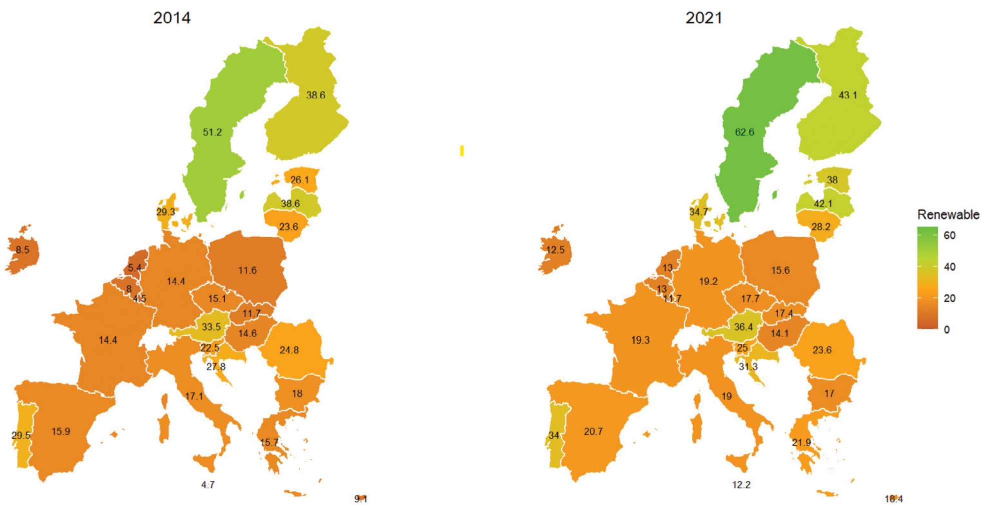


Source: own elaboration in R.

On the other hand, the UE countries are also characterized by a large energy mix diversification. While the CEE (Central and Eastern Europe) countries still strongly use fossil fuels and have a small share of renewable energy, in Northern European countries (especially in the case of Sweden and Finland with RES levels of 62.6% and 43.1% respectively, as well as in Latvia (42.1% of RES) and Estonia (38% of RES)) the share of renewable energy sources is much higher (Graph 2). Therefore, countries based on hydrocarbons need a relatively quick energy transformation to catch up with the leading ones.

However, the long-standing architecture of oil and gas pipelines determined the long-standing deep dependence on supplies of Russian fossil fuels, especially in the case of Central and Eastern Europe. Countries such as Estonia, Lithuania, Latvia and Slovakia were still 100% dependent on Russian gas in 2013 and mainly depended on Russian oil. However, the dynamics of change are emerging. The aspirations of EU countries for climate neutrality are possible not only thanks to RES but to a large extent thanks to investments in nuclear energy. Its most prominent supporter is the Czech Republic, which currently has six nuclear reactors, generating more than a third of the electricity it uses. The use of nuclear power, supplementing the developed RES infrastructure, could help in the gentlest possible way in going through the process of full energy transformation, also in the case of Poland[4].

Graph 2. Share of energy from renewable sources (%) in EU countries in 2014 and 2021



Source: own elaboration in R.

4 In the REPowerEU program announced by the European Commission, which is intended to help the European Union move away from Russian fossil fuels and support a just transition, nuclear power is mentioned as one of the basic tools for quickly becoming independent from imports of raw materials from the East.

Even though energy transformation is becoming the main topic of contemporary debates in EU countries, both the paths of energy transformation in individual Member States and the pace of planned changes differ significantly. However, all EU countries seem to be aware of the fact that the energy transition, which in essence means a profound transformation of energy markets consisting of a gradual shift away from conventional energy sources to renewable or low- or zero-carbon ones, will generate more costs due to the greater use of fossil fuels and more outdated energy systems. However, the high dependence of economies on imports of energy resources, which has been maintained for years, determines the high risk of their shortages and the increase in energy prices in the EU[5].

What is equally important is that changing energy carriers from hydrocarbons to low-emission ones will also be an impulse for the expected changes in technologies, taking into account a higher level of energy efficiency and equipment efficiency. Therefore, there is the conclusion that this transformation directly affects the entire economy, not just the energy sector.

