Ministry of Education and Science of Ukraine

National University of “Kyiv-Mohyla Academy”

Faculty of Economics

Department of Finance

Bachelor`s thesis

educational degree - bachelor

on the topic: « **PROSPECTS FOR ADOPTION CARBON TAXES: MODELING THE ECONOMIC IMPACT** »

на тему: « **ПЕРСПЕКТИВИ ВПРОВАДЖЕННЯ ПОДАТКУ НА ВУГЛЕЦЬ: МОДЕЛЮВАННЯ ЕКОНОМІЧНОГО ВПЛИВУ** »

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072 Finance, Banking and Insurance

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Bachelor`s thesis is assessed with a grade

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Kyiv 2024

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INTRODUCTION

Environmental protection is one of the most important problems of the modern world. International commitments, such as those under the Paris Agreement, require countries like Ukraine to reduce emissions. In this context, financial regulation plays a vital role, contributing to the achievement of environmental policy goals. Particularly, carbon taxation is crucial for shaping economic landscapes by addressing the urgent problem of climate change. By pricing emissions, carbon taxes aim to reduce greenhouse gas emissions and encourage investments in cleaner technologies. However, the effectiveness of these taxes in achieving environmental goals while balancing economic growth remains a contentious issue. This raises the question of whether carbon taxes effectively contribute to sustainable development and whether they can be integrated effectively into national economic strategies without detrimental effects on competitiveness and social equity.

Ukraine faces significant environmental challenges, including high levels of industrial pollution and greenhouse gas emissions. The ongoing war and destruction in Eastern Ukraine have severely impacted the industrial and economic landscape, making it essential to support post-war reconstruction with sustainable practices.

This research explores the theoretical framework of carbon taxation, focusing on its dual role in environmental protection and fiscal policy. Specifically, it investigates the implementation of carbon taxes in Ukraine, analyzing their impact on various economic sectors and assessing their effectiveness in fostering a low-carbon economy.

Actuality. While many studies explore carbon taxes in broad contexts or within more economically stable and developed countries, this research focuses on carbon taxes performance in Ukraine developing market. The study covers an extensive period from 2014 to 2022 which was not investigated in detail by Ukrainian researchers but is crucial for future fiscal policy decisions. As part of the Eastern European region and with strong economic ties to the EU, Ukraine's alignment with environmental goals is crucial. This research on Ukraine’s carbon tax model provides valuable lessons on the challenges and successes of aligning national policies with broader regional strategies.

Aim. The aim of this work is to examine the impact of carbon taxes on Ukraine's economic and environmental landscape. It seeks to evaluate how carbon taxes have performed in terms of revenue generation, environmental protection, and economic impact, particularly considering Ukraine's specific socio-economic conditions and industrial structure. By integrating empirical data and economic modeling, it pursues to test whether industrial polluters in Ukraine tend to pass on the burden directly to consumers and/or invest in cleaner technologies.

Task. Compound regression models using statistical application EViews 12 and provide logical conclusions.

Object. The research centers on carbon tax and its macroeconomic impact in Ukraine.

Subject. Work’s subjects are theoretical and empirical aspects of interrelations between revenues from carbon taxes and economic indicators in Ukraine during 2014-2022 period.

Structure. The paper is organized into three main chapters: Literature Review, Methods and Materials, and Results. The "Literature Review" chapter discusses the theoretical concept of carbon taxes and its intended role in sustainable development, also reviews foreign and Ukrainian researches on this topic. "Methods and Materials" describes the selected regressors and empirical models that used to analyze the impact of carbon taxes in Ukraine. Finally, the "Results" chapter presents the findings of the model analysis, offering insights about the effectiveness of carbon taxes and discussing the broader implications for Ukraine's strategies.

Keywords: carbon taxes, economic impact, environmental policy, Ukraine, sustainable development.

1 LITERATURE REVIEW

In the following section, we draw on existing literature to discuss the arguments for implementing carbon pricing in Ukraine based on foreign practices. We also examined empirical evidence for effective CO2 tax rate and its potential socio-economic effect.

1.1 The theoretical concept of carbon pricing

The problem of climate change is one of the most important environmental problems facing humanity, as it can lead to irreversible catastrophic consequences for the environment and society. The world's leading scientists have concluded that the rise in global temperature should not exceed 2°C, as this figure is a turning point for the planet's climate system [1]. Given the profound nature of the social, economic, and political impact of environmental degradation, ecological issues began to play a vital role in the study of global economic regulation. The link between the economy and the environment, coupled with the need to take collective action to deal with common resource issues, has made contemporary environmental issues affect fiscal policy.

After the Rio de Janeiro Conference in 1992, environmental problems finally moved from the periphery to the national and international political centers. The concerns of environmentalists are no longer considered outdated or senseless but have been chosen to join the policy agenda.

The idea of taxing environmentally harmful activities to limit their scale, and thus environmental pollution, was first introduced by Arthur Cecil Pigou in 1920. The economist considered that harmful emissions are externalities and proposed to apply an environmental tax at a level appropriate to marginal external costs, i.e. the cost of eliminating each subsequent unit of emissions. Thus, polluters will be fully responsible for all the negative consequences of their activities [2]. The main purpose of the introduction of environmental taxes is the internalization of externalities, which helps to include the cost of environmental pollution in the prices of goods and services. Environmental taxes also promote the "polluter pays principle" - the emitter must be liable for damage to the environment [3].

One of the instruments aimed to eliminate the negative impact of carbon dioxide on the environment and ensure sustainable environmental development is natural resource payments, in particular a tax on carbon dioxide emissions. The Carbon Tax Center defines the Carbon tax as a “fee imposed on the burning of carbon-based fuels (coal, oil, gas)” [4]. However, focusing government policy solely on the environmental aspect will not yield the expected results, since the important thing for the country is to achieve ecological and economic equilibrium. It will solve the country's environmental problems and improve the economic situation, thereby increasing the country's competitiveness and investment attractiveness.

The National Ecological Centre of Ukraine has defined the main advantages and disadvantages of carbon taxation, which are relevant to our investigation of economic impact [5]. Among the wide range of advantages, carbon taxation performs a fiscal function, i.e. brings profit to the state, which can be redirected to eco-investments. Also, it does not require the creation of new institutions for implementation and relatively easy to administer. As a result, it can promote the introduction of energy-efficient technologies, strengthening national security. In contrast, the disadvantages of carbon taxation: it does not guarantee the achievement of the environmental goal, a low rate will not lead to emission reductions. High rates may cause the rise of the unemployment rate as well as the level of income inequality since manufacturers may push the additional carbon cost onto the consumer by increasing the price of the final product (electricity, flying, etc). Therefore, a solid analytical basis for determining the optimal tax rate is required to gain absolute effectiveness of carbon taxation implementation. It can also face strong political opposition if a high-rate tax is introduced, especially in Ukraine, where “low tax rates” are usually used to encourage voters.

Currently, 78 national and local jurisdictions have applied carbon pricing, including Ukraine. In total, it covers 22% of global emissions, with an annual value of $45 billion - an amount that underscores the importance of recycling these resources in the industry. Carbon prices vary widely: from less than $1/tCO2e in Ukraine, Mexico to $119/tCO2e in Sweden, Switzerland in 2020 (Appendix 1). According to the World Bank in 50% of the cases, the price is less than $10/tCO2e, which is far from recommended level to meet global environmental goals till 2030 [6]. While the proportion of parties to the Paris Agreement remains low, a number of carbon pricing initiatives are scheduled for implementation and under consideration. One example of such initiative in Ukraine was the adoption of the Law of Ukraine on the Principles of Monitoring, Reporting, and Verification of Greenhouse Gas Emissions in December 2019 – it defines the legal and organizational principles of monitoring, reporting, and verification of greenhouse gas emissions [7].

Ukraine introduced a carbon tax in 2011 (tax rate was UAH 0.2/tCO2e) which mainly applies to fossil fuels and CO2 emissions from facilities emitting at least 500 tCO2e annually, covering about 70% of the country's greenhouse gas emissions. However, the tax's main issue was its low price, which failed to incentivize emission reduction measures. Since 2019, it is still collected as part of the environmental tax, but on a separate budget account, and the rate has increased to UAH 10/tCO2e. Despite reaching the level of UAH 30/tCO2e in 2021, it remains below USD 1/tCO2e. The tax primarily serves as a fiscal tool, with revenues directed to the state budget and local budgets' special funds. In 2020, 7,347 companies paid a total of 940 million UAH in carbon taxes [8].

In terms of carbon pricing initiatives, in 2019 European Commission developed a European Green Deal striving to promote a clean, circular economy. The one component of the European plan is the carbon border adjustment mechanism (CBAM) – the concept implies additional import duty for goods whose production leaves a significant carbon footprint. According to preliminary estimates by industry experts, additional payments by Ukrainian companies for exports to the EU could increase by almost 600 million euros a year, mainly affecting electricity, coal, cement production, and the chemical industry [9]. In 2021 EU export accounted for 39% of total export in Ukraine among which 22% is exports from the industrial sectors covered by the CBAM (such as electricity and ferrous metals) [10]. According to a study conducted in 2021, the potential losses for the Ukrainian mining and metallurgical sector due to the CBAM could lead to decrease of tax revenue to State Budget up to EUR 140 million annually, based on an EU ETS carbon price of EUR 42/tCO2e [11]. However, the destroy of infrastructure in Eastern Ukraine and many production facilities (The Azovstal, Illyich metallurgical, Zaporizka nuclear power plants) leads to a decline in Ukrainian exports from the CBAM sectors to the EU as well as much lower economic impact of CBAM.

To avoid huge financial losses due to introduction of CBAM in the EU Ukraine should start preparation in environmental legislation taking into account the needs of post-war reconstruction. In particular, begin the development of requisite regulatory and legal frameworks aimed to enhance climate policy. This entails the transition to a green taxonomy based on the requirements of EU legislation, the creation of our own emission trading system (EST) and plans for the future gradual increase of the tax on CO2 emissions in Ukraine. Implementing carbon pricing in sectors affected by the EU CBAM can help avoid associated fees, but broader application across the economy offers greater benefits, including promoting a low-carbon transformation and generating revenues.

Some steps toward CBAM adaptation were already taken by Ukraine government. In April 2023, the Ukrainian Parliament passed Law No3035-IX to establish the State Decarbonization and Energy Efficiency Transformation Fund. Environmental taxes imposed on enterprises will finance this fund and then be directed towards financing initiatives aimed at enhancing energy efficiency, adopting alternative energy sources, and facilitating decarbonization efforts. [12]. These legislative revisions adhere to the "polluter pays" principle and imposes polluters financial accountable for their actions. However, it is worth noting, that low ecological tax rate in Ukraine (30 UAH/tCO2e) leads to considerable deviation from the emission valuation practices observed in Europe, where the average tax rate approaches 40 EUR/tCO2e. Consequently, the anticipated funding for the newly created Fund is sufficiently constrained. According to 2024 State Budget the Fund will be financed for only 759.2 million UAH, leading to the limited effective implementation of decarbonization measures in Ukraine. By comparison, the State Budget for 2024 earmarks substantial support for the coal industry, amounting to 3.8 billion UAH [12].

The EU remains Ukraine's main economic partner - the share of trade in goods and services is over 40% of total trade [13]. If products exported from Ukraine are subject to a carbon tax, it reduces foreign exchange earnings, state budget revenues and, as a result, reduces income growth and employment. Therefore, it is essential for Ukraine to develop an effective carbon tax policy in order to meet European import requirements and sustain trade partnership.

1.2 Distributional effects of environmental taxation

Environmental taxation has multifaceted socio-economic impacts beyond its direct influence on GDP and tax revenues. In particular, it affects income distribution by potentially burdening low-income households more, influences employment dynamics and industrial competitiveness, stimulates innovation and technological change, shapes fiscal policy and government revenue, alters consumer behavior and preferences, contributes to public health and well-being, and poses challenges related to social acceptance and equity.

