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The agrarian question in dairy farms: An analysis of dairy farms in the European Union countries

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Abstract
In this article, we review the Agrarian Question focusing on dairy farms. We have the dual aim of adding to the debate surrounding the economic profitability of small and large dairy farms and increasing what is known about the decline of dairy farms. The agrarian question at the heart of our research centres on the paradoxical endurance of family farms, despite predictions from both liberal and Marxist perspectives that they would diminish in number over time. By addressing these complex issues, we hope to shed light on the challenges and opportunities facing the dairy industry today. We focus on analysing dairy farms in the European Union countries, using panel regressions from 2008 to 2018 to define the relationship between the average number of cows per farm, profit margins and Farm Net Income. The most important results show that (i) paradoxically, profits were higher on smaller farms; (ii) however, empirical data show that small dairy farms are disappearing; (iii) this is because when including subsidies, farms with a higher number of cows are more profitable than smaller farms.

Keywords Agrarian question · Dairy sector · Self-exploitation · Subsidies · European Union · Dairy farmers

Introduction

The great social theorists did not doubt that small livestock or agricultural farm would be the victim of capitalist concentration (Servolin 1977). For more than a century, the debate about small and large farms centred on the question of the economic advantages of large farms. Despite long-standing and persistent predictions of the imminent extinction of small farms, these entities persist in the agricultural and livestock sector, defying prevailing conditions (Brokfield 2008; Brokfield & Parsons 2007). In this study, our primary emphasis will be on dairy farms. This choice is motivated by our prior examination of dairy farms in Catalonia, as documented in Barbeta-Viñas & Requena-i-Mora 2022, 2023). Additionally, we aim to investigate the transformative shifts that have occurred within the dairy sector of the European Union (EU), as detailed in Appendix 2. Notably, we found that in 2016, more than 30% of dairy farms in the EU were comprised of merely one or two cows.

The main aim of this article is to examine the agrarian question in the contemporary context, adding the role of the state and subsidies into an understanding of the agrarian question. The paper seeks to add to the debate on the economic viability of small and large farms, and to understand the factors behind the slow but steady disappearance of the small family farm. We analyse dairy farms in the European Union countries through panel regressions from 2008 to 2018. We then try to detect a relationship between the average number of cows per farm and country and profit margins. A key consideration pertains to the methodology employed in the analysis, which relied on average cow numbers per farm across the countries under study. The dataset used for analysis; namely, the Farm Accountancy Data Network (FADN), does not provide disaggregated data at the individual farm level. However, it is worth noting that a significant majority of holdings in every country, ranging from over 60% to even exceeding 90% in certain cases, align closely with this average figure. Consequently, this average represents the size of the most representative farms within the country.

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Furthermore, the decision to conduct the analysis on a country-specific basis was motivated by the objective of examining variations between central and certain eastern European countries. As we will later observe, this approach also holds implications for the agrarian question and the phenomenon of self-exploitation within family-based agricultural enterprises. The article is structured as follows. First, in the literature review, three sets of theories regarding the disappearance of smallholdings: Marxist and liberal theories that advocate for their disappearance, Marxist theories that view small farms as self-exploitative, and studies inspired by Chayanov that defend small farms' economic profitability and survival. We then explain the methodology and data we used to do the empirical research to meet our objective. Our analysis is focused on the examination of dairy farms in the European Union. We employ panel regressions spanning from 2008 to 2018 to establish the connection between the average number of cows per farm and country, profit margins, and Farm Net Income, drawing on data from the Farm Accountancy Data Network (FADN). Finally, we highlight the results that answer the questions "What is the relationship between farm size and economic profitability?", and, of greater sociological relevance, "How is this related to the disappearance of smallholdings?". The main results suggest that, paradoxically, although countries with smaller farms have the highest profit margins, self-exploitation and subsidies associated with Farm Net Income help explain why larger farms have the best economic returns. The last section includes the discussion and conclusions.

Literature review

The debate on large and small farms: a chronicle of a death foretold

Conventional discourse-imposed categories of economic development on the agrarian world, leading to concepts such as "residual" or "backward" (Alonso et al. 1991). Thus, different theoretical movements taught us about the economic advantages of large farms and forecast the inevitable end of the smallholding.

On the one hand, Marxists saw the oppression of livestock farmers with smallholdings where it was impossible to adopt technical advances and where farmers resorted to self-exploitation to compete with the big farms. The historical view of agricultural transformation following the capitalist mode of production was adopted, focusing on the fundamental question raised by Kautsky (1988), of how capital takes over agriculture, transforms it, and makes the old forms of production and ownership unsustainable, creating the need for new ones. Lenin (1969) argued that the penetration of commercial products into the countryside made the wealth of each farming family dependent on the market but that the ups and downs of the market created inequality, which was accentuated by concentrating capital in the hands of some and ruining others. This capital was used to exploit smallholders who, despite being on the verge of ruin, kept their farms and continued to work, employing old, technically irrational methods, thereby exploiting them via the purchase of the products of their labour. However, the extent of the smallholder's ruin eventually forced them to abandon their farm altogether; as they were no longer able to sell the products of their labour, they had no choice but to sell their work (ibid.).

Chayanov (1931) was an exception among Marxist thinkers. Chayanov considered the smallholder economy as a particular "economic subject" based on domestic or family labour, in which the categories of wages and profit were absent in the strict sense. He thought that to link agriculture to the general economy and to ensure agricultural development, it was necessary to encourage association and the forming of cooperatives of family farming businesses.

Liberal thought, on the other hand, which advocated the modernization and rationalization of the economy, saw smallholdings as unproductive (see, for example, Adam Smith ([1776] 2010). Liberal approaches saw a revival in the 1960 and 1970s (Ortí 1997). The concept of modernization, which involves the economic and technological rationalisation of economic growth, as well as the restructuring and development of rural life that may be eliminated by urban-industrial life. According to Schultz (1966), agricultural modernisation focuses on production growth and productivity improvements through technological diffusion, substituting labour with capital and leading to labour and agricultural product surpluses. Therefore, the end of the agricultural smallholding was forecast by various theoretical movements, both conservative and progressive, either because of technology, which not only served to de-agrarianize the population but also to transfer it to industrial production or for its transformation into another, more homogeneous and combative, social entity (Bernstein 2010; Banaji 2016).

The total disappearance of the small family farm has been confidently predicted for almost a century and a half and is still predicted today. While many small family farms have not survived into the twenty-first century, the fact that so many have done is remarkable (Brokfield & Parsons 2007; Newby & Sevilla-Guzman 1981). However, it is time to invert the old agrarian question and to ask how and why family farming survives and, especially, under what conditions (Brokfield 2008).

The continued existence of the smallholding

Without trying to apply the logic of economic development to the existing heterogeneity of farmers, the only way

to explain the survival of smallholders is that it works in modern and developed commercial systems because it is integrated into the capitalist system (Servolin 1977; Friedman 2006). The persistence of small farms in Europe and North America is occurring irrespective of the rapid changes occurring in these regions due to commercialisation of agriculture, globalisation and increasing forces of urbanisation (Rathi 2022). Etxezarreta (1979) noted that smallholders are able to survive despite the technical superiority of large farms, due to the adoption of technological advances. Friedmann (1978), who drew heavily on Chayanov in explaining the success of the small farm, noted an important technical aspect. Machinery introduced in the Great Plains of the USA made mechanized farming feasible for a family labour force of 1.5 people, reducing the need for farm labour and allowing household farms to compete with industrial farms (Brookfiel 2008).

