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Article

Cost of Energy Consumption and Return of Excise Tax on Motor Fuels vs. the Durability of Operations and Financial Sustainability in Polish Agriculture

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Abstract: For the European Union, the course of the Community's energy and climate policy as well as changes in the objectives and priorities of the Common Agricultural Policy, as reflected, among others, in rural development programs subject to ex ante, environmental and ex post evaluation, should be considered. Individual EU countries are still implementing their own programs focused on improving energy efficiency, energy modernisation and supporting renewable energy, and they also intervene in the energy market on an ad hoc basis, as was the case after the outbreak of the war in Ukraine. This article fits into such a broadly understood research perspective, and its primary goal is to identify the impact of the costs of energy consumption and the reimbursement of excise tax on motor fuels on the operational durability and financial sustainability of 103 farms belonging to the Polish FADN network, which in 2017–2021 implemented modernisation projects under the rural development program. Logistic and linear multivariate regression were used to estimate the strength, direction and significance of correlation relationships. It was found that relative energy costs were significantly negatively correlated with financial sustainability only in the linear model, while the impact of excise tax return was positive but not significant. Thus, an empirical proof of the advisability of a possible public intervention aimed at making farmers' access to energy cheaper was obtained. All public interventions in agricultural energy use should be subject to careful and systematic ex ante, mid-term and ex post assessments based on sound program theory. It is necessary to identify the cause-and-effect chains, in which the regression proposed in the article may be helpful.

Keywords: cost of energy in agriculture; operational durability; financial sustainability; return of excise tax on motor fuels in agriculture; energy in EU agriculture; modernisation of farms; financing of investments in agriculture; Poland; the Polish FADN

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1. Introduction

In 2020, EU agriculture and forestry consumed a total of 886 million tonnes of oil equivalent in direct energy, which was lower by 5.6%, as compared to 2019. This decrease resulted directly from the crisis caused by the COVID-19 pandemic. The two distinguished sectors consumed only 3.2% of the energy consumed directly in the EU, but at the same time, they recorded an increase in the given two-year period by 0.6%. The increase occurred in only fifteen countries. Relatively, these two sectors consumed the most energy among the Member States in: the Netherlands (9.0%), Poland (5.5%) and Lithuania (5.4%). On the other hand, there were: Luxembourg (0.7%), Malta and Slovakia (1.4%). EU agriculture and forestry generally rely on petroleum products, including biofuels (56% of consumption in 2020). Since the EU has been positioned as a world leader in the decarbonisation of its economies for years, it should be assumed that the EU agriculture will also be covered by the reduction effort. Various energy policy instruments will be used for this purpose. This article presents only the problem of the costs of energy carriers and the return of excise tax on motor fuels. We do not address the implications of the conflict between Israel and Hamas for energy markets at all.

The COVID-19 pandemic has already caused major perturbations on international energy markets. When the situation seemed to be stabilising in the second half of 2021, in February 2022 war broke out in Ukraine. Problems with the rhythmic supply of energy at prices acceptable to its recipients have become so severe that the International Energy Agency (IEA) began to write and talk about the global energy crisis [1]. Due to the drastic increase in natural gas prices, difficulties in supplying farmers with artificial fertilisers, primarily nitrogen fertilisers, appeared very quickly [2]. In turn, the Russian blockade of Ukrainian Black Sea ports sharply reduced the country's agricultural and food exports. Thus, a food crisis appeared on the horizon [3]. The threat of a humanitarian and refugee crisis has become real. Therefore, Tooze was right when he described the situation at the turn of 2022/2023 as a "polycrisis", i.e., a combination of global, cumulative and cascading threats. However, limiting ourselves only to the latest energy crisis, it should be pointed out that it shows some similarities to earlier crises of such a type (local energy shortages, outbreak of war, market manipulation and speculation in derivatives, weather shocks) [4]. What sets it apart, however, is that it basically co-occurred with the COVID-19 pandemic [5]. It is also indisputable that the current crisis has hit the economies and societies of the European Union countries the hardest. This was mainly due to the fact that most of them over-relied on imports of hydrocarbons from Russia, and natural gas in the first place. When Russia limited its exports and the EU started to introduce sanctions, gas prices increased 4–5 times. This immediately translated into a similar increase in the prices of nitrogen fertilisers, which directly threatened agri-food production. In such conditions, the EU institutions have introduced a number of ad hoc measures and initiated operations that, in the long term, mean a deep energy and climate transformation of the Community. The implemented programs will also cover the EU agriculture and food sector. Policy interventions in the energy market in EU agriculture should be subject to careful ex ante and ex post evaluation by the relevant public institutions. Unfortunately, the evaluations are usually treated as formal and statistical obligations [6–8]. It should definitely change, because in the CAP for 2023–2027, the issues of energy modernisation of rural areas and agriculture gained a high priority, which was reflected in the national strategic plans and rural development programs. The problem often becomes even more complicated, as energy modernisation will also be subsidised in the cohesion policy and other EU programs, which will usually also be supported from budgets of member states. Therefore, any intervention should be evaluated on a sound scientific basis. This article contributes to their creation.

In the above context, the primary goal of this article was to identify the impact of energy costs and excise tax return on the durability of operations financed from EU funds and financial sustainability at FADN (Farm Accountancy Data Network) farms that implement modernisation projects under the Polish rural development program for 2013–2020. The results can be incorporated into the ex post evaluation methodology of the projects. Achieving the aforesaid goal is intended to support the following thesis: The high generality of the definition of the category of "durability of financial operations" by the European Commission, the widespread lack of systematic accounting in EU agriculture and the orientation of the FADN to the needs of mainly CAP assessment make it difficult to link it to energy costs and excise tax return. The "financial sustainability" category seems to be better in this respect. From the knowledge available to the authors of the article, no one has yet published a paper on a similar topic that uses the same tools of empirical analysis. In this sense, this article represents a novelty.

2. Review of Literature and Context Analysis

The presented article is directly and indirectly related to many detailed issues concerning the use of energy in agriculture, which are discussed in the literature on the subject and reviewed below.

The issue of measuring, assessing and identifying determinants of energy consumption (also expressed as a monetary cost) or energy efficiency of farms in the EU is reflected in the literature on agricultural economics. The research conducted so far can be classified into the following areas: (1) methodological; (2) empirical. It should be noted that only a few empirical studies using FADN resources as sources of secondary data were identified, while an in-depth bibliometric analysis in the Web of Science and Scopus databases did not reveal any study exploring energy consumption and durability of investment projects (operational durability) and financial sustainability.

Economic assessment of the effects of changes in European law is an important and current area of research related to energy consumption in the agricultural sector.

Research on energy consumption in the agricultural sector in the EU is based on aggregated Eurostat data. For example, Rokicki et al. [9] analyzed the energy intensity of agriculture in EU countries. In their study, they recognised and presented the current situation and changes in the energy intensity of agriculture in the EU Member States. A high concentration of energy consumption in agriculture was found in several EU countries, the highest in countries with a significant agricultural sector, i.e., France and Poland. Only in the case of renewable energy was a gradual decrease in concentration visible. However, EU countries differed in the structure of energy sources used in agriculture. Liquid fuels were the most significant source of energy, while solid and gaseous fuels were gradually abandoned in favour of electricity and renewable sources.

Bratka and Prauliņš [10] determined the level of energy consumption in farms per unit of livestock and hectare of agricultural land in dairy farms since Latvia's accession to the EU, i.e., 2004.

The disruption of natural gas supplies by Russia to the European Union caused by the outbreak of war in Ukraine and the subsequent sanctions imposed by the latter on Russia resulted in a sharp increase in the price of this energy carrier. In the wake of this, a large number of EU members began to implement various shielding packages, the main aim of which was to reduce the impact of this price shock on households and businesses. Such measures were also introduced in Poland, and Polish farmers were particularly privileged. Budget subsidies applied to virtually all energy sources used in agriculture. In addition, the excise duty reimbursement limit for agricultural fuel was increased.

