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MSc Thesis Report

Are viable farms in mainland Portuguese LFAs the exception or the rule?

An assessment of farm business economic viability

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SUMMARY

The objective of this study is to assess farm economic viability and explore farm characteristics associated with economic viability in commercial farms located in mainland Portuguese Less Favoured Areas (LFAs). We define economic viability as the capacity of a farm to renumerate its unpaid labour and owner equity. Our results are conducted for 2184 commercial farms with the majority of their utilized agriculture land in mainland Portuguese LFAs, spanning the years between 2010 and 2018. We go beyond the headcount way of measuring viability and apply a measure of relative viability level, based on the concept of the viability gap, to provide in-depth information about the extent of non-viability. Returns on owner equity and returns on labour are also reported to analyse the sensitivity of the viability measure to the unitary opportunity costs considered. To explore the farm characteristics associated with economic viability we regress the relative viability level on some of the farm structural characteristics.

Our results show that between 46% and 59% of the analysed farms are economically viable. The majority of the non-viable farms are at least profitable and, on average, are able to renumerate between 53.3% and 60.9% of their unpaid labour and owner equity at the national minimum wage and the average annual return rate of 5-year Portuguese national treasury certificates, respectively. Excluding LFA subsidies from the farm net income would slightly increase the ratio of non-viable farms that were not profitable, besides slightly reducing the capacity of non-viable profitable farms to cover their unpaid labour and owner equity. Regarding farms structural characteristics associated with economic viability, our results suggest that the share of own land and unpaid labour are negatively associated with economic viability, while the share of income coming from other farm activities is positively associated with economic viability. While these associations followed our expectations and the empirical results of previous viability analysis, the negative quadratic association found between farm size and the relative viability ratio was not expected and might be caused by model endogeneity.

This study contributes to the scarce literature on economic viability of LFA areas in Portugal and its results provide important insights into the extend of non-viability of farms in mainland Portuguese LFAs. It also contributes to the literature on economic viability of European farms that is exploring farm characteristics associated with economic viability.

Considering the importance of having viable farms in LFAs for the future of the Portuguese farming sector, further research on other than structural farm characteristics associated with farm viability in LFA areas in Portugal is needed. Furthermore, future research on economic viability in LFAs would highly benefit from changes in the data available and sampling methods used by PT FADN to reach more accurate results.

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1. INTRODUCTION

1.1 Problem statement

The vast majority (90.05%) of the utilised agricultural land (UAA) in Portugal falls within less favoured areas (LFAs) (EU Agridata, 2021). Such areas present, in most cases, biophysical characteristics less favourable for agriculture, such as steep slopes, high altitude, or poor soil quality, which undermines the productivity of farms and, consequently, their viability and survival (Subedi et al., 2021; Giannakis & Bruggeman, 2015).

This disadvantaged situation of farms in LFAs has been recognised by the European Union (EU) since 1975, which tries to compensate them through an annual payment per UAA located in LFAs – the LFA subsidies. However, as shown by Jones et al. (2014) there are commercial farms in mainland Portuguese LFAs not able to consistently have a positive farm net income and others where the return on labour is consistently below the national minimal wage. Both situations included the LFA subsidies.

Although such results are based on just four LFA municipalities and therefore not representative of all commercial farms in mainland Portuguese LFAs, they flag the existence of farms that are not economically viable, despite the allocation of LFA subsidies to compensate for their extra costs. Since a low level of farm economic viability is one of the main drivers of farmland abandonment (Terres et al., 2015) and most of the agricultural land available in mainland Portugal is located in LFAs (Portaria 5/2019; EUROSTAT, 2019), the Portuguese farming sector hinges crucially on having viable farms in LFAs. It is therefore important to assess farm viability in mainland Portuguese LFAs. Nevertheless, to the best of our knowledge no further research thus far has been conducted to address this issue.

1.2 Research questions

This study aims to assess farm economic viability and explore farm characteristics associated with economic viability in commercial farms located in mainland Portuguese LFAs. It will be reached by focusing on the following sub-research questions:

1. What is the % of viable farms in those areas, and how would that change if LFA subsidies were not available?
2. How far are non-viable farms in those areas from being viable, and how would that change if LFA subsidies were not available?
3. Which farm characteristics are associated with economic viability?

2. Less Favoured Areas (LFAs)

2.1 Definition

Less Favoured Areas (LFAs) was a terminology used by the European Economic Community (EEC) and European Commission (EC) from 1975 to 2013 to designate disadvantaged agriculture areas entitled to additional payments from the Common Agricultural Policy (CAP) to compensate for the extra costs of farming in those less favoured areas (Directive 75/268/EEC).

In its first definition, in 1975, the concept of "less favoured areas" was further detailed using three categories: "Less-favoured mountain areas", "Less-favoured areas in danger of depopulation" and "Less-favoured areas with specific handicaps". The first LFA category ("Less-favoured mountain areas") referred to areas where the growing season is largely reduced due to altitude and climate conditions or where steep slopes limit or make it too costly to use agricultural machinery. The second one ("Less-favoured areas in danger of depopulation") referred to areas with low land productivity, low agriculture economic performance and in danger of depopulation. The third category ("Less-favoured areas with specific handicaps") referred to areas where farming needs to be preserved to protect the countryside, tourism potential and the coastline (Directive 75/268/EEC).

While from 1975 to 2005, the definition of each LFA category just had minor adjustments (see Appendix A for more details on LFA definitions over time), a significant change was about to be introduced following the European Court of Auditors recommendation, in 2003, for a "[…] complete and in-depth review of existing classifications of all LFAs" and to "develop […] a more appropriate set of indicators for identifying LFAs that would be consistent and guarantee an equitable treatment of the beneficiaries". (Special Report 4/2003). In their report, they argued that the second LFA category was being defined based on broad criteria, which allowed countries to establish their own indicators and thresholds based on their own discretion and interests. (Special Report 4/2003).

Therefore, in the EU Council Regulation 1698/2005 (Regulation 1698/2005), the economic and population criteria were dropped from the second LFA category, which focused only on the biophysical handicaps related to climate and soil. However, no indicators were included to harmonise the identification of LFA areas for all EU countries and consequently, no fine-tuning to the list of LFAs areas was performed at that moment. Such indicators and thresholds were later developed by van Orschoven et al. (2012) at the request of the Directorate General for Agriculture and Rural Development (DG AGRI).

With the EU Council Regulation 1305/2013 (Regulation 1305/2013), the terminology "Less favoured areas was replaced by "Areas facing natural or other specific constraints" (ANCs), marking the introduction of consistent criteria across countries to define "Areas, other than mountain areas, facing significant natural constraints" (previous second category of LFAs) and in part also the "Other areas affected by specific constraints" (previous third category of LFAs).

Although EU Council Regulation 1305/2013 has been in force since 2013, it also contemplated a transition period (until 2018) for country members to classify their LFAs in ANCs (Regulation 1305/2013).

2.2 LFAs in mainland Portugal

The first delimitation of LFAs in mainland Portugal occurred in 1987, with some adjustments made one year later (Portaria 170/87, Portaria 377/88). Then, with the reorganisation of Portuguese Local Administrative Units (LAU) in 2013 (Lei n.º 11 -A/2013), the list from 1988 was updated with the new LAUs designations (Portaria 22/2015). Although at that date Regulation 1305/2013 already described the need to fine-tune the LFA lists according to the new ANC criteria, that was not done because Portugal made use of the transition period allowed by the European Commission until 2018 (Regulation 1305/2013).

The delimitation of the mainland Portuguese ANCs came into force in 2019 (Portaria 5/2019). As shown in Table 1, areas previously classified as 'Mountain areas' kept the same, as well as those classified as

'Affected by specific constraints'. In the new category "Areas, other than mountain areas, facing significant natural constraints, " changes occurred slightly. All areas previously classified as 'other than mountain areas' were moved to the new category, except one LAU that was excluded from the list and 22 LAUs were added to the list and this category (Portaria 5/2019).

Table 1 Distribution of mainland Portugal area, in hectares and percentage, throughout the 3 LFA classifications in 2019 and in 2015/1988. Own calculations based on Portaria 5/2019, Portaria n.º 22/2015 and EUROSTAT (2019).

Categories	2019		2015/1988	
	1000 ha	%	1000 ha	%
Mountain areas	3741.98	42.00	3741.98	42.00
Areas, other than mountain areas, facing significant natural constraints	3495.56	39.23	3340.36	37.49
Other areas affected by specific constraints	153.08	1.72	153.08	1.72
TOTAL in LFAs	7390.61	82.95	7235.41	81.20

2.3 LFA subsidies in mainland Portugal

An important reason for the delimitation of LFAs by EU Member states is the attribution of LFA subsidies. They aim to ensure farming activity in LFAs by compensating farmers for the disadvantaged situation of operating in such areas (Regulation 1305/2013). That is done through annual direct payments.

According to the most recent legislation on LFAs, to be eligible for such payments in mainland Portugal, an agricultural holding needs to have at least one hectare of UAA in a LFA area during that year (Portaria n.º 6/2019). It is not a requirement that the total UAA is located in LFAs, but the payment will just apply to the UAA in LFA areas. The amounts provided are shown in Table 2.

Table 2 Subsidies scale provided per UAA in mainland LFAs from 2015 until now. Values in Euros/ha. Source: Portaria 24/2015, Portaria n.º 6/2019.