The impact of environmental taxation on consumer prices is significant, manifesting through various channels and affecting market dynamics. Negative externalities, such as carbon emissions or pollution, lead to consumer prices increase by growing the cost of goods and services. For instance, a tax on fossil fuels raises the price of gasoline, electricity, and other energy-intensive products, leading to higher expenditures for consumers. This direct pass-through of taxes to consumers is commonly used practice where businesses, instead of absorbing the cost of imposed taxes themselves, pass on the burden directly to consumers and is one of the main drawback of ineffective environmental policy.

However, the idea of consumer prices going up because of taxes is not always true. Sometimes enterprises might actually pay more of the cost themselves, and in some cases, they might even benefit from higher prices caused by things like carbon taxes. This usually depends on how competitive the industry is. The least competitive industries (also called monopolies or oligopolies) characteristics exhibits the highest level of pass-through effect [14]. Typically, industries that are resource-based or have characteristics such as limited competition, high entry barriers, or concentration of market power tend to exhibit lower levels of competition. These industries may include sectors such as mining, extraction, or agriculture, where firms rely heavily on natural resources and face challenges related to market competition. In such industries, the ability of firms to pass on costs, including those associated with carbon taxes, to consumers may be higher due to their market power or limited alternatives available to consumers. On the contrary, in highly competitive markets, firms often have limited ability to pass on increased costs to consumers due to price sensitivity and competition. As a result, when carbon taxes are imposed, firms in these markets may face greater pressure to absorb the costs internally, leading to reduced profit margins.

While carbon taxation may pose challenges for firms in highly competitive markets, it can also drive innovation and encourage market-driven solutions to reduce emissions. The substitution mechanism refers to the ability of firms to adjust their production methods or inputs in response to changes in prices or costs, such as those resulting from environmental taxation. In the context of environmental taxation, firms may employ substitution mechanisms by replacing or substituting inputs that are subject to taxation with alternatives that are not taxed or taxed at lower rates. For example, if a carbon tax increases the cost of fossil fuels, firms may invest in energy-efficient technologies or switch to renewable energy sources to reduce their energy consumption and, consequently, their tax burden. Similarly, firms may substitute raw materials or production processes with less environmentally harmful alternatives to mitigate the impact of environmental taxes on their operations. So, the company of any market, competitive or not, which initially responsible for paying a tax can either pass on its effects to consumer or mitigate its payment entirely through substitution mechanisms [14].

As it was mentioned above, environmental taxes can lead to higher prices for goods and services that are subject to taxation, such as energy, transportation, and basic necessities. Low-income households, which allocate a larger share of their income to these essentials, may experience a more significant increase in their cost of living relative to higher-income households. This phenomenon, known as regressive taxation, exacerbates income inequality by placing a relatively heavier burden on those with lower incomes. The regressive nature of environmental taxation can be compounded by limited access to alternatives and resources among low-income households. For instance, low-income individuals may have fewer options for energy-efficient appliances, public transportation, or renewable energy sources, making it challenging to mitigate the impact of environmental taxes through behavioural changes or technological upgrades. As a result, these households may face greater difficulty in coping with the additional financial strain imposed by environmental taxes [15].

Several researches of USA market were conducted among which one about the distributional effects of a $49 tax per ton of CO2 emissions across different income groups. It reveals that households in the lowest income decile would, on average, incur $575 in additional costs due to higher prices resulting from the carbon tax. In contrast, households in the highest income decile would face an average burden of $2,576. Despite wealthier individuals paying more in absolute terms, the carbon tax is found to be regressive, with the poorest decile spending a larger proportion of their income (3.1%) on the tax compared to the richest decile (2%) [16].

Moreover, environmental taxes may indirectly affect low-income households by influencing employment opportunities and economic growth. Industries that are heavily taxed due to their environmental impact, such as manufacturing or extractive industries, may experience job losses or reduced wages, particularly in regions with limited diversification or high dependency on polluting industries.

1.3 Empirical review

The issue of ecological taxation was studied by Ukrainian scientists such as Volkovets T.V., Mandryk V.O., Galushkina T.P., Bulavynets V.M., Khlobistova E.V., Mishchenko S.V., Maslyukivska O.P. and others. In their studies the attention is primarily paid to the investigation of foreign carbon taxation practices, improving the management of environmental taxes, their fiscal significance, the distribution of revenues among various levels of budgets, and the use of these funds to ensure the country's sustainable development.

As we mentioned before, the optimal carbon tax rate is a key for effective environmental policy to benefit all stakeholders, therefore many scientists and organizations studied effective tax rate. Figure 1.1 illustrates the role of environmental taxation in the internalization of externalities. For the optimal case, environmentally harmful production should be at a level at which the marginal benefit (MB) from each subsequent unit of emissions (or from non-limitation of emissions for each additional unit) should be equal to the marginal social cost (MSC) of this production, which is equal to the private marginal cost (MC) plus marginal external cost (MEC) from each additional unit of pollution. If the market is unregulated, a certain production emits emissions at the Q level, at which the marginal benefit from pollution (MB) is equal to private costs (MC).

In order to reduce the level of pollution to the socially optimal level Q *, it is necessary to introduce an indirect tax t per unit of emissions. The ideal tax rate t should be equal to the vertical distance between the curves MSC and MC. In addition, the tax rate should be equal to the marginal external cost (MEC) at the socially optimal level of pollution Q*.

The introduction of tax t causes the marginal benefit curve MB to shift to MB*. Thus, the application of the tax ensures the internalization of externalities and the achievement of a socially optimal level of pollution [17]. Since the main purpose of the tax is to internalize negative externalities, the tax rate should be equal to the marginal loss.

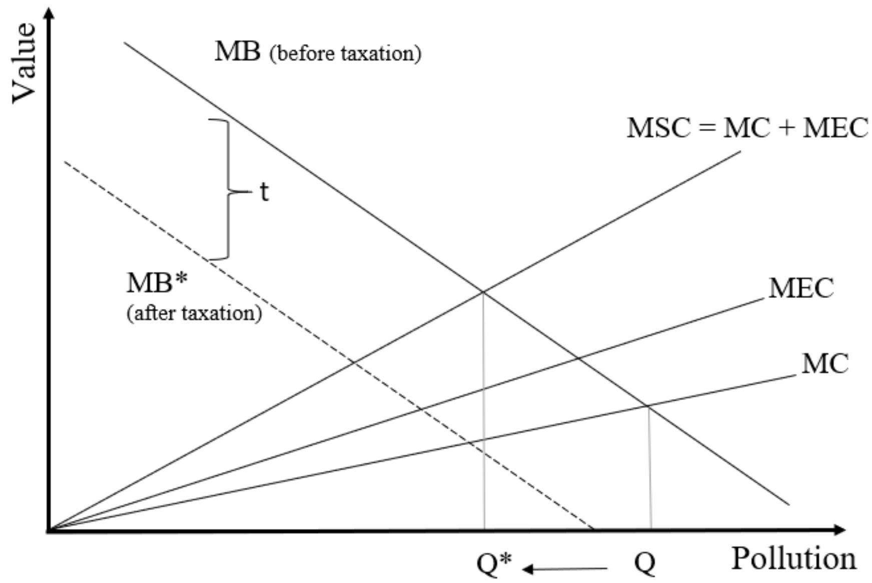


Figure 1.1 – The socio-economic optimal tax rate.
Source: OECD [17].

However, it is very difficult to practically estimate the damage caused. Therefore, a different approach is often used. Firstly, an environmental goal is set as a result of the political process. Then the tax rate is determined, which should ensure the achievement of the goal. However, it should be noted that the tax rate needs to be revised depending on the effectiveness of the tax in practice. In addition, a gradual increase in the tax rate promotes the application of primarily the cheapest solutions with a gradual transition to more costly measures [17].

A large amount of research has already been conducted on the economic consequences of implementing low-carbon development policies. While they differ in sectoral coverage, time frame, and GHG reduction targets, they are united by the fact that GDP is declining slightly as a result of policy implementation. To make relevant assumptions regarding carbon tax economic impact we investigated the empirical studies of a carbon tax in developing counties, particularly in Brazil and Thailand.

Gurgel examined the cost of implementing policies to reduce GHG emissions in Brazil by 43% in 2030 and by 50% in 2050 (compared to 2005). The results show that with the use of carbon tax for all sectors, GDP will decrease by 0.5% in 2035 and by 3.3% in 2050, while tax rates will be $3/tCO2e, respectively in 2030 and $103/tCO2e in 2050 [18].

Rajbhandari explored a set of ways to develop carbon pricing in Thailand, using the model of general equilibrium. The tax is imposed on all sectors of the economy, and revenues are redistributed to households. The results show that in order to achieve the goal of reducing GHG emissions by 25% in 2030, the required tax rate is $54.6/tCO2e, and the level of GDP will decrease by 2.5%. At the same time, to achieve an even more ambitious 50% reduction target till 2050, the CO2 price must be $91/tCO2e in 2050, and GDP will decrease by 11.9% in 2050. But if energy efficiency and technology efficiency increase by 40%, the price of CO2 may decrease by 53%-69% depending on the scenario [19].

Some studies have analysed the impact of the carbon tax on Ukraine's economy. In particular, Frey [20] using a static model of general equilibrium demonstrates that the tax rate of $3.46/tCO2e will reduce GHG emissions by 22%. The use of tax revenues together with a decrease in the level of other taxes leads to positive macroeconomic consequences, GDP grows by 0.1%.

A report of PMR “Ukraine Carbon Pricing Options” (2019) [21] for Ukraine showed that in order to achieve a 5% reduction in GHG emissions in Ukraine in 2030, it is necessary to set the tax at $2.68/tCO2e. The report also shows that GDP at this level of tax is almost unchanged, as it decreases by only 0.1%.

An empirical study about carbon emissions taxation in Ukraine compared the volume of carbon dioxide emissions from stationary pollution sources in 2019 with the revenue from the environmental tax on carbon dioxide emissions into the atmosphere. The share of untaxed emissions was 21.5%, or 26.1 million tons. It was established that a 1% increase in the tax rate leads to a 9.7% decrease in CO2 emissions. According to the conducted research, carbon dioxide emissions during 2019–2020 decreased by 10.1% with a 24.4-fold increase in the tax rate, and in 2021 – increased by 9.9% compared to the previous year [22].

In conclusion, carbon taxes serve to internalize the externalities associated with pollution, thereby making polluters financially accountable for the environmental damage they cause. This approach not only reflects the true cost of goods and services but also promotes the adoption of cleaner technologies. The case study of Ukraine highlights both the successes and challenges in implementing carbon taxes, demonstrating they generate fiscal revenue and can drive technological innovation, while having low impact on GDP. Achieving substantial environmental improvements requires careful calibration of tax rates and comprehensive policy frameworks. It is essential to balance environmental goals with economic stability to ensure that carbon pricing mechanisms do not disproportionately burden the less affluent sectors of society or compromise economic competitiveness.

2 METHODS AND MATERIALS

In order to analyse the impact of CO_2 taxation in Ukraine different macroeconomic variables were taken into account with time range of 6 years by quarter (2014-2022). Such time range was chosen, firstly, considering the date of CO_2 taxation implementation in Ukraine and, secondly, due to the data availability from official government sources. As a result, the main model will be based on 36 observations.

Before defining any hypothesis for macroeconomic impact, firstly, the structure of CO_2 emissions in Ukraine was investigated by region and industries that helped to note which parts of economic might be affected the most by CO_2 taxation. Since the Tax Code of Ukraine implies tax rates on emissions into the atmosphere of pollutants by stationary sources of pollution (Article № 243), the descriptive statistics excludes emissions from mobile pollution sources. According to the Tax Code a stationary pollution source is an enterprise, workshop, unit, installation, or other immovable object that keeps its spatial coordinates for a certain period and emits pollutants into the atmosphere, which are the subject and basis for environmental tax for emissions into the atmospheric air [23].