Changes in energy prices, also known as energy inflation, affect the inflation of agricultural and food prices (agflation) and the overall consumer price change index (CPI). Here, then, we have an obvious link between energy prices and fundamental macroeconomic categories (growth, inflation, unemployment, the exchange rate and the fiscal position of states). In turn, agflation itself should also be implicitly linked to such general phenomena as globalisation, international trade and geopolitical risk [11]. Of course, the links between agflation and agricultural production should not be lost from sight. The study of the relationship between energy inflation, agflation, the CPI and the volume of agricultural production is not easy, as it can be non-linear and asymmetric, i.e., different when agflation increases and different when it decreases.

The effect of energy prices on agricultural production was one of the topics examined by Mam et al. [12]. They built a model (PEM) that integrated energy price, energy consumption, carbon emissions and agricultural production as variables. They found that energy costs had a very small effect on agricultural production, but that producers would lose 0.6% to 1.4% of their welfare if energy prices increased, depending on different scenarios. They also showed that total costs were clearly affected by energy price fluctuations. Total costs changed by more than 0.9% in the low scenarios, and by 1.91% and 1.80% in the high scenarios. Moreover, they observed a clear negative relationship between welfare and energy prices, which implies that lower energy prices would benefit producers. The effect of energy prices on welfare was about a quarter smaller than the effect on total costs of agricultural production.

Karkacier et al. [13] presented the regression model where agricultural productivity was as a function of its energy consumption and gross additions to fixed assets. The model referred to Turkish agriculture. They found that there was a very strong and significant relationship between energy use and agricultural productivity.

Energy costs in agriculture can have a multichannel effect on agricultural prices and final food prices. Firstly, modern agriculture is based on the use of machinery, equipment and technologies that are mainly powered by petroleum fuels and electricity. However, the impact of the costs of their use is limited by their relative share in direct and total costs. Secondly, the costs of petroleum fuels affect the price of maize, which in turn is linked to the price of biofuels. The third channel is the link between maize prices and livestock production costs, and this is then reflected in dairy and meat prices. The fourth channel is the relationship between fuel prices, maize prices and the cost of other agricultural products [14]. The challenge for researchers now is to adapt methodological tools so that the above channels can be studied in the convention of whole food chains and not just narrowly defined agriculture. Among other things, this means that it is necessary to study the transmission of energy price shocks in all links of these chains, and thus also how they affect the prices of inputs (e.g., fertilisers) used in agriculture.

Prices of energy carriers show greater volatility than prices of other goods [15]. This circumstance is a challenge for researchers, as it prompts a slightly different view of the putty clay model by Atkeson and Kehoe [16], which reflects the relationship between energy prices and the prices of internal combustion engine-powered machinery, equipment and vehicles, and the decisions above should maximise firms' profits and household utility. If the volatility of fuel prices increases, the price elasticity of fuel demand decreases. As a consequence, users of, for example, motor vehicles pay less attention to prices when considering their purchase decisions. This further implies that high price volatility is negatively correlated with sales of internal combustion engine-powered equipment. However, the actual reactions of companies and households are largely modified by their level of risk aversion. An additional factor that must be taken into account in the analysis is fuel taxation. If they are introduced or increased during a period of low price volatility and achieved quickly, their impact on demand for combustion engine equipment will be higher than if the same tax changes are made but at a time of high volatility and achieved slowly.

The return of the excise duty contained in agricultural fuel analyzed in this article is worth placing in a broader context, namely, the general theory of taxation of energy carriers. It emphasises that these taxes are intended to achieve several objectives: the environmental friendliness of economic activity and household behaviour; securing a sustainable energy supply at socially and economically acceptable prices; stimulating energy and economic efficiency; accelerating the energy transition that will reduce greenhouse gas emissions, thereby slowing the build-up of the climate crisis; and providing states with adequate fiscal revenues [17,18]. The issue of replacing them with sales and income taxes, which would mitigate the effects of the commonly used regressivity of energy taxation, which privileges wealthier economic actors and households, also features prominently [19]. In general, theorists in the field of energy taxes also emphasise their favouring of behavioural flexibility on the demand and supply side of energy carrier markets [20]. Finally, it devotes a great deal of space to the use of simplified uniform tax rates and the abandonment of exemptions from these public tributes [21]. This is to counteract the so-called implicit cross-subsidies of richer consumers by poorer ones and the scaled up investments in renewables. On the other hand, transaction costs in energy carrier supply chains and systems are then expected to fall, while the tax base remains stable. At the same time, the general literature tends to oppose exemptions and reductions in energy tax rates and thus the application of, for example, excise duty refunds to farmers.

Optimal taxation of motor fuels, and therefore imposition of excise tax on agricultural fuel, refers to the fundamental work of Mirrlees in 1971 [22], in which he concluded that the marginal income tax rate should always be nonnegative. Parry and Small, concretising the Mirralees model on the example of gasoline taxation, determined that the optimal uniform rate of gasoline taxation should consist of: Pigou's tax, which will reflect environmental damage due to their combustion; the Ramsey tax, which is pure fiscal income; and compensation for congestion caused by petrol powered vehicles, as society benefits when congestion is reduced [23]. However, this reasoning assumed the existence of perfect taxes and the lack of external effects related to the intensity of use of gasoline burning vehicles. An even more fundamental problem with this convention was the omission of taxation of the vehicles themselves. The issue became serious when countries, especially in Europe, began to introduce exhaust emission standards. A key change was also the climate convention in Paris in 2015, where countries declared their readiness to reduce greenhouse gas emissions, including those from the use of motor fuels. Another impulse to look for new concepts for taxing these fuels was the introduction of electric cars to the market. Electric, methane and biomethane drives are also beginning to appear in agriculture. Hence, researchers increasingly often combined the taxation of these fuels with vehicle purchase prices in one model. Let us add that CO_2 emission reduction standards also apply to tractors, vehicles and agricultural machines (Stage V standard in the European Union).

Following the outbreak of the war in Ukraine, Europe, and the European Union in particular, experienced major disruptions on energy markets, which resulted in a sharp increase in their prices. Some governments have introduced new shielding measures for companies and households. These packages also included reductions in taxes charged on motor fuels, which is related to the issue of refund of excise tax on fuels purchased by farmers, discussed in this article. Such fiscal intervention may result in the phenomenon of pass-through from energy suppliers to its final consumers. Its source is insufficient competition at the level of general energy markets and imperfect information to end users about the price setting mechanisms and transmission of prices themselves [24]. What usually happens is that energy suppliers, knowing about the upcoming tax changes, increase the prices of their products in advance. Passing on taxes and their changes, including reductions, may be full or partial. This is shown by research conducted for Germany, where the taxation on gasoline and diesel oil was reduced in June–August 2022. The pass on of this reduction to end users was within a wide range: from 34 to 90% in the case of gasoline and from 70 to 100% for diesel [25,26]. Interestingly, after the expiry of the fiscal intervention, fuel prices increased again, but to a lesser extent than the reduction caused by it. For the refund of excise duty on agricultural fuel, we are probably dealing with similar mechanisms, but this problem has not yet been empirically examined. The pass-through phenomenon also applies to energy subsidies, energy costs and energy prices [27]. It is also a good verifier of the distribution of forces between contracting parties on energy markets and between links in supply chains and networks as well as value creation.

All vehicles, machinery and equipment powered by combustion engines, including those used in agriculture, are an important source of greenhouse gas emissions on a global scale. Hence, various policy instruments are being implemented to reduce their specific fuel consumption already at the manufacturing stage.