UAA, in ha	LFA Mountain area	LFA non-Mountain area
[1, 3]	260	130
]3, 10]	190	95
]10, 30]	60	27
]30, 150]	20	18

3. OVERVIEW OF EMPIRICAL METHODS

3.1 Measuring economic viability

As highlighted by O'Donoghue et al. (2016), in most definitions of economic viability a farm is considered economically viable if it allows for a minimum standard of living. How that standard is understood leads to different measurements of economic viability that can be categorised into one of two approaches: a household welfare measure or an opportunity cost measure (O'Donoghue et al., 2016). In a household welfare approach, the focus is on the capacity of the farm to generate enough income to cover the farm household needs. That requires information not just about the farm's financial performance but also about household off-farm income and expenses. However, most EU countries do not collect or do not make available financial data about off-farm income and expenses of the household (O'Donoghue et al., 2016; Loughrey et al., 2022; FADN, 2020).

To overcome that data limitation, most of the economic viability studies applied to EU countries make use of the opportunity cost approach where mainly farm business economic data is needed (Hennessy et al.; 2008; Vrolijk et al., 2010; O'Donoghue et al., 2016; Cappola et al., 2020; Barnes et al., 2020; Hlavsa et al., 2020). Under that approach, the economic concept of opportunity cost is used to determine the cost of unpaid labour and owner equity based on an alternative use. A farm business is then considered viable if it is profitable and can cover such costs.

To address the opportunity cost of unpaid labour, working against a paid wage is the alternative use usually considered. While it is reasonable to expect that a person's working experience and the local market opportunities might influence one's paid wage, the complexity and extra data needed to determine what that paid wage is per unpaid labour unit is rarely considered. Most studies use a minimum or average national/regional salary per hour or full-time working unit as a proxy of the unitary opportunity cost of unpaid labour (see Table 3).

To address the opportunity cost of owner equity, its application in another investment is the alternative use usually considered. While it is reasonable to expect that the farmer owner's investment preferences, knowledge, and owner equity might influence one's decision on what that alternative investment is, the complexity and extra data needed to determine it per holding are rarely considered. Most studies assume a low-risk investment as the alternative, usually an investment in 10-year governmental bonds. They use its average annual return to proxy the unitary opportunity cost of owner equity (see Table 3). Some studies distinguish between non-land own capital and own land when the land is not considered "an easily liquidated asset" (Hennessy et al., 2008). In such a scenario, no remuneration is considered for land, or the average rent paid per ha in each region is assumed (see Table 3).

Table 3 Unpaid Labour and Owner equity valorisation in European farm viability studies using the opportunity cost approach.

Region	Study	Unpaid labour	Owner equity
Ireland	Hennessy et al. (2008)	• Average agricultural wage	• 5% return for non-land assets representing a low-risk conservative investment, such as a bank account
Europe	Vrolijk et al. (2010)	• Average paid wage in a specific region	• Fixed percentage based on 10-year government bonds (Eurostat)
Some European countries	O'Donoghue et al. (2016)	• Average wage of full-time employees in the total economy per country OR • Average paid wage (based on sample farms per country)	• Fixed percentage based on long-term ECB interest rates

Italy	Cappola et al. (2020)	• National average wage, net of social security contributions, provided for qualified agricultural workers.	• Average annual return on Italian government bonds, net of tax charges for working capital (!) • Average rent Paid per relative values of land capital
Scotland	Barnes et al. (2020)	• Minimum agricultural wage	• Annual return on UK government bonds per year
Czech Republic	Hlavsa et al. (2020)	• Average paid wage without security charges	• 5% return for non-land assets • Rent Paid per ha for land assets
Ireland	Loughrey et al. (2022)	• Minimum wage OR • Living Wage (Minimum Income Standard	• 1% for non-land assets OR • 5% for non-land assets OR • 2.66% for non-land assets

A known limitation of the opportunity cost approach is that the viability results are extremely sensitive to the valorisation of unpaid labour and owner equity, which gets aggravated by the fact that the results are reported in a headcount way (O'Donoghue et al., 2016; Loughrey et al.,2022). This results in the impossibility to distinguish between a farm covering its unpaid labour costs with a positive return to equity but lower than the threshold considered, from a farm not even able to cover half of its unpaid labour. While both farms are categorised as non-viable, their position in the viability spectrum differs greatly.

Some studies move away from this binary "viable/non-viable" classification into multiple classifications to provide more information about the viability of farms. O'Donoghue et al. (2016) defined three disjoint categories of viability: viable, sustainable, and vulnerable farms. A viable farm is one that is able to remunerate unpaid labour and owner equity, while a sustainable one is not viable, but the household has off-farm income. The remaining ones are considered vulnerable. Barnes et al. (2020) also used categories of viability and extended O'Donoghue et al. (2016) with two others, resilient and robust farms, to incorporate a long-term dimension. Coppola et al. (2020) go in another direction and defines four types of farms in terms of their short-term and medium to long-term viability.

While such categorisations provide more information about the viability of farms, they still perpetuate some limitations by just reporting the results in a headcount way and not considering the distances to the viability thresholds. Drawing on poverty literature, Loughrey et al. (2022) propose a viability gap analysis in combination with a headcount analysis to overcome such limitations. That way, the distance – gap – to the selected threshold is measured, allowing for an understanding of how far a farm is from being viable.

3.2 Explaining economic viability

Exploring the factors associated with economic viability is not always done in viability assessment analysis. From the studies reviewed in the previous section, just Vrolijk et al. (2010), Coppola et al. (2020), Barnes et al. (2020) and Hlavsa et al. (2020) extended the economic viability analysis with the exploration of potential explanatory factors.

Vrolijk et al. (2010) considered six farm structural characteristics that could differentiate a viable farm from a non-viable one, in the absence of decoupled payments: economic size, capital productivity, labour productivity, land productivity, share of paid labour and share of liabilities. The authors pointed out that economic viability can only be partially explained by structural characteristics. Other aspects, such as management skills, might also help explain economic viability, but their dataset didn't provide information on that. They used discriminant function analysis between viable and non-viable farms per country to

identify the main factors correlated with economic viability per country. Barnes et al. (2020) classified farms into five ordered categories of viability and then applied a proportional odds model to evaluate which farm characteristics lead to a higher viability category. The explanatory variables considered were rented vs owned vs mixed UAA, farm specialization in livestock, land quality, remoteness, existence of successor, farmer education, farm size and if main farm income was coming from dairy farming. Coppola et al. (2020) classified farms into four disjoint categories of viability and then applied a multinomial logit model to analyse the probability of a farm being in each of those four categories. The explanatory variables considered to explain viability was firstly based on data availability on farm socio-demographic and structural characteristics as well as farmer productive choices. From that point, a stepwise reduction was applied, resulting in farmer's age, farmer's gender, farmer's education, farm UAA, land quality, capital intensity, share of family work, share of irrigated UAA, geographic location, productive specialization, share of other on-farm revenues and share of revenues from processed products or direct sales as the explanatory variables. Hlavsa et al. (2020) focused on testing if farm location and farm specialization were associated to farm economic viability in Czech Republic, using one-way ANOVA analysis.

As these studies show, there is no common applied model to explain economic viability. Explanatory variables chosen are mainly based on data availability. Farm structural characteristics are the mainly tested explanatory factors, probably due to its presence on the main European dataset on farm accountancy data, the FADN.

4. METHODS AND DATA

4.1 Measuring economic viability

Following an opportunity cost approach, we will consider a farm viable if its farm net income is able to cover the opportunity cost of unpaid labour and owner equity. We assume those conditions are a good proxy of farm owner willingness to keep investing their own human and capital resources into the farm business.

We define a farm *i* in year *t* as economically viable if:

$$Farm\ Net\ Income_{it} \geq Unpaid\ Labour_{it} * w_t + Owner\ Equity_{it} * r_t \quad (1)$$

$$Unpaid\ Labour_{it} \geq 0$$
$$Owner\ Equity_{it} \geq 0$$

where:

w_t = *unitary opportunity cost of unpaid labour in year*$_t$
r_t= *unitary opportunity cost of owner equity in year*$_t$

By counting the number of farms satisfying Equation (1) in a given year and dividing it by the total amount of farms in the sample in that same year we have the headcount ratio of viable farms per year. To analyse how the headcount ratio of the sampled farms would change if LFA subsidies were not available, we use the farm net income net of LFA subsidies instead of the farm net income in Equation (1) and compare the headcount ratios. We assume, for this analysis, no other financial or farm structural change would result from the non-existence of LFA subsidies.

Following Loughrey et al. (2022), we complement the headcount measure with a viability gap measure, given the limitations of the sole use of a headcount measure already discussed in Section 3. By using the same definition of viability expressed in Equation (1), we define the viability level (VL) for a farm *i* in year *t* as:

$$VL_{\ it} = Farm\ Net\ Income_{it} - (Unpaid\ Labour_{it} * w_t + Owner\ Equity_{it} * r_t) \quad (2)$$
$$Unpaid\ Labour_{it} \geq 0$$
$$Owner\ Equity_{it} \geq 0$$

where:

w_t = *unitary opportunity cost of unpaid labour in year*$_t$
r_t= *unitary opportunity cost of owner equity in year*$_t$

$Unpaid\ Labour_{it} * w_t + Owner\ Equity_{it} * r_t$ is then the viability threshold (VT_{it}) of farm *i* in year *t.* Positive values of VL mean that a farm is viable. Negative values mean that a farm in not viable.