As it can be observed from the Figure 2.1 electricity and gas supply sector and manufacturing are the two largest contributors, together accounting for 92.2% of the total emissions in 2021. The electricity and gas supply sector emits 52 mio tons of CO_2, representing 46.5% of the total emissions. This sector comprises 488 enterprises with an average emission of 107 thousand tons per enterprise. Manufacturing follows closely behind, emitting 51 mio tons of CO_2, making up 45.7% of the total emissions. This sector consists of 1,671 enterprises, comprising 28% of the emitting enterprises, with an average emission of 31 thousand tons per enterprise. Within manufacturing sector, the biggest contributor is production of basic and fabricated metals, accounting for 65.2% (512,711 k tons) of total manufacture emissions. Other industries, such as mining and quarrying, information and telecommunication, financial activities, and transportation, also contribute to CO_2 emissions, although to a much lesser extent.

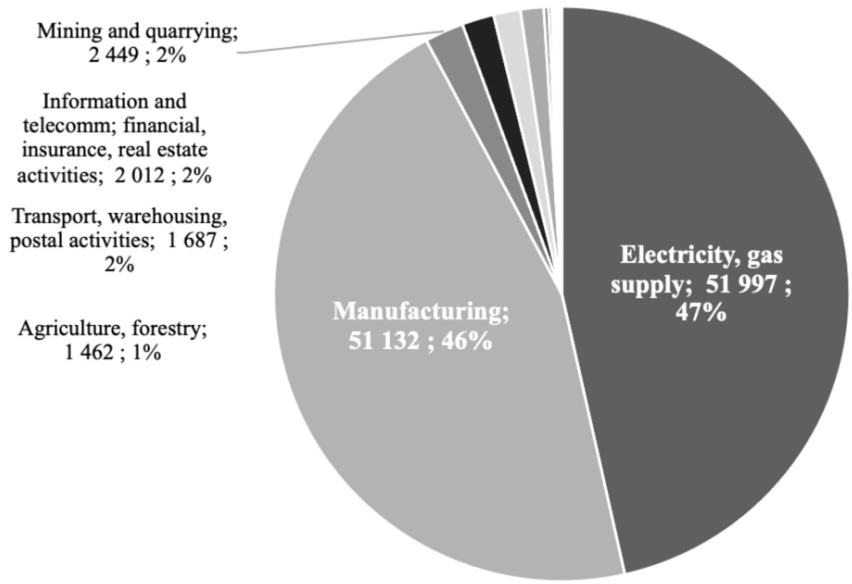


Figure 2.1 – CO_2 emissions in Ukraine by industry in 2021, k tons.

Source: composed by author based on Appendix 2 and [24].

Overall, increase of CO_2 taxation has significant implications for industries in Ukraine with high emissions per enterprise, notably in sectors like electricity and gas supply as well as manufacturing of metal products. It may result in increased operational costs, prompting companies to invest in cleaner technologies and potentially placing them at a disadvantage compared to less emission-intensive sectors. Nevertheless, it is supposed to fosters innovation and adaptation, but can also lead to increased price for electricity, gas and metal materials. Since these sectors usually do not produce final goods but rather supply materials to further production and services, the carbon tax will not only affect the price level of high emission industries but can also impact price index of all industries which highly rely on electricity, gas and metal products. Any changes in carbon tax policies in Ukraine should be accurately monitored by enterprises to avoid or predict any supply disruptions or cash flow problems. It is also highly important for investors to understand that gas, electricity and manufacturing sectors depend the most on carbon taxation, so before making any investment decision they should evaluate whether enterprise corresponds to environmental policy changes by developing low-carbon solutions.

In today's context it is also important to understand the regional distribution of carbon emissions by stationary pollution sources. The figure 2.2 presents in 2021 both industrial centres, Donetsk and Dnipropetrovsk, contributed 20% of the overall emissions with CO2 emissions of 22,7 mio tons and 22,3 mio tons, respectively. The mining and metallurgical sectors are the main sources of CO2 emissions there. These areas are typified by heavy industrial operations, such as ironworks, steel manufacturing, which reflects the industrial character of their economies and the environmental difficulties they confront. Zaporizhzhya followed closely behind, contributing 12% of emissions with 12,9 mio tons, where metallurgical plants and energy generation facilities are located. Meanwhile, Ivano-Frankivsk in the western part of the country emitted 11% of total CO2 emissions, totalling 12 mio tons, where the primary sources of air pollution is electricity production and distribution companies (86.9% of total regional emissions), namely Burshtynska and Kaluska TES.

Since the beginning of Russian-Ukrainian war some territories were occupied, many industrial plants were closed, partially destroyed or limitedly operating which led to the change of carbon emissions by stationary pollution sources. Making any conclusions on carbon tax efficiency should also be adjusted on the fact of losing control over some high-emission regions as well as numerous missiles strikes on Kryvyi Rih industrial infrastructure and power plants in Ivano-Frankivsk region. While analysing the impact of CO2 on Ukraine economy it is important to know that 32% of emissions were concentrated in Donetsk and Zaporizhzhya regions. Therefore, we expect lowering of carbon tax income because of temporary territory occupation and missile strikes.

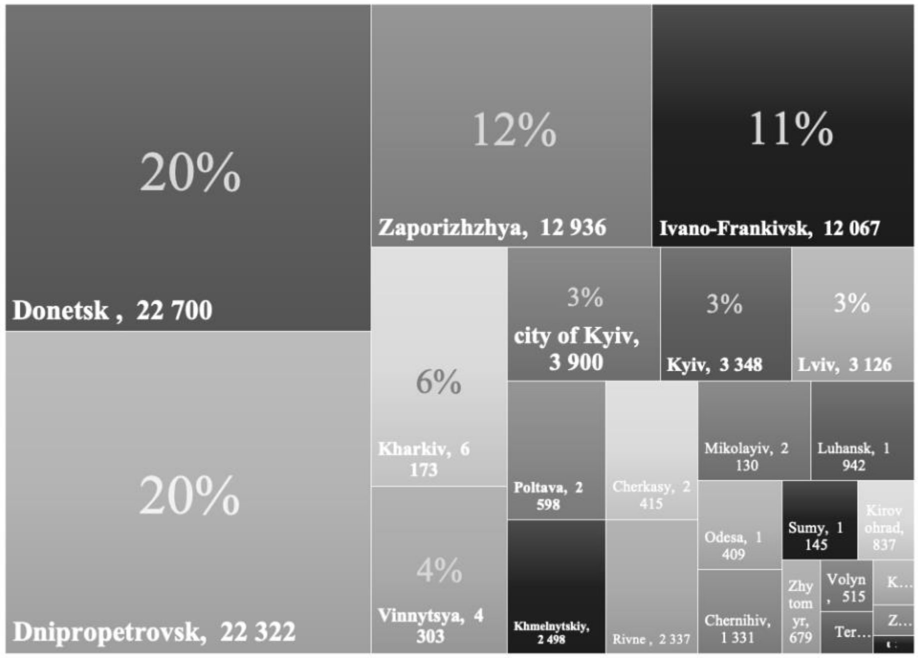


Figure 2.2 – Regional structure of CO2 emissions in Ukraine in 2021, k tons.

Source: composed by author based on Appendix 2 and [24].

The historical data analysis of carbon dioxide emissions in Ukraine from 2014 to 2023 years (Figure 2.3) shows the rapid drop down in 2022 when the full scale war started, and many industrial producers stopped operations. It seems the uplift of tax rate (to 30 UAH/ tCO2e) lead to emissions decline, however, in reality it is explainable by regional structure changes - the major emissions were concentrated in Eastern regions of Ukraine where production has been suspended. Before 2022 there was a decreasing trend however there is no strong correlation between CO2 tax rate increase and CO2 emissions decrease. Hypothetically the result of tax rate grown in 2019 (+2339% vs PY) will be visible in long-term. Overall, this leads to the conclusion that the tax rate in Ukraine has not reached the effective level yet or that enterprises simply do not invest in low-carbon solutions and pass-through tax to consumers. Nevertheless, the analysis of this work focuses mostly on macroeconomic effects of carbon taxation, but the effectiveness of CO2 taxation in Ukraine requires further investigation in the future with more years of the data available.

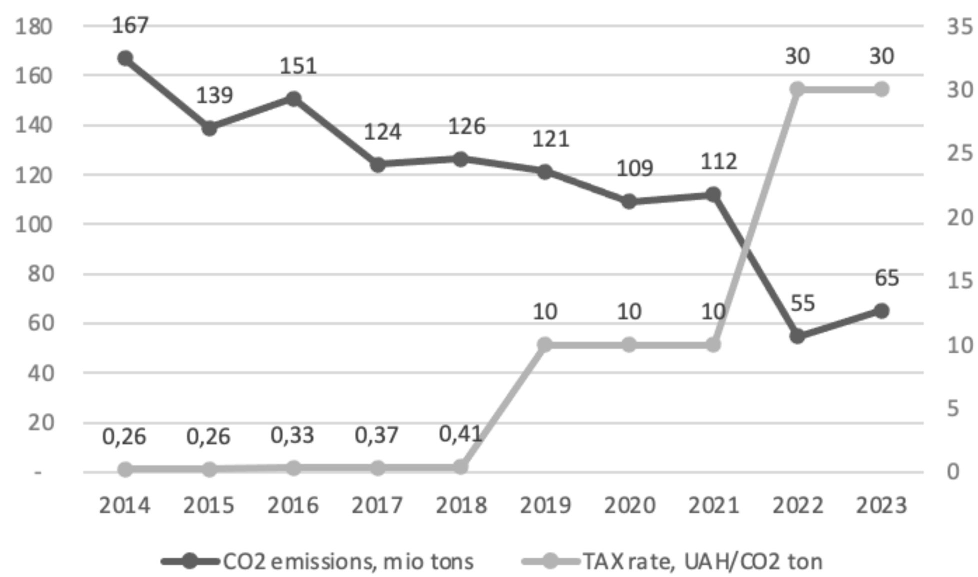
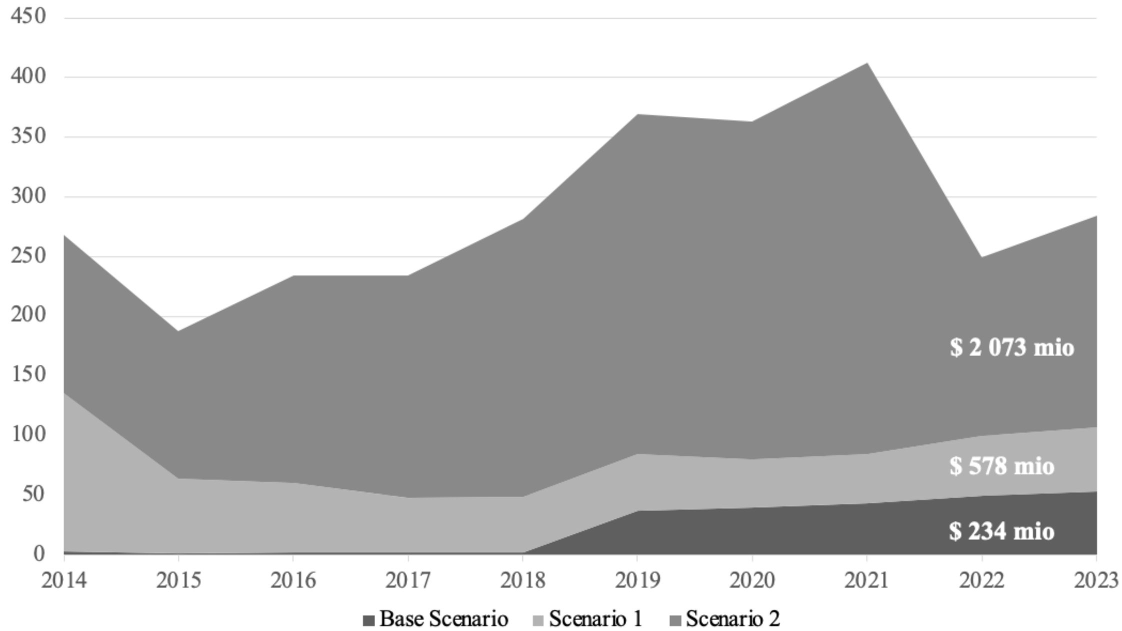


Figure 2.3 – Comparison of CO2 emissions and carbon tax rate in Ukraine.