The high level of poorly targeted subsidies to agriculture may result in many people with low income and low social status remaining in this sector [28]. In the case of the CAP, it was observed that, even though they had a negative impact on technical change throughout the Community, on the other hand, there were significant differences between individual member states [29]. For investment subsidies, it was also found that sometimes they had a positive impact on generating added value and diversification, but it was negative when direct payments were used to reduce incentives to respond to signals coming from the markets. On the other hand, broadly understood innovations had a definitely positive impact on the added value. The problem, however, appeared on small farms, as their managers generally had lower competences, especially digital ones, and were poorly integrated into the industry food chains. Improved governance of agricultural and rural policy with respect to regional governance may be a remedy for it.

The durability of operations is a narrow category of farm achievement measurement. The financial sustainability is definitely broader, with a greater informative and decision-making value. This, in turn, is a component of the economic status of farms, but it falls within the broader concept of their viability [30,31]. In this article, however, we will limit ourselves to financial sustainability only. Literature review shows that few authors have so far dealt with defining and measuring financial sustainability and identifying its determinants. For example, three Italian researchers have the phrase "financial sustainability" in the title of their article, but in fact they do not define this category [32]. However, they use a measure of sustainability in the form of two quotients: free cash flows and equity, and the same flows and depreciation. Dono et al. [32] also performed a regression calculation, but the dependent variable was operating cash flow divided by family workforce. The set of independent variables included: agricultural area, stocks, investments, subsidies from the first and second pillar of the CAP, return on assets, changes in equity and two relations: price and production benefits, which, however, were not defined. Virtually all of the above variables are expressed in absolute terms.

Lakhani et al. [33] understand financial sustainability as achieving specific returns on investment. The essence of the approach is presented by means of the procedure of determining profitability of formalisation of traditional cattle and buffalo breeding in Pakistan (the Adhyara system). For this purpose, a hedonistic model of determinants of the final price of cow and buffalo heifers was constructed, and it was then subjected to stochastic simulation. In this way, return on a five-year investment of farmers was obtained, which was then compared with the possible real returns on the Pakistani stock exchange and on international markets in 2002–2020. The simulation model was also used to study the impact of various rearing parameters on the above return.

References to financial sustainability, even though indirectly, can also be found in authors who dealt with the general financial analysis of farms, their economic sustainability and vitality. Ahrenson and Katchowa [34] as well as Farm Financial Ratios and Guidelines [35] use the replacement margin ratio (the difference between debt servicing capacity and cash replacement expenses), which may be a surrogate of financial sustainability. Financial stability ratios also show some affinity to the category of financial sustainability in the construction of the aggregate index of economic durability by Zorn et al. [31]. Smale et al. [36], in their definition of farm viability, also mention the rate of capital replacement and the ability to repay loans taken out for this purpose. Frawley and Commins [37], as a second condition of viability, require a return of at least five percent on farm assets other than land. We also find the same requirement in Hennessy et al. [38]. In turn, Barners et al. [39] and Vrolijk et al. [40], in their definition of viability, mention the ability of farms to repay financial liabilities. In all the above cases, however, it would be necessary to define some desirable or critical values in order to be able to treat these indicators as dependent variables in regression models.

It is common in the world to subsidise the production and use of energy in various ways. Overland [41] presents the relationship between subsidies to fossil fuel prices and climate change. There is also a rich general literature on energy prices, their reduction and the reaction of economic entities and households to them. Let us limit ourselves here to selected items from 2023 only. Dressler and Weiergraeber [42] deal with the inertia of electricity consumers and their low understanding of the rules of the market, which discourages them from changing suppliers, even when it may improve their welfare. Gelman et al. [43] constructed a model with which they studied reactions of American consumers' spending to changes in gasoline prices. In turn, He and Tanaka [44] worked on determining the impact of non-monetary variables on the demand for electricity in Japan after the disaster at the nuclear power plant in Fukushima.

The complex nature of the return of excise tax contained in agricultural fuels, i.e., the combination of the nature of other operating income with cost reduction, is most fully reflected in the literature on public finance. In addition, however, it is also worth using publications on energy economics. For example, this issue is addressed by Bhattacharyya [45] and Zweifel et al. [46]. Fiscal incentives supporting activity in the field of modernisation investments of private entities are also of interest to public financiers. However, it is also worth looking for inspiration among energy economists. The book by Sadler [47] is, for example, a good introduction. In the case of investments in households, Berkouwer and Dean [48] show their broad determinants if the income is low. In turn, Tuominen et al. [49] constructed a *cost effectiveness assessment* (CEA) system that can be used to assess the effectiveness of energy-saving investments. There are also more and more publications that are interested in the use of fiscal preferences for the implementation of renewable energy sources. Articles by Afridi et al. [50] and Takeshima et al. [51] can be given as an example.

Summing up, the literature review carried out by the authors shows the existence of several research niches concerning the use of energy in agriculture. In particular, the research gap related to exploring the relationship between energy consumption and investment durability and financial sustainability of farms is acute. This authorises the authors to undertake empirical research in this respect.

3. Materials and Methods

Econometric models, being the result of empirical analysis, use economic and financial data on individual farms, as collected in the Polish FADN system (Farm Accountancy Data Network), an integral part of the "European system for collecting accountancy data from farms". The Institute of Agricultural and Food Economics–National Research Institute is the FADN Liaison Agency in Poland. FADN is one of the tools that help in the programming and implementation of CAP tasks, as the data in this system are used, among others, for: "(1) annual determination of the income of farms operating in the Community, (2) analysis of farm activity, (3) assessment of the effects of the planned changes in the Community's agriculture". In the field of observation of the European FADN system, there are commercial farms producing about 90% of the value of Standard Output (SO) in a given region or country. SO defined as the 5-year average production value of a specific crop or livestock production activity obtained from 1 ha or 1 livestock head in 1 year, in average production conditions for a given region. Classification of farms in FADN is carried out according to two criteria: (1) economic size, (2) agricultural type. The economic size of a farm is determined by the total of SO obtained from all agricultural activities on the farm, while the agricultural type of the farm is determined by the share of SO from particular groups of agricultural activities in the total value of SO from the farm [52–54].

In accordance with the assumptions of this article, it was limited only to farms that received modernisation subsidies under the Rural Development Program 2014–2020. Due to normal delays in such schemes, this support only started to be disbursed to a greater extent in 2017. Hence, a group of 103 entities that implemented subsidised investments in 2017–2021 was distinguished. This five-year period is necessary to determine durability of operations. The assessment of meeting the conditions is one of the tools for evaluating modernisation projects in EU development programs. This category of durability in relation to operations financed from the EU funds, including the Common Agricultural Policy (CAP), has not been precisely defined. As a rule, related terms are used, referring indirectly to the assessment of durability, consisting in answering the following questions: (1) How are the changes caused by the implementation of the investment permanent and long-term? (2) Will the beneficiaries continue to function after the end of support? The measurement and assessment of durability is particularly important from the point of view of the activities of the Rural Development Program (RDP), which in fact leads to an increase in the investment activity of farms.

The legislative "core" for the durability assessment concerns Regulation (EU) No. 1303/2013 of the European Parliament and of the Council of 17 December 2013, laying down common provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the Euro–European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund and laying down general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund and the European Maritime and Fisheries Fund and repealing Council Regulation (EC) No. 1083/2006. According to art. 71 par. 1 of the regulation, durability concerns projects in fixed investments or production investments, i.e., investments in fixed assets or intangible assets, necessary to conduct production or service activities (cf. [55] (p. 5)).

In agriculture, the category of gross value added is often used as a measure of potential, along with efficiency and effectiveness [56]. Instead, however, the structure "ordinary financial result plus staff costs" can be used. Then we can compare family farms with entities that are profit-oriented. It is good to relate both of these figures to one employee. In the strategic dimension, generating added value is conditioned by creating opportunities for the growth of farms and the scale of their activity. It should be added that value added is often used as a measure of the overall productivity of agriculture and the food sector, and in econometric models it appears as a dependent variable whose determinants often appear as absolute, not relative values (indicators) [57].