On the other hand, plant and animal production processes are unsuited to industrial manufacturing due to biological rhythms and weather conditions (Servolin 1977). In the case of dairy cattle, income relative to the nutritional quality of milk is higher on smaller farms (Maynegre & Nogué 2018).

Similarly, Mann and Dickinson (1978) and Contreras (1977), in an attempt to explain the uneven development of capitalism in agriculture recalled Marx's distinction between labor time and production time. Labor time consists of the periods when labor is actually applied. Production time encompasses the entire production cycle, "when the unfinished commodity is 'abandoned to the sway of natural processes' without at that time being in the labor process" (Mann and Dickinson 1978: p. 472). The non-identity of production time and labor time characteristic of certain agricultural commodities, according to Mann and Dickinson (1978), is considered to impede capitalist development. The variance of labor time and production time is said to produce "an adverse effect on the rate of profit, the efficient use of constant and variable capital, and the smooth functioning of the circulation and realization process" (Mann & Dickinson 1978: p. 466).[1]

More recently, Riccardi et al. (2021) argue that smaller farms, on average, have higher yields but also more biodiversity than do larger farms. On the contrary, large farms that employ industrialised production methods have negative impacts that have been well-documented, including deforestation, desertification, loss of biodiversity and habitats, the decline in soil fertility, and water pollution (Clay et al. 2020). These findings align with Moore's (2008) argument that addressing the agrarian question necessitates recognizing the metabolic rift and its profound implications for ecological well-being. The metabolic rift concept illuminates how unsustainable practices within capitalist systems disrupt the ecological integrity of our planet, exacerbating the ecological crises we face today. Finally, small farms depend predominantly on family labour (Rapsomanikis 2015). Family labour farms have been underestimated due to their economies of scale and lower transaction costs (Schmitt 1991). Wolf (1971) and Cayuela (2013) both point out that the work of the household group can be increased, and the family takes on different functions, leading to lower costs. By experimentation over time, farmers and their families learn how to allocate the resources at their disposal in a manner that is consistent with their own interests, that is, in an "efficient" manner (Abler & Sukhatme 2006; Schultz 1966; Brookfield 2008; Hazell 2005; Gül et al. 2018). According to Hazell (2005), small farms exploit family labour using technologies that increase yields, and they use labour-intensive methods rather than capital-intensive machines. Family workers also tend to think in terms of whole jobs or livelihoods rather than hours worked and are less driven by wage rates at the margin than hired workers (ibid.). In fact, family labour makes a difference: small farms are more productive than larger farms (Rapsomanikis 2015).

While small farms and family labour are commonly associated worldwide (ibid.), a difference exists between old and new Europe within the European Union. Klikoca et al. (2021) claim that family labour is less significant in some new member states, particularly those that were post-Communist countries, where collective or socialized agriculture predominated for almost 50 years. Although the privatisation of many agricultural enterprises, Klikoca et al. (2021) argue that the institutional and organisational structures that were put in place during the communist era may have persisted in some form, leading to a lower percentage of family labour in some countries.

The subsumption of dairy farmers by capital and self-exploitation

In the previous section, we saw the main "advantages" of smallholding. However, this type of farm bears little resemblance to the traditional farm.[2] The sector has thus modified its structure, moving from a relatively large number of

[1] This thesis has been highly criticized. For instance, using empirical data Mooney (1982) claimed that it appears that the development of identity in labor and production time is not a route for capitalist penetration. On the contrary, it may be a barrier to capitalist penetration insofar as it allows for the more efficient use of a stable family labor supply.

[2] The term traditional farm refer to an agricultural operation that follows conventional farming practices that have been passed down through generations. It often involves methods and techniques that have been practiced for an extended period, relying on established knowledge, skills, and cultural norms within a particular region or community.

small and medium-sized farms to the development of a much smaller number of large, highly technical, specialized, high-productivity farms (Davidova et al. 2013). This process of intensive industrialization has meant, more than the continuity of smallholders and farmers with traditional family farms (Shmitt 1991; Friedman 1980), the transformation of these family farms into capitalist units and the predominance of intensive farming (Newby and Sevilla-Guzman 1981; Bernstein 2010; Ashwood et al. 2014; Vanclay et al. 1998). Inserted into commercial structures, dairy farms have become one more link in the industrial system, occupying positions of subordination to and dependence on the associative structure of capitalism (Barbeta-Viñas & Requena-i-Mora 2022; Banaji 2016; Requena-i-Mora et al. 2018).

The structural understanding of this process of the transformation of the dairy farming sector can be found in Marx's idea (1976: pp. 54, 55) that this is a "process of subsumption of the rural world by capital". In connection with this process of subsumption, another socio-economic dimension is self-exploitation by farmers. Kautsky and Lenin used the concept of self-exploitation to explain why agricultural smallholdings should not persist. Other research has focused on demonstrating that it is precisely self-exploitation that has enabled small farms to survive at the beginning of the twenty-first century (Monrad Hansen 2012). Finally, several studies have referred to self-exploitation to show that the hard work of family farmers and the undervaluation of the labour force effectively result in a value transfer process (Galt 2013; Guthman 2004). As part of a value chain that includes processing companies, this becomes more evident as the power exercised by the processing industry and the effect of market fluctuations increase. This implies a rise in owner-operated farming, especially among smallholder farmers, as raw milk prices have not changed substantially in the last 30 years (Barbeta-Viñas & Requena-i-Mora 2022; Marcoantonio 2018; Levins 2000). It has been pointed out that self-exploitation, with its dimensions of "low remuneration" and "exhaustion" due to the amount of work, is one of the reasons that livestock farming is abandoned or, at least, for the low expectations of its development (Barbeta-Viñas & Requena-i-Mora 2022; Lass et al. 2003). However, self-exploitation is a "double-edged sword": when it is not supported and coordinated with other incentives, it can lead to farming being abandoned, but at the same time, as Friedman (1978) stated, self-exploitation can be an "effective" endeavour in the case of smallholders in the context of global competition. The logic of integrating the rural world, in this case, dairy farmers, into the service of the capitalist economy entails a double paradox (Ortí 1997). Firstly, agricultural activity tends to be increasingly more productive, but less profitable. Technological and efficiency improvements increase productivity, but with a high degree of capitalization and a significant cost increase. In addition, there is a progressive worsening of the real terms of trade of agricultural products with goods and services from the urban-industrial sector, and farming may not be able to compete at all in the long term if industrial price inflation (machinery, fertilisers, etc.) continues. Farmers produce more agricultural products with less land and/or livestock but earn less. In order to survive, they resort to the mechanical practice of continuously expanding the minimum profitable size of their farms (Barbeta-Viñas & Requena-i-Mora 2022; Requena-i-Mora et al. 2018). In this increasingly asphyxiating loop, made worse by progressive indebtedness, farmers feel dependent on the market and industry and permanently trapped by obligations that overwhelm them (Alonso et al. 1991).

Secondly, but closely related to the above, there is a social paradox that the modernization of the production of many livestock farms means contributing to their suicide as a social class and the end of their way of life, and to the extinction of the rural world (Bernstein 2010; Ortí 1997). The number of dairy farms in the European Union has fallen by 62% since 2005, but the number of cows has not gone down proportionally, so we are witnessing the disappearance and concentration of dairy farms (Barbeta-Viñas & Requena-i-Mora 2022, see also Appendix 2).

