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An analysis of technical efficiency in Icelandic dairy and sheep farms

Usable agricultural land in Iceland is predominantly represented by permanent grasslands and pasture used for livestock grazing, while the cultivation of arable crops such as cereals and potatoes has a very modest incidence on the total agricultural surface area. The main purpose of this research, therefore, was to assess the technical efficiency of dairy and sheep farming across Iceland's regions using annual census data for the years 2008 and 2017. The assessment of the technical efficiency of farms – one that is able to analyse multi-input/output production functions – has been estimated through the use of the non-parametric approach of Data Envelopment Analysis (DEA). The research findings have highlighted the need for farmers to reduce certain inputs such as labour costs and general productive overheads, as well as to address their efforts to extensive forms of livestock farming, notably sheep rearing, which is able to take advantage of the abundant and rich grasslands. In general, sheep farms have been found to be technically more efficient than dairy, while farms located in the capital region have been shown to have lower levels of technical efficiency overall.

Keywords: Data Envelopment Analysis, rural areas, labour, dairy farms, sheep farms, Iceland.

JEL classification: Q12

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Introduction

In sharp contrast to fishing and related industries, agriculture in Iceland is not a primary economic sector, and its contribution to the country's total export revenue and gross domestic product is relatively minor (Agnarsson, 2000; Jóhannesson, 2010). Nevertheless, agriculture is of crucial importance due to its role in protecting the Icelandic environment and safeguarding its landscape (Agnarsson, 2000).

Soil characteristics and climate have strongly influenced the country's agricultural activities, with dairy and sheep farming representing the most important and widespread enterprises within this sector. Consequently, Iceland is largely self-sufficient in the production of lamb and beef, and of milk, butter, and other processed dairy products (Helgadóttir *et al.*, 2013). According to Helgadóttir and other authors, grassland represents one of the predominant and fundamental crops for animal feed, while the diffusion of arable crop cultivation is very modest, and has seen significant changes in recent times. The economic crisis that struck Europe from 2008, as investigated in relation to other economic sectors by various authors, has also had a notable impact on farms and their level of technical efficiency (Oh *et al.*, 2009). These researchers have assessed technical efficiency in certain productive processes in the primary and secondary economic sectors, noting that Icelandic enterprises have for a long time had lower levels of technical efficiency than other European countries, and that this gap has actually been increasing due to various inherent socio-economic factors at play in Iceland (Oh *et al.*, 2009). They argue that the low level of innovation, skills and competence, and labour investments directly and negatively affect technical efficiency in many Icelandic enterprises.

Meanwhile, Tor Jóhannesson argues that a low population density in small rural villages has also had significant effects on the primary sector (Jóhannesson, 2010). He argues that these socio-demographic constraints in the primary sector have had direct implications for the growth of agri-food enterprises, technical services available to farmers, and the development of the farming industry in general. As a consequence of the small dimension of villages, rural depopulation, the low level of specialised crop cultivation, and the prevailing climatic conditions, agricultural production is predominantly addressed towards small local markets. Furthermore, farms are not as competitive as retail firms, with relatively few farms reaching levels of technical and allocative efficiency due to the fact that they are not able to implement competitive management strategies owing to their small size and the low level of investment in costly labour- and time-saving innovative technologies (Seyfrit *et al.*, 2010). In order to reduce the skills and knowledge gap in rural areas, various on-line courses have been proposed by different universities with the core purpose of increasing skills and competence and, conversely, reducing the levels of permanent emigration from, and poverty in, rural villages (Bjarnason and Edvardsson, 2017; Seyfrit *et al.*, 2010).

The most recent FAO statistical data reported in literature show that more than 70% of Iceland's land area is unproductive, and only around 4,000 people are engaged full-time in farming (Bjarnason and Edvardsson, 2017), although there are many who are part-time farmers, working predominantly in other economic sectors.

Summing up, greater job opportunities elsewhere are the main drivers influencing the rural emigration of the younger generations, while specific investments aimed at increasing technical efficiency in Icelandic farms that would lead to a coherent and cohesive rural development are crucial to reducing the socio-economic marginalisation of rural areas (Seyfrit *et al.*, 2010).