Gross value added will be used to measure durability of operations, but after adjustments. It means that it will be expressed in constant prices, using the GDP deflator for 2017–2021. Then, changes in agricultural land and number of livestock animals in the given period in each farm will be taken into account. According to the EU regulations, durability of operations will be achieved when the added value after adjustments in 2021 is at least 10% higher than its 2017 level. There were 103 farms that met the above condition in the sample. The durability of operations determined in the above way in the regression model will be a binary dependent variable, i.e., it will take 1 when there is a minimal increase in added value, and 0 otherwise. As part of the study of the stability of the obtained estimates of regression parameters, additional calculations will be made, in which the durability of operations will be measured by the added value indicator. It is a quotient of this (gross) value and the farm production value.

Based on the literature review, we used the ratio of gross investment (SE516) and depreciation (SE360) (both as binary and continuous variables) as a proxy for financial sustainability.

Research on the impact of subsidising modernisation investments on the total and partial efficiency and productivity of agriculture was carried out by, among others: Harris and Trainor [58], Nillson [59], Nillson and Wixe [60], Ratinger et al. [61] and Serra et al. [62], using as explanatory variables in their models, among others:

- Amount of support;
- Additional subsidies received under rural development programs;
- Total assets;
- Number of employees on farms;
- Education of farm managers, including farm managers;
- Age of the farm manager;
- Ecological nature of the farm;
- Area of land eligible for direct payments;
- Agricultural area of the farm;
- Other variables (share of export production, population density in the administrative unit where the farm was located, natural conditions in which agricultural production was carried out, region and time).

The impact of the above determinant on dependent variables was very diverse in terms of its direction, strength and statistical significance. What is interesting, however, is that more often positive, significant correlations between modernisation subsidies and efficiency were observed in smaller farms (e.g., Nilson [59]; Ratinger, et al. [61]; Rizov et al. [63]). One possible explanation for this phenomenon may be that smaller farms face greater constraints and find it difficult to implement investments without subsidies at all [64]. Similar conclusions were also drawn by Blomquist and Waldo [65] but using the example of *a deadweight loss* in the Swedish aquaculture and fish processing sector. In this context, an alternative to subsidising the modernisation of farms themselves may be to focus on agricultural credit in order to reduce market imperfections [66]. There is also a lot of research that shows that it may be more socially effective to subsidise public investments in the countryside and in the vicinity of agriculture than simply subsidise the investments of farmers themselves due to the acceleration of technology transfer and diffusion of innovations (for example: Bergström [67]; De Long and Summers [68]; Gullec and Potthelsberghe [69]).

By using the above valuable empirical experience, a set of independent control variables describing the use of energy and control variables was proposed for econometric models, as listed in Table 1.

Table 1. Description of key and control independent variables.

Variable	Description
Agricultural land area	Agricultural land area (in ha)—SE025 variable in FADN Standard Results
Crop type	1—agricultural type, in accordance with the FADN TF8 typology, field crops, horticultural crops, permanent crops, 0—other
Livestock type	1—dairy cows, herbivores; granivores; 0—other
Mixed type	1—mixed type, 0—other
FADNREG1	1—Pomerania and Mazury; 0—other regions
FADNREG2	1—Wielkopolska and Śląsk; 0—other regions
FADNREG3	1—Mazowsze and Podlasie; 0—other regions
FADNREG4	1—Malopolska and Pogórze, 0—other regions
MobileAge	1—age up to 44; 0—over 44
Agricultural education	1—basic agricultural education, agricultural secondary education, agricultural higher education; 0—other
Secondary education and more	1—non-agricultural secondary, secondary agricultural, higher non-agricultural, higher agricultural; 0—other.
Total profitability index	Total profitability ratio calculated according to the formula: $\frac{\text{total production}}{\text{total costs}} \times 100$
Increase in equity	Increase in equity calculated according to the formula: $\frac{\text{equity capital (SK)} - \text{equity capital (SP)}}{\text{equity capital (SP)}} \times 100$
Increase in working capital	Increase in working capital calculated according to the formula: $\frac{\text{eworking capital (SK)} - \text{working capital (SP)}}{\text{working capital (SP)}} \times 100$
Total assets-to-equity ratio	$\frac{\text{equity capital (SK)}}{\text{total assets (SK)}} \times 100$
Asset immobilisation ratio	$\frac{\text{fixed assets (SK)}}{\text{current assets (SK)}} \times 100$
Subsidy rate (I)	$\frac{\text{operating subsidies} + \text{investment subsidies} + \text{milk compensation}}{\frac{\text{crop production} + \text{livestock production}}{\text{family farm income}}} \times 100$

Note: SK—end balance; SP—start balance. Source: own development based on: [70,71].

Table 2 presents basic descriptive statistics (i.e., mean, standard deviation, minimum and maximum) for a set of dependent and independent variables (including binary variables) for an empirical sample of 103 farms. The surveyed group of farms is not homogeneous, as it includes units that differ regionally in terms of natural and soil conditions, production type, socio-personal characteristics of farm managers and their families, the level of subsidisation and the method of asset management and financing. The factors must clearly translate into the basic descriptive statistics of the set of variables.

Table 2. Basic descriptive statistics for a set of dependent and independent variables.

Variable	Average	SD	Min.	Max.
Cash flow (II)/depreciation [multiples]	2.19	2.91	−20.90	11.20
Gross investment/depreciation [multiples]	1.353	2.76	−1.876	19.57
Gross investment/depreciation *	0.32	0.46	0	1
Net investment/depreciation [multiples]	0.35	2.76	−2.87	18.57
aGV/total production [multiples]	0.69	0.29	0.195	2.11
Energy [%]	44.98	13.67	17.07	78.15
Energy [PLN/ha UR]	692.70	525.40	74.76	4.56
Excise duty [%]	5.67	2.43	0	9.85
Excise duty [PLN/ha UR]	81.33	32.82	0	153.00
Agricultural land area [ha]	60.09	56.37	12.35	457.6
Crop type *	0.44	0.50	0	1
Livestock type *	0.35	0.48	0	1
Mixed type *	0.19	0.39	0	1
FADNREG1 *	0.14	0.35	0	1
FADNREG2 *	0.24	0.43	0	1
FADNREG3 *	0.43	0.49	0	1
FADNREG4 *	0.17	0.38	0	1
Mobile age *	0.70	0.45	0	1
Agricultural education *	0.65	0.47	0	1
Secondary education and more *	0.73	0.44	0	1
Total profitability ratio [%]	133.50	38.24	37.64	227.80
Increase in equity [%]	5.90	9.32	−12.97	52.65
Increase in working capital [%]	32.96	81.08	−305.90	349.70
Total assets-to-equity ratio [%]	92.04	9.98	45.87	100.00
Asset immobilisation ratio [%]	7.48	5.42	1.83	37.09

Note: GV—adjusted gross value added in 2021 compared to the level of gross value added from 2017; * binary variables. Source: own study.

In order to carry out the empirical analysis, several econometric methods were used, i.e., modeling with the use of logistic regression and multiple linear regression (OLS regression).