Methods and models

Following Fogila [2022], Nikolaidou and Vogiazas [2013; 2014], Solarin et al. [2011], and Zheng et al. [2020], we use the ARDL model to study NPL determinants. We investigate the long-run relationship between panel data and the models. The first model (1) includes the energy price index as an explanatory variable, and the second model (2) includes inflation, expressed by the HICP, instead of the energy price index. This approach makes it possible to compare the results of the two models and assess the relevance and impact of the particular variables on the level of NPLs. Models take the following form:

$$NPL = f\,(UNEMPL,\ GDP,\ ENER\,/\,HICP) \tag{3}$$

where:
NPL means non-performing loans,
UNEMP is the unemployment rate,
GDP is the percentage GDP change compared to the same period in the previous year (seasonally and calendar adjusted),
ENER is the energy basket contains normalised series of crude oil, natural gas, coal and ETS prices, and
HICP is the Harmonised Indices of Consumer Prices.

5 The price of fuels in the EU has risen due to Russia's aggression against Ukraine, which has also led to concerns about the energy supply's security [European Council, 2022].

Secondly, we proposed an additional model (3) for checking the robustness of the results and to assess whether the level of NPLs can be explained by the type of energy used in the country, split between energy from renewable sources and fossil fuels:

$$NPL = f(\textit{Share of FF}, \textit{Share of RE}) \tag{4}$$

where:
Share of FF means the share of fossil fuels in gross available energy.
and
Share of RE means the share of energy from renewable sources[6].

The choice of the appropriate model in both cases above will be made after an analysis of the characteristics of the data. Therefore, Dickey Fuller [1979], Phillips and Perron [1988], and Levin et al. [2002] unit root tests were used to test the integration order of the variables. Pedroni Residual Cointegration test [1999; 2000; 2001; 2004] was also used to investigate the long-run relationship in panel data. In order to choose the best estimator for the model, we employed the Hausmann test to check whether the fixed effects model or the random effects model is appropriate.

Panel Autoregressive distributed lag (ARDL) approach was used to reveal the long- and short-run impact of the share of fossil fuels in gross available energy and the share of energy from renewable sources on the NPL level in all UE-27 countries. We assumed that growing renewables in the energy mix of these countries should Granger cause of NPLs decline. In other words, it can be expected that the direct impact of the price of fossil fuels on NPLs should be quite effectively limited. Moreover, to address potential endogeneity issues that may arise due to reverse causality or omitted variable bias, we rely on the ARDL panel model's ability to capture both short- and long-run dynamics.

Both (1), (2) and (3) models have panel ARDL representations:

$$\Delta NPL_{it} = \sum_{k=1}^{p-1} \lambda_{ik} \Delta NPL_{i,\,t-k} + \sum_{k=0}^{q-1} \delta'_{ik} \Delta x_{i,t-k} + \varphi_i \left(NPL_{i,\,t-1} + \beta'_i X_{it} \right) + \omega_t + \varepsilon_{it}, \tag{5}$$

where:
Δ denotes the difference operator,
X is the vector of explanatory variables,
φ_i is the group-specific speed of adjustment coefficient (expected that $\varphi_i < 0$),
β'_i are our vector of interest, which measures the long run impact of the explanatory variables on the NPL,

[6] The indicator measures the share of renewable energy consumption in gross final energy consumption according to the Renewable Energy Directive. The gross final energy consumption is the energy used by end-consumers (final energy consumption) plus grid losses and self-consumption of power plants (Eurostat database).

λ_{ik}, δ'_{ik} are the short run dynamic coefficients,
p et q are optimal lag orders,
ω_t is the constant, and
ε_{it} is the error term;
and

1) where the subscript i (i = 1,…, N) denotes the country i in our sample; N being equal to 27. t (t = 1,…, T) indicates the time period: quarter. Our panel has 27 countries and 33 quarters (Q3 2014 – Q4 2022), so it has more quarters (T) than countries (N), and therefore we assumed heterogeneous dynamic panel data modelling with a long panel.

or

2) where the subscript i (i = 1,…, N) denotes the country i in our sample; N being equal to 27. t (t = 1,…, T) indicates the time period: year. Our panel has 27 countries and only eight years (2014–2021), so it has fewer years (T) than countries (N), and therefore, we assumed dynamic panel data modelling based on a short panel.