Within this context of the subsumption of dairy farmers by capital, we intend to return to the debate about the agrarian question. To recapitulate, we have three sets of theories. Firstly, the Marxist and liberal theories advocate the disappearance of smallholdings that cannot incorporate technical advances and becomes less productive and profitable. Secondly, Marxist theories insist that the small farm implies self-exploitation by farmers. Thirdly, the group of studies, inspired by the work of Chayanov (1931), defended the small farm's greater economic profitability and survival. Among other factors, they list: the possible application of technical advances in smallholdings; the availability and motivation of family labour, which makes small farms more efficient; the willingness to accept lower remuneration for their produce; the many tasks the farmer does in-house and does not outsource, thereby reducing costs; the dependence of agricultural activity on biological and meteorological rhythms, which makes it different from the rhythms of industrial production, and which helps small farms produce better quality products and more environmentally sustainable products; and the difficulties of the process of land concentration when making larger farms.

In the following pages, we will compare and contrast the above theories with data from the Farm Accountability Data Network (FADN) and Eurostat. We will analyse the relationship between the size of dairy farms in the European Union and their economic profitability, as well as the evolution of this relationship, to better understand why small farms are being abandoned.

Methodology

Data collection

Our empirical work is based on two main sources of quantitative data. To study the relationship between farm size and farm economic performance we have used the Farm Accountability Data Network (FADN).[3]

The FADN is a survey conducted by EU member states to assess farm incomes and the impact of the Common Agricultural Policy (CAP). The sample comprised 'commercial farms' that account for the large majority of production, more than 90 per cent (Hill et al. 2016). The data from this survey has been complemented with Eurostat[4] data on dairy farms in EU countries. This data has been used to analyse the evolution and distribution of farms and to study, on the one hand, processes of concentration and, on the other hand, to analyse which types of farms have survived, large or small.

Operationalization and analytical methods

To test the relationship between farm size and economic profitability, several variables from the FADN were analysed. Firstly, farm size was operationalised on the basis of the *average number of cows per farm* in each of the countries being studied.[5] Several control variables, previously mentioned in the literature, were added, namely: (i) the *proportion of family workers*—theories inspired by Chayanov (1931) highlight the role of this type of labour force in the higher profitability of small farms; (ii) *productivity* (tonnes of milk per cow)—Marxist and liberal theories argue that productivity on large farms is higher and this makes such farms more economically profitable; (iii) *investment in maintaining machinery and expenditure on energy* (both variables in euros per tonne of milk)—these are the only variables that allow us to analyse the use of technology, a factor highlighted by all the theoretical currents analysed; and, finally, (iv) *hours worked* [Annual Work Units, see the definition in Eq. (2)] this variable enables us to examine the potential substitution of labor by technology, as proposed by both Marxist and liberal perspectives.

Secondly, to study the economic profitability of farms, three types of profit margins have been used: (i) net profit margin, defined as the total revenue from milk minus the total production cost; (ii) net economic margin, composed of the net profit margin minus imputed family factors, which are the imputed family labour cost[6] and the own-capital cost.[7] (This second type of margin was used to test the importance of unpaid family labour; an important factor in theories of exploitation and self-exploitation in family farming); and (iii) Farm Net Income (FNI), which is equal to Farm Net Value Added[8] after the deduction of external factors of production and the addition of the balance of subsidies and taxes. (FNI is used to see the exact amount received by farms after the deduction of taxes and by adding together the various types of subsidies). Table 1 summarises the operationalization of our initial question and its concepts.

The analysis techniques used were panel regressions expressed by the following equations, (1) and (2):

$$Economic\ profitability = \alpha + \beta_1 Dairy\ Cows_{it} + \beta_7 (Dairy\ Cows_{it} - \overline{Dairy\ Cows_i})^2 + \mu_{it} \quad (1)$$

[3] The data analysed was for dairy farms and is available at: https://agridata.ec.europa.eu/extensions/DairyReport/DairyReport.html.

[4] Data from Eurostat comes from the Farm Structure Survey (FSS) and is carried out every 3 or 4 years as a sample survey and once every 10 years as a census by all Member States. Its purpose is to obtain reliable data on the structure of agricultural holdings in the EU, particularly land use, livestock and the labour force.

[5] According to the Farm Structure Survey more than 60% of the holdings—in some cases more than 90%—are around this average. So, this is the size of the country's most representative farm. The FADN sample has a weight corresponding to the number of agricultural holdings it represents. The holdings in the sample and the population are stratified (i.e. formed into groups) according to region, type of specialisation and economic size.

[6] According to the European Commission (2016: p. 70) This cost is estimated on the basis of wages which farm owners would have to pay if they were to hire employees to do the work carried out by family members. It is estimated as the average regional wage per hour based on the FADN data33 multiplied by the number of hours worked by family workers on the farm. It is commonly acknowledged that the number of hours worked by family workers is typically overestimated. Thus, a ceiling of 3000 h per Annual Work Unit is applied (this is the equivalent of 8.2 h a day, 365 days a year, and corresponds more or less corresponds to the time that can be spent on a farm by farmers milking cows.

[7] According to the European Commission (2016), own capital cost is compounded by own land cost and cost of own capital. Own-land cost is estimated based on the rent that farm owners would have to pay if they were to rent the land they are using. It is estimated as the owned area multiplied by the rent paid per hectare on the same farm or, if there is no rented land on the farm, multiplied by the average rent paid per hectare in the same region and for the same type of farming. And Cost of own capital (except land) is the cost of own capital (permanent crops, buildings, machinery and equipment, forest land, livestock and crop stocks) is estimated at its opportunity cost. That is how much money the farmer could earn if he were to invest the equivalent of its capital value in 'safe' financial assets (the European Commission 2016: p. 71),

[8] Farm Net Value Added equals gross farm income minus depreciation costs. It is used to remunerate the fixed factors of production (labour, land, and capital), whether they are external or family factors. As a result, agricultural holdings can be compared regardless of the family/non-family nature of the factors of production used. FNVA = output + Pillar I and Pillar II payments + any national subsidies + VAT balance—intermediate consumption—farm taxes (income taxes are not included)—depreciation.

Table 1 Operationalization of the initial question

Initial question	Concepts	Variables	Units	Source	Unit of analysis
Does the size of dairy farms influence their economic profitability?	Farm size and control variables	Dairy cows	Livestock unit	FADN	25 EU countries
		Milk yield	Tonnes per cow		
		Energy (fuel, electricity)	EUR/t of milk (nominal)		
		Machinery and building upkeep	EUR/t of milk (nominal)		
		Annual work	Unit		
		Family labour	parts per unit		
	Economic profitability	Total Net Margin	Euros		
		Total Net Economic Margin	Euros		
		Total Farm Net Income	Euros		

$$\begin{aligned} Economic\ profitability = {} & \alpha_i + \beta_1 Dairy\ Cows_{it} + \beta_2 Milk\ yield_{it} \\ & + \beta_3 Energy_{it} + \beta_4 Machinery_{it} \\ & + \beta_5 AWU_{it} + \beta_6 Family\ Labour_{it} \\ & + \beta_7 (Dairy\ Cows_{it} - \overline{Dairy\ Cows_i})^2 + \mu_{it} \end{aligned} \quad (2)$$

Where: i: are the 25 countries of the EU, t: are the years (2008 to 2018), *Economicprofitability*: are Net Margin, Net Economic Margin and Farm Net Income (absolute and by Annual Work Unit—AWU), *Milk yield*: average production of milk and milk products per cow (in tonnes per cow), *Energy*: motor fuels, lubricants, and electricity per tonne of milk, *Machinery*: cost of upkeep of equipment and buildings per tonne of milk, $DairyCows_{it} - \overline{DairyCows_i}^2$: to avoid ignoring the nonlinear effects of farm size, we added the squared term of average dairy cows into the model (Hu et al. 2019). Moreover, following Steinberger et al. (2013) to prevent co-linearity between the linear and quadratic terms, we subtracted the mean value for dairy cows in the quadratic term. $FamilyLabour_{it}$: proportion of family labour out of total labour. AWU_{it}: Annual Work Unit (AWU) is the equivalent of full-time employment, i.e., the total hours worked divided by the average annual hours worked in full-time jobs in the country. One annual work unit corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis.