The logistic regression model, commonly known as the logit model, is mainly used to describe qualitative phenomena. In the basic version of the model, dichotomous variables are considered, the variants of which are assigned the value 1 when the desired event occurs, or the value 0 when such an event does not occur; hence, the model is also called the binomial model [72]. The logit model has the following form [73]:

$$y_i^* = \ln \frac{p_i}{1 - p_i} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki} + u_i$$

where y_i^*—unobservable variable, $\ln \frac{p_i}{1-p_i}$—logit; β_j—model structural parameter; x_{ji}—values of explanatory variables of the model; u_i—random component; p_i—probability of the dependent variable y_i assuming the value 1, determined on the basis of the density function of the logistic distribution:

$$p_i = \frac{\exp(x_i'\beta)}{1 + \exp(x_i'\beta)} = \frac{1}{1 + \exp(-x_i'\beta)} = \frac{1}{1 + e^{-y_i}} = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki})}}$$

The unobservable variable y_i^* is a hidden variable. On the other hand, the observable variable is the variable y_i, which takes the form y_i^*. y_i, [74]:

$$y_i = \begin{cases} 1; \ y_i^* > 0 \\ 0; \ y_i^* \leq 0 \end{cases}$$

Logit is the logarithm of the odds ratio of accepting and not accepting the value 1 by the variable y_i. If the odds are the same (p_i = 0.5), the logit is 0. However, if p_i < 0.5, the logit takes negative values, and for p_i > 0.5—positive. The logit transformation of probability enables replacing the p_i value by a number from the range (−∞, +∞). It can be written as follows [74]:

$$\frac{p_i}{1-p_i} = \exp\left(x_i'\beta\right) = \exp(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki})$$

The above formula shows that increase in the X_{ji} value by one unit is associated, *ceteris paribus*, with $\exp\left(\beta_j\right)$-fold change in the odds ratio. If $\exp\left(\beta_j\right) > 1$, an increase in the odds ratio $\frac{p_i}{1-p_i}$ is observed, while in the case of $\exp\left(\beta_j\right) < 1$—its decrease [74].

Assessment of the quality/fitness of logistic regression models was also investigated [75], using e.g., McFadden's pseudo-R-square, log-likelihood and the counting R-square relating to the accuracy of the forecast (total).

A multiple regression model, also referred to as a multiple/multivariate regression model, is a model that uses multiple explanatory variables to predict the predicted value:

$$y = a_0 + a_1 x_1 + a_2 x_2 + \ldots + a_k x_k + \varepsilon$$

where y—explained variable (dependent); a_0—free expression; a_j—regression coefficients; x_j—explanatory variables (independent); ε—random component of the model (error).

Post-estimation testing of the model included the use of tests for autocorrelation, heterogeneity of variance and normal distribution. Collinearity analysis was also performed.

In the case of measuring financial sustainability, logistic regression models will be used, in which the dependent variable will be the ratio of gross investment (SE516) and depreciation (SE360). In both cases, the variables will assume 1 when their values are greater than one. Otherwise, they will receive the value 0.

To measure durability of operations, an attempt was made to estimate a logistic regression model in which the dependent variable was the adjusted gross value added calculated for 2021. This variable will assume 1 when its value is at least 10% higher than its 2017 level. Otherwise, it will assume 0. Unfortunately, this model turned out to be statistically insignificant.

What is more, multiple linear regression (OLS) models will be estimated. In the case of durability of operations, the dependent variable will be the quotient of gross value added and total production. However, when it comes to financial sustainability, dependent variables will be the ratio of gross investment to depreciation (similar to the logit model), and, additionally, coverage of depreciation with cash flow 2 (cash flow 1 plus sales of fixed assets minus purchases and investments in fixed assets plus/minus changes in liabilities). It is assumed that in both cases it is desirable that the quotients be greater than one. All such farms will be considered financially sustainable.

In the regression, logit and multiple models, two key independent variables will be used, they will characterise the energy aspects of the surveyed farms:

1. The cost of energy consumption as a percentage of general farming costs and per 1 ha of agricultural land.
2. Return of the excise tax on the used motor fuels as a percentage of subsidies to operating activities and will also refer to 1 ha of agricultural land.

However, the use of the independent variables as absolute values was abandoned, as it resulted in many collinearities appearing, which significantly deteriorated the quality of model estimates.

For each case, in both the durability of an operation and financial sustainability, two variants of the models will be considered. Models 1, 3, 1a and L1 will include only key variables expressed as percentages, while models 2, 4, 1b and M2 will include only those per 1 ha of agricultural land (cf. Table 3).

Table 3. Estimation results of logit models explaining financial sustainability.

	L1		L2	
Variable	**Logitcoeff**	**Odds Ratio**	**Logitcoeff**	**Odds Ratio**
Energy [%]	−0.147 *** (0.0447)	0.864 *** (0.0386)		
Energy [PLN/ha UR]			0.00149 (0.00109)	1.001 (0.00109)
Excise duty [%]	0.00858 (0.213)	1.009 (0.214)		
Excise duty [PLN/ ha UR]			0.00605 (0.0170)	1.006 (0.0171)
Agricultural land area [ha]	0.00293 (0.0115)	1.003 (0.0116)	−0.00208 (0.0100)	0.998 (0.00999)
Crop type	2.048 * (1.166)	7.753 * (9.042)	−0.0222 (1.265)	0.978 (1.237)
Livestock type	0.241 (1.605)	1.272 (2.042)	0.170 (1.308)	1.185 (1.551)
FADNREG1	0.665 (1.601)	1.944 (3.112)	1.562 (1.577)	4.767 (7.520)
FADNREG2	0.525 (1.203)	1.690 (2.034)	2.039 (1.400)	7.681 (10.75)
FADNREG3	3.382 *** (1.242)	29.44 *** (36.56)	3.082 *** (1.186)	21.80 *** (25.85)
Mobile age	−4.649 ** (2.222)	0.00957 ** (0.0213)	−2.683 ** (1.357)	0.0684 ** (0.0928)
Agricultural education	0.465 (1.122)	1.591 (1.786)	0.686 (1.394)	1.986 (2.769)
Secondary education	−1.105 (1.161)	0.331 (0.385)	−0.118 (1.317)	0.889 (1.170)
Total profitability ratio [%]	0.0771 ** (0.0355)	1.080 ** (0.0383)	0.0443 (0.0278)	1.045 (0.0290)
Increase in equity [%]	0.991 *** (0.359)	2.694 *** (0.966)	0.801 *** (0.221)	2.227 *** (0.493)
Increase in working capital [%]	−0.0371 ** (0.0164)	0.964 ** (0.0158)	−0.0250 ** (0.0124)	0.975 ** (0.0121)
Total assets-to-equity ratio [%]	−0.267 *** (0.102)	0.766 *** (0.0784)	−0.164 ** (0.0732)	0.849 ** (0.0621)
Asset immobilisation ratio [%]	0.132 (0.141)	1.141 (0.161)	0.112 (0.0901)	1.118 (0.101)
Subsidy rate (I)	−0.0187 (0.0146)	0.981 (0.0144)	−0.0225 (0.0165)	0.978 (0.0161)
Constant	13.98 (9.477)	1.18×10^{-6} (1.18×10^{-7})	1.014 (5.265)	2.757 (14.51)
	Wald chi2 (17) = 36.00 Prob > chi2 = 0.0046 Pseudo R2 = 0.7345 Log pseudolikelihood = −17.153862 R2 Count = 0.951		Wald chi2 (17) = 24.79 Prob > chi2 = 0.0994 Pseudo R2 = 0.6477 Log pseudolikelihood = −22.759593 R2 Count = 0.848	

Note: n = 103, gross investment/depreciation (SE516/SE360) as the explained variable *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; shaded values—for statistically significant values. Source: the authors' own analysis based on FADN data.

4. Results

Table 3 presents results of estimation of logistic regression models, thanks to which the impact of all possible combinations from the set of selected independent variables on the binary dependent variable was estimated. The table contains estimates of logit models for all coefficients (using the maximum likelihood method) and the so-called odds ratios, i.e., exp(β_j), which refers to impact of a change by a unit of the *j* variable with other explanatory variables fixed [76] (p. 314). It should be recalled that, in the case of durability measurement, the binary dependent variable is the ratio of gross investment (SE516) to depreciation (SE360). In the L1 model, key dependent variables were the cost of energy consumption as a percentage of general farming costs and the return of excise tax on diesel oil as a percentage of operating subsidies. In turn, in the L2 model, the variables were given per 1 ha of agricultural land. The estimation of logit models made it possible to select a set of predictors, i.e., features that make it possible to forecast the value of the dependent variable.