Table 2. Panel ARDL model estimations – model (1)

Variable	Coefficient	Std. Error	t-Statistics	P-value
Long-Run equations				
UNEMP	0.658707	0.054215	12.14999	0.0000
GDP	–0.049747	0.019288	–2.579173	0.0101
ENERGY	1.737960	0.329757	5.270428	0.0000
Short-Run equations				
Cointeg	–0.183234	0.036392	–5.034975	0.0000
D (UNEMP)	0.013949	0.082008	0.170089	0.8650
D (GDP)	–0.000392	0.004168	–0.093989	0.9251
D (ENER)	–0.476166	0.264588	–1.799652	0.0723
C	1.882798	0.819297	2.298066	0.0218
TREND	–0.074323	0.027401	–2.712413	0.0068
Statistics				
Mean dependen var	–0.385409	S.D. dependent var		1.945812
S.E. of regression	0.787331	Akaike info Criterion		1.407570
SUM of squared resid	450.0398	Schwarz criterion		2.295041
Log likelihood	–462.0724	Hannan-Quinn criterion		1.746754

Source: own elaboration.

Table 3. Panel ARDL model estimations – model (2)

Variable	Coefficient	Std. Error	t-Statistics	P-value
Long-Run equations				
UNEMP	0.460702	0.043996	10.47146	0.0000
GDP	–0.051768	0.017191	0.017191	0.0027
HICP	0.030151	0.016301	1.849621	0.0648
Short-Run equations				
Cointeg	–0.207485	0.032206	–6.442375	0.0000
D (UNEMP)	–0.11259	0.896365	–0.137951	0.8903
D (GDP)	0.002366	0.004528	0.522684	0.6014
D (HICP)	–0.034834	0.035634	–0.977531	0.3286
C	2.245373	0.896365	2.504976	0.0125
TREND	–0.073101	0.029601	–2.469565	0.0138
Statistics				
Mean dependen var	–0.385409	S.D. dependent var		1.945812
S.E. of regression	0.780326	Akaike info Criterion		1.356435
SUM of squared resid	442.0672	Schwarz criterion		2.243906
Log likelihood	–439.2918	Hannan-Quinn criterion		1.695619

Source: own elaboration.

Table 4. Panel ARDL model estimations – model (3)

Variable	Coefficient	Std. Error	t-Statistics	P-value
Long-Run equations				
Share of FF	0.032468	0.00430	7.012262	0.0000
Share of RE	–0.056366	0.018782	–3.001079	0.0034
Short-Run equations				
Cointeg	–0.287550	0.090834	–3.165654	0.0020
D (Share of RE)	0.281794	0.258038	1.092066	0.2773
D (Share of FF)	0.267217	0.193295	1.382427	0.1697
C	–1.476670	1.217805	–1.212567	0.2280
Statistics				
Mean dependen var	–1.909959	S.D. dependent var		2.982549
S.E. of regression	1.758754	Akaike info Criterion		2.384430
SUM of squared resid	327.8809	Schwarz criterion		4.103322
Log likelihood	–147.5184	Hannan-Quinn criterion		3.078866

Source: own elaboration.

Moreover, descriptive statistics for all variables used in the econometric models (see Table A1 and B1), and panel data unit root tests (see Table A2 and B2), are included in the Appendix. Model 3 has been presented in a simplified form, without a trend and any control variables used in Models 2 and 3. The main purpose is to verify the results from the other two models and assess their stability in the context of the key relationships.

Results and discussion

Impact of Energy Price Index on NPLs and comparison with traditional inflation indices

Our research evaluated the effects of the calculated energy price index on Non-Performing Loans (NPLs). It has been demonstrably established that energy price dynamics significantly influence the level of NPLs across European Union member states. Notably, a distinct, statistically significant, long-term causal relationship has been identified between the energy price index and NPL levels in the EU-27 region. An increase of 1% in the energy index corresponds to a 1.738% rise in NPLs, whereas a similar 1% increment in unemployment or GDP incites changes in NPLs by 0.659% and –0.05%, respectively (see Table 2).