Since the viability thresholds are farm and year dependent, the viability levels between and within farms are not comparable. To overcome that we need to transform the viability level into a ratio of its threshold. We define the relative viability level (RVL) for a farm *i* in year *t* as:

$$RVL_{it} = \frac{VL_{it}}{\mathrm{VT}_{it}}, \mathrm{VT}_{it} > 0 \quad (3)$$

To analyse how far non-viable farms in the sample are from being viable in a given year, we aggregate the RVL per year using a measure of central tendency. To analyse how the RVL of the sampled farms would

change if LFA subsidies were not available, we use the farm net income net of LFA subsidies instead of the farm net income in Equation (2) and compare the RVLs.
Given the sensitivity of the economic viability measure to the selected unitary opportunity costs (UOC) for the owner equity and the unpaid labour, we calculate the return on farm equity (ROFE) and return on unpaid labour (ROUL) to analyse how the farms renumerate their owner equity and unpaid labour, respectively.
Keeping UOC of unpaid labour, *w*, constant per year, we calculate the ROFE of a farm in a given year and compare it with the threshold considered in this analysis in that year, as well as other thresholds reflecting different farmer investment opportunities.
We define $ROFE$ of a farm *i* in year *t* as:

$$ROFE_{it} = \begin{cases} \dfrac{Farm\ Net\ Income_{it} - Unpaid\ Labour_{it} * w_t}{Owner\ Equity_{it}}, & Owner\ Equity_{it} > 0 \\ 0, & Owner\ Equity_{it} = 0 \end{cases} \quad (4)$$

where

w_t = *unitary opportunity cost of unpaid labour in year*$_t$

Keeping UOC of owner equity, r, constant per year, we calculate the ROUL of a farm in a given year and analyse the ratio of farms that are able to provide a ROUL above the national minimum wage. We also compare it with average wages in the Portuguese agriculture sector.
We define $ROUL$ of a farm *i* in year *t* as:

$$ROUL_{it} = \begin{cases} \dfrac{Farm\ Net\ Income_{it} - Owner\ Equity_{it} * r_t}{Unpaid\ Labour_{it}}, & Unpaid\ Labour_{it} > 0 \\ 0, & Unpaid\ Labour_{it} = 0 \end{cases} \quad (5)$$

where

r_t= *unitary opportunity cost of owner equity in year*$_t$

To analyse how the ROFE and ROUL of the sampled farms would change if LFA subsidies were not available, we use the farm net income net of LFA subsidies instead of the farm net income in Equation (4) and Equation (5) and compare them.

4.2 Regression model

To explore farm characteristics that might be associated with economic viability, we define a regression model with relative viability level (RVL) as the dependent variable. Following similar studies that tried to explain economic viability, we focus on farm structural characteristics available in the sample analysed. The set of explanatory variables considered to represent farm characteristics are *Farm Size, Own land share, Irrigated area share, Unpaid labour share, Other farm output share* and *LFA Mountain area*. Their description and expected coefficient signals are presented in section 4.5. We consider year dummy variables to capture year heterogeneity such as differences over time in national minimum wage and average annual return rate of 5-year Portuguese national treasury certificates.
We use the following fixed effects regression model:

$$RVL_{it} = \delta D_t + \beta X_{it} + a_i + u_{it}$$

where:

D_t, the vector of year dummy variables
X_{it}, the vector of time-variant explanatory variables
a_i, the unobserved heterogeneity of agricultural holding i
u_{it}, the idiosyncratic error term

One important aspect about this regression model is that it might suffer from endogeneity. That endogeneity might be caused by potential unobserved time-variant heterogeneity and simultaneity. While the model makes use of fixed effects to control for unobserved time-invariant heterogeneity of each agricultural holding, it cannot control for potential unobserved time-variant heterogeneity. Regarding simultaneity, it is possible that some explanatory variables not just influence the dependent variable, but they also are influenced by the dependent variable. For example, farm size: farm size might influence farm viability through its impact in the farm cost structure, but farm viability might also influence a farmer's decision to adjust its farm size. Therefore, causal interpretations cannot be drawn from our regression results.

4.3 Data

We use a subset of the EU Farm Accountancy Data Network (FADN) panel data containing farms in mainland Portuguese LFAs, spanning the years 2010 to 2018. FADN is an EU-harmonized dataset with yearly economic microdata representative of commercial agricultural holdings in the European Union (FADN, 2020). A commercial agricultural holding is defined based on its economic size. For Portuguese farms, it means that just agricultural holdings with a standard output of at least 4.000€ are represented in FADN (Regulation 1291/2009).
FADN takes a stratified sampling approach based on EU territorial units level 2 (NUT2), economic size and farm typology. Given we analyse the FADN subset of farms in mainland Portuguese LFAs and LFA location is not a variable considered in the stratification process, representativeness cannot be claimed. The subset of FADN farms in mainland Portuguese LFAs spanning the year 2010 to 2018 comprises 10726 observations (2194 farms). Economic viability was measured for 10654 observations (2184 farms), after the exclusion of an outlier (see Appendix B) and the data restrictions imposed by Equation (1), (2) and (3). Regression was run for 10548 observations (2161 farms) due to the exclusion of incomplete cases (observations where one of the variables needed for the model is not defined). Figure 1 shows the sample reduction.

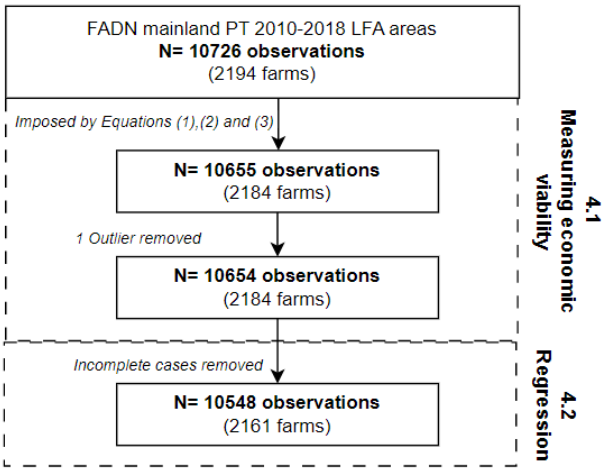

Figure 1 Sample reduction from the initial FADN subset of Portuguese farms in mainland LFAs, from 2010 to 2018.

4.4 Economic viability input variables

To measure economic viability, we use variables from FADN dataset to account for unpaid labour, owner equity and farm net income, and we use publicly available data from PORDATA and IGCP to calculate opportunity costs.

To proxy unpaid labour we use variable SE016 from FADN. It accounts for the amount of unpaid labour hours provided by any person working at least one day per week in the holding without renumeration or renumerated bellow market price (FADN, 2016; FADN 2012). To proxy owner equity we use variable SE501. It accounts for the total assets closing valuation net of short, medium and long-term loans (FADN, 2022). To proxy farm net income we use SE420 from FADN which is defined as "remuneration to fixed factors of production of the family (work, land and capital) and remuneration to the entrepreneur's risks (loss/profit) in the accounting year." (FADN, 2022)

The opportunity cost for unpaid labour is based on the national minimum wage in year t, assuming it represents Portugal's minimum standard of living for that year. The opportunity cost for owner equity is based on the average annual return rate of 5-year Portuguese national treasury certificates ("*Certificados do Tesouro*" in Portuguese) if the investment is done in $year_t$. National treasury certificates are considered instead of governmental bonds ("*Obrigações do Tesouro*" and "*Bilhetes do Tesouro*") due to its guaranteed capital return and direct access (no stock market involved) to every citizen with an initial investment from 1000€ (Resolução do Conselho de Ministros 40/2010) We assume this better represents the investment preferences and opportunities of the mode of Portuguese farms (sole hole holder with 65 years old or more), based on the Portuguese Household Finance and Consumption Survey (Banco de Portugal & Instituto Nacional de Estatística, 2019).

To account for the scenario where LFA subsidies wouldn't be available, we use variable SE622 from FADN and subtract it from the farm net income.

Table 4 shows the descriptive summary of the variables considered.

Table 4 Descriptive summary of variables considered for the measurement of economic viability. Q2 = median.

	Unpaid Labour (hours)			Own Equity (€)			Farm Net Income (€)			LFA subsidies (€)			Min Wage (€)[a]	PT Certif (%)[b]
YEAR	Q2	mean	sd	Q2	mean	sd	Q2	mean	sd	Q2	mean	sd		
2010	2400	2539	1117	64242	117568	232839	10285	15503	22882	1440	1456	1193	3.197	1.932
2011	2420	2544	1114	68608	122478	240461	9968	14897	20660	1498	1482	1210	3.264	2.876
2012	2400	2547	1129	70349	122358	228608	10834	16490	28446	1557	1539	1225	3.264	2.495
2013	2400	2531	1081	67719	119223	226207	11811	17253	23695	1606	1579	1181	3.264	4.994
2014	2112	2403	1098	63581	116493	196317	10592	16255	23690	1380	1382	1196	3.264	4.985
2015	2100	2433	1109	64897	116342	193910	12702	19920	33238	1654	1738	1248	3.399	2.953
2016	2152	2443	1141	63126	117453	200789	12405	18312	29124	1687	1721	1197	3.567	2.454
2017	2080	2403	1135	63352	112918	190960	12520	19579	34373	1577	1620	1126	3.749	2.909
2018	1960	2352	1092	61698	115546	213640	12643	20905	43060	1524	1589	1090	3.904	1.531

[a] National Minimum Salary, in €, from 2010-2018. The mandatory 14 annual salaries were divided by 12 months. All values reported are before taxes. Source: PORDATA (2023a)

[b] Average annual return rate of 5-years Portuguese national treasury certificates, in %, from 2010-2018. All values reported are before taxes. Source: IGCP

4.5 Regression explanatory variables

The farm characteristics selected as explanatory variables are *Farm Size, Own land share, Irrigated area share, Unpaid labour share, Other farm output share* and *LFA Mountain area*. Farm type dummy variables were added to capture farm type heterogeneity, such as differences in agroecological settings. All monetary variables used are represented in ratios, so no deflation was applied. Table 5 describes those variables as well the as expected coefficient signs. Table 6 shows descriptive statistics of the dependent variable (RVS) and the explanatory variables considered.