In Eq. 1 we saw the effect of farm size on perceived profits. In Eq. 2 we studied this same effect while introducing the control variables discussed above.

We used these models with additional dependent variables, namely: (i) production costs[9]; (ii) revenues; (iii) family labour; and (iv) total balance of subsidies and taxes,[10] in euros.

The Hausman and Larange Multiplier tests indicated the most efficient models. The models were corrected for heteroscedasticity, serial correlation, and cross-sectional dependence. Following Hoechle (2007), we used Driscoll and Kraay standard errors. These standard errors present heteroscedasticity and are consistent and robust to very general forms of cross-sectional and temporal dependence. We used the xtscc command from Stata. Furthermore, we checked for multicollinearity using the correlation matrix of coefficients of the xtscc model—estat vce, corr command. Following Alison (1999: p. 141), we eliminated control variables when correlations where greater than 0.6.

Finally, we applied variance decomposition and an analysis of the weight of the components of Farm Net Income.

Results: too big or too small to be profitable?

Here we tested our main research question. Firstly, we analysed the relationship between the number of cows and net and economic profit margins. Second we tried to look at the relationship between the number of cows and Farm Net Income.

Too big to be profitable

The differences between profit margins in different countries and the average number of cows per farm showed the economic paradox of agricultural modernization and increased production. In the current phase of agricultural modernization, countries with larger farms tended to be less profitable. Firstly, we observed how countries with smaller farms—a lower average number of cows per farm—tended to have higher profit margins.

The results of the panel regression are—shown in Fig. 1. The negative and significant coefficient for the variable of

[9] Total operating costs include livestock-specific inputs; herd renewal purchases; machinery and building upkeep; contract work; energy; milk levy.

[10] Here we include coupled and decoupled payments, the balance of subsidies and taxes, and the balance of investment and subsidies and taxes.

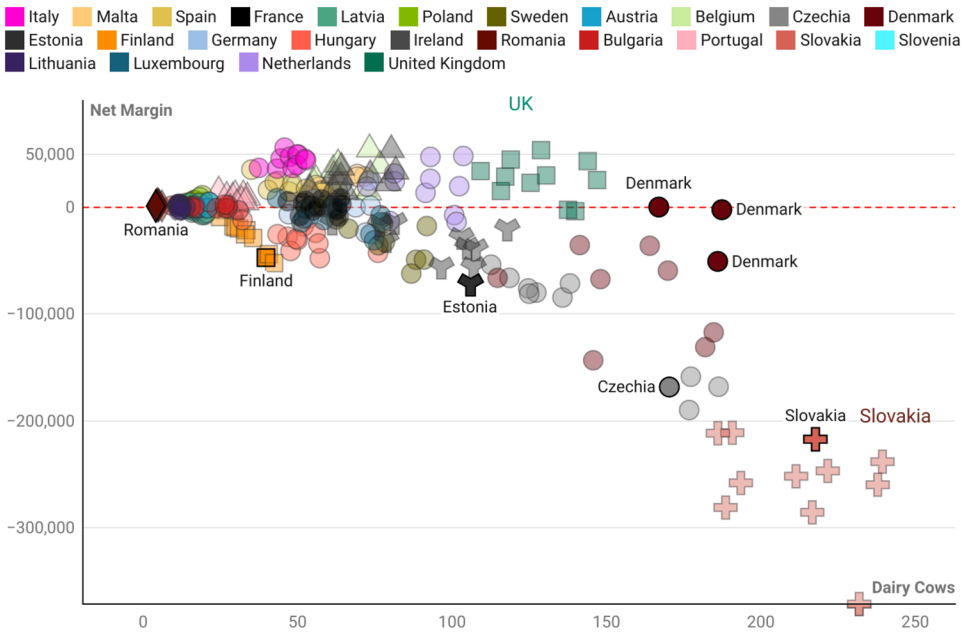

Fig. 1 The relationship between number of cows and Net margin in EU countries (2008–2018). *Net margin is defined as the total revenue from milk minus the total production cost. Source: authors' own work based on FADN data. Interactive view: https://datawrapper.dwcdn.net/sq39T/8/

the number of cows indicates that there was a negative and significant relationship between farm size and profit margins. Furthermore, the square coefficient of dairy cows was also negative and significant (see first model Table 2). The negative quadratic coefficient indicates that profits first increase but then decreases as the number of cows moves away from the vertex. However, when we introduced all the control variables, the square coefficient was no longer significant, but the number of cows did remain negative and significant. The higher the average number of cows per farm, the lower the profit margin. One cow more implies losing 617 euros. Of the other variables, only energy expenditure was significant (10% level of significance) and positive. Thus, the second model is in line with the theses inspired by Chayanov (1931), which posit the higher economic profitability of small farms. Moreover, the significance of the energy expenditure variable was related to a higher use of technology. Hence, the net profit margin is explained by a lower number of cows and greater energy use (as a crude approximation of the use of technology).

The main reason for the negative relationship between the average number of cows and net profit margin was the gap between production costs and revenues. Figure 2 shows the results of the relationship between the number of cows and costs, and the number of cows and revenues. The X-axis denotes the number of cows, while the Y-axis displays the corresponding total costs and revenues. It is worth noting that as the number of dairy cows increases, both costs and revenues also increment. However, in the first instance we saw that the number of cows had a positive relationship with profit margins—the black line (revenues) is above the dashed line (costs). The intersection point between the two trend lines shows that from 47.8 cows onwards, profit margins were negative. At this point, the black line (revenues) reminds under the dashed line (costs). The trend lines and the intersection point were taken from two panel regressions—one between costs and average number of cows per country, and one between revenues and average number of cows per country. The results can be found in Table A1 in the annexes.

In the FADN surveys we also found another type of cost that does not normally appear in farms' balance sheets: imputed family factors. The most important part of these costs is unpaid family labour[11], [12] but they also include own-capital costs. When these costs are included in the total production costs, and subtracted from income, we obtain the Net Economic Margin.

We can draw two important conclusions pertinent to the discussion of agriculture from our analysis of Net Economic Margins—which include imputed family factors. Firstly, we observed that most dairy farms did not make a profit. Only occasionally did we see medium-sized farms that managed to have positive margins (see Fig. 3). The data also showed that dairy farms survived through self-exploitation, relying on family labour. It is clear when we compare net and economic margins in Figs. 1 and 3.

[11] As some studies have shown, family labour tends to be rewarded in terms of occupation, inheritance, retirement support and certain life situations (Jervell 1999).

[12] This cost is estimated on the basis of wages that farm owners would have to pay if they were to hire employees to do the work carried out by family members.