Moreover, as illustrated by our second model, within the identical temporal bracket and geographical region (EU-27), the Harmonised Index of Consumer Prices (HICP) inflation is statistically insignificant at 0.05 (see Table 3). Additionally, it is worth noting that even at an expanded significance level (0.1), the influence of HICP on NPLs remained barely perceptible. A 1% upswing in HICP resulted in a negligible 0.03% increase in the NPLs level, making inflation a less important variable than the energy price index.

In both models, there are the error correction coefficient values (speed of adjustment) negative and significant, which means that about 0.05% (in case of (1)) and 0.29% (in case of (2)) of departures from long-run equilibrium is corrected each period (quarter and year, respectively). Therefore, we also conclude that variables are cointegrated and regressors jointly Granger-cause NPLs in the long run. The order of magnitude of the directional coefficients of the explanatory variables tested (change in GDP, unemployment and inflation) is consistent with other empirical results [Makri et al., 2014], although it is noteworthy that many models find that the change in GDP affects the level of NPL to a greater extent [Messai, Jouini, 2013; Golitsis et al., 2022]. Nevertheless, it must be taken into account that the strength of the impact of individual variables is influenced not only by the type of econometric model used[7] but also by the time

[7] For example, in ARDL models, exogenous variables affect the endogenous variable in the long and short term as well.

horizon adopted and the geographical area of the study. In addition, the directional coefficients of the explanatory variables turned out to be in line with the expectations (the only uncertainty was the inflation coefficient, which, depending on the research, had both a negative and a positive value).

Our empirical findings collectively articulate a crucial aspect: energy price indices offer a more precise and reliable predictive variable than traditional inflation indices in modelling NPLs. Compared with conventional inflation, energy prices' verifiable long-term causal impact on NPL levels underscores the potential advantage of integrating energy price indices into economic modelling. This lends credence to the approach that recommends the incorporation of more nuanced and sector-specific economic variables, such as energy prices, into economic models as opposed to generic variables like inflation.

A few reasons explain why energy prices can be a more precise and reliable NPL determinant than inflation. First, it could be explained by an extensive basket of goods and services in HICP that do not have much in common with NPLs, as opposed to energy prices. Some components of HICP, such as clothing prices, may not significantly impact loan repayments. Consumers have more discretion in these areas and can reduce their expenditures when prices rise. This is not the case for energy prices, as energy is necessary – the share of energy prices in production and services is high. This is also of great importance in the context of corporate loans. Moreover, considering that the energy price index has far fewer components than the HICP, its construction is more straightforward and understandable.

In addition, as can be seen from the construction and components of inflation (HICP), energy prices are often 'ahead of inflation', which is derived from energy prices. This was demonstrated, for example, by the increase in energy prices on world markets in 2022, as a result of the unjustified aggression of the Russian Federation against Ukraine and the consequences of this. Moreover, changes in energy prices are a global phenomenon – unlike the level of inflation, which can (and in practice does) vary widely from country to country – making energy prices better able to anticipate global financial crises resulting from increases in NPLs.

However, the question becomes reasonable: 'energy prices beyond inflation, or energy prices alongside inflation'? In response, from a research methodology perspective, there is no justification for including both the energy price and the level of inflation in the study due to the relatively high correlation coefficient between these variables. For the period Q4 2014 to Q4 2022, the Pearson correlation coefficient was above 0.85 (see Table C1). This stems from the fact that energy prices are a significant inflationary factor affecting production costs. Thus, energy prices often influence the general level of prices in an economy, contributing to inflation.

Finally, in our view, energy prices may also reflect changes in environmental awareness and climate policy. Thus – in the context of individual countries – changes in energy prices may be associated with changes in the structure of the energy mix, e.g. through the transition to a low-carbon economy with a high share of renewable energy sources. This area of our investigation will be explored in more depth in the following subsection.

Influence of Renewable Energy Share on NPLs

To assess the impact of renewable energy share on NPLs, valuable conclusions can be drawn from the model (3). There is the conclusion that if the share of fossil fuels rises by 1%, the NPLs rise by 0.03%, while the increase in renewable sources in the energy mix by 1% Granger causes a decrease in NPL level by 0.057% (see Table 4). Despite the low values of the directional coefficients for the explanatory variables in this model, it is essential that our research suggests that a more balanced energy mix can have a positive impact on credit risk and, therefore, on a country's financial stability.