Source: composed by author based on [24].

As it was said previously, Ukraine has undergone fluctuations in its approach to carbon taxation over the years and was more a political subject rather than environmental policy. Despite the implementation of carbon taxation as a policy instrument, the effectiveness of revenue generation was hampered by the inadequacy of the tax rates – less than 1 UAH/tCO2e until 2019. Budget revenues are essential to macroeconomic management because they give governments the money, which are necessary to support growth, stability, and equitable development of the economy. Therefore, the retro perspective potential budget earnings (unachieved revenues) from the higher CO2 tax rate in Ukraine were calculated considering different scenarios.

As a base scenario the real tax rates, carbon emissions and budget revenues from carbon tax are taken for comparison. To mitigate inflation and exchange rate impacts, budget earnings are converted to USD based on average FY forex rates. The detailed calculations of budget revenue sensitivity are shown in Appendix 3.



UAH/CO2 ton	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Base Scenario	0,26	0,26	0,33	0,37	0,41	10	10	10	30	30
Scenario 1	10	10	10	10	10	10	10	10	30	30
Scenario 2	10	20	30	40	50	60	70	80	90	100

Figure 2.4 – Comparison of Real (base scenario) and Potential (scenario 1-2) budget revenues from carbon tax in Ukraine from 2014 to 2023 years.

Source: composed by author based on calculations and [23], [24], [25], [26].

In our sensitivity analysis Scenario 1 represents a moderate approach when the government starts raising the tax rate earlier but not significantly, aiming for a more realistic and sustainable transition. In this scenario, we assume the tax rate increase to 10 UAH/tCO2e starting from 2014 instead of 2019 (as in base scenario), reflecting an earlier adjustment for businesses. The tax growth to 30 UAH/tCO2e happens in 2022 which is equal to base scenario. The maximum tax rate reaches the same level as in base scenario (30 UAH/tCO2e) which makes this approach pragmatic and feasible towards achieving both environmental sustainability and fiscal objectives. The budget revenue from carbon taxation increases steadily over the years, reaching a total of 578 mio USD by 2023. In this case, the total budget loss amounts to 344 mio USD, indicating the potential for substantial revenue growth under this moderate scenario.

On the contrary, Scenario 2 adopts a more aggressive and radical approach to carbon taxation, aiming for a faster transition towards higher tax rates aligned with those of European Union countries. In this scenario, the government raises the tax rate every year on additional 10 UAH, starting from 10/tCO2e in 2014 and reaching 100 UAH/tCO2e in 2023. The maximum tax rate in this case is much higher than in base scenario (100 UAH vs 30 UAH), however it is still lower than the average in European Union countries (only $2.7/ tCO2e). We assume that further tax rate growth will be implied after 2023. This aggressive scenario indicates tremendous income potential, with a total of 2073 mio USD in budget revenue by 2023. The total unachieved budget earnings count to 1840 mio USD which could potentially be utilized to invest in or subsidy the renewable energy programs, green technologies or education campaigns.

Both scenarios show the potential of adopting carbon taxation by generating substantial budget revenues which can be directed towards various sustainable initiatives or other social-economy aspects. It is essential to choose the right policy, moderate or aggressive, to achieve economic efficiency from CO2 tax, however it is undeniable that time gives the most value - the sooner tax rates will be adjusted the more tax revenues can be distributed. Early implementation of carbon taxation also allows a gradual transition, giving businesses and industries time to adjust and innovate in response to the new tax regime. Following that, the next paragraphs provide the empirical assessment of relationships between carbon tax (expressed as budget revenues from CO2 tax) and different macro-economic variables in Ukraine.

The variety of economic-mathematical modelling in this direction is limited due to the complex and interrelated linkages among all macroeconomic elements, as well as the absence of statistical data for the early stages of the carbon tax's implementation in Ukraine. The study's object is Ukraine's carbon emission tax, which is determined by the amount of budget revenue it brings. Increasing the efficiency of fiscal environmental policy requires an understanding of the elements which the CO2 tax influence on. Therefore, the research's challenge is to identify the key macroeconomic variables that the revenue from the carbon tax has an impact on, create quantitative linkages, and evaluate their significance.

In general, several models were designed, which included various combinations of the indicators testing whether carbon taxation impacts export, import of goods, foreign direct investment, unemployment rate, consumer price index, industrial producer index or petrol price. The developed models did not show stable interrelationships (low coefficient of determination and autocorrelation issues), which suggests that the relationship between the indicators is not linear or that the influence of other factors is complex (i.e. the impact of other variables is reflected in the indicator itself). Nevertheless, other macroeconomic indicators showed stronger interrelations with revenues from CO2 taxation, in particular household expenditures and average salary rate. Additionally, corelation of CO2 tax rate with capital investments was tested to verify whether combination of indicators described in subsection 2 based on foreign experience is relevant for Ukraine.

The budget revenue from CO2 tax is taken as an independent variable in three different empirical models, each representing separate depending variable (household expenditures, average salary, capital investments). Those models include additional independent variables where relevant to outline meaningful regression model.

Data from the website of the State Statistics of Ukraine, National Bank of Ukraine and Ministry of Finance in Ukraine are used as statistical sources for the models. A range of six years by quarter (2014–2022) of macroeconomic indicators were considered in order to assess the effects of CO2 taxing in Ukraine, which in total amounts to 36 observations.

The first factor that was considered as dependent variable is HEXPGS which denotes household expenditure of goods and services purchasing, presented in mio UAH and was obtained based on the data from State Statistics of Ukraine [27]. This factor intends to verify whether Ukrainian manufactures are prone to pass-through the tax to consumer. In comparison to Consumer Price Index (CPI) and Industrial Price Index (IPI), Household expenditures (HEXPGS) include tax component of goods and services price which is essential for our analysis. Prices for products and services that are carbon-intensive or that depend on fossil fuels for manufacturing may increase because of CO_2 tax, respectively impacting household expenditures. For this variable a hypothesis is issued: HEXPGS to have positive effect by the growth of CO_2 tax revenues (H1: $\beta 1 > 0$).

In the second model the dependent variable is SALAR that denotes average nominal salary in Ukraine in UAH based on information from State Statistics in Ukraine [28]. To align the data with model's time range, quarter values were calculated as an average of three months for each year. For the model this variable will describe how manufactures respond to the CO_2 tax increase in regard to their employees. The hypothesis for this model is that CO_2 tax revenue has a positive impact on an observed variable (H2: $\beta 1 > 0$) due to such reasons: firstly, the CO_2 tax's higher production costs could put the economy under inflationary strain, so salary rate would increase to be in line with rising costs of households; secondly, as industries adapt to new technologies associated with CO_2 emissions (such as renewable energy, green technology) there may be a shift in employment to the more qualified specialists with higher payment of labor.

The third model is calculated with dependent variable CAPI which stands for total Capital Investments in mio UAH extracted from State Statistics of Ukraine [29]. It indicates the costs of acquisition or production of tangible and intangible fixed assets on companies of all sectors of economic. This model assumes that shift to the higher CO_2 tax rates will initiate business to invest in cleaner and more environmental-safer technologies to reduce their carbon emissions and minimize tax liabilities (H3: $\beta 1 > 0$).

Each of three models have one independent variable in common which is BREVCO – budget revenue from carbon tax, presented in mio UAH and obtained based on data from Ministry of Finance in Ukraine [25]. The actual financial effect of carbon taxes on the economy is reflected immediately in revenues from the carbon tax. It offers an actual measure of the funds generated through carbon fiscal policy. In comparison to simple tax rate indicator tax revenue from CO_2 taxes is calculated using other elements such as the volume of emissions subject to taxation, changes in economic activity, and the efficiency of policy. It gives a more thorough assessment of the total economic impact of carbon pricing regimes. All three hypotheses described above are based on indicator BREVCO.

In addition to this, models were appended by other independent variables to improve model performance and enhance interpretability. Current research does not include any hypothesis for these variables; however, the results of the models can be used for their further economic interpretation. The following indicators are added:

- GASP - price of petrol 95, UAH/litre, MFU [30].
- CAPIM - capital investments in machines, equipment and tools, mio UAH, State Statistics [29].
- CREDIT - interest rates on loans to non-financial corporations, %, NBU [31].
- IMPORTP – import of scientific services, k UAH, State Statistics [32].
- IPPIMAN – industrial producer price index in manufacturing sector, %, State Statistics [33].
- PPOP - present population of Ukraine, k people, State Statistics [34].

The table below (Table 2.1) summarises the three models and issued hypotheses on selected macroeconomic variables. To sum up, all hypotheses regarding CO2 tax impact are assumed to have positive impact on household expenditures, salary rate and capital investments. These presumptions aim to define the behaviour pattern of Ukrainian industrial producers: either their pass-through carbon tax to consumer or invest in sustainable technologies to increase the profit in the future; or both.

Table 2.1 Summary of issued models and hypotheses

No.	Dependent variable	Independent Variables	Expected impact of BREVCO	Hypothesis
1.	HEXPGS	BREVCO, CAPI, GASP	positive	H1: $\beta 1 > 0$
2.	SALAR	BREVCO, CAPIM, CREDIT	positive	H2: $\beta 1 > 0$
3.	CAPI	BREVCO, IMPORTP, IPPIMAN, PPOP	positive	H3: $\beta 1 > 0$

Source: composed by author based on own calculations.

The first model with dependent variable HEXPGS can be described by the equation (2.1):

$$HEXPGS = \beta_0 + \beta_1 * BREVCO + \beta_2 * CAPI + \beta_3 * GASP \ , \qquad (2.1)$$

The analysis of the impact of independent variables on the dependent variable is performed by using the statistical package EViews 12.0, using the data given in Appendix 4. The obtained results are presented in Figure 2.5.

Dependent Variable: HEXPGS
Method: Least Squares
Date: 04/27/24 Time: 20:17
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	134420.6	60495.78	2.221983	0.0335
BREVCO	868.3219	130.1472	6.671846	0.0000
CAPI	3.203125	0.434600	7.370291	0.0000
GASP	4256.977	2734.650	1.556681	0.1294

R-squared	0.885736	Mean dependent var	696543.2
Adjusted R-squared	0.875024	S.D. dependent var	272255.5
S.E. of regression	96247.52	Akaike info criterion	25.89167
Sum squared resid	2.96E+11	Schwarz criterion	26.06762
Log likelihood	-462.0501	Hannan-Quinn criter.	25.95308
F-statistic	82.68478	Durbin-Watson stat	1.249650
Prob(F-statistic)	0.000000		

Figure 2.5 – The results of 1st model research in the EViews 12.0 program.

Source: composed by author based on own calculations.

The results of the first model show relatively strong relationship between the independent and dependent variables, however it still has potential for improvement. Normalising the data and stabilising the variance can be achieved through the application of a logarithmic transformation, so the first model is transformed to nonlinear logarithmic, and the equation (2.2) is the following:

$$LOG(HEXPGS) = \beta_0 + \beta_1 * BREVCO + \beta_2 * LOG(CAPI) + \beta_3 * LOG(GASP), \quad (2.2)$$

The figures 2.6 presents the results of the changed equation. The R-squared is higher than in previous version, and the statistical significance of variable GASP increases breaking the point of probability <0.05.

Dependent Variable: LOG(HEXPGS)
Method: Least Squares
Date: 04/27/24 Time: 17:07
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.367061	0.636840	9.997895	0.0000
LOG(CAPI)	0.525226	0.070407	7.459852	0.0000
BREVCO	0.001135	0.000176	6.442812	0.0000
LOG(GASP)	0.257563	0.121192	2.125242	0.0414

R-squared	0.912260	Mean dependent var	13.37100
Adjusted R-squared	0.904034	S.D. dependent var	0.426234
S.E. of regression	0.132040	Akaike info criterion	-1.106979
Sum squared resid	0.557909	Schwarz criterion	-0.931033
Log likelihood	23.92562	Hannan-Quinn criter.	-1.045569
F-statistic	110.9041	Durbin-Watson stat	1.351639
Prob(F-statistic)	0.000000		

Figure 2.6 – The results of 1st model research in the EViews 12.0 program.