A review of the available literature reveals that many studies have adopted a non-parametric approach to estimate the technical efficiency of farms in various European countries, comparing the impact of financial subsidies with the levels of technical efficiency found in different countries (Laurinavičius and Rimkuvienė, 2017; Galluzzo, 2013; 2015; Latruffe *et al.*, 2017; Gorton *et al.*, 2008; Bojnec and Latruffe, 2008). At the same time, various authors have focused their research on assessing the levels of crop specialisation (Gorton *et al.*, 2008; Galluzzo, 2015; 2017; Latruffe *et al.*, 2017; Bojnec and Latruffe, 2008). In many European countries, technical efficiency in farms has been assessed using non-parametric and deterministic methods such as the DEA, but it seems that studies of technical efficiency in farms in Iceland using a non-parametric approach for comparing two different types of livestock farming are not so common in the literature. This paper, therefore, represents an innovative study, introducing the assessment of technical efficiency in Icelandic farms and, in particular, in relation to farms specialised in sheep rearing and dairy production, highlighting the inputs that should be minimised in the productive process, taking into account the fact that Icelandic farms do not receive any payments or subsidies disbursed by national authorities which might have the potential to influence the technical efficiency in farms, as many studies for other countries have argued (Laurinavičius and Rimkuvienė, 2017; Galluzzo, 2013; 2015; Latruffe *et al.*, 2017; Gorton *et al.*, 2008; Bojnec and Latruffe, 2008).

The core purpose of this research was to assess the technical efficiency in a sample of Icelandic farms specialised in typical and fundamental agricultural productions such as dairy farming and sheep rearing through a quantitative approach, using data for dairy and sheep farms in the various Icelandic regions gathered by the National Institute of Statistics from 2008 to 2017 and published in its income statements and balance sheets. The novelty of the research is in relation to the economic framework of farming in Iceland, where technical efficiency has previously been estimated predominately for the secondary sector but not the primary sector, in order to identify which types of livestock farming are more technically efficient, while also taking into consideration the effect that the ending of quotas in 1992 has had on farming in Iceland (Bjarnason and Edvardsson, 2017).

The farms have been grouped in two clusters, in function of their productive specialisation as sheep and dairy farms, in all Icelandic regions (Appendix 1). Through the application of a quantitative non-parametric model to a multi-input oriented technical efficiency model, it has been possible to assess the technical efficiency in farms over the period 2008 to 2017, comparing the data in terms of constant prices for the 2017 year.

The investigated variables for output were operating income and owner's equity. Operating income is able to express profit after subtracting operating expenses and other daily costs of running the business. The investigated variables for input were operating expenses, comprising costs correlated to productive activity in farm, the cost of goods and raw materials or, rather, costs to buy seeds, fertilizers, forage, labour costs, other expenses, liabilities, and costs for assets, by means of which it is possible to estimate the level of investments in farms.

Methodology

Technical efficiency can be estimated through two different approaches: a parametric or stochastic modelling using Stochastic Frontier Analysis (SFA), and a non-parametric modelling using Data Envelopment Analysis, or DEA (Farrell, 1957; Lovell, 1993; Coelli *et al.*, 2005; Battese and Coelli, 1992). The assessment of technical efficiency in a parametric approach using Stochastic Frontier Analysis requires a specific and well-defined function such as the Cobb-Douglas or other typologies of function (Coelli *et al.*, 2005; Lovell, 1993). Using DEA, on the other hand, it is possible to assess multiple inputs and multiple outputs through a linear programming methodology without using *a priori* defined functions of production such as the Cobb-Douglas or a Translog (Coelli *et al.*, 2005; Bravo-Ureta and Pinheiro, 1993).

In general, the Stochastic Frontier Approach (SFA) can be used where there is a consolidated functional form and *a priori* knowledge of the productive function. This is not the case in this paper, hence the DEA, which is more flexible and deterministic, is more suitable since it fits well to the aim of this research that is focused on investigating the level of inputs used in an assessment of technical efficiency in farms, based on a modest sample size.

The non-parametric approach can be input- or output-oriented in function of the target of the frontier in terms of the minimising of inputs or the maximising of outputs (Coelli *et al.*, 2005; Farrell, 1957). This paper has used an input-oriented model with the aim of assessing which input variables could be minimised by farmers, in terms of both constant returns to scale (CRS) and variable returns to scale (VRS) that are able to measure the efficiency in each Decision Making Unit (DMU) of observation (Galluzzo, 2013; 2015; Chavas and Aliber, 1993), which in this research are represented by farms specialised in dairy farming or in sheep breeding in each Icelandic region.