The results of model (3) are, to some extent, an extension of the conclusions based on model (1). The results obtained provide a basis for the conclusion that since the increase in energy prices increases the level of NPLs, changes in an area of energy policy, including a change in the energy structure (energy mix), may be associated not only with benefits in terms of less environmental pollution and lower consumption of energy resources but also with benefits in terms of the functioning of banks and thus in terms of the stability of the financial system. An economy that relies more on renewable sources of electricity will be less dependent on energy commodity prices on the global market. The dynamic increase in the prices of primary energy carriers, such as crude oil or natural gas, causes a very violent reaction in the economies. This is a consequence of the impact of secondary energy prices on the production of every good and service today and the critical role of transport costs. The level of sensitivity to price changes is a function of the degree of dependence on a given hydrocarbon and imports of a shared energy resource and the level of diversification of both geographical directions of trade and the structure of the energy mix.

Therefore, energy price increase is particularly exposed to countries that are dependent on imports of energy resources and do not have sufficient resources to meet demand for electricity production, as well as countries where the type structure of hydrocarbons used is slightly diversified, the share of other energy sources and marginal. Central and Eastern European economies are particularly exposed, where the share of fossil fuels in their energy mix is still high. As a result, these economies are particularly exposed to any shocks related to the increase in energy prices, and therefore, the vulnerability to the threat of unpaid loans increases.

Thus, in the event of perturbations, including crises in global markets and associated increases in commodity prices, an economy based on renewable energy will not be affected by energy price increases as much as economies based on fossil fuels. It can be assumed that this channel of influence will contribute to production costs not rising as dynamically, and thus, credit quality will remain at a better level (lower NPL). We observe that the economies of EU countries are still undergoing a gradual energy transformation. However, this process is long-term and capital-intensive, which makes these changes gradual. The effects of energy price increases may, on the one hand, translate into the level of NPLs and, on the other hand, become a catalyst for changes aimed at energy-saving and pro-efficiency measures, as well as the development of investments in renewable energy sources.

These findings provide a further rationale for the benefits of changing countries' climate policies to low-carbon ones. Moreover, this finding fits into the megatrend related to sustainable development [Boguszewski et al., 2023] and, on the other hand, complements the already rich body of work on the banking sector, financial stability and macroprudential supervision. It confirms that research into the impact of a country's energy structure on credit quality should be expanded. Especially as our approach to studying this matter is one of the first and can undoubtedly be improved.

Limitations and Future Implications

We are aware of some limitations that make it very difficult to confirm the validity of using the energy price index instead of inflation in studies of NPLs and to confirm the impact of the energy mix on NPL levels. First, due to the war in Ukraine and rising electricity prices, some EU governments have introduced measures to protect households from sudden increases in electricity prices. Regardless of the assessment of such corrective policies, they hamper research on the impact of energy on NPL levels. Moreover, it is essential to realise that energy policy is a topic that affects society and can, therefore, become the object of many political (including regulatory) solutions, especially in pre-election periods.

Other caveats may arise in the construction of the energy price index variable. As previously described, we calculated the energy price index as an average of normalised oil, natural gas, coal and ETS prices, giving all these components the same weighting. The equal weights approach may seem controversial given that the energy mix in EU countries varies widely and may not correspond to the weights we have adopted. Nevertheless, we justify this approach by the lack of data available to calculate the average share of each energy commodity in each country's energy mix over the entire period analysed (2014-2022). In addition, data on the energy mix are presented in annual data. At the same time, our econometric model is based on data in quarterly intervals, which would make it necessary to adopt certain simplifications. Nonetheless, we see further implications arising from the possibility of controlling the weights in the energy price index. For example, when researching the determinants of NPL in a country, it becomes possible to improve the energy price index variable in such a way as to adjust the component weights according to the energy structure of the country. On the other hand, for large-scale (international) studies, it remains to make certain assumptions and simplifications.