Source: composed by author based on own calculations.

Since the variable GASP showed relatively small probability, the equation excluding this indicator was built and tested in EViews. The results are visible on the figure 2.7.

Dependent Variable: LOG(HEXPGS)
Method: Least Squares
Date: 04/27/24 Time: 21:41
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.113913	0.658091	9.290372	0.0000
BREVCO	0.001340	0.000155	8.633405	0.0000
LOG(CAPI)	0.617847	0.058169	10.62158	0.0000

R-squared	0.899875	Mean dependent var	13.37100
Adjusted R-squared	0.893807	S.D. dependent var	0.426234
S.E. of regression	0.138898	Akaike info criterion	-1.030502
Sum squared resid	0.636655	Schwarz criterion	-0.898542
Log likelihood	21.54904	Hannan-Quinn criter.	-0.984445
F-statistic	148.2948	Durbin-Watson stat	1.576447
Prob(F-statistic)	0.000000		

Figure 2.7 – The results of 1st model research in the EViews 12.0 program.

Source: composed by author based on own calculations.

$$LOG(HEXPGS) = \beta_0 + \beta_1 * BREVCO + \beta_2 * LOG(CAPI)\,, \qquad (2.3)$$

After the change elements of a model specification, the nonlinear regression model show relatively strong relationship between variables (R-squared = 0.89) and all variables are statistically significant, so the regression equation (2.3) is taken as final for results analysis.

The second model with dependent variable SALAR can be described by the linear equation (2.4). The independent variable CAPIM is taken as logarithm to stabilize the variance.

$$SALAR = -\beta_0 + \beta_1 * BREVCO + \beta_2 * LOG(CAPIM) - \beta_3 * CREDIT\,, \qquad (2.4)$$

The analysis of relationship between variable is performed using the data given in Appendix 5. The results (figure 2.8) show approximately 90% of the variability in the dependent variable is explained by the independent variables included in the model, which indicates a strong interdependence between variables. So, we keep this model specification for the final results evaluation.

Dependent Variable: SALAR
Method: Least Squares
Date: 04/28/24 Time: 18:51
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-28403.49	5328.954	-5.330031	0.0000
BREVCO	10.48237	1.629808	6.431658	0.0000
LOG(CAPIM)	3989.851	522.3415	7.638396	0.0000
CREDIT	-41546.28	8278.335	-5.018676	0.0000

R-squared	0.907940	Mean dependent var	8703.844
Adjusted R-squared	0.899309	S.D. dependent var	3809.746
S.E. of regression	1208.902	Akaike info criterion	17.13725
Sum squared resid	46766192	Schwarz criterion	17.31320
Log likelihood	-304.4705	Hannan-Quinn criter.	17.19866
F-statistic	105.1995	Durbin-Watson stat	1.511222
Prob(F-statistic)	0.000000		

Figure 2.8 – The results of 2nd model research in the EViews 12.0 program.

Source: composed by author based on own calculations.

The final model with dependent variable CAPI is outlined by nonlinear equation (2.5):

$$LOG(CAPI) = -\beta_0 + \beta_1 * LOG(BREVCO) + \beta_2 * LOG(IMPORTP) \; - -\beta_3 * IPPIMAN + \; PPOP, \qquad (2.5)$$

The data in Appendix 6 is used to analyse relationships between these variables and the results are shown on the figure 2.9. The R-squared is relativity high (0.88) and acceptable to make any conclusions. However, the variable BREVCO (which is main indicator of the research) does not show statistical significance (prob >0.05), which leads to the conclusion that our third hypothesis is not proved. Therefore, this model will not be analysed in detail further and respective results about BREVCO and CAPI interdependence will be described.

Dependent Variable: LOG(CAPI)
Method: Least Squares
Date: 04/28/24 Time: 15:49
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-10.25134	3.176829	-3.226910	0.0030
LOG(BREVCO)	0.018006	0.021804	0.825796	0.4152
LOG(IMPORTP)	0.994748	0.097827	10.16843	0.0000
IPPIMAN	-2.058657	0.669653	-3.074213	0.0044
PPOP	0.000770	0.000190	4.045734	0.0003

R-squared	0.881348	Mean dependent var	11.44066
Adjusted R-squared	0.866038	S.D. dependent var	0.434808
S.E. of regression	0.159143	Akaike info criterion	-0.709776
Sum squared resid	0.785125	Schwarz criterion	-0.489843
Log likelihood	17.77596	Hannan-Quinn criter.	-0.633013
F-statistic	57.56690	Durbin-Watson stat	2.052705
Prob(F-statistic)	0.000000		

Figure 2.9 – The results of 3rd model research in the EViews 12.0 program.

Source: composed by author based on own calculations.

In conclusion, this section provided the intuition behind selecting variables which will be tested further, described the dynamic of data and its structure. It was also discovered how the model will operate and the hypotheses to be tested.

3 RESULTS

With described and tested for significance explanatory variable (BREVCO) and explained approach of researching the dependent variables (HEXPGS, SALAR, CAPI), this section will check two selected models' hypotheses.

In order to proceed with the direct analysis of the equation, we firstly evaluate the adequacy and explanatory power of the first model (Figure 3.1).

Dependent Variable: LOG(HEXPGS)
Method: Least Squares
Date: 04/27/24 Time: 21:41
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.113913	0.658091	9.290372	0.0000
BREVCO	0.001340	0.000155	8.633405	0.0000
LOG(CAPI)	0.617847	0.058169	10.62158	0.0000

R-squared	0.899875	Mean dependent var	13.37100
Adjusted R-squared	0.893807	S.D. dependent var	0.426234
S.E. of regression	0.138898	Akaike info criterion	-1.030502
Sum squared resid	0.636655	Schwarz criterion	-0.898542
Log likelihood	21.54904	Hannan-Quinn criter.	-0.984445
F-statistic	148.2948	Durbin-Watson stat	1.576447
Prob(F-statistic)	0.000000		

Figure 3.1 – The results of 1st model research in the EViews 12.0 program.

Source: composed by author based on own calculations.

The coefficient of determination (R-squared) is 89.98% - this is how much the change in the dependent variable depends on the change in the independent variables and, accordingly, 10.02% depends on other factors not considered. The p-value of all independent variables is less than 0.05, and the t-criterion is greater than 2 (modulo), which points the adequacy of the obtained results. It is crucial to note the value of the constant C is significant, therefore, the model confirms the opinion about the difficulty of studying the interactions between macroeconomic factors. It should be emphasized that the problem is that some parameters are not included due to insufficient statistical data. F-statistics is less than 0.05, so it can be assumed that the model is correctly specified. The value of the Durbin-Watson criterion is close to 2, so we can claim the absence of autocorrelation of residuals of the 1st order, however, for more thorough conclusions, we will evaluate the autocorrelation zones of residuals. For the given model (36 observations and 2 independent variables), the lower limit is 1.354, and the upper limit will be 1.587. So, for the given model, if the Durbin-Watson criterion falls within the range of 1.35-1.6, then there is no autocorrelation of residuals of the first order, which means that the previous statement is correct.

The LM test is performed to check the autocorrelation of the residuals of higher orders in order to validate the findings obtained; the test results are displayed on Figure 3.2. The higher-order autocorrelation test revealed that a probability value is greater than 0.05, which suggests that second-order autocorrelation is absent.

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	1.166974	Prob. F(2,31)	0.3246
Obs*R-squared	2.520618	Prob. Chi-Square(2)	0.2836

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 04/27/24 Time: 21:42
Sample: 2014Q1 2022Q4
Included observations: 36
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.334028	0.693367	0.481747	0.6334
BREVCO	-3.83E-05	0.000156	-0.244785	0.8082
LOG(CAPI)	-0.028717	0.061120	-0.469845	0.6418
RESID(-1)	0.200670	0.182348	1.100477	0.2796
RESID(-2)	0.172490	0.185916	0.927785	0.3607

R-squared	0.070017	Mean dependent var	-1.63E-15
Adjusted R-squared	-0.049981	S.D. dependent var	0.134871
S.E. of regression	0.138200	Akaike info criterion	-0.991980
Sum squared resid	0.592078	Schwarz criterion	-0.772047
Log likelihood	22.85564	Hannan-Quinn criter.	-0.915218
F-statistic	0.583487	Durbin-Watson stat	1.830872
Prob(F-statistic)	0.676897		

Figure 3.2 – The results of 1st model LM-test.

Source: composed by author based on own calculations.

The resulting figure 3.3 also shows how accurately this model reproduce the real values of the deficit level based on calculations.

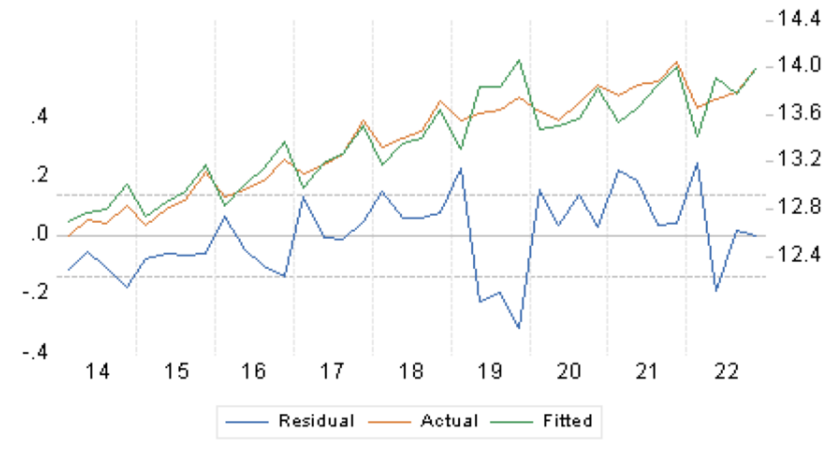


Figure 3.3 – Graphic assessment of 1st model adequacy.

Source: composed by author based on own calculations.

Testing the regression model for heteroscedasticity (Test White) demonstrated the presence of homoscedasticity (=heteroscedasticity absence), as the probability test value is higher than 0.05. The obtained results are on Figure 3.4.

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	1.227570	Prob. F(5,30)	0.3207
Obs*R-squared	6.114439	Prob. Chi-Square(5)	0.2952
Scaled explained SS	4.004503	Prob. Chi-Square(5)	0.5488

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/27/24 Time: 21:43
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.940463	2.989080	0.649184	0.5212
BREVCO^2	-1.32E-07	1.80E-07	-0.730488	0.4708
BREVCO*LOG(CAPI)	-5.11E-05	9.22E-05	-0.554374	0.5834
BREVCO	0.000696	0.001085	0.641323	0.5262
LOG(CAPI)^2	0.015251	0.023344	0.653333	0.5185
LOG(CAPI)	-0.343515	0.528571	-0.649892	0.5207

R-squared	0.169846	Mean dependent var	0.017685
Adjusted R-squared	0.031486	S.D. dependent var	0.022393
S.E. of regression	0.022038	Akaike info criterion	-4.641089
Sum squared resid	0.014570	Schwarz criterion	-4.377169
Log likelihood	89.53959	Hannan-Quinn criter.	-4.548974
F-statistic	1.227570	Durbin-Watson stat	1.737853
Prob(F-statistic)	0.320684		

Figure 3.4 – The results of 1st model test White.

Source: composed by author based on own calculations.

To prove the absence of multicollinearity, it is necessary to build a correlation matrix of pairwise dependencies between independent variables. The obtained results are shown on Figure 3.5.

	CAPI	BREVCO
CAPI	1.000000	0.330266
BREVCO	0.330266	1.000000

Figure 3.5 – Correlation matrix of dependencies between independent variables.

Source: composed by author based on own calculations.

Covariance analysis shows absence of high pairwise correlation. It is visible there are no direct or inverse relationships between the independent variables, therefore, it can be stated that there is no problem of multicollinearity.