The LR (likelihood ratio) statistic has a chi-square distribution with degrees of freedom equal to the number of all explanatory variables. Table 3 shows the empirical significance level (Prob > chi2): the L1 model is significant already at the level of 5%, while the L2 model is significant at the level of 10%.

The estimation results show that the following independent variables were statistically significant in the case of the L1 model:

- At 1%: energy [%], FADNREG3, increase in equity, asset-to-equity ratio;
- At 5%: mobile age, increase in working capital;
- At 10%: crop type.

In the case of the L2 model, the following independent variables were statistically significant:

- At 1%: energy [%], FADN REG 3, increase in equity;
- At 5%: mobile age, increase in working capital, asset-to-equity ratio.

It should be noted that in both of the models presented above, coefficients were negative for the following variables: mobile age, working capital increase and asset-to-equity ratio. It should be emphasised that the coefficients with variable energy [%] were negative. This means that as the share of energy in general farming costs increased, the probability of obtaining the gross investment/depreciation value above 1 decreased. For the other independent variables, the coefficients were positive. The *Odds Ratio* can be interpreted as follows for the L1 model, for example:

- Increased share of energy in general farming costs by 1 percentage point increases the chance of achieving financial sustainability ($y = 1$) by 13.6%;
- Chance of achieving the above-mentioned durability (y = 1) in the case of managers in the mobile age (i.e., 18–44 years old) is lower by as much as 99%.

The *Odds Ratio* can be interpreted as follows for the L2 model, for example:

- Chance of achieving the above-mentioned durability ($y = 1$) in the case of managers in the mobile age (i.e., 18–44 years old) is lower by as much as about 93%;
- Higher "increase in equity" by 1 percentage point decreases the chance of achieving financial sustainability ($y = 1$) by 2.5%;
- Higher ratio "total assets to equity" by 1 percentage point decreases the chance of achieving financial sustainability ($y = 1$) by 15.1%;

The interpretations are important in a given set of explanatory variables of the model, as well as assuming *ceteris paribus.*

The quality of the models should be assessed as satisfactory, as indicated by e.g., a realistically high value of MacFadden's pseudo-R^2 (over 60% for both models) or the counting R^2, indicating a very high overall prediction accuracy.

Table 4 summarises the estimation results for linear regression models with two types of dependent variables. Models 1–4 relate to financial sustainability, while models 1a and 1b relate to operational durability. The *p*-value of the F statistics was lower than the assumed level of statistical significance, which means that we have grounds to reject the null hypothesis, according to which the values of all estimated coefficients are equal to 0. The basis for assessing the degree of fit of the model to the data is the coefficient of determination R^2. In the case of explanatory models of gross value added (GVA) for total production (1a, 1b), the value of R^2 was relatively high, i.e., above 80%. In turn, the degree of fit of the model to the data in the case of financial sustainability was lower, as indicated by R^2 at the level of 60–65%.

Table 4. Estimation results of OLS models explaining financial sustainability and operational durability.

Variable	Model 1	Model 2	Model 3	Model 4	Model 1a	Model 1b
Energy [%]	−0.0240 * (0.0143)		−0.0173 (0.0119)		0.00140 (0.000848)	
Energy [PLN/ha UR]		0.000143 (0.000246)		−0.000247 (0.000286)		1.66×10^{-5} (2.13×10^{-5})
Excise duty [%]	0.147 * (0.0862)		−0.0819 (0.0872)		−0.00596 (0.00381)	
Excise duty [PLN/ha UR]		0.00871 (0.00603)		−0.00307 (0.00715)		−0.000108 (0.000346)
Agricultural land area [ha]	−0.0117 ** (0.00554)	−0.0128 ** (0.00558)	0.0138 ** (0.00531)	0.0120 ** (0.00569)	−0.000127 (0.000174)	-4.65×10^{-5} (0.000164)
Crop type	−0.134 (0.396)	−0.0427 (0.408)	0.107 (0.458)	0.168 (0.503)	0.0522 * (0.0288)	0.0495 (0.0299)
Livestock type	0.189 (0.481)	0.271 (0.490)	0.592 (0.464)	0.796 * (0.450)	0.00428 (0.0261)	−0.00597 (0.0284)
Mixed type	-	-	-	-	-	-
FADNREG1	-	0.527 (0.569)	-	−0.957 (0.621)	-	−0.0357 (0.0484)
FADNREG2	−0.0218 (0.493)	0.468 (0.519)	0.607 (0.636)	−0.334 (0.683)	−0.00535 (0.0482)	−0.0421 (0.0331)
FADNREG3	0.366 (0.506)	0.776 ** (0.379)	0.314 (0.503)	−0.666 (0.487)	0.0384 (0.0470)	0.00851 (0.0303)
FADNREG4	−0.245 (0.517)	-	1.015 * (0.603)	-	0.0287 (0.0467)	-
Mobile age	−0.243 (0.425)	−0.115 (0.414)	0.479 (0.379)	0.577 (0.388)	−0.0592 ** (0.0294)	−0.0670 ** (0.0305)
Agricultural education	0.228 (0.345)	0.290 (0.353)	−0.251 (0.413)	−0.231 (0.421)	−0.0123 (0.0222)	−0.0109 (0.0232)
Secondary education	0.308 (0.425)	0.410 (0.433)	−0.496 (0.473)	−0.498 (0.483)	0.0435 (0.0335)	0.0398 (0.0334)
Total profitability ratio [%]	−0.00938 (0.00956)	−0.0104 (0.00981)	0.0549 *** (0.0131)	0.0525 *** (0.0135)	0.00435 *** (0.000386)	0.00448 *** (0.000398)
Increase in equity [%]	0.269 *** (0.0620)	0.275 *** (0.0619)	−0.254 *** (0.0895)	−0.249 *** (0.0918)	4.54×10^{-6} (0.00115)	−0.000141 (0.00121)
Increase in working capital [%]	−0.000692 (0.00304)	−0.000299 (0.00319)	−0.00838 * (0.00448)	−0.00845 * (0.00452)	0.000123 (0.000167)	0.000116 (0.000173)
Total assets-to-equity ratio [%]	0.000244 (0.0295)	−0.00148 (0.0313)	−0.0139 (0.0274)	−0.0174 (0.0269)	−0.00337 *** (0.00127)	−0.00316 ** (0.00127)
Asset immobilisation ratio [%]	0.113 ** (0.0540)	0.108 ** (0.0536)	−0.124 * (0.0652)	−0.131 ** (0.0634)	0.000276 (0.00208)	0.000256 (0.00204)
Subsidy rate (I)	0.00155 (0.00602)	−0.00126 (0.00657)	0.0204 ** (0.00801)	0.0199 ** (0.00938)	0.00774 *** (0.000303)	0.00794 *** (0.000317)
Constant	−0.249 (2.778)	−1.555 (3.302)	−1.971 (2.675)	−1.228 (2.746)	0.0963 (0.123)	0.121 (0.128)
R-squared	0.639	0.631	0.622	0.614	0.903	0.900
F test	F (17.85) = 3.77 Prob > F = 0.0000	F (17.85) = 3.60 Prob > F = 0.0000	F (17, 85) = 3.30 Prob > F = 0.0001	F (17.85) = 2.89 Prob > F = 0.0007	F (17.85) = 59.94 Prob > F = 0.0000	F (17.85) = 69.58 Prob > F = 0.0000

Note: dependent variables in models 1 and 2—gross investment/depreciation (SE516/SE360), 3 and 4—cash flow/depreciation, 1a and 1b—GVA for total production; shaded values—for statistically significant values. Source: the authors' own analysis based on FADN data. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In model 1, energy and excise tax (both variables in percentage terms) turned out to be independent variables, statistically significant at the level of 10%. While the increase in the share of energy in general farming costs lowered the level of financial sustainability (expressed as gross investments/depreciation), the sign at the value of the excise tax coefficient was positive. In the remaining models (2–4, 1a–1b), energy-related variables turned out to be statistically insignificant. Utilised agricultural area (UAA) was a destimulant of financial sustainability (expressed as the ratio of gross investment to depreciation). A different direction of the statistically significant relationship (at the level of 5%) concerned UAA and financial sustainability expressed as cash flows/depreciation.