It would also be valuable to our research if bank-specific variables such as banking sector assets, capital adequacy ratio or bank profitability levels were included in the model explaining NPL levels [Koju et al., 2018]. This would confirm that even when extending the model to include non-macroeconomic variables, energy prices positively and statistically significantly impact NPLs. It would also make sense to include more macroeconomic variables in the model, such as the government debt to GDP or the interest rates.

Other limitation of our study pertains to potential endogeneity issues, particularly reverse causality between NPL levels and macroeconomic variables such as GDP or unemployment. While the ARDL model partially addresses this by considering lagged variables and cointegration relationships, further research employing instrumental variable techniques or structural equation modelling could provide deeper insights into causality. This would enhance the robustness of findings and strengthen the theoretical implications of energy prices as determinants of NPL levels.

We also see merit in comparing the quality of the exogenous variables by including both the energy price index and the inflation index, excluding electricity prices, in the model, explaining the level of NPL. We assume that the correlation coefficient between these variables will be lower, making it methodologically correct to include both variables in the same model. Such a process would be beneficial for two reasons. Firstly, it could confirm the results of our research, according to which, in modelling the level of NPL, the inflation index can be successfully replaced by an index representing energy prices. Secondly, it could initiate a new research area in which selecting the appropriate variable (inflation or energy prices) into the model would depend on whether corporate or household loans were being explained. However, this would require checking how the individual categories of non-performing loans respond to these variables.

Conclusion

Our study examined the impact of energy prices (including fossil fuels and ETS prices[8]) on NPLs through the inflation channel. We proved that energy strongly impacts inflation, and therefore, it impacts NPL levels in EU countries. The statistically significant long-run causal effect on NPLs level in EU-27 countries could be summarised as

[8] ETS are an indispensable cost element that should be considered when using fossil fuels.

if the energy index rises by 1%, NPLs rise by 1.738%, while if unemployment or GDP rise by 1%, the NPLs rise and fall by 0.659% and –0.05%, respectively. Furthermore, as model (2) shows, in the same time range and in the same EU-27 countries, inflation (HICP) is statistically insignificant at the level of 0.05. The results also show that even at a higher level of significance (0.1), the impact of the HICP on NPLs was marginally low, as a 1% increase in HICP would increase the level of NPLs by only 0.03%.

Useful initial conclusions can also be drawn from the model (3). There is the conclusion that if the share of fossil fuels rises by 1%, the NPLs rise by 0.03%, while the increase in renewable sources in the energy mix by 1% Granger causes a decrease in NPL level by 0.057%. Despite the low values of the directional coefficients for the explanatory variables in this model, it is essential that our research confirms that a more balanced energy mix can have a positive impact on credit risk and, therefore, on a country's financial stability. On the other hand, economies of countries more dependent on fossil fuels are more vulnerable to the risk of NPL growth. However, further analysis of the energy cost produced from renewable sources is also strongly recommended. In order to offset the impact of energy prices on the NPL level, these energy prices should be as low as possible and stable over time.

Additionally, we acknowledge that several EU member state governments have proposed measures aimed at mitigating the adverse impact of energy costs on households and businesses. We recognise that such interventions could potentially attenuate the influence of the energy price index on the level of Non-Performing Loans (NPLs). This provides a rationale for future research to consider the mitigating actions taken by governments to dampen the negative effect of rising energy costs on the economy. The reason is, it could suggest that these measures, designed to cushion the blow of rising energy costs, may not only be beneficial for households and non-financial businesses but may also indirectly benefit lenders (banks) by preserving the quality of their loan portfolio. The interplay between energy prices, government interventions, and the quality of bank loans opens up a new avenue of research that could further our understanding of the mechanisms driving NPLs and financial stability. Furthermore, this underscores that financial stability, including the relationship between energy prices and NPLs, should not be analysed solely at the EU-wide level. Future research should account for national-level differentiation, particularly given the significant heterogeneity among EU economies in terms of energy dependence, financial sector resilience, and macroeconomic structures. Recognising these spatial disparities fosters a more integrated approach that connects financial stability with financial geography – a rapidly evolving subdiscipline [Węgrzyn, 2024]. This perspective aligns with the growing body of research emphasising the need for geographically differentiated macroprudential policies that consider the spatial distribution of financial risks and economic vulnerabilities [Węgrzyn, 2025].