Finally, it is necessary to conduct a test for the normal distribution of residuals, the results of which are shown on Figure 3.6.

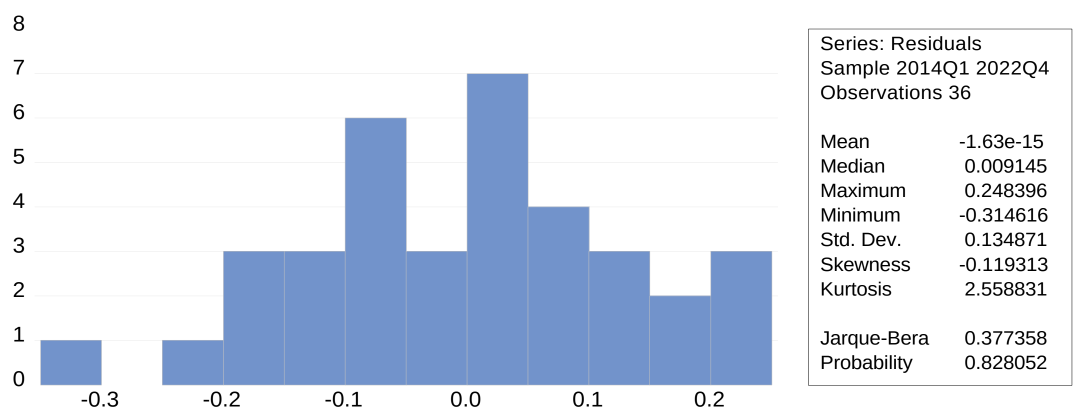


Figure 3.6 – Results of the test for normal distribution of residuals.

Source: composed by author based on own calculations.

The probability value of the Jarque-Bera test is 82.8%, meaning there is no strong evidence to reject the assumption of normality. It indicates a normal distribution of residuals.

According to the conducted tests, the first model is adequate, there are no problems of autocorrelation and multicollinearity, the residuals have a normal distribution, in addition, the regression equation has a high explanatory power. All factors are influential, none of the parameters is zero. Therefore, the equation for model with HEXPGS will be following:

$$LOG(HEXPGS) = 6.11 + 0.0013 * BREVCO + 0.617 * LOG(CAPI), \quad (3.1)$$

After evaluating the parameters, we can compare the obtained results with the initial hypothesis on HEXPGS and BREVCO interdependence. The derived economic interpretation is the following: an increase in budget revenue from carbon tax leads to a higher level of household expenditures which proves the initial hypothesis. Although the extent of this effect is relatively small - household expenditures grow for 0.0013% for each 1 mio UAH increase in budget revenue from CO2 tax.

As the next step we assess the second model adequacy explanatory power to test the interrelations between SALAR and BREVCO (Figure 3.7).

Dependent Variable: SALAR
Method: Least Squares
Date: 04/28/24 Time: 18:51
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-28403.49	5328.954	-5.330031	0.0000
BREVCO	10.48237	1.629808	6.431658	0.0000
LOG(CAPIM)	3989.851	522.3415	7.638396	0.0000
CREDIT	-41546.28	8278.335	-5.018676	0.0000

R-squared	0.907940	Mean dependent var	8703.844
Adjusted R-squared	0.899309	S.D. dependent var	3809.746
S.E. of regression	1208.902	Akaike info criterion	17.13725
Sum squared resid	46766192	Schwarz criterion	17.31320
Log likelihood	-304.4705	Hannan-Quinn criter.	17.19866
F-statistic	105.1995	Durbin-Watson stat	1.511222
Prob(F-statistic)	0.000000		

Figure 3.7 – The results of 2nd model research in the EViews 12.0 program.

Source: composed by author based on own calculations.

This linear regression model is well-specified and provides a strong explanatory framework for the relationship between variables as evidenced by the high R-squared value of 0.907, indicating that 90.7% of the variability in the dependent variable is explained by the independent variables. The F-statistics value of 105 and a probability Prob(F-stat) of <0.05 confirm the model's overall statistical significance. Moreover, the T-statistics values (>|2|) of each independent variable, along with their associated p-values (<0.05) reveal their individual significance in predicting the dependent variable. The value of the Durbin-Watson criterion is close to 2. For the given model (36 observations and 3 independent variables), the lower limit is 1.295, and the upper limit will be 1.654. So, for the given model, Durbin-Watson criterion (1.5) is within the range of 1.3-1.65, so we can claim the absence of autocorrelation of residuals of the 1st order.

To verify the results, the LM test is run and shown in Figure 3.8. A probability value larger than 0.05 indicates the absence of second-order autocorrelation.

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	1.303729	Prob. F(2,30)	0.2865
Obs*R-squared	2.878743	Prob. Chi-Square(2)	0.2371

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 04/28/24 Time: 18:57
Sample: 2014Q1 2022Q4
Included observations: 36
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2486.581	5499.461	0.452150	0.6544
BREVCO	-0.488089	1.647987	-0.296173	0.7691
LOG(CAPIM)	-200.1667	532.0944	-0.376186	0.7094
CREDIT	-2420.493	8340.255	-0.290218	0.7736
RESID(-1)	0.254186	0.188721	1.346889	0.1881
RESID(-2)	0.124549	0.186912	0.666352	0.5103

R-squared	0.079965	Mean dependent var	-2.92E-12
Adjusted R-squared	-0.073374	S.D. dependent var	1155.931
S.E. of regression	1197.588	Akaike info criterion	17.16502
Sum squared resid	43026530	Schwarz criterion	17.42894
Log likelihood	-302.9703	Hannan-Quinn criter.	17.25713
F-statistic	0.521492	Durbin-Watson stat	1.887742
Prob(F-statistic)	0.757999		

Figure 3.8 – The results of 2^{nd} model LM-test.

Source: composed by author based on own calculations.

Test White also proves the existence of homoscedasticity since the probability value is greater than 0.05. Figure 3.9 shows the results that were achieved.

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	1.796654	Prob. F(9,26)	0.1172
Obs*R-squared	13.80406	Prob. Chi-Square(9)	0.1295
Scaled explained SS	8.241955	Prob. Chi-Square(9)	0.5100

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/28/24 Time: 18:57
Sample: 2014Q1 2022Q4
Included observations: 36

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.87E+08	1.75E+08	-1.064077	0.2971
BREVCO^2	2.827309	15.67000	0.180428	0.8582
BREVCO*LOG(CAPIM)	9726.020	10963.10	0.887160	0.3831
BREVCO*CREDIT	-313301.3	177089.9	-1.769165	0.0886
BREVCO	-61915.35	100347.1	-0.617012	0.5426
LOG(CAPIM)^2	-1365986.	1823509.	-0.749098	0.4605
LOG(CAPIM)*CREDIT	2985416.	39972639	0.074686	0.9410
LOG(CAPIM)	29014583	34925641	0.830753	0.4137
CREDIT^2	-1.59E+09	6.28E+08	-2.527511	0.0179
CREDIT	4.41E+08	4.36E+08	1.013081	0.3204

R-squared	0.383446	Mean dependent var	1299061.
Adjusted R-squared	0.170024	S.D. dependent var	1619668.
S.E. of regression	1475566.	Akaike info criterion	31.47712
Sum squared resid	5.66E+13	Schwarz criterion	31.91698
Log likelihood	-556.5881	Hannan-Quinn criter.	31.63064
F-statistic	1.796654	Durbin-Watson stat	2.174898
Prob(F-statistic)	0.117237		

Figure 3.9 – The results of 2^{nd} model test White.

Source: composed by author based on own calculations.

Correlation matrix (Figure 3.10) reveals no significant dependencies, indicating no direct or inverse relationships among the independent variables, thereby indicating no multicollinearity issue.

	BREVCO	CAPIM	CREDIT
BREVCO	1.000000	0.501603	-0.463320
CAPIM	0.501603	1.000000	-0.074863
CREDIT	-0.463320	-0.074863	1.000000

Figure 3.10 – Correlation matrix between independent variables.

Source: composed by author based on own calculations.

Finally, to ensure normality of residuals, a Jarque-Bera test was conducted, showing a probability value of 63.3% (Figure 3.11). It proves no compelling evidence to reject normality assumptions. Thus, residuals are normally distributed.

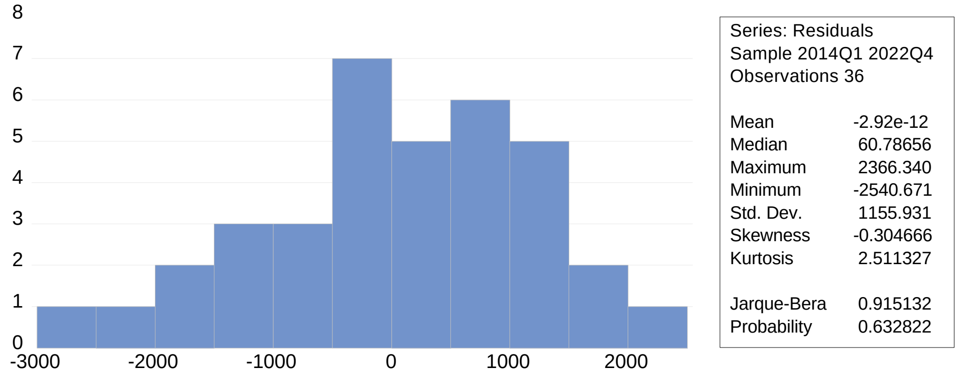


Figure 3.11 – Results of the test for normal distribution of residuals.

Source: composed by author based on own calculations.

Based on the tests conducted, the second model proves to be suitable, with no issues of autocorrelation or multicollinearity. Residuals demonstrate a normal distribution, and the regression equation exhibits strong explanatory capability. Each factor holds influence, with none of the parameters being zero. Hence, the equation for the model incorporating SALAR is as follows:

$$SALAR = -28403 + 10.5 * BREVCO + 3990 * LOG(CAPIM) - $$
$$- 41546 * CREDIT, \quad (3.2)$$

Upon assessing the parameters, we can check the findings of 2nd model comparing to the initial hypothesis regarding the relationship between SALAR and BREVCO. The resulting economic interpretation is as follows: a growth in budget revenue from carbon tax leads to a higher average salary in Ukraine which proves the initial hypothesis. So, when budget revenue from CO2 tax increase by 1 mio UAH, the average salary grows by 10.5 UAH.

The last dependent variable included in the investigation is CAPI. However, the preliminarily 3rd model analysis showed no relationship between variables BREVCO and CAPI. On top of this the scatter diagram analysis was used to check the dependence between these series, for both linear and nonlinear cases. The results on the figures 2.10 and 2.11 rejects our third hypothesis, showing that companies in Ukraine do not intent to make capital investments to clean and sustainable technologies, at least during the actual carbon tax rate in Ukraine from 2014 to 2022 years.

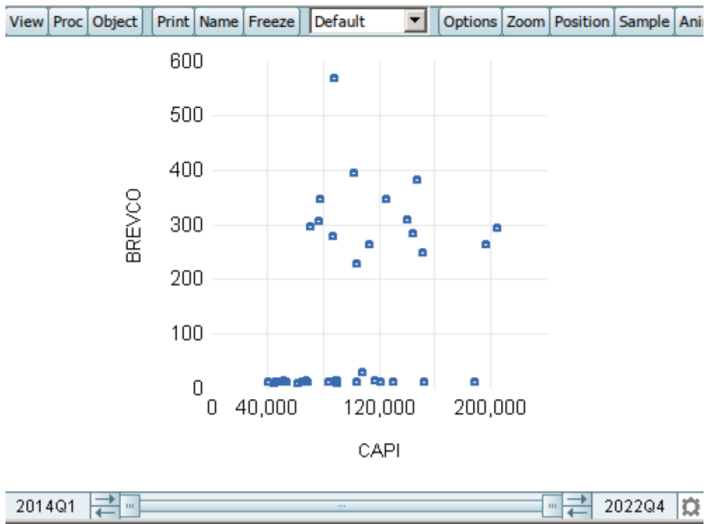


Figure 2.10 – The scatter diagram analysis in the EViews 12.0 program.