Table 2 Panel regression results comparing net margin and number of cows

EU countries 25 (2008–2018)	(1) Net Margin (in Euros) Random effects	(2) Net Margin (in Euros) Fixed effects
Constant	− 32,228.2***	1782.7
	(9791.7)	(37,212.9)
Dairy cows	− 702,38***	− 617.3623**
	(203.62)	(300.36)
Dairy cows^2	− 14.93**	− 10.12
	(6.58)	(8.57)
Family labour	–	− 21,247.39
		(28,343.91)
Milk yield–t/cow	–	6394.6
		(4284.8)
Machinery	–	− 675.74
		(845.82)
AWU	–	− 3432
		(40,076.0)
Energy	–	918.58[a]
		(291.6)
Prob > F	0.00	0.00
Ovearll R-squared	0.47	0.60
p_value (Hausman test)	0.4	0.01
p_value (LM test)	0.00	0.00

The Hausman and LM tests indicate the most efficient model. All panels are cointegrated

[a]Net margin is defined as the total revenue from milk minus the total production cost. Driscoll-Kraay standard errors are shown in parentheses

Asterisks correspond to the p-value: * for $p < 0.10$, ** for $p < 0.05$ and *** for $p < 0.01$

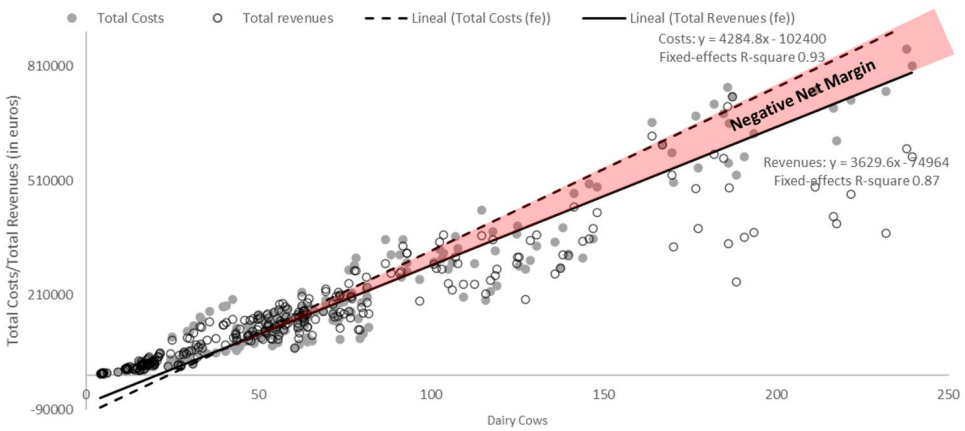

Fig. 2 The relationship between number of cows, production costs and revenue in EU countries (2008–2018). Source: authors' own work based on FADN data

Secondly, the relationship between the economic margin and the number of cows remained negative and significant even when we introduced control variables—one more cow implies losing 745 euros. Again, we saw that the Net Economic Margin was higher (or less negative) in those countries with a lower number of cows per farm, but also with higher energy use (model 2, Table 3). So this type of profit was not only explained by a lower number of cows, but also by a higher use of energy per tonne of milk. The rest of the control variables remained insignificant.

It should also be noted that, contrary to Marxist theses, the countries with the largest farms were those with the highest self-exploitation of the family—operationalizing self-exploitation on the basis of the variable cost attributed to unpaid labour (see Fig. B1 and Table A2 in the Appendix 1). This relationship was seen in two very different clusters of countries: in Eastern European EU countries—especially

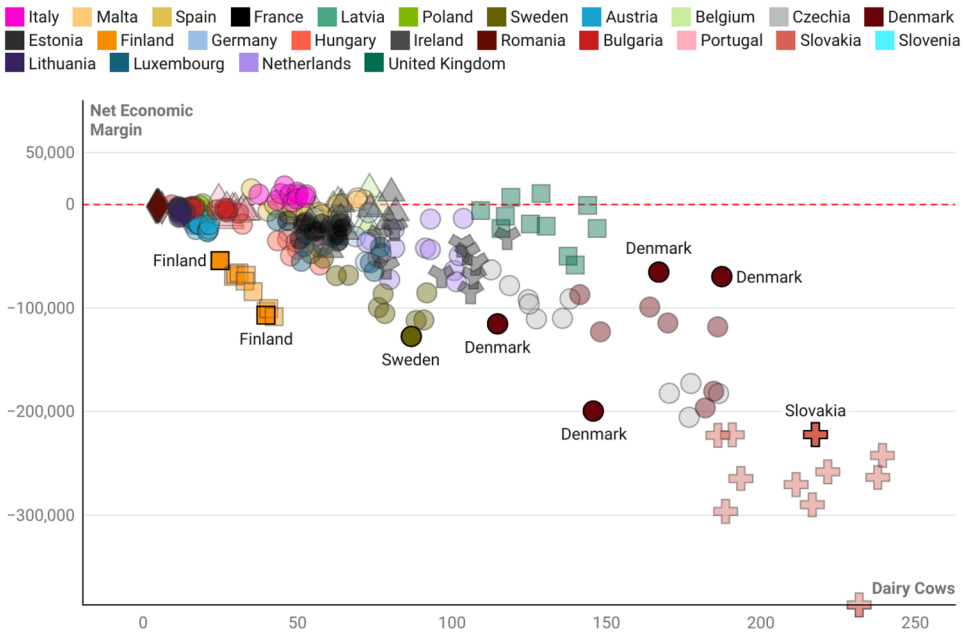

Fig. 3 The relationship between number of cows and Net economic margin in EU countries (2008–2018). *Net economic margin, composed of the net profit margin minus imputed family factors, which are the imputed family labour cost and the own-capital cost. Source: authors' own work based on FADN data. Interactive view: https://datawrapper.dwcdn.net/fMbUL/10/

Bulgaria, Hungary, Estonia Check Republic and Slovakia—there was not a positive relationship between the number of cows and costs attributed to unpaid labour—in the countries with the largest farms, the costs attributed to unpaid labour were lower, i.e., there was a lower degree of family farming (see also Fig. B2)—but in the other EU countries, we saw a positive relationship between the imputed family labour cost and the number of cows.

Too small to be profitable

If smaller farms are more profitable, why is there a process of farm concentration? (see Appendix 2). What, then, is the element of the economic performance of farms that might help us understand why smaller dairy farming is disappearing?

The fact that most farms made a loss when unpaid labour was taken into account could partially explain, on the one hand, the disappearance of dairy farming in the European Union and, on the other hand, the issue, discussed in the introduction of self-exploitation in family farms. However, we still do not know why there was a process of concentration when everything seems to indicate that small farms made the most profit or, at least, smaller losses.

We have yet to talk about the relationship between Farm Net Income—which includes subsides—and the average number of cows per country. The first thing we observed was that taking into account this indicator, farms had a positive income regardless of the number of cows (Fig. 4 and Table 5 model 1). This shows the importance of subsidies in aiding the survival of dairy farms. Only occasionally, in some farms in Estonia and Denmark, but especially in Slovakia, were losses registered. The relationship between Farm Net Income and the number of cows was positive and significant, both when only this variable was considered (Table 5, model 1) and when the control variables were included (see Table 5, model 2). One cow more implies earning 943.5 or 1404.57 euros more, respectively. Moreover, milk yield (t/cow) was also significant. These results are in line with the liberal and Marxist theses that large farms are more productive and profitable.