Table 5 Description of the regression explanatory variables used and the expected coefficient signs.

Variable name	Definition	FADN variables	Expected estimate coefficient sign	
Farm size	Total farm utilized agriculture area (UAA), in hectares	$SE025$	U	A positive quadratic relation between economic viability and farm size is expected, based on the assumption that production costs, due to scale and efficiency, tend to increase when the farm decides to grow but it is not large enough to make full use of their technology. When farm size reaches the point where it allows for the full use of more efficient and large-scale technology, production costs start decreasing (Helfand and Levine, 2004; Hansson, 2008; Sheng et al., 2019).
Own land share	Owned UAA divided by total UAA	$\frac{UAAOWNED}{\mathrm{SE025}}$	+/-	Previous studies show both positive and negative associations between economic viability and own land share (Barnes et al., 2015; Latruffe et al., 2007).
Irrigated area share	Irrigated UAA divided by total UAA	$\frac{IRRAA\_X}{\mathrm{SE025}}$	+	A positive association between economic viability and share irrigated area is expected, given that irrigation can avoid significant decreases in production, specially during water stress periods (Darko et al., 2015; Foudi & Erdlenbruch, 2011). Cappola et al. (2020) reports a positive association.
Unpaid labour share	Unpaid labour input, in hours, divided by total labour input, in hours	$\frac{SE016}{\mathrm{SE011}}$	-	Previous studies show both negative and non-significant associations between economic viability and unpaid labour (Latruffe et al., 2007; Kostov et al., 2018). Cappola et al. (2020) report a negative association.
Other farm output share	Other farm output divided by total farm output	$\frac{SE256}{SE131}$, $SE131 > 0$	+	A positive association between economic viability and share of other farm output is expected, since diversifying farm income beyond the agricultural production can be seen an income stabilisation strategy (Barnes et al., 2015; Arru et al., 2019). Cappola et al. (2020) reports a positive association.
LFA Mountain area	Indicates if a farm has the majority of its UAA in a LFA Mountain area	$LFA = 3\ or\ ANC = 3$	-	We expect a negative association between economic viability and having most of the farm UAA in a mountain area, given the potential extra cost due to the use of machinery in steep slopes and the reduction of production due to a shorter growing season (Regulation 1305/2013; Barnes et al., 2015).
Farm type	Distinguishes farms into: • Mixed crops (TF14=60) • Mixed crops & livestock (TF14=80) • Mixed livestock (TF14=70) • Specialized livestock (TF14 in {45,48,49,50}) • Specialized non-perennial (TF14 in {15,16,20})			A negative association between economic viability and the specialized farm types is expected, following a recent meta-analysis on farm diversification and profitability (Sánchez et al., 2022) and empirical results from viability studies (Barnes et al., 2015; Barnes et al., 2020)

- Specialized perennial crops (TF14={ 35,36,37,38})

Table 6 Descriptive summary of the explanatory and dependent variables. N=10548 observations.

Variable	**Mean**	**Std.dev**	**Min**	**Max**
Dependent variable: RVL	0.61	2.69	-20.97	106.92
Farm size (ha)	41.76	87.74	0.01	1058.00
Own land (% UAA)	0.46	0.46	0.00	1.00
Irrigated area (% UAA)	0.08	0.24	0.00	1.00
Unpaid labour (% Total labour)	0.84	0.26	0.00	1.00
Other farm output (% Total output)	0.03	0.12	-0.04	4.13
LFA Mountain area	0.59			
Farm type				
Mixed crops	0.06			
Mixed crops & livestock	0.08			
Mixed livestock	0.01			
Specialized livestock	0.42			
Specialized non-perennial crops	0.09			
Specialized perennial crops	0.34			

5. RESULTS AND DISCUSSION

5.1 Economic viability

As shown in Figure 2, the percentage of viable farms in the sample oscillated between 46% and 59% between 2010 and 2018. That means that, on average, 53.1% of the farms were able to remunerate their unpaid labor at the national minimum wage and their owner equity at the average annual return rate of 5-year Portuguese national treasury certificates. When the LFA subsidies are excluded, the ratio of viable farms is on average 6.2 percentual points lower, corresponding on average to less 74 viable farms per year.

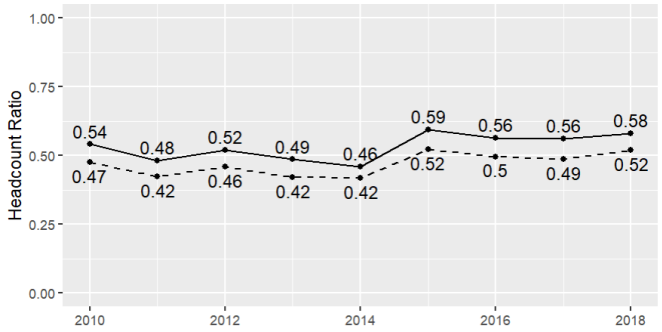

Figure 2 Headcount ratio of viable farms, per year, including (continuous line) and excluding (dashed line) LFA subsidies.

When we look in more detail to the non-viable farms, the percentage of non-viable that were at least financially profitable - their farm net income is non-negative- oscillated between 82% and 87.6% from 2010 to 2018 (see Table 7). This distinction between financially profitable and non-profitable is relevant for a proper interpretation of the results. As Table 7 shows, non-viable but profitable farms were, on average, between 39.1% and 46.7% from being viable. This is the percentage of unpaid labour and equity owner opportunity costs that, on average, was not able to be covered by the farm. For the financially non-profitable ones, by definition, none of the unpaid labour and equity owner opportunity costs are covered.

Table 7 Descriptive statistics of the relative viability level (RVL) for non-viable farms, distinguishing profitable from non-profitable. Values are presented in ratios.

		Non-viable profitable						Non-viable non-profitable				
YEAR	**P/NV[a]**	**median**	**mean**	**sd**	**min**	**max**	**NP/NV[b]**	**median**	**mean**	**sd**	**min**	**max**
2010	0.820	-0.458	-0.467	0.274	-0.999	-0.001	0.180	-1.497	-1.951	1.444	-9.842	-1.000
2011	0.822	-0.423	-0.449	0.263	-0.997	-0.005	0.178	-1.409	-1.960	2.224	-20.968	-1.001
2012	0.824	-0.421	-0.433	0.271	-0.997	-0.000	0.176	-1.418	-1.850	1.371	-11.987	-1.002
2013	0.862	-0.427	-0.437	0.267	-0.998	-0.002	0.138	-1.371	-1.541	0.663	-5.391	-1.013
2014	0.840	-0.435	-0.454	0.267	-0.997	-0.002	0.160	-1.317	-1.553	0.741	-5.613	-1.002
2015	0.838	-0.384	-0.418	0.262	-0.997	-0.002	0.162	-1.449	-1.788	1.113	-7.545	-1.004
2016	0.841	-0.352	-0.391	0.267	-0.996	-0.000	0.159	-1.424	-2.028	1.979	-16.033	-1.022
2017	0.876	-0.378	-0.408	0.256	-0.999	-0.005	0.124	-1.589	-1.932	1.292	-9.997	-1.000

	Non-viable profitable						Non-viable non-profitable					
YEAR	P/NV[a]	median	mean	sd	min	max	NP/NV[b]	median	mean	sd	min	max
2018	0.849	-0.391	-0.414	0.270	-0.985	-0.003	0.151	-1.607	-2.166	1.570	-7.527	-1.001

[a] Number of non-viable profitable farms / Number of non-viable farms

[b] Number of non-viable non-profitable farms / Number of non-viable farms

When the LFA subsidies are excluded, we see from Table 8 how both, the percentage of non-viable profitable farms as well as the percentage of non-viable non-profitable farms slightly increase. In this scenario non-viable but profitable farms would be, on average, between 42.7% and 50% from being viable.

Table 8 Descriptive statistics of the relative viability level (RVL) excluding LFA subsidies for non-viable farms, distinguishing profitable from non-profitable. Values are presented in ratios.

	Non-viable Profitable						Non-viable Non-profitable					
YEAR	P/NV[a]	median	mean	sd	min	max	NP/NV[b]	median	mean	sd	min	max
2010	0.795	-0.495	-0.490	0.276	-0.998	-0.002	0.205	-1.418	-1.865	1.363	-9.842	-1.000
2011	0.811	-0.492	-0.494	0.271	-0.998	-0.004	0.189	-1.413	-1.902	2.083	-20.968	-1.003
2012	0.802	-0.470	-0.468	0.266	-0.981	-0.002	0.198	-1.431	-1.785	1.281	-11.987	-1.002
2013	0.853	-0.481	-0.477	0.269	-0.996	-0.002	0.147	-1.349	-1.537	0.634	-5.428	-1.013
2014	0.834	-0.500	-0.500	0.270	-0.997	-0.002	0.166	-1.376	-1.576	0.726	-5.613	-1.025
2015	0.830	-0.420	-0.433	0.257	-0.999	-0.002	0.170	-1.408	-1.726	1.056	-7.632	-1.002
2016	0.842	-0.393	-0.427	0.261	-0.999	-0.003	0.158	-1.415	-1.980	1.895	-16.285	-1.017
2017	0.874	-0.399	-0.431	0.254	-0.984	-0.004	0.126	-1.539	-1.883	1.237	-9.997	-1.005
2018	0.846	-0.434	-0.452	0.267	-0.997	-0.006	0.154	-1.516	-2.117	1.533	-7.682	-1.001

[a] Number of non-viable profitable farms / Number of non-viable farms

[b] Number of non-viable non-profitable farms / Number of non-viable farms

To address the sensitivity of the economic viability measure to the UOC chosen, we also report the ROFE and ROUL provided by the sampled farms in the period of analysis. The detailed distribution of ROFE and ROUL can be found in Appendix C and Appendix D, respectively.