Source: composed by author based on own calculations.

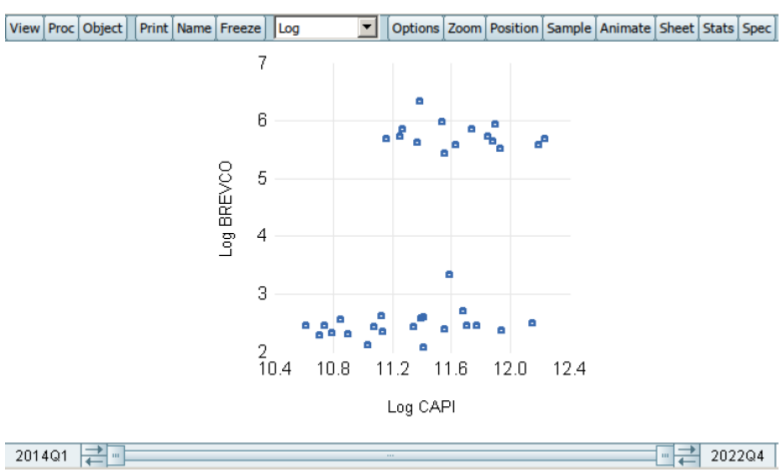


Figure 2.11 – The scatter diagram analysis in the EViews 12.0 program.

Source: composed by author based on own calculations.

According to the conducted research and tests, two regression model are adequate, there are no problems of autocorrelation and multicollinearity, the residuals have a normal distribution, in addition, the regression equation has a high explanatory power. All factors are influential, none of the parameters is zero. Therefore, it can be concluded that household expenditures and average salary rate depends on the revenues from carbon tax (positive correlation). At the same time, no evidence found regarding the relationship between capital investments and carbon tax revenue. So, it can be concluded that in Ukraine the practice of passing-through the carbon tax to consumer is present and industrial producers tend not to invest in sustainable technologies. It is important to note that the indicator c, which is the sum of all factors not included in the model, was significant, which indicates the need to continue research in this direction, including more observation after 2022 period.

For the representatives of the institutional system who ensures the functioning of fiscal policy, this study demonstrates that such low level of carbon tax does not motivate business to switch to green solution and the rates should be revised to achieve carbon free future and be aligned with EU CBAM requirements. On the other hand, the study demonstrates that carbon tax is a valuable source of state budget replenishment which can be distributed to support sustainable technologies. However, it is necessary to ensuring the appropriate level of carbon tax is chosen to avoid pushing the additional cost onto the households.

To enhance the effectiveness of carbon taxation in Ukraine, the following measures are recommended:

– Increase carbon tax rates: establish conditions where the tax rate is sufficiently high to encourage emission reductions. This can include gradually increasing rates to reach levels comparable to those in European countries.

– Invest in energy-efficient and green technologies: utilize revenues from the carbon tax to fund investments in new technologies that reduce emissions, creating long-term economic and environmental benefits.

– Ensure transparency and efficiency in revenue use: ensure that revenues from the carbon tax are used effectively and transparently, directing them towards projects that promote sustainable development and reduce the carbon footprint.

– Develop and implement regulatory frameworks: create necessary regulatory and legal frameworks to support businesses in transitioning to low-carbon technologies. This includes developing a domestic emissions trading system and plans for gradually increasing the CO2 emissions tax.

– Adapt to EU requirements: prepare for changes in environmental legislation to avoid significant financial losses due to the introduction of the EU's Carbon Border Adjustment Mechanism (CBAM). This includes transitioning to a green taxonomy based on EU legislation and establishing a domestic emissions trading system.

– Educational and awareness campaigns: conduct educational programs and awareness campaigns to increase understanding of the importance of emission reductions and the benefits of carbon taxes. This will help gain public and business support.

– Encourage innovation and technological change: promote research and development in environmental technologies. Providing grants and preferential loans to businesses implementing new energy-efficient technologies can help reduce emissions.

So, effective implementation of carbon taxation can become a crucial tool in combating climate change, promoting sustainable economic development, and ensuring Ukraine's competitiveness in international markets.

CONCLUSIONS

To make a conclusion, the work is aimed to explore the economic impact of carbon taxation in Ukraine, emphasizing its theoretical and empirical aspects. The first chapter reviewed the theoretical background, underscoring the importance of addressing climate change through fiscal measures like carbon taxes. The concept of carbon pricing, introduced by Arthur Cecil Pigou, highlights the internalization of externalities, making polluters financially accountable for the environmental damage they cause. The study discussed the advantages of carbon taxation, emphasizing its potential to generate state revenue, promote energy-efficient technologies, and strengthen national security. However, it pointed out potential drawbacks such as the possibility of increased unemployment, consumer prices and income inequality if tax rates are not optimally set.

While the theoretical model of optimal tax rate provides a clear framework, estimating the exact damage caused by emissions in practice is challenging. Therefore, tax rates often start from a political consensus on environmental goals and are adjusted based on observed effectiveness.

The empirical review included a detailed examination of carbon taxation practices globally and within Ukraine. The examples of developing countries showed that implementation of carbon taxes resulted in a projected GDP decline of 0.5% by 2035 in Brazil and GDP decrease of 2.5% by 2030 in Thailand, demonstrating the economic costs associated with ambitious emission reduction targets. Meanwhile, the GDP impact in Ukraine is estimated to decrease by only 0.1% to achieve a 5% reduction in GHG emissions by 2030.

The "Methods and Materials" section presented the descriptive analysis of carbon taxation and emissions in Ukraine. It was found manufacturing, electricity and gas supply industries are the biggest pollution contributors, together responsible for 93% of emissions, which makes these sectors the most vulnerable to tax rate changes. The regional analysis showed 32% of emissions were concentrated in Donetsk and Zaporizhzhia regions, which drove the decrease of carbon emissions and carbon tax revenues during war period. From the historical data analysis, it was concluded the carbon tax rate in Ukraine has not reached the effective level yet or that enterprises do not invest in green solutions, rather pass tax to consumers.

Sensitivity analysis of potential budget revenues under different scenarios demonstrated that a moderate increase as of 2014 would have resulted in substantial revenue growth, giving additional 344 million USD to state budget by 2023, while an aggressive approach (more aligned with EU standards) could have generated additional 1.8 billion USD by 2023 (Figure 2.4). It highlights the fiscal benefits of higher tax rates. So, for Ukraine to meet both environmental and economic objectives, it is essential to increase the carbon tax rate significantly and align it with international standards, ensuring that it provides strong incentives for emission reductions and sustainable investments.

In addition, different regression models were tested to investigate the impact of CO2 taxation on various macroeconomic variables in Ukraine over a six-year period (2014-2022). The study employed several models to test the hypotheses that carbon tax revenues (BREVCO) positively impact household expenditures (HEXPGS), average salaries (SALAR), and capital investments (CAPI). The empirical models, based on 36 observations, are adequate, there are no problems of autocorrelation and multicollinearity, the residuals have a normal distribution, in addition, the regression equation has a high explanatory power. All chosen factors are influential.

The "Results" section summarized the findings of the regression models. The first model demonstrated a strong relationship between carbon tax revenues and household expenditures, indicating that an increase in carbon tax revenue (+1mio UAH) leads to higher household expenditures (+0.0013%). This suggests that manufacturers might pass on the tax burden to consumers. The second model showed that higher carbon tax revenues (+1mio

UAH) positively correlate with increased average salaries (+10.5 UAH), implying that the economic strain from higher production costs might be compensated by increased wages. However, the third model did not find a significant relationship between carbon tax revenues and capital investments, suggesting that businesses in Ukraine do not heavily invest in cleaner technologies despite the carbon tax.

Overall, the research concludes that carbon taxation can serve as a valuable fiscal tool for Ukraine, potentially generating substantial state revenue and promoting environmental sustainability. However, the effectiveness of carbon taxes in reducing emissions and encouraging green investments depends on setting optimal tax rates and ensuring comprehensive policy frameworks. So, it is essential for policymakers to choose a robust carbon tax policy aligned with international standards, while balancing environmental goals with economic stability to avoid disproportionate burdens on low-income households and maintain economic competitiveness. Future research should continue to explore the long-term impacts of carbon taxation and its effectiveness in promoting sustainable development in Ukraine, as well as analyse further post-war impact.

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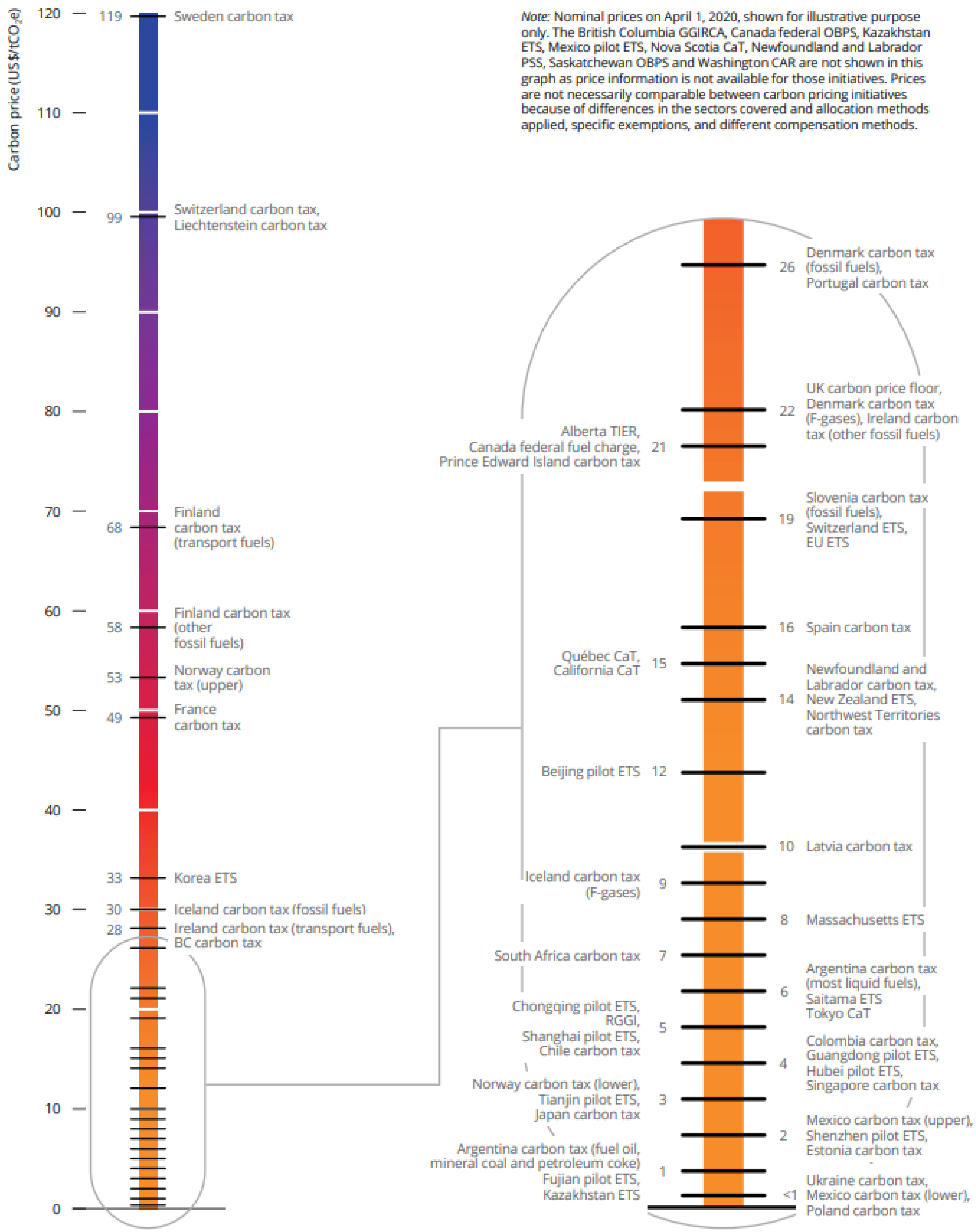
Appendix 1

Prices in implemented carbon pricing initiatives in 2020



Source: World Bank [6].