However, there were other significant control variables. Firstly, we saw that there was a positive and significant relationship between a higher proportion of family labour and Farm Net Income (see Table 5, model 2), a fact related to the theses inspired by Chayanov (1931) that stress the importance of family labour in the economic profitability of farms. It is important to note that, although there was a negative relationship between the proportion of family labour and the number of cows per farm (Fig. B2, Appendix 1), this relationship was not, in any case, decisive, and there were two very different clusters of countries: in Eastern European countries, as the number of cows increased, the proportion of family labour decreased more sharply than in the rest of the European Union. Thus, it was observed that there were Central European countries with a higher number of cows, but a high proportion of family labour Moreover, when we limited our panel to only include Eastern countries, the proportion of family labour remained insignificant and did not explain the Farm Net Income (as shown in Table 4). In other words, the proportion of family labour only explains Farm Net income in Central and Northern European countries. Finally, the relationship between the Annual Work Unit

Table 3 Panel regression results comparing net economic margin and number of cows

EU countries 25 (2008–2018)	(1) Net Economic Margin (in Euros) Random effects	(2) Net Economic Margin (in Euros) Fixed effects
Constant	− 13,863.92	− 32,277.18
	(8370.9)	(47,012.45)
Dairy cows	− 833.46***	− 744.80**
	(189.79)	(310.11)
Dairy cows^2	− 9.8	− 5.33
	(6.22)	(8.79)
Family labour	–	− 6321.78
		(29,321.27)
Milk yield–t/cow	–	6815.77
		(4926.91)
Machinery	–	− 664.61
		(736.30)
AWU	–	− 2716.46
		(4101.9)
Energy	–	884.78**
		(333.13)
Prob > F	0.00	0.00
Overall R-squared	0.62	0.68
p_value (Hausman test)	0.7	0.02
p_value (LM test)	0.00	0.00

Driscoll-Kraay standard errors are shown in parentheses

The Hausman and LM tests indicate the most efficient model. All panels are cointegrated

*Net economic margin, composed of the net profit margin minus imputed family factors, which are the imputed family labour cost and the own-capital cost

Asterisks correspond to the p-value: * for $p<0.10$, ** for $p<0.05$ and *** for $p<0.01$

(AWU) variable was significant and negative, i.e. 1 AWU more implies losing 13,398.72 euros of Farm Net Income.

One could argue that more cows also mean more working hours, and therefore the Farm Net Income of larger farms should also be higher. However, we got very similar results if we analysed the relationship between Farm Net Income per AWU and the number of cows (see Table 5 model 3). Furthermore, when we included the control variables, we still saw a positive and significant relationship in the coefficients of family labour, productivity, and energy use per tonne of milk (as a proxy for technology use) and a negative and significant relationship with AWU (see Table 5 model 4).

We observed, in both cases—Farm Net Income and Farm Net Income per AWU—a significant but low coefficient of determination. As can be seen in Fig. 4, the data were very widespread. In many periods we saw losses in Slovakia and Denmark, which are the country with the highest number of cows per farm.

What, then, was the differential element between profit margin and Farm Net Income? As already mentioned, the profit margins discussed so far omitted the balance of subsidies and taxes. But we observed that this variable had a stable and very important weight within Farm Net Income. In the variance decomposition of Farm Net Income, for EU dairy farms as a whole, we saw that the balance of taxes and subsidies varied by only 11% (Fig. 5), and that its weight was 50% or higher in all the periods studied (Fig. 5), even covering losses in 2009 (the weight of the balance over total Farm Net Income is 102%).

Moreover, most importantly, we observed a significant and positive relationship between the average number of cows in each country and the balance of subsidies and taxes (see Fig. B3 and Table A4 in the Appendix). Countries with larger farms were more likely to receive more subsidies, thus contradicting the supposed post-productivist theses of the CAP (Bowler 1996 and Appendix 2). This would partially explain the positive relationship between number of cows and Farm Net Income. Furthermore, the positive relationship between number of cows and costs attributed to unpaid family labour, as discussed in previous sections and Figs. B1 and B2 in the Appendix 1, should also be taken into consideration. Thus, a higher amount in the balance of subsidies and taxes and the low remuneration of family labour—especially in Central European countries, see Fig. B1—could explain a higher income in countries with larger farms.

Discussion

Within the debate about the size of farms and economic profitability, the three blocks of theories set out in the introduction are necessary to explain our results.

Firstly, we need the body of research that argues for the higher economic profitability and survival of the small farm. As we have seen, margin profits were higher on farms that were smaller and more energy intensive per tonne of milk. This aligns with Chayanov's (1931) theses, which suggest that small farms are more economically profitable. Some studies (Maynegre and Nogué 2018) have stated that profit margins of small dairy cow farms are higher because of the nutritional quality of their milk. For example, in the case of Catalonia, Barbeta-Viñas & Requena-i-Mora (2023) concluded that these variables explain between 80 and 90% of the variance in the fat content of milk. This fact is closely linked to milking cows 3 times a day; the farms that milk 3 times a day are the largest farms. However, farms with a smaller number of cows only milk their cows twice a day, and therefore the amount of fat per tonne is higher. Furthermore, additional studies have presented arguments indicating variations in fat content across different breeds of dairy cattle (DePeters et al 1995). As an example, it is noteworthy

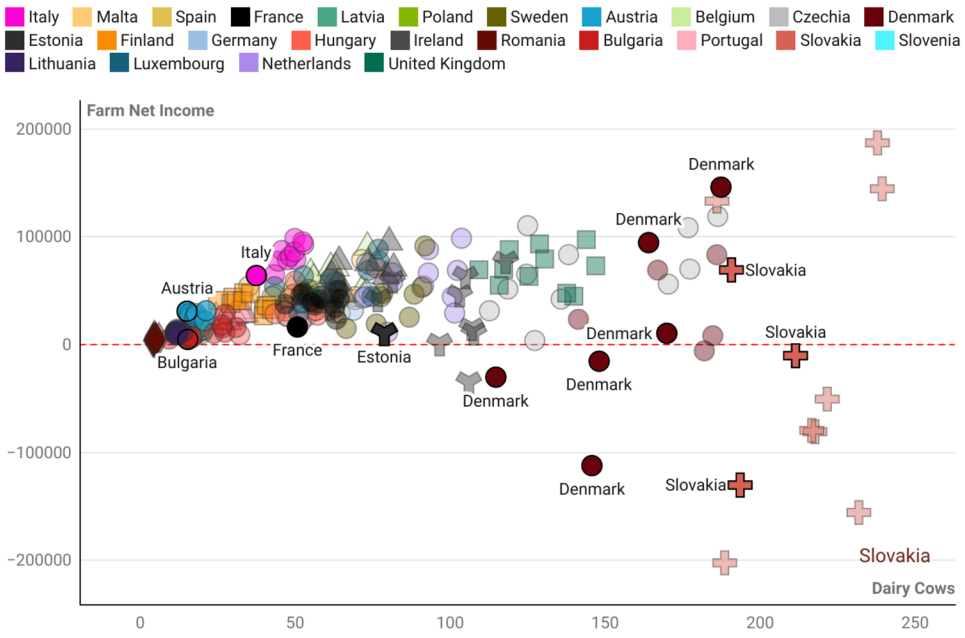

Fig. 4 The relationship between number of cows and Farm Net Income in EU countries (2008–2018). Source: authors' own work based on FADN data. Interactive view: https://datawrapper.dwcdn.net/kGOoU/3/

that the preponderant bovine population in the largest dairy farms of the United States comprises predominantly Holstein breed-derived cows. While these cows exhibit high productivity, it is important to note that they possess a relatively lower fat content in comparison to other breeds renowned for their capacity to yield milk with elevated fat content, such as Jerseys (ibid.). Nevertheless, the latter breeds are not ideally suited for high throughput operations. Consequently, the aforementioned high-volume cows are primarily found in expansive, industrialized farming facilities where they undergo a thrice-daily milking regimen.