Table 9 shows the ratios of farms that can provide (1) a positive ROFE, (2) a ROFE above the average annual return rate of 5-years Portuguese treasury certificates - the UOC considered in the economic viability measure -, (3) a ROFE above the Portuguese 10-years governmental bonds at the secondary market and (4) a ROFE above 5% - a frequently considered UOC of owner equity in viability studies. Note that the ratios presented for threshold (2) are the headcount ratios reported in Figure 2. Between 57% and 67% of the farms present a positive ROFE, meaning that they were able to cover their unpaid labour at the national minimum wage. We can also interpreter that ratio as the proportion of farms that will keep farming if they see farming "as a way of life rather than an activity which has to make money" (O'Donoghue et al., 2016). In 2013 and 2014 we observe that 15%-16% of the farms considered as non-viable were also able to fully remunerate their unpaid labour at least at the minimum wage. Those are also the two years where the UOC of owner equity was considerably higher (see Table 5), confirming how sensitive the measure of economic viability is to the UOC selected.

When using unitary opportunity costs representing alternative higher risk investments, the ratio of viable farms could decrease to 30%. That was the case in 2011, when the Portuguese 10-years governmental bonds yielded 10.2% (PORDATA, 2022).

Table 9 Ratio of farms with ROFE above different thresholds. A distinction is made between viable and non-viable but profitable farms.

	ROFE > 0%			ROFE > PT Certif. %[a]			ROFE > PT Bonds %[b]			ROFE > 5%		
	All	Profitable		All	Profitable		All	Profitable		All	Profitable	
YEAR		NV	V		NV	V		NV	V		NV	V
2010	0.61	0.07	0.54	0.54	0.00	0.54	0.43	0.00	0.43	0.44	0.00	0.44
2011	0.57	0.09	0.48	0.48	0.00	0.48	0.30	0.00	0.30	0.43	0.00	0.43
2012	0.61	0.09	0.52	0.52	0.00	0.52	0.33	0.00	0.33	0.45	0.00	0.45
2013	0.64	0.15	0.48	0.48	0.00	0.48	0.44	0.00	0.44	0.48	0.00	0.48
2014	0.62	0.16	0.46	0.46	0.00	0.46	0.49	0.03	0.46	0.46	0.00	0.46
2015	0.67	0.08	0.59	0.59	0.00	0.59	0.61	0.02	0.59	0.53	0.00	0.53
2016	0.64	0.08	0.56	0.56	0.00	0.56	0.54	0.00	0.54	0.48	0.00	0.48
2017	0.64	0.08	0.56	0.56	0.00	0.56	0.55	0.00	0.55	0.49	0.00	0.49
2018	0.62	0.04	0.58	0.58	0.00	0.58	0.57	0.00	0.57	0.49	0.00	0.49

[a] Average annual return rate of 5-year Portuguese treasury certificates

[b] Portuguese 10-years Government Bonds at the secondary market. Source: PORDATA (2023b)

When the LFA subsidies are excluded, we see from Table 10 how the ratios decrease. Nevertheless, more than 50% of the farms would still be able to have a positive ROFE, after renumerating their unpaid labour at the national minimum wage and between 36% and 46% could provide at least a 5% annual return to their owner equity.

Table 10 Ratio of farms with ROFE, excluding LFA subsidies, above different thresholds. A distinction is made between viable and non-viable but profitable farms, also in the scenario where LFA are not available.

	ROFE > 0%			ROFE > PT Certif. %[a]			ROFE > PT Bonds %[b]			ROFE > 5%		
	All	Profitable		All	Profitable		All	Profitable		All	Profitable	
YEAR		NV	V		NV	V		NV	V		NV	V
2010	0.54	0.06	0.47	0.47	0.00	0.47	0.37	0.00	0.37	0.37	0.00	0.37
2011	0.51	0.09	0.42	0.42	0.00	0.42	0.26	0.00	0.26	0.36	0.00	0.36
2012	0.54	0.08	0.46	0.46	0.00	0.46	0.29	0.00	0.29	0.40	0.00	0.40
2013	0.58	0.16	0.42	0.42	0.00	0.42	0.39	0.00	0.39	0.42	0.00	0.42
2014	0.55	0.14	0.42	0.42	0.00	0.42	0.44	0.03	0.42	0.42	0.00	0.42
2015	0.61	0.09	0.52	0.52	0.00	0.52	0.54	0.02	0.52	0.46	0.00	0.46
2016	0.58	0.08	0.50	0.50	0.00	0.50	0.48	0.00	0.48	0.43	0.00	0.43
2017	0.58	0.09	0.49	0.49	0.00	0.49	0.48	0.00	0.48	0.43	0.00	0.43
2018	0.55	0.03	0.52	0.52	0.00	0.52	0.52	0.00	0.52	0.42	0.00	0.42

[a] Average annual return rate of 5-year Portuguese national treasury certificates

[b] Portuguese 10-years Government Bonds at the secondary market. Source: PORDATA (2023b)

Table 11 shows the ratios of farms that can provide (1) a positive ROUL, (2) a ROUL above the national minimum wage – the UOC considered in the economic viability measure - and (3) a ROUL above the national average salary for an employee in the agriculture, animal production, hunting, forestry and fishing sector. Note that the ratios presented for threshold (2) are the headcount ratios reported in Figure 2. Between 81 and 92% of the farms present a positive ROUL, meaning that they were able to cover their owner equity at the average annual return rate of 5-years Portuguese treasury certificates. However, when the ROUL is set above the national minimum wage, the ratio largely decreases, highlighting those non-viable profitable farms that are able to cover their owner equity cost, but are not able to renumerate all their unpaid labour with at least the national minimum wage.
When using unitary opportunity costs representing alternative higher wages, the ratio of viable farms decreases. Between 41-53% of the farms in the sample were able to provide at least an average wage paid to an employee in the *agriculture, animal production, hunting, forestry and fishing* sector for their unpaid labour. Nevertheless, it is important to note that this average wage despite being slightly higher than the national minimum wage, it is also, next to the average wages of workers in the hospitality industry, the lowest national average wage. (PORDATA, 2023c).

Table 11 Ratio of farms with ROUL above different thresholds. A distinction is made between viable and non-viable but profitable farms

	ROUL > 0			ROUL > Min Wage [a]			ROUL > Emp Wage[b]		
	All	Profitable		All	Profitable	V	All	Profitable	V
YEAR		NV	V		NV			NV	
2010	0.87	0.33	0.54	0.54	0.00	0.54	0.46	0.00	0.46
2011	0.84	0.36	0.48	0.48	0.00	0.48	0.41	0.00	0.41
2012	0.86	0.34	0.52	0.52	0.00	0.52	0.44	0.00	0.44
2013	0.83	0.35	0.49	0.49	0.00	0.49	0.42	0.00	0.42
2014	0.81	0.35	0.46	0.46	0.00	0.46	0.41	0.00	0.41
2015	0.89	0.30	0.59	0.59	0.00	0.59	0.52	0.00	0.52
2016	0.90	0.34	0.56	0.56	0.00	0.56	0.50	0.00	0.50
2017	0.91	0.35	0.56	0.56	0.00	0.56	0.51	0.00	0.51
2018	0.92	0.34	0.58	0.58	0.00	0.58	0.53	0.00	0.53

[a] PT minimum wage

[b] Average salary for an employee in the agriculture, animal production, hunting, forestry and fishing sector. Source: PORDATA (2023c)

When the LFA subsidies are excluded, we see from Table 12 how the ratios decrease. In this scenario, most of the farms would have a positive return on labour, after renumerating their owner equity at the average annual return rate of 5-years Portuguese treasury certificates and between 37% and 48% of the farms would be able to renumerate their unpaid labour above the national average salary for employees in the agriculture sector.

Table 12 Ratio of farms with ROUL, excluding LFA subsidies above different thresholds A distinction is made between viable and non-viable but profitable farms, also in the scenario where LFA are not available.

	ROUL > 0			ROUL > Min Wage [a]			ROUL > Emp Wage[b]		
	All	Profitable		All	Profitable	V	All	Profitable	V
YEAR		NV	V		NV			NV	
2010	0.84	0.37	0.47	0.47	0.00	0.47	0.40	0.00	0.40
2011	0.80	0.38	0.42	0.42	0.00	0.42	0.36	0.00	0.36
2012	0.84	0.38	0.46	0.46	0.00	0.46	0.40	0.00	0.40
2013	0.80	0.38	0.42	0.42	0.00	0.42	0.37	0.00	0.37
2014	0.78	0.36	0.42	0.42	0.00	0.42	0.37	0.00	0.37
2015	0.87	0.35	0.52	0.52	0.00	0.52	0.46	0.00	0.46
2016	0.88	0.39	0.50	0.50	0.00	0.50	0.44	0.00	0.44
2017	0.89	0.41	0.49	0.49	0.00	0.49	0.43	0.00	0.43
2018	0.90	0.38	0.52	0.52	0.00	0.52	0.48	0.00	0.48

[a] PT minimum wage

[b] Average salary for an employee in the agriculture, animal production, hunting, forestry and fishing sector. Source: PORDATA (2023c)

As ROUL and ROFE show, measuring economic viability is highly sensitive to how we define the unitary opportunity costs. Moreover, they run under the assumption that all farms have the same alternative use for their unpaid labour and owner equity. Further research could explore defining farm-specific unitary opportunity cost that represent the alternative options of each farm (see for example David, Hirsch & Padley, 2018 on how to measure more accurately the "minimum standard of living").