Appendix 2

Quantity of carbon dioxide emissions in Ukraine in 2021 by industry

Industry name	CO2 emissions, k tons	in % of Total	Enterprises, with CO2 emissions, units	in % of Total	CO2 emissions per 1 enterprise, k tons
Electricity, gas supply	51 997	46,5%	488	8%	107
Manufacturing	51 132	45,7%	1 671	28%	31
Mining and quarrying	2 449	2,2%	318	5%	8
Information and telecomm; financial, insurance, real estate activities	2 012	1,8%	290	5%	7
Transport, warehousing, postal activities	1 687	1,5%	781	13%	2
Agriculture, forestry	1 462	1,3%	867	14%	2
Professional, scientific and technical activities; education	290	0,3%	389	6%	1
Water supply	208	0,2%	126	2%	2
Wholesale and retail trade	159	0,1%	189	3%	1
Public administration and defence	157	0,1%	344	6%	0
Human health activities; arts, entertainment, recreation	126	0,1%	445	7%	0
Accommodation and food service activities	107	0,1%	50	1%	2
Construction	67	0,1%	89	1%	1

Source: composed by author based on State Statistics Service of Ukraine [24].

Appendix 3

Calculation of potential budget revenues from carbon tax in Ukraine

Year	CO2 emissions, mio tons	Base Scenario		
		TAX rate, UAH/CO2 ton	Budget revenue from CO2 tax, mio UAH	Budget revenue from CO2 tax, mio USD
2014	167	0,26	43	3,4
2015	139	0,26	36	1,6
2016	151	0,33	50	1,9
2017	124	0,37	46	1,7
2018	126	0,41	52	1,9
2019	121	10	951	37,2
2020	109	10	1 062	39,4
2021	112	10	1 184	43,4
2022	55	30	1 640	49,8
2023	65	30	1 953	53,4
TOTAL			**7 017**	**234**
Year	**Scenario 1**			
	TAX rate, UAH/CO2 ton	**Budget revenue from CO2 tax, mio UAH**	**Budget revenue from CO2 tax, mio USD**	**Variance vs Base Scenario, mio USD**
2014	10	1 669	133	129
2015	10	1 389	62	60
2016	10	1 506	58	56
2017	10	1 242	47	45
2018	10	1 264	47	45
2019	10	1 213	47	10
2020	10	1 091	40	1
2021	10	1 119	41	- 2
2022	30	1 640	50	-
2023	30	1 953	53	-
TOTAL		**14 085**	**578**	**344**

Appendix 3

Year	Scenario 2			
	TAX rate, UAH/CO2 ton	**Budget revenue from CO2 tax, mio UAH**	**Budget revenue from CO2 tax, mio USD**	**Variance vs Base Scenario, mio USD**
2014	10	1 669	133	129
2015	20	2 778	124	122
2016	30	4 518	174	172
2017	40	4 968	186	184
2018	50	6 320	233	231
2019	60	7 278	285	248
2020	70	7 636	283	244
2021	80	8 948	328	285
2022	90	4 919	150	100
2023	100	6 511	178	125
TOTAL		**55 545**	**2 073**	**1 840**

Source: composed by author based on calculations and [23], [24], [25], [26].

Appendix 4

Data for the 1st econometric model

Period	Household expenditure (goods and services purchasing), mio UAH	Total Capital Investments, mio UAH	Budget revenue from CO2 Tax, mio UAH	Petrol A95 price, UAH/litre
	HEXPGS	CAPI	BREVCO	GASP
2014-Q1	288,334	40809.9	11.716	13.07
2014-Q2	330,552	46050.1	11.499	15.18
2014-Q3	322,743	48616.8	10.198	16.77
2014-Q4	375,128	68584.9	10.415	16.92
2015-Q1	317,417	44741.7	9.751	17.01
2015-Q2	362,950	53982.9	10.112	20.64
2015-Q3	391,157	61998	8.306	19.52
2015-Q4	496,649	90431.7	7.945	21.6
2016-Q1	401,794	51591.7	12.921	20.08
2016-Q2	425,152	68251.1	13.667	22.32
2016-Q3	460,391	84607.3	11.431	22.37
2016-Q4	552,925	121713.6	11.679	23.67
2017-Q1	491,551	64754.4	11.259	24.5
2017-Q2	526,830	90330.7	13.327	24.59
2017-Q3	573,186	104459.9	10.799	26.27
2017-Q4	768,418	153267.7	10.569	30.2
2018-Q1	610,202	88955.1	13.121	29.09
2018-Q2	664,803	117938.5	14.882	29.18
2018-Q3	702,981	130152	11.724	32.08
2018-Q4	906,985	189296.2	12.097	34.7
2019-Q1	762,520	108298	27.798	28.49
2019-Q2	817,197	125697.5	347.678	30.22
2019-Q3	840,703	145207.6	282.549	28.76
2019-Q4	936,573	205245.5	293.443	27.32
2020-Q1	831,189	76914.3	307.510	25.35
2020-Q2	763,707	86867.2	278.080	22.08
2020-Q3	890,310	104215	228.257	23.01

Appendix 4

Period	Household expenditure (goods and services purchasing), mio UAH	Total Capital Investments, mio UAH	Budget revenue from CO2 Tax, mio UAH	Petrol A95 price, UAH/litre
	HEXPGS	**CAPI**	**BREVCO**	**GASP**
2020-Q4	1,035,340	151840.2	248.518	25.18
2021-Q1	948,664	78178.5	347.093	29.05
2021-Q2	1,030,205	112954.5	264.418	27.74
2021-Q3	1,073,677	140532.9	308.470	30.01
2021-Q4	1,252,879	197136.1	263.523	30.21
2022-Q1	854,650	70590.46426	297.091	30.4
2022-Q2	915,313	88503.57719	568.005	45.3
2022-Q3	972,748	102786.6026	393.471	49.47
2022-Q4	1,179,731	147779.3289	381.046	51.94

Source: composed by author based on calculations and [27],[29],[25],[30].

Appendix 5

Data for the 2nd econometrical model

Period	Average salary in Ukraine, UAH	Budget revenue from CO2 Tax, mio UAH	Capital investments in machines, equipment and tools, mio UAH	Interest rates on new loans to non-financial corporations
	SALAR	BREVCO	CAPIM	CREDIT
2014-Q1	3,264	11.7	13,503	15%
2014-Q2	3,488	11.5	14,475	14%
2014-Q3	3,463	10.2	14,767	14%
2014-Q4	3,685	10.4	21,469	14%
2015-Q1	3,650	9.8	12,758	15%
2015-Q2	4,113	10.1	18,006	18%
2015-Q3	4,313	8.3	20,230	18%
2015-Q4	4,753	7.9	26,347	17%
2016-Q1	4,622	12.9	22,687	17%
2016-Q2	5,072	13.7	25,616	16%
2016-Q3	5,311	11.4	30,475	15%
2016-Q4	5,744	11.7	39,098	14%
2017-Q1	6,323	11.3	35,653	14%
2017-Q2	6,953	13.3	33,265	13%
2017-Q3	7,268	10.8	37,278	13%
2017-Q4	7,878	10.6	48,571	14%
2018-Q1	7,974	13.1	32,199	15%
2018-Q2	8,782	14.9	39,135	16%
2018-Q3	9,063	11.7	44,519	17%
2018-Q4	9,650	12.1	58,302	17%
2019-Q1	9,629	27.8	37,713	16%
2019-Q2	10,430	347.7	45,003	16%
2019-Q3	10,732	282.5	48,816	16%
2019-Q4	11,223	293.4	67,178	14%
2020-Q1	11,007	307.5	35,439	12%
2020-Q2	10,850	278.1	29,106	11%
2020-Q3	11,750	228.3	33,607	9%

Appendix 5

Period	Average salary in Ukraine, UAH	Budget revenue from CO2 Tax, mio UAH	Capital investments in machines, equipment and tools, mio UAH	Interest rates on new loans to non-financial corporations
	SALAR	**BREVCO**	**CAPIM**	**CREDIT**
2020-Q4	12,780	248.5	44,366	9%
2021-Q1	12,833	347.1	26,394	9%
2021-Q2	13,785	264.4	35,956	9%
2021-Q3	14,194	308.5	40,046	9%
2021-Q4	15,260	263.5	56,329	9%
2022-Q1	13,735	297.1	35,295	10%
2022-Q2	12,856	568.0	44,252	13%
2022-Q3	13,211	393.5	51,393	16%
2022-Q4	13,695	381.0	73,890	17%

Source: composed by author based on calculations and [28], [25], [29], [31].

Appendix 6

Data for the 3rd econometrical model

Period	Total Capital Investments, mio UAH	Budget revenue from CO2 Tax, mio UAH	Import of scientific services, k UAH	Industrial Producer Price Index (Manufacturing)	Present population, k people
	CAPI	BREVCO	IMPORTP	IPPIMAN	PPOP
2014-Q1	40,810	11.7	169891.09	2.20%	45,246
2014-Q2	46,050	11.5	293358.556	14.40%	45,246
2014-Q3	48,617	10.2	293070.125	5.40%	45,246
2014-Q4	68,585	10.4	351410.872	6.60%	45,246
2015-Q1	44,742	9.8	438461.052	14.00%	42,760
2015-Q2	53,983	10.1	579176.464	10.20%	42,760
2015-Q3	61,998	8.3	594114.44	0.60%	42,760
2015-Q4	90,432	7.9	697394.346	0.30%	42,760
2016-Q1	51,592	12.9	436336.807	1.90%	42,591
2016-Q2	68,251	13.7	673002.549	7.90%	42,591
2016-Q3	84,607	11.4	756788.49	3.60%	42,591
2016-Q4	121,714	11.7	869770.11	5.30%	42,591
2017-Q1	64,754	11.3	565887.945	8.20%	42,415
2017-Q2	90,331	13.3	914340.046	3.00%	42,415
2017-Q3	104,460	10.8	965752.155	1.50%	42,415
2017-Q4	153,268	10.6	1135394.41	6.00%	42,415
2018-Q1	88,955	13.1	654257.575	4.40%	42,217
2018-Q2	117,939	14.9	1036699.36	1.30%	42,217
2018-Q3	130,152	11.7	1230289.46	1.30%	42,217
2018-Q4	189,296	12.1	1335218.09	2.30%	42,217
2019-Q1	108,298	27.8	727591.484	-1.50%	41,984
2019-Q2	125,698	347.7	1156199.83	0.50%	41,984
2019-Q3	145,208	282.5	1155874.22	-1.30%	41,984
2019-Q4	205,246	293.4	1165418.38	-3.20%	41,984
2020-Q1	76,914	307.5	662089.53	-0.20%	41,733
2020-Q2	86,867	278.1	942881.391	1.80%	41,733
2020-Q3	104,215	228.3	1086246.38	3.40%	41,733

Appendix 6

Period	Total Capital Investments, mio UAH	Budget revenue from CO2 Tax, mio UAH	Import of scientific services, k UAH	Industrial Producer Price Index (Manufacturing)	Present population, k people
	CAPI	**BREVCO**	**IMPORTP**	**IPPIMAN**	**PPOP**
2020-Q4	151,840	248.5	1279384.14	6.70%	41,733
2021-Q1	78,179	347.1	782653.426	9.90%	41,419
2021-Q2	112,955	264.4	1330662.36	9.40%	41,419
2021-Q3	140,533	308.5	1449415.18	4.90%	41,419
2021-Q4	197,136	263.5	1736017.42	2.00%	41,419
2022-Q1	70,590	297.1	958480.109	5.30%	40,998
2022-Q2	88,504	568.0	869219.712	11.30%	40,998
2022-Q3	102,787	393.5	1489242.81	5.20%	40,998
2022-Q4	147,779	381.0	1653614.7	3.70%	40,998

Source: composed by author based on calculations and [29], [25], [32], [33],[34].