The possible impact of energy prices on financial stability is not an entirely new finding. For example, even the European Systemic Risk Board [ESRB, 2023] is aware that higher energy prices can pose increased risks to financial stability in various sectors, including households, non-financial firms and financial institutions, and financial markets. Nevertheless, our study is one of the first to confirm such a relationship using empirical research. The perspective raised in our study can provide valuable information to policymakers and financial institutions.

To sum up, we thought that our energy price index (or another index following energy prices) and share of renewable energy in the energy mix – as important sustainability elements – can constitute one of the important macroeconomic variables impacting NPLs levels. Indeed, there are more reasons for this than just the fact that literature frequently quotes the NPL issue as “financial pollution” [Manz, 2019].

Appendix

Appendix A. Models (1) and (2) descriptive statistics and panel data unit root tests

Table A1. Descriptive statistics for models (1) and (2)

Variable	Mean	Median	Min.	Max.	Std. Dev.	Kurtosis	Jarque--Bera Test	Skewness
NPL	10.28980	6.034001	0.388500	57.20014	11.39154	7.803233	1591.769	2.225134
ENER	0.265305	0.190903	0.025842	0.974372	0.236404	4.686787	505.7389	1.641444
GDP	2.866105	2.80000	–21.90000	26.7000	4.679241	8.540310	1147.678	–0.233910
UNEMP	7.439955	6.50000	1.800000	26.1000	3.967709	7.706642	1384.191	1.945001
HICP	2.485859	1.30000	–2.50000	25.0000	3.930975	10.45945	3005.982	2.516237

Source: own elaboration.

Table A2. Panel data unit root tests for models (1) and (2)

Test	UEMPLOY		GDP		ENER		HICP		NPL	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
LLC	–0.71492	0.0000	0.0002	-	0.9842	0.0000	1.0000	0.0000	0.0000	-
ADF	50.7701	0.0000	0.0000	-	1.0000	0.0000	0.9916	0.0000	0.0016	-
PP	60.6155	0.0000	0.0000	-	0.9999	0.0000	1.0000	0.0000	0.0000	-

Source: own elaboration.

Appendix B. Model (3) descriptive statistics and panel data unit root tests

Table B1. Descriptive statistics for model (3)

Variable	Mean	Median	Min.	Max.	Std. Dev.	Kurtosis	Jarque-Bera Test	Skewness
NPL	11.04434	6.430632	0.633701	57.16367	11.94422	7.000377	299.2437	2.076432
Share of FF	72.63884	73.15500	30.29000	99.12000	14.90646	3.529692	20.85270	–0.713511
Share of RE	21.78818	18.11550	4.471000	62.57300	11.73972	3.721803	38.98125	0.975993

Source: own elaboration.

Table B2. Panel data unit root tests for model (3)

Test	Share of FF		Share of RE		NPL	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
LLC	1.0000	0.0000	0.9999	0.0000	0.0000	-
ADF	0.8121	0.0000	1.0000	0.0001	0.0004	-
PP	0.9537	0.0000	1.0000	0.0000	0.0000	-

Source: own elaboration.

Appendix C. Correlation of macroeconomic variables used in NPL studies

Table C1. Correlation matrix of macroeconomic quarterly variables

Correlation	NPL	GDP	UNEMP	ENERGY	HICP	DEBT	IR3M
NPL	1.000	-	-	-	-	-	-
GDP	0.022661	1.000	-	-	-	-	-
UNEMP	0.620888	–0.134926	1.000	-	-	-	-
ENERGY	–0.273511	0.266443	–0.231874	1.000	-	-	-
HICP	–0.317587	0.143062	–0.297716	0.852910	1.000	-	-
DEBT	0.516773	–0.107176	0.617124	0.004342	–0.140238	1.000	-
IR3M	–0.076301	0.038901	–0.191709	0.356923	0.521309	–0.126983	1.000

Notes: DEBT is government consolidated gross debt (central government) as a percentage of GDP, and IR3M is a 3-month benchmark interest rate.

Source: own elaboration.

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