5.2 Regression

Table 13 shows the results of the estimation of the parameters. We tested for multicollinearity, homoskedasticity and serial correlation in the idiosyncratic errors. Variance inflation factors (VIF) were calculated and showed no indication of multicollinearity (see details in Appendix E). Breusch-Pagan test was performed and showed the presence of heteroskedasticity (see details in Appendix F). Breusch-Godfrey/Wooldridge test was performed and showed the presence of serial correlation (see details in Appendix F). Robust standard errors to heteroskedasticity and serial correlation are therefore reported in Table 13.

The results show a statistically significant negative quadratic association between *farm size* and *relative viability level* (p-value = 0.001), suggesting that viability tends to increase with farm size until a point where increases in farm size lead to decreases in viability. Such association differs from our expectations that were based on efficiency studies (Helfand and Levine, 2004; Hansson, 2008; Sheng et al., 2019). On the one hand the association observed can result from non-controlled endogeneity, as suggested by Sheng et al. (2019). On the other hand, it could be related, for example, with regressive subsidy amounts per hectare, such as the LFA subsidies, or the increasing "greening" conditions required for larger farms (Regulation 1307/2013), which might better support the viability of smaller farms.

Own land share shows a statistically significant negative association with *relative viability level* (p-value < 0.001), suggesting that viability tends to decrease with the increase of the ratio of farm own land. This is in line with previous empirical results (Barnes et al., 2015) that argue that farmers with more rented land are potentially more efficient and adaptive.

Unpaid labour share also shows a statistical significant negative association with *relative viability level* (p-value < 0.001), suggesting that farms using unpaid labour as their main labour source are less economically viable. This is in line with our expectation and with previous empirical results (Cappola et al., 2020).
Other farm output share output shows a statistical significant positive association with *relative viability level* (p-value < 0.001), suggesting that increasing the sources of income provided by the farm but not linked with agricultural production are a good strategy to promote farm viability. This is in line with our expectations and with previous empirical results (Barnes et al., 2015; Cappola et al., 2020).
The location of a farm in a *LFA Mountain area* shows no statistical significance with *relative viability level,* as well as *Farm typology* (for p-value < 0.05).
Regarding the year dummies, most of the years show a significant statistical association with *relative viability level* (for p-value < 0.05), which is not surprising given that we have used UOC for unpaid labour and owner equity that vary over time.

Table 13 Regression Coefficients. Robust standard errors to heteroskedasticity and serial correlations are applied.

Variables	***Coeff. estimate***	***std. Error***	***p-value***
Farm size	0.007553	0.002329	**0.001**
Farm size (squared)	-0.000010	0.000003	**0.001**
Own land share	-1.078818	0.269857	**<0.001**
Irrigated area share	0.000140	0.117719	0.999
Unpaid labour share	-1.779441	0.212143	**<0.001**
Other farm output share	1.580965	0.223963	**<0.001**
LFA Mountain area	-0.014288	0.083374	0.864
2011	-0.217468	0.076953	**0.005**
2012	-0.017393	0.078258	0.824
2013	-0.309046	0.079455	**<0.001**
2014	-0.290275	0.085278	**0.001**
2015	0.209593	0.084951	**0.014**
2016	0.175861	0.083959	**0.036**
2017	0.122107	0.083823	0.145
2018	0.437247	0.087080	**<0.001**
Mixed Crops&Lisvestock	0.100824	0.199172	0.613
Mixed Livestock	0.018089	0.421501	0.966
Specialized Livestock	0.042533	0.223414	0.849
Specialized non-permanent crops	0.312599	0.210660	0.138

Specialized permanent crops	-0.300578	0.175004	0.086
Observations	10548		
R^2 (within)	-0.214		

5.3 Limitations

This study contributes to the scarce literature on economic viability of LFA areas in Portugal and its results provide important insights into the extend of non-viability of farms in mainland Portuguese LFAs. The methodology applied went beyond the widely used headcount measure to provide more in-depth information into the extend of non-viability. It also contributes to the literature on economic viability of European farms that is exploring farm characteristics associated with economic viability.

Nevertheless, there are limitations that should be acknowledged for a correct handling of the results and to support future research.

First, the FADN data sample used is not representative of all commercial farms in mainland Portuguese not making it possible to extrapolate our results beyond our sample. Since FADN samples are obtained from a stratified randomisation, representativeness could just be ensured if the location of a farm in a LFA would be a stratification variable.

Second, the FADN LFA classification is based on the location of the majority of UAA. We might therefore have left out from our analysis farms that were not classified as LFA but had a considerable amount of land in an LFA area. Collecting data on the UAA per LFA category in the future would allow for more reliable analysis of farms located in LFAs.

Third, the assumption that nonexistence of LFA subsidies would imply no changes in farm structure might not be realistic. Although the subsidy is not tied to other demands besides the obligation that the land in LFAs is farmed during the year, we might expect that some farmers stop farming land that is too costly to be farmed, without the compensation provided by LFA subsidies. Future research with access to farm UUA per LFA category could use an economic and bio-physical modelling approach to capture the extra costs inherent from farming in Portuguese LFAs and analyse how much is covered by LFA subsidies.

Fourth, the FADN data doesn't report the reason why a farm drops from the dataset. It is possible that missing data on some farms throughout the period analysed is not always random and that unviable farms leaving business is one reason for those dropouts. A future addition of the reason of dropout to the FADN data could provide important information for future viability assessments.

6. CONCLUSION

The objective of this study was to assess farm economic viability and explore farm characteristics associated with economic viability in commercial farms located in mainland Portuguese LFAs.

Our findings suggest that viable commercial farms in mainland Portuguese LFAs are not an exception. On average more than half of the analysed farms would be able to cover their unpaid labour and owner equity at the national minimum wage and at the average annual return rate of 5-years Portuguese treasury certificates. The majority of the non-viable farms were at least profitable and, on average, able to renumerate more than half of their unpaid labour and owner equity. Regarding farms structural characteristics associated with economic viability, our results suggest that the share of own land and unpaid labour are negatively associated with economic viability, while the share of income coming from other farm activities is positively associated with economic viability.

Considering the importance of having viable farms in LFAs for the future of the Portuguese farming sector, further research on other than structural farm characteristics associated with farm viability in LFA areas in Portugal is needed. Furthermore, future research on economic viability in LFAs would highly benefit from changes in the data and sampling methods used by FADN to reach more accurate results.

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APPENDIX A - LFAs definitions over time

Table 14 LFAs definitions over time

Legislation	Definition
Directive 75/268/EEC[1]	*Mountain areas*: " […] local government districts or parts thereof characterised by a considerable limitation of the possibilities for using the land and an appreciable increase in the cost of working it, due : — either to the existence, because of the altitude, of very difficult climatic conditions the effect of which is substantially to shorten the growing season, — or, at a lower altitude, to the presence, over the greater part of the district in question, of slopes too steep for the use of machinery or requiring the use of very expensive special equipment, — or to the combination of these two factors, where the handicap resulting from each taken separately is less acute, provided that this combination gives rise to a handicap equivalent to that caused by the situation referred to in the first two indents." *Less-favoured areas in danger of depopulation where countryside conservation is needed:* "[…] farming areas which are homogeneous from the point of view of natural production conditions and must simultaneously exhibit all the following characteristics: (a) the presence of infertile land, unsuitable for cultivation or intensification, with a limited potential which cannot be increased except at excessive cost, and mainly suitable for extensive livestock farming; (b) because of this low productivity of the environment, results which are appreciably lower than the mean as regards the main indices characterising the economic situation in agriculture; (c) either a low or dwindling population predominantly dependent on agricultural activity, and the accelerated decline of which would jeopardise the viability of the area concerned and its continued habitation." *Less-favoured areas with specific handicaps:* " […] areas affected by specific handicaps and in which farming must be continued in order to conserve the countryside and to preserve the tourist potential of the area or in order to protect the coastline."
Regulation 950/97[2]	*Mountain areas*: "1. […] local government districts or parts thereof characterised by a considerable limitation of the possibilities for using the land and an appreciable increase in the cost of working it, due : (a) either to the existence, because of the altitude, of very difficult climatic conditions the effect of which is substantially to shorten the growing season; (b) or, at a lower altitude, to the presence, over the greater part of the district in question, of slopes too steep for the use of machinery or requiring the use of very expensive special equipment; (c) or to the combination of these two factors, where the handicap resulting from each taken separately is less acute, provided that this combination gives rise to a handicap equivalent to that caused by the situation referred to in (a) and (b). 2 . Areas north of the 62nd parallel and certain adjacent zones are to be included as mountain areas in so far as they are subject to very difficult climatic conditions the effect of which is substantially to shorten the growing season." *Less-favoured areas in danger of depopulation where countryside conservation is needed:* "[…] farming areas which are homogenous from the point of view of natural production conditions and must simultaneously exhibit all the following characteristics: (a) the presence of land of poor productivity, unsuitable for cultivation and with a limited potential which cannot be increased except at excessive cost, and mainly suitable for extensive livestock farming; b) the production which results from the low productivity of the natural environment is appreciably lower than the average, with regard to the main indices of economic performance in agriculture; (c) either a low or dwindling population predominantly dependent on agricultural activity, and the accelerated decline of which would jeopardise the viability of the area concerned and its continued habitation." *Less-favoured areas with specific handicaps:*