However, in our case, the main reason for the negative relationship between average number of cows and net profit margin was the gap between production costs and revenues (Fig. 2) in other words, the main reason why larger farms tend to be less profitable is that their production costs are higher than their revenue.

Moreover, analysis of the Net Economic Margin, which includes the cost of imputed family factors, showed that most farms made a loss. We observed only infrequent occurrences of medium-sized farms that managed to have positive margins (see Fig. 3). From Fig. 3 we can reduce the need for farms to look for other complementary activities to be viable, as has been happening in recent decades (Loughrey et al. 2013), to add value to their milk (e.g., cheese production, etc.), or even to consider abandoning farming altogether. The data also revealed that dairy farms sustained themselves through self-exploitation by relying on labour from family members. As mentioned in the introduction, this process has been partially studied in the existing literature in different contexts and from different perspectives (Cayuela 2013; Schewe and White 2017; Galt 2013; Friedmann 1978).

This is also consistent with the Marxist theses of self-exploitation. In the literature review we included a section that might explain this fact: the subsumption of agriculture and dairy farming to capital transforms the condition of farms. As Kautsky argued, smallholders survived because of self-exploitation and underconsumption; neither deemed to be socially desirable (Birner and Resnick 2010). However, contrary to what Marxist theses argue, we saw that family self-exploitation tended to be higher in countries where farms were larger, especially in Northern and Central European countries (see Fig. B1). Similar results have been seen in other research: Barbeta-Viñas & Requena-i-Mora (2022) explain that, in Catalonia, incomes are higher in farms with a higher number of cows, but also with a higher percentage of family labour.

Nevertheless, the study found that the positive relationship between imputed family labour costs and the number of cows was not decisive and varied among different clusters of countries. In Eastern European countries, as the number of cows increased, the imputed family labour remains constant (see Fig. B1). That is explained by the fact that the proportion of family labour decreased more sharply in Eastern countries than in the rest of the European Union (See Fig. B2). According to Klikoca et al. (2021) some EU countries that joined in the recent decade, family labour is less significant on farms compared to older EU member states. This is due to the fact that many of these countries were post-Communist, and it is possible that the institutional and organizational structures established during the communist era, which involved collective ownership and management of farms, have continued to some extent, resulting in a reduced proportion of family labour.

Table 4 The relationship between number of cows and Farm Net Income in Central and Eastern European countries

	(1) Farm Net Income (in Euros) Post-Communist Countries
	Fixed effects
Constant	24,346.73
	(58,785.88)
Dairy cows	2121.363***
	(590.1)
Dairy of cows^2	37.57
	(21.21)
Family labour	3712.9
	(50,866.97)
Milk yield–t/cow	–
Machinery	− 1288.304
	(863.7)
AWU	− 17,546.8**
	(6917.6)
Energy	105.711
	(611.0)
Prob > F	0.00
Overall R-squared	0.27
Within R-squared	0.32
p_value (Hausman test)	0.00
p_value (LM test)	1.0

Yield has been removed form model 1 because of multicollinearity. Driscoll-Kraay standard errors are shown in parentheses

The Hausman and LM tests indicate the most efficient model. All panels are cointegrated

Asterisks correspond to the p-value: * for $p < 0.10$, ** for $p < 0.05$ and *** for $p < 0.01$

The phenomenon of farm concentration (see Appendix 2), despite the supposed economic advantage of smaller farms, presents a puzzling issue. Some studies have suggested that larger farms can reduce costs, contradicting the notion of smaller farms as more profitable. However, recent observations in the United States indicate a persistent trend in which smaller farms fail to generate profits (McDonald et al. 2013). Thus, in our case, other variables may account for this trend.

We saw that it is only when we studied the relationship between farm size and Farm Net Income that we observed that larger farms earn more. The large differences in Farm Net Income between different sizes of farm explain the constant disappearance of smaller farms as seen in this article. But it was not only the larger farms that had higher income but also the most productive farms and the ones with the lowest labour hours. Both Marxist and liberal theories support this idea.

However, we also saw that a higher proportion of family labour was important for higher profits, as pointed out by the Chayanov-inspired studies. As Chayanov himself (1931) pointed out, a family-labour farm aims to satisfy its collective needs rather than to make a profit; not having to pay wages, it is able to increase or decrease its inputs according to the prevailing external conditions. Brookfield (2008) also argues that because of the internal flexibility provided by the family mode of decision-making, family-labour farms can pay above the going rate for credit and for land and can survive low prices for their outputs that would bankrupt a wage-labour farm. Needless to say, that again we observe huge differences between Eastern and Central European countries. When we limited our panel to only include Eastern countries, the proportion of family labour remained insignificant and did not account for the Farm Net Income (as shown in Table 4).

There are, though, more variables that might explain the higher profitability of larger farms that are not mentioned in the literature. One of the possible variables that explain why larger farms earn more is the greater amount received in the balance of subsidies and taxes. This, moreover, is the differential element between profit margin and Farm Net Income, with a very important weight within Farm Net Income (Fig. 5). A positive relationship was found between the average number of cows per country and the balance of subsidies and taxes, indicating that larger farms tend to receive more subsidies, which contradicts the post-productivist theses of the CAP (see Fig. B3). This relationship could partly explain the positive relationship between the number of cows and Farm Net Income.

Conclusion

The study examined the relationship between the size of dairy farms and economic profitability, taking into account different theoretical perspectives. First, when examining the profit margins, the study found that smaller and more energy-intensive farms were more economically profitable, consistent with Chayanov's theory. Then, when including the imputed family labour in the profit margins, most farms made a loss. Most of the farms sustained themselves through self-exploitation by relying on unpaid labour from family members, this is also consistent with the Marxist theses of self-exploitation. However, contrary to what these theses suggest, are the largest farms who rely more on this unpaid labour cost, as can be observed in Fig. B1. This is especially true for Central European countries, however, do not apply for Eastern countries. Finally, only when analgising the Farm Net Income, we observe that large farms earn more than the smaller ones, as both liberal and Marxist thesis suggested. However, is not only the productivity the main

Table 5 Panel regression results comparing farm net income and number of cows

EU countries 25 (2008–2018)	(1) Farm Net Income (in Euros)	(2) Farm Net Income (in Euros)	(3) Farm Net Income per AWU (in Euros)	(4) Farm Net Income per AWU (in Euros)
	Fixed effects	Fixed effects	Fixed effects	Fixed effects
Constant	− 277,543.49	− 231,645.9**	− 4944.07	− 40,825.11**
	(32,815.02)	(87,739.57)	(5819.5)	(12,879.41)
Dairy cows	943.51*	1404.57**	180.6*	227.78**
	(496.7)	(501.70)	(86.4)	(96.59)
Dairy of cows^2	26.93	21.2	− 0.7	− 0.54
	(19.5)	(17.30)	(3.2)	(2.73)
Family labour	–	137,000.5**	–	24,634.7**
		(62,671.4)		(11,754.7)
Milk yield–t/cow	–	17,436.82**	–	3276.7*
		(7838.8)		(1109.8)
Machinery	–	0.51	–	–
		(1030.57)		–
AWU	–	− 13,398.72**	–	− 13,021.4**
		(5715.71)		(537.25)
Energy	–	532.15	–	334.8**
		(606.31)		(121.9)
Prob > F	0.00	0.00	0.00	0.00
Overall R-squared	0.02	0.18	0.01	0.26
Within R-squared	0.1	0.28	0.08	0.14
p_value (Hausman test)	0.00	0.00	0.00	0.00
p_value (LM test)	0.00	0.00	0.00	0.00