While increased equity and asset immobilization ratios turned out to be statistically significant stimulants of the relation gross investment/depreciation (models 1–2), in the case of the cash flow/depreciation variable (models 3–4) as the dependent variable, the sign ratios for equity and asset immobilisation ratio was negative.

The analysis of values of coefficients indicates important dependencies. The coefficient reflects the expected change in the dependent variable for every 1 unit change in the associated explanatory variable, holding all other variables constant: in M1, a −0.240 decrease in gross investment/depreciation for increase "Energy" (%) by unit leads to a 0.147 increase in the dependent variable for increase "Excise duty" (%) by unit.

Models explaining financial sustainability as a relation of cash flows to depreciation (3–4) and explaining operational durability, i.e., GVA to total production (1a–1b), had some common features, namely, an increase in the value of the total profitability ratio and the level of subsidy rates resulted in improvements in both types of durability. Moreover, the equity-to-assets ratio turned out to be a destimulant for the above-mentioned durability, even though in the case of operational durability this relationship was significant at the level of 1%.

The post-estimation verification (including tests for auto-correlation, heterogeneity of variance and normal distribution) as well as collinearity analysis (before regression analysis) showed the correctness of the model construction (results of the above-mentioned verification on request of the authors). This entitles us to discuss the results of the econometric analysis

Table 5 summarises the results of all the econometric models. The variable related to the share of energy in total costs turned out to be a significant destimulant of financial sustainability in a logistic regression model. The explanatory variable related to excise duty was a significant stimulant of financial sustainability, expressed as gross investment/depreciation in the OLS model (M1).

Table 5. Results of econometric models—overview of significant dependencies.

Model	**L1**	**L2**	**M1**	**M2**	**M3**	**M4**	**M1a**	**M1b**
Dependent Variables	**FS**	**FS**	**FS**	**FS**	**FS**	**FS**	**DO**	**DO**
Independent Variables								
Energy [%]	– ***		– *					
Excise duty [%]			+ *					
Agricultural land area [ha]			– **	– **	+ **	+ **		
Crop type	+ *						+ *	
FADNREG3	+ ***	+ ***		+ **				
Mobile age	– **	– **					– **	– **
Total profitability ratio [%]	+ **				+ ***	+ ***	+ ***	+ ***
Increase in equity [%]	+ ***	+ ***	+ ***	+ ***	– ***	– ***		
Increase in working capital	– **	– **						
Total assets-to-equity ratio [%]	– ***	– ***					– ***	– **
Asset immobilization ratio [%]			+ **	+ **	– *	– **		
Subsidy rate (I)					+ **	+ **	+ ***	+ ***

Note: M—OLS model, L—a logistic regression model, – positive + negative impact; FS—financial sustainability (L1, L2—gross investment/depreciation (as a binary variable), M1, M2—gross investment/deprecation, M3, M4—cash flow/depreciation, M1a, M1b—GVA/total production; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; shaded cells—for statistically significant values.

5. Discussion

Based on the FADN data, it is impossible to calculate the increase in added value, and thus to determine the durability of operations, in the strict meaning given to it by the European Commission, i.e., for specific modernisation projects on farms subsidised under the Polish rural development program. An attempt to bypass this barrier, based on at least a ten-percent increase in added value for entire farms, turned out to be unreliable, as no meaningful correlation relationships could be established, and the entire logistic regression models were unacceptable on the basis of generally used criteria of their statistical goodness. In view of the above, multiple regression calculations were additionally performed, in which the dependent variable was the gross value added index, i.e., its share in the value of agricultural production. Unfortunately, neither the cost of energy consumption nor the excise tax return were statistically significantly correlated with it. Nevertheless, it seems that it is worth looking for new approaches to the impact of energy categories on the above indicator. This is due to the simple fact that the added value generated at the level of farms is its component in terms of sectors, and then for the entire national economy. By doing so, we have a chance to contribute to a deeper understanding of the fundamental relationship between energy and socio-economic growth and development, both in agriculture and beyond, and in all economic activities.

Estimations of multiple and logit regression models for energy determinants of financial sustainability turned out to be much better. However, it should be noted right away that this concerns, in the first place, the expression of energy consumption costs as a percentage of general farming costs and the return of excise tax as a share in the amounts of operating subsidies received by farmers. Presenting the two variables as monetary values per 1 ha of UAA did not result in their statistically significant correlation with the distinguished types of financial sustainability anywhere. This is probably due to the broader observation that it is difficult to determine the statistical impact of variables of little significance for the economics and finances of farms [77,78]. In further research, it is worth taking a closer look at this hypothesis.

The independent variable "cost of energy consumption as a percentage of general economic costs" was negatively statistically significantly correlated with financial sustainability measured by the quotient of gross investment and depreciation, in multiple and logit regression models. This means that a series of simple logical relationships functioned here: a higher percentage → a decrease in the resulting economic and financial categories → a deterioration in financial sustainability. This logic is perhaps used by agricultural circles and agricultural politicians who, during crises, try to implement various interventions to reduce energy costs for farms. The possibility was widely used in the EU in 2022. In the short term, it certainly improves liquidity of farms and secures continuation of their activity. In the longer term, however, it inhibits structural changes in agriculture and reduces incentives to implement energy-saving technologies [79]. Added to this is the accumulation of certain energy carriers by farmers, especially when inflation is high and their supplies are uncertain. This situation occurred after the outbreak of war in Ukraine. The consequence of such behaviour may be an increase in energy consumption costs due to its storage [80,81]. In Poland, however, there is a very unfavourable combination of factors: the domestic energy sector is based on hard coal and lignite, and the sphere of electricity generation and its distribution is highly oligopolised. In such conditions, the so-called freezing prices of energy carriers per balance supports this expensive, highly emission-intensive energy system, which Polish farmers are also confronted with. It is also worth noting that Poland, as compared to other EU countries, is characterised by high inflation, a significant source of which is the domestic energy sector. High inflation by itself discourages investment and shortens the decision-making perspective of investors. It is an unfavourable economic environment, among others, for the implementation of energy saving projects and in the area of renewable energy sources. The development of the latter is additionally hampered by the inadequacy of power grids to fluctuations in the supply of electricity generated by photovoltaics and wind energy.

In none of the estimated regression models was the independent variable "excise tax return as a percentage of subsidies to operating activities" statistically significantly correlated with measures of financial sustainability. However, the relationship between it and the dependent variables was positive. It can therefore be assumed that the following sequence of logical consequences may occur here: obtaining a return of excise tax → improvement of economic and financial relations → increase in financial sustainability. This hypothesis should be thoroughly analyzed in the future, because the impact of the form of indirect subsidisation on the agricultural sector and farms is far more complicated [82].

Excise tax return on agricultural fuels, mainly diesel oil, may have several interesting implications (effects). First of all, it is about the rebound effect (RE) and the phenomenon of dematerialisation. The former is also referred to as the "*take-back effect*" in the literature on environmental and ecological economics as well as energy economics. Generally, this is about reducing the expected benefits from the implementation of new technologies and innovations that were supposed to increase the efficiency of the resources involved, but due to behavioural and systemic reactions, it did not happen [83]. At this point, an increase in the total consumption of motor fuels is usually cited as buyers of vehicles with lower specific fuel consumption simply drive more.