	"[…] areas affected by specific handicaps and in which farming must be continued , where necessary and subject to certain conditions, in order to conserve the environment, maintain the countryside and to preserve the tourist potential of the area or in order to protect the coastline ."
Regulation 1257/1999[3]	*Mountain areas*: "[…] characterised by a considerable limitation of the possibilities for using the land and an appreciable increase in the cost of working it due: - to the existence, because of altitude, of very difficult climatic conditions, the effect of which is substantially to shorten the growing season, - at a lower altitude, to the presence over the greater part of the area in question of slopes too steep for the use of machinery or requiring the use of very expensive special equipment, or - to a combination of these two factors, where the handicap resulting from each taken separately is less acute but the combination of the two gives rise to an equivalent handicap. 2. Areas north of the 62nd Parallel and certain adjacent areas shall be treated in the same way as mountain areas." *Other less-favoured areas:* "[…] farming areas which are homogeneous from the point of view of natural production conditions and exhibit all of the following characteristics: - the presence of land of poor productivity, difficult cultivation and with a limited potential which cannot be increased except at excessive cost, and which is mainly suitable for extensive livestock farming, - production which results from low productivity of the natural environment which is appreciably lower than the average, with regard to the main indices of economic performance in agriculture, - a low or dwindling population predominantly dependent on agricultural activity, the accelerated decline of which would jeopardise the viability of the area concerned and its continued habitation." *Areas affected by specific handicaps:* "[…] areas affected by specific handicaps, in which farming should be continued, where necessary and subject to certain conditions, in order to conserve or improve the environment, maintain the countryside and preserve the tourist potential of the area or in order to protect the coastline."
Regulation 1698/2005[4]	*Mountain areas*: "[…] characterised by a considerable limitation of the possibilities for using the land and an appreciable increase in the cost of working it due to: (a) the existence, because of altitude, of very difficult climatic conditions, the effect of which is substantially to shorten the growing season; (b) at a lower altitude, the presence over the greater part of the area in question of slopes too steep for the use of machinery or requiring the use of very expensive special equipment, or a combination of these two factors, where the handicap resulting from each taken separately is less acute but the combination of the two gives rise to an equivalent handicap. Areas north of the 62nd parallel and certain adjacent areas shall be regarded as mountain areas." *Other than mountain areas:* "(a) affected by significant natural handicaps, notably a low soil productivity or poor climate conditions and where maintaining extensive farming activity is important for the management of the land; or (b) affected by specific handicaps, and where land management should be continued in order to conserve or improve the environment, maintain the countryside and preserve the tourist potential of the area or in order to protect the coastline."
Regulation 1305/2013[5]	*Mountain areas*: "[…] characterised by a considerable limitation of the possibilities for using the land and by an appreciable increase in production costs due to: (a) the existence, because of altitude, of very difficult climatic conditions, the effect of which is to substantially shorten the growing season; (b) at a lower altitude, the presence over the greater part of the area in question of slopes too steep for the use of machinery or requiring the use of very expensive special equipment, or a combination of these two factors, where the constraints resulting from each taken separately are less acute but the combination of the two gives rise to an equivalent constraints.

Areas north of the 62nd parallel and certain adjacent areas shall be considered to be mountain areas."

Areas, other than mountain areas, facing significant natural constraints:
"at least 60 % of the agricultural area meets at least one of the criteria listed in Annex III at the threshold value indicated."

Other areas affected by specific constraints
"[…] affected by specific constraints and if it is necessary for land management to be continued in order to conserve or improve the environment, to maintain the countryside, to preserve the tourist potential of the area or to protect the coastline.
In addition, areas may also be eligible for payments under this paragraph, where:
— at least 60 % of the agricultural area meets at least two of the criteria listed in Annex III each within a margin of not more than 20 % of the threshold value indicated, or
— at least 60 % of the agricultural area is composed of areas meeting at least one of the criteria listed in Annex III at the threshold value indicated, and areas meeting at least two of the criteria listed in Annex III each within a margin of not more than 20 % of the threshold value indicated."

[1]*Directive 75/268/EEC. COUNCIL DIRECTIVE of 28 April 1975 on mountain and hill farming and farming in certain less-favoured areas (75/268/EEC). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31975L0268*
[2]*Regulation 950/97. COUNCIL REGULATION (EC) No 950/97 of 20 May 1997 on improving the efficiency of agricultural structures. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31997R0950*
[3]*Regulation 1257/1999. COUNCIL REGULATION (EC) No of 17 May 1999 on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF) and amending and repealing certain Regulations. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999R1257*
[4]*Regulation 1698/2005. COUNCIL REGULATION (EC) No 1698/2005 of 20 September 2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD).https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32005R1698*
[5]*Regulation 1305/2013. Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R1305*

APPENDIX B – Outlier removed

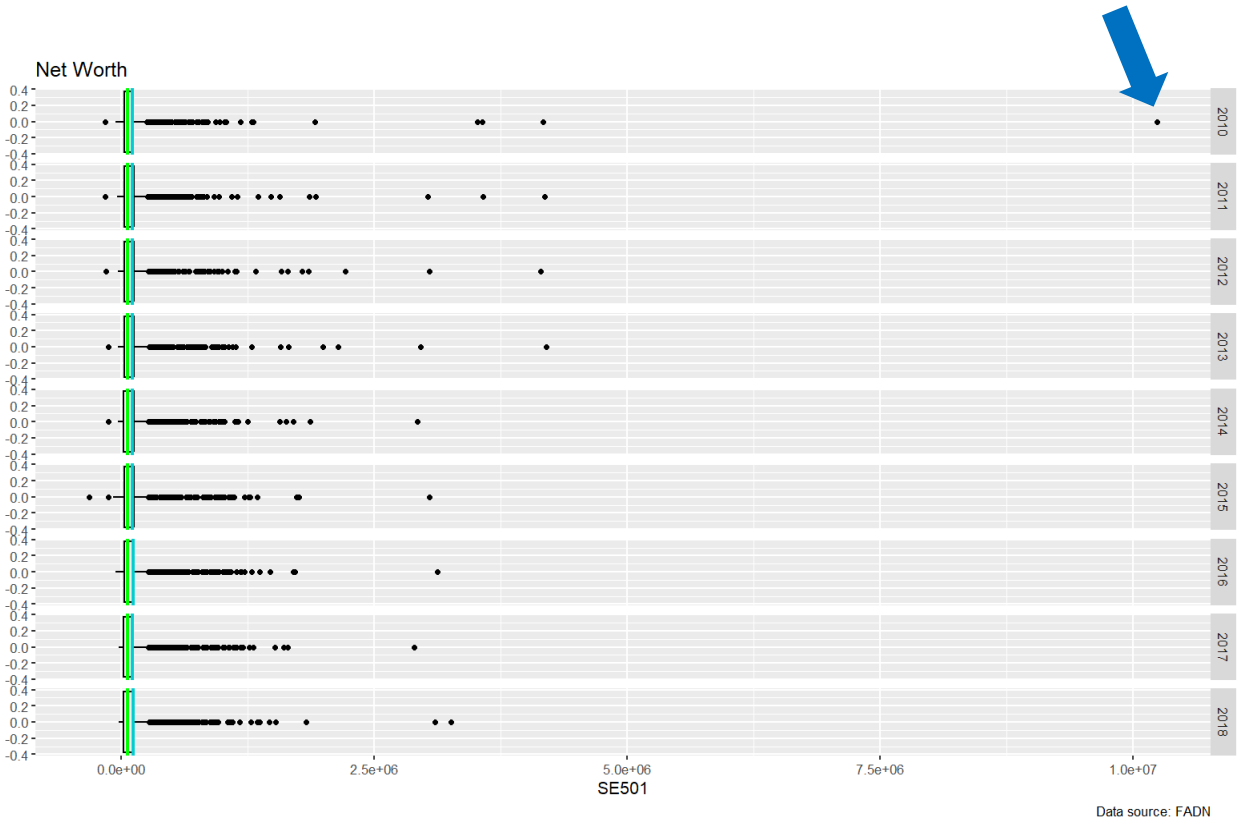

Figure 3 When comparing the Net Worth value of that holding in that year and in previous and following years, the value was around 10 times higher. We assume that was a data entering problem, removing that observation from the sample.