The machinery variable was eliminated from Model 4 due to collinearity problems

Driscoll-Kraay standard errors are shown in parentheses

The Hausman and LM tests indicate the most efficient model. All panels are cointegrated

Asterisks correspond to the p-value: * for $p < 0.10$, ** for $p < 0.05$ and *** for $p < 0.01$

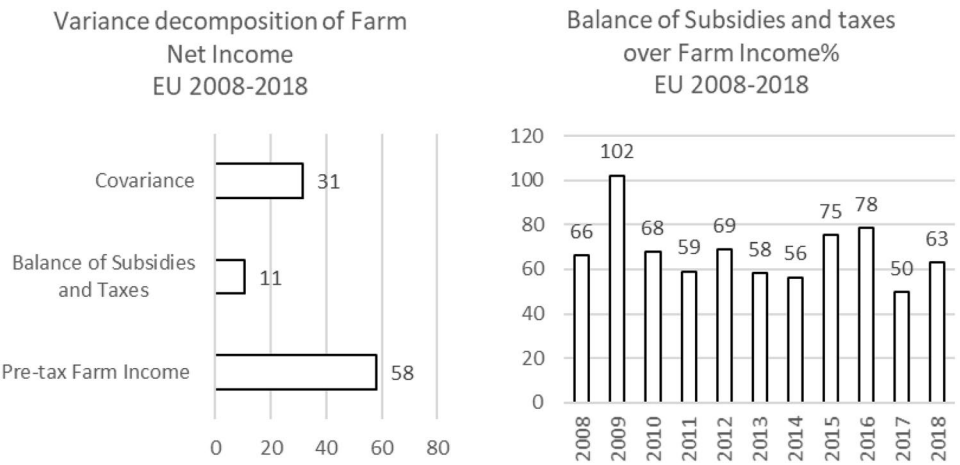

Fig. 5 Variance decomposition of Farm Net Income (EU 2008–2018). Balance of subsidies and taxes over Farm Net Income (%, EU 2008–2018). Source: authors' own work based on FADN data

reason. Larger farms tend to receive more subsidies and taxes, which could explain the positive relationship between the number of cows and Farm Net Income. On the other hand, the higher incomes in Central European countries with larger farms may be attributed to the utilization of family labour, which would be consistent with theses inspired by Chayanov. But it remains to say that, as Kautsky and Lenin suggested, this implies self-exploitation because, most the time, family labour costs are unpaid. However, we would like to highlight three basic limitations of this study. Firstly,

the farm data is aggregated at country level. This makes it impossible to get a true picture of the reality of the farms. The FADN data is also at regional level (NUTS2). However, only data from 2018 have been made available. We have added a correlation matrix to the main variables studied here (see Table A5). These correlations confirm the analyses presented here by country. The second limitation of the study is the poor estimate of the technology variable. We would need a better measurement, such as investment in technology or, better still, inventories of machinery and other technological advances applied on farms.

An additional significant limitation of the study is the omission of crucial supply-chain issues resulting from post-farm-gate consolidation, which have implications for the viability of small farms. For instance, multiple studies have presented evidence of the dairy industry exerting its dominance during the negotiation process for milk purchase and sale, as well as influencing the terms of the associated contracts. This power imbalance among actors has been recognized as a contributing factor to unfair business practices (see Marcantonio et al. 2020). Furthermore, the literature also highlights the asymmetric costs of executing contracts, asymmetric information, clauses in the contracts or unilateral changes in them and the proliferation of milk commercialised on the free market (Bonanno et al. 2018; Di Marcantonio et al. 2018, 2020). Broadly speaking, the influence of neoliberal governance can be observed in the promotion of an oligopsonic structure within the milk market, facilitating the industry's control over prices and conditioning transactions with farmers (Čechura et al. 2015).

Finally, we have differentiated between large and small farms, with the largest farms in Slovakia having an average of no more than 250 cows. However, if we compare these farms with mega dairy farms, these farms should be considered small farms. In Spain, there are already mega farms with more than 5000 dairy cows, and there are projects for farms with more than 20,000 cows. Nevertheless, we have not been able to obtain data for this type of farm.

It remains to be added that, although we have seen a steady disappearance of small farms, their role has been underestimated in recent decades. For example, several negative impacts of the industrialized way large farms produce have been documented, such as deforestation, desertification, loss of biodiversity and habitats, decline in soil fertility, and water pollution (Clay et al. 2020). Many studies have also demonstrated that the livestock sector is a significant source of global anthropogenic greenhouse gas (GHG) emissions, estimated at 6.3% of the total (IPCC 2014; Opio et al. 2013). It has also been shown that pollution increases with the number of cows, and that so-called mega farms have negative environmental consequences (Fodor et al. 2018). The current agri-food system involves large-scale monopolization of land and livestock, very precarious working conditions, unequal distribution of food and exacerbated inequalities (Bales 2016). All of this suggests that the overall capacity of today's capitalism to sustain agricultural and livestock productivity within the current conventional mode of production is reaching its ecological and social limits (Wittman 2009). However, to be sustainable, socio-economic systems must not only be ecologically sound, but also socially just in terms of the distribution of costs and benefits for present and future generations of farmers (Pungas 2019). Therefore, if smallholder farming is to be strengthened and maintained, it cannot be done at the expense of self-exploitation of dairy farmers.

Self-exploitation is largely linked to the milk market and the pressure exerted by the dairy industry and distribution chains on the downward evolution of raw milk prices (Barbeta-Viñas & Requena-i-Mora 2022; Marcoantonio et al. 2018). Thus, the neoliberal, "deregulatory" policies implemented in EU countries, especially the end of quotas in 2015, although evident in previous CAP reforms, aggravate the problem, creating increasingly difficult conditions for dairy farms (for more information see the appendix 2). In some countries, such as Spain, where the crisis in the sector is clear, recent attempts have been made to "reduce" the opportunity cost by including it in milk purchase contracts between industry and farmers, with the aim of distributing the value (Barbeta-Viñas & Requena-i-Mora 2023; Glover 2015; see: Bellemare and Bloem 2018).[13] However, these policies are clearly insufficient to bring about significant changes in the structural power relationships among those involved. Decisive intervention by public authorities aimed at rebalancing relationships in the dairy sector is needed.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10460-023-10488-6.

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Declarations

Conflict of interest The authors certify that there is no actual or potential conflict of interest in relation to this article and did not receive support from any organization for the submitted work.

[13] There is an interesting debate in the literature on the effects of contracts between the processing and distribution industry and farmers. The data generally available testifies to a situation that is at least controversial. However, the literature on the dairy sector in Europe seems to support the thesis of unequal and non-welfare related effects on smallholders.

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