There is already a huge range of literature on empirical estimates of the rebound effect. The return of excise tax in agricultural fuels is closely related to the possibility of a rebound effect. Its mechanism can be described by the following logical relationship: excise tax return → greater physical consumption of energy carriers, which, with the stability of their prices, would result in higher energy costs → deterioration of economic and financial categories → decrease in financial sustainability. Fortunately, in the studied population, the risk of this effect is not high, as the Pearson correlation coefficient between the excise tax return and the costs of energy consumption in PLN per 1 ha of agricultural land was only 0.14. However, when both of the variables are expressed as a percentage, partial correlation increases to 0.27. It is, therefore, worthwhile in future research to identify more closely the conditions that may lead to the rebound effect. In general, it was found that the above effect is more pronounced in households with lower incomes and in the group of developing countries [84–86]. This is understandable, as then we are dealing with higher price and income elasticities of energy demand. Secondly, the rebound effect also occurs in the case of renewable energy.

Any subsidisation of agriculture, and thus including its energy modernisation, is associated with a number of undesirable phenomena that can be identified using the methodology of examining the extent of support (an incidence), i.e., identifying their final beneficiaries [87].

The provision of subsidies for the modernisation of farms, including their energy modernisation, within the framework of EU rural development programmes is linked, among other things, to the process of innovation implementation. It is clear from the economy-wide literature that appropriate combinations of budget subsidies and taxes are most effective here [88]. In turn, small firms confronted with financial constraints tend to respond more positively to subsidies alone [89]. The effectiveness and efficiency of budget support for innovation is generally higher in specialised entities than in mixed ones. This is mainly because, in the latter, budget funds crowd out in-house expenditures and non-operational costs follow suit.

Budgetary support for energy modernisation should not be limited solely to agriculture, but should encompass entire rural areas, including the financial institutions operating there. Only then is there a chance of successfully implementing innovative and coherent and sustainable strategies for rural transformation, energy transition, GHG emission reduction and, on the other hand, ensuring an adequate level of food and social security for local residents [90]. As far as rural financial institutions are concerned, the state also has many opportunities to indirectly influence their operation and development so that they offer low-cost, reproducible and customised products to farmers, non-farmers and rural residents. A study by Zhang et al. [90] found that, under Chinese conditions, the development of rural financial institutions led to a reduction in greenhouse gases, but that this negative correlation between these variables was nevertheless shaped like an inverted U.

The energy modernisation of EU agriculture, co-financed inter alia in the relevant national rural development programmes, must be integrated into the overarching energy–climate transformation initiatives of the European Community. Of the latter, the EU Green Deal (EGD) is currently the most important. According to this, the EU should achieve climate neutrality by 2050. In parallel, the EU intends to implement a carbon border adjustment mechanism (CBAMs) to be paid by exporters to the European market from countries with less stringent environmental regulations.

The issue of stimulating research and development of low-carbon technologies, inter alia through fiscal instruments, is on the agenda of the day, with the reduction or preferably complete cessation of subsidies for the extraction, processing and use of fossil fuels.

The rapid removal of fiscal preferences for the oil, gas and snake oil sectors is bound to lead to a decline in production and value added generated and profits in these sectors, and may cause social tensions in regions dominated by them [91]. Hence, appropriate reform must be carefully designed and implemented, with some kind of shielding solutions available to firms and households most negatively affected. However, even changes that are gradual and stretched out over time will trigger adjustment mechanisms throughout the economy and society [92].

6. Conclusions

The methodological approach used in the article is not free from some weaknesses. First of all, the small size of the research sample should be mentioned here, which certainly had some negative impact on the statistical quality of the estimates of the parameters of the regression equations. Another problem is the study of the impact of energy variables on financial sustainability for only one year (2021). Relationships have been identified for only one EU country, while sometimes they do not have to be checked in other countries, where, for example, the relationship between the growth and development of agriculture and its energy supply is looser. Finally, it should be added that a more solid theoretical superstructure is needed to conduct similar research. Future research should include: models of the relationship between energy costs and investments in energy consuming technologies; determinants of energy demand in the convention; determinants of energy demand in the bottom-up and top-down convention; and mechanisms explaining the phenomenon of pass-through energy prices and costs as well as energy subsidies and taxes. Despite these limitations, the article can be treated as a kind of introduction to conducting in-depth studies.

The thesis was supported by empirical evidence and confirmed. Indeed, the definition of operational durability proposed by the European Commission makes it very difficult to identify its statistically significant energy determinants in regression accounts. Even though the application of the value added index to its description clearly improved the coefficient of determination, still, the impact of energy costs and excise tax return on its development was insignificant and difficult to interpret. Significant progress was noted only when financial sustainability was adopted as the dependent variable in regression models. It should be noted, however, that the correlations were significant and substantively correct when energy costs and excise tax return were presented as relative values.

The fact that the relative cost of energy was statistically significantly negatively correlated with financial sustainability may suggest that public interventions aimed at its reduction or at least suppression may be attempted. This set of political influences also includes subsidies for modernisation in general and energy modernisation in particular, paid to farmers under rural development programs. However, the set of instruments must be very carefully analyzed, constructed and implemented, because, by definition, one has to take into account the appearance of unintended and undesirable effects. One of them may be the rebound effect, the source of which may be the return of excise tax charged in agricultural fuels. Its appearance results in increased energy intensity causing results in additional greenhouse gas emissions. Subsidising energy carriers in agriculture may also create behavioural distortions among agricultural producers who manage water less rationally and pay less attention to durability issues. In this context, economic and agricultural politicians should try to find a compromise in terms of the trilemma of influencing the use of energy in agriculture: certainty of supplies, price and cost acceptance by farmers, a course towards greater importance of renewable energy sources.

All public interventions in agricultural energy use should be subject to careful and systematic *ex ante*, *mid-term* and *ex post* assessments based on sound program theory. It is necessary to identify the cause and effect chains, in which the regression proposed in the article may be helpful. However, it cannot stop there, because under the rural development programs financed or co-financed by the European Union, very different projects are already being implemented: in the area of improving energy efficiency, modernising systems and technologies of energy use, thermal modernisation of buildings and implementing renewable energy sources. Therefore, a whole set of different tools for quantitative and qualitative assessment of the effectiveness, efficiency, impact and durability of the results of individual interventions is needed. In the case of simple projects, indicators characterising the energy management of the beneficiaries are sufficient, while in the case of capital-intensive investments, advanced tools for assessing their profitability and effectiveness will be needed. To measure effectiveness of entire programs, it will be necessary to use advanced econometric tools (e.g., *propensity score matching*).

In the above context, it seems that future analyses of a similar nature should be extended and enriched with new areas. Firstly, it is justified to move to constructing regression models on panel data for all EU countries where the FADN operates. Secondly, efforts must be made to have access to sufficiently large populations of sample farms. Thirdly, the set of measures in the field of financial sustainability should be improved and possibly linked to with the above-mentioned energy trilemma and the agricultural policy trilemma (at the same time achieving satisfactory efficiency/productivity, durability and resilience). Fourthly, it is worth deepening the knowledge on the impact of energy variables on generating added value in agriculture. Fifthly, the threat of a rebound effect requires an assessment of its scale and determinants. Sixthly, interactive variables should also appear in regression models, for example, "cost of energy consumption × production type of a farm". Seventhly, the assessment of the impact of energy related variables on financial sustainability could be carried out, at least on the basis of data from the Polish FADN, in panel terms. Eighthly, in addition to financial sustainability, it is also necessary to analyze the vitality and resilience of crop farms. Ninthly, a properly prepared diagnostic survey would make it possible to obtain qualitative data, including that related to managers' attitude towards risk and his behavioural inclinations, which could expand the set of independent variables in the models. Tenthly, it would be advisable to also use time series analysis tools, especially to study the "pass-through" phenomenon of energy prices and costs.

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