APPENDIX C – Distribution of ROFE

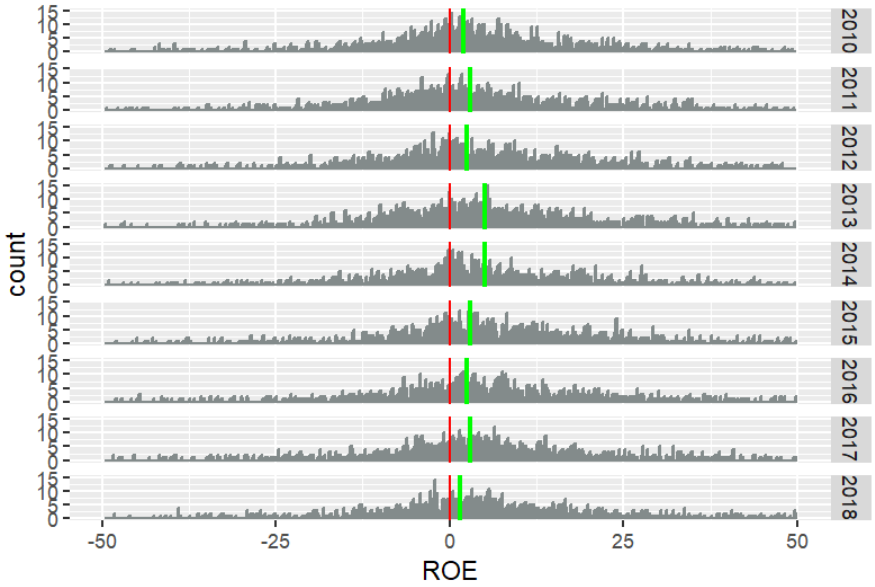

Figure 4 Distribution of ROFE, in %, for all farms (viable or not, profitable or not). Green line represents the average annual return rate of 5-year Portuguese national treasury certificates per year. Red line marks a ROFE=0. ROFE is presented in %. Data truncated between -50 and 50 for visualization purposes.

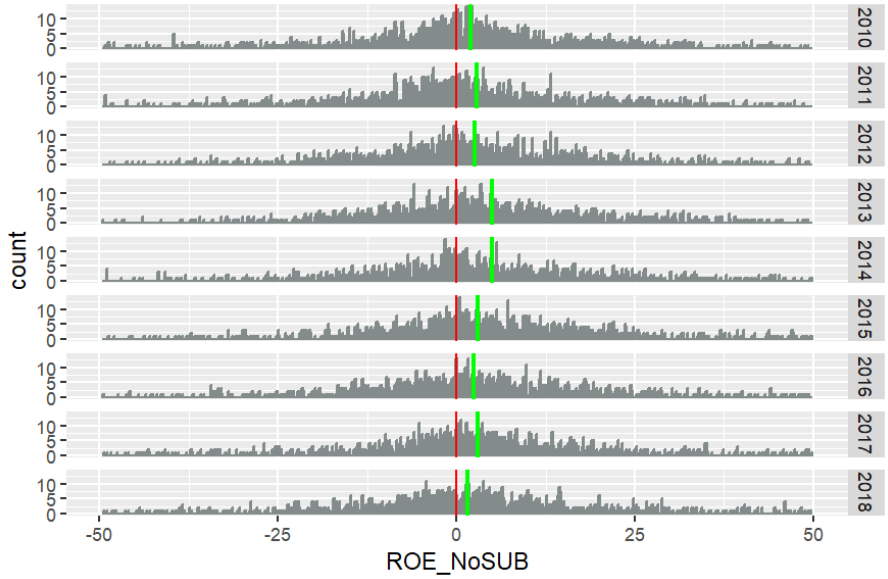

Figure 5 Distribution of ROFE, in %, for all farms (viable or not, profitable or not) excluding LFA subsidies. Green line represents the average annual return rate of 5-year Portuguese national treasury certificates per year. Red line marks a ROFE=0. ROFE is presented in %. Data truncated between -50 and 50 for visualization purposes.

APPENDIX D – Distribution of ROUL

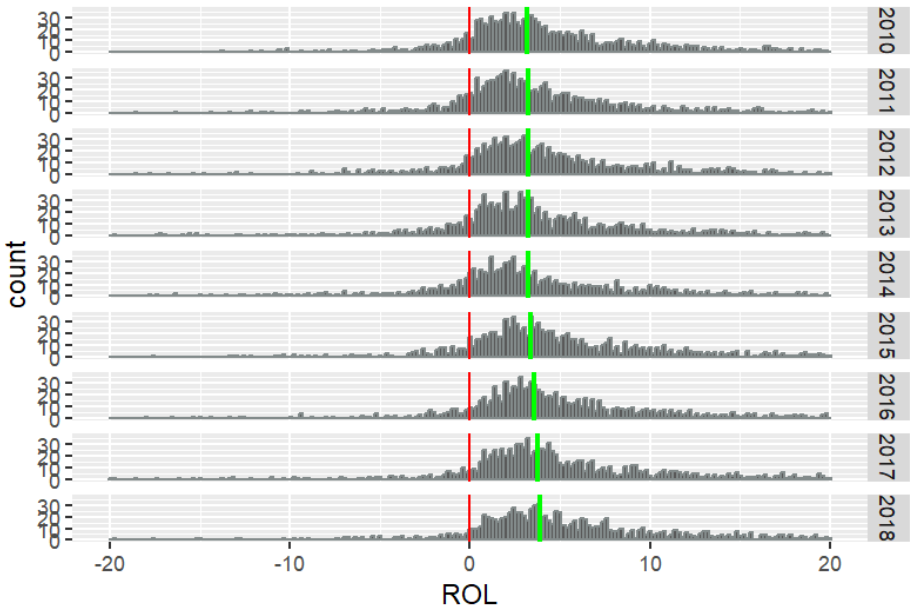

Figure 6 Distribution of ROUL for all farms (viable or not, profitable or not). Green line represents the national minimum wage per year. Red line marks a ROUL=0. ROUL is presented in €. Data truncated between -20 and 20 for visualization purposes.

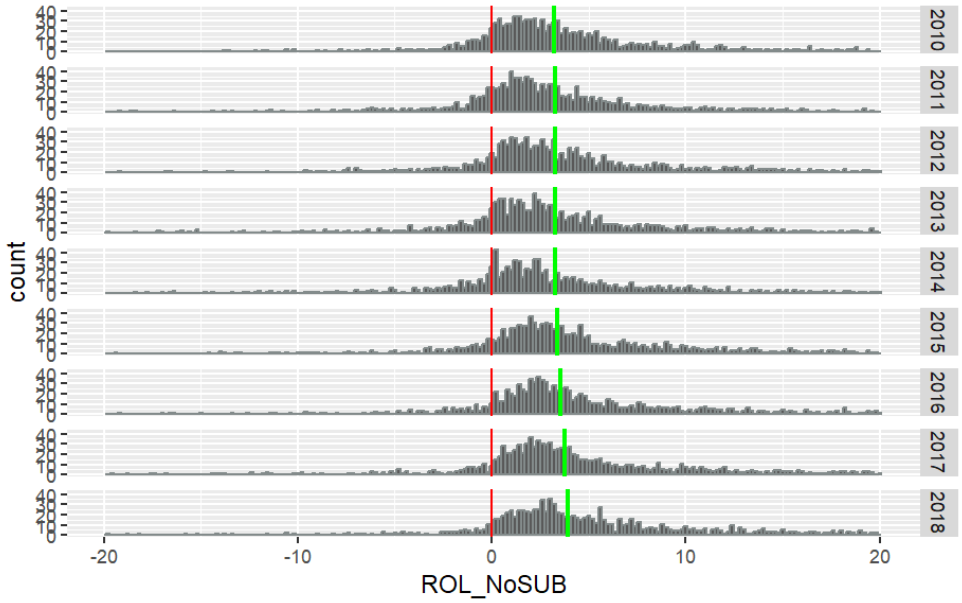

Figure 7 Distribution of ROUL for all farms (viable or not, profitable or not), excluding LFA subsidies. Green line represents the national minimum wage per year. Red line marks a ROUL=0. ROUL is presented in €. Data truncated between -20 and 20 for visualization purposes.

APPENDIX E - Multicollinearity check

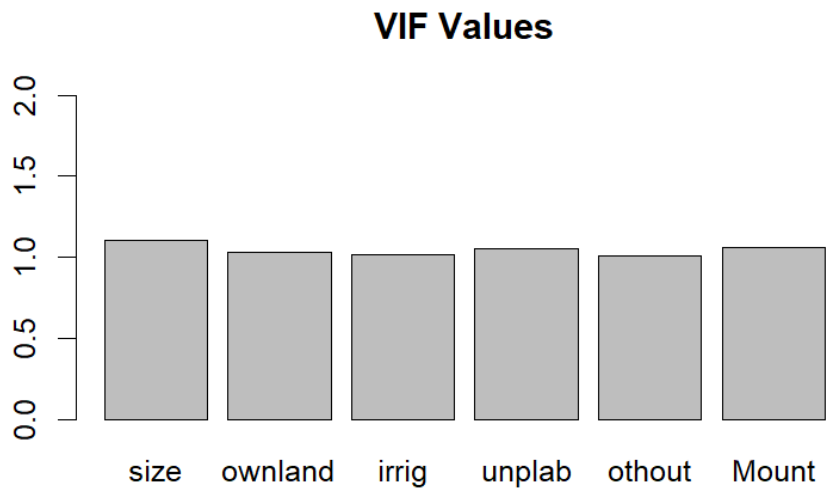

Figure 8 Multicollinearity check using variance inflation factors (VIF) for regression model independent variables. All below 1.5.

APPENDIX F – Heteroskedasticity and serial correlation check

```
        studentized Breusch-Pagan test

data:  FE_PLM
BP = 181.6, df = 20, p-value < 2.2e-16
```

Figure 9 Heteroskedasticity test. Null hypothesis rejected, so heteroskedasticity is present.

```
        Breusch-Godfrey test for serial correlation of order up to 1

data:  FE_PLM
LM test = 2524.8, df = 1, p-value < 2.2e-16
```

Figure 10 Serial correlation test. Null hypothesis rejected, so serial correlation of idiosyncratic errors is present