In this study, each DMU represents the different Icelandic regions investigated over the period of study, clustered according to the function of its own productive specialisation, be it dairy or sheep farming. The sample size for both the 2008 and 2017 years of investigation involved almost 2,500 farms.

The optimal level of efficiency is represented by all the DMUs placed on the frontier of technical efficiency, while all the DMUs placed under this frontier can be considered as inefficient, having a value lower than the optimal threshold that is equal to 1 (Coelli *et al.*, 2005; Galluzzo, 2013; 2015; Chavas and Aliber, 1993; Bravo-Ureta and Pinheiro, 1993). As proposed by Charnes *et al.* (1978), and by Banker *et al.* (1984), the DEA model assumes that there are n DMUs which produce a quantity s of output y in such a way that $y \in RS^{+}$ by using m inputs in multiple arrangement and in combination of $x \in R^{+}$. The technical efficiency of a DMU k, under the assumption proposed by Charnes *et al.* (1978), can be evaluated by solving a linear programming problem minimising the level of input used in the production process (Charnes *et al.*, 1978, Banker *et al.*, 1984; Coelli *et al.*, 2005; Bravo-Ureta and Pinheiro, 1993; Battese and Coelli, 1992):

$$\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right), \quad (1)$$

$s.t.$

$$\sum_{j=1}^{n} \lambda_j\, x_{ij} + s_i^- = \theta\, x_{ik}, \quad i = 1, 2 \ldots, m, \quad (2)$$

$$\sum_{j=1}^{n} \lambda_j\, y_{rj} + s_i^+ = y_{rk}, \quad r = 1, 2 \ldots, s, \quad (3)$$

$$\theta, \lambda_j, s_i^-, s_r^+ \geq 0, \quad (4)$$

$$\sum_{j=1}^{n} \lambda_j = 1, \quad (5)$$

The formulas 2 and 3 describe the main constraints in the minimisation assessment of the input-oriented function.

The aim of the DMU is to assess the value of θ, which is the optimal level of technical efficiency equal to 1; ε is a non-Archimedean infinitesimal value, proposed by Charnes *et al.* (1978), aimed at overcoming some difficulties linked to testing multi-optimum solutions; and λ is a convex coefficient in the input x in each DMU j producing a level of output y in the farms j (Oh *et al.*, 2009). S_r^+ and S_r^- are non-negative output and input slacks or rather an excess in input or an output shortfall. Thus, if θ is equal to 1 and all input and output slacks are equal to zero, the DMU is operating on the CRS frontier and, therefore, is technically efficient (Charnes *et al.*, 1978, Banker *et al.*, 1984; Coelli *et al.*, 2005; Bravo-Ureta and Pinheiro, 1993; Battese and Coelli, 1992). On the contrary, if θ is not equal to 1 and all input and output slacks are different to zero, there is an improper or inefficient use of resources in the enterprise, with the consequent need for the entrepreneur to eliminate inefficiencies.

Variable returns to scale (VRS) in the DEA model can be used for measuring the pure technical efficiency (PE) and also the scale efficiency (Banker *et al.*, 1984; Banker, 1984; Zhu, 2000) which, as argued by these latter authors, is the ratio of the technical efficiency under the constant returns to scale assumptions to the technical efficiency under the variable returns to scale assumptions. If the scale efficiency is equal to 1, the firm or DMU is efficient. Furthermore, the increasing returns to scale (IRS) and the decreasing returns to scale (DRS) are assessed with the aim of analysing the primary cause of scale efficiency; in fact, if the CRS technical efficiency score is higher than the VRS technical efficiency value there is an increasing returns to scale (IRS), otherwise there is a decreasing returns to scale (DRS).

For the purposes of this analysis, a cross-section of data has been used in order to assess the change in technical efficiency over the two years of investigation, 2008 and 2017, without considering environmental variables, such as the quality of the land, that could have a direct impact on technical efficiency.

Results and discussion

According to the statistical data of the most recent census in Iceland, published in 2010, the highest concentration of farms is in the South and Northwest regions. In contrast, the lowest concentration of farms is to be found in the capital area and in the Southwest region, where less than 100 enterprises were detected operating in the primary sector. Focusing attention on the main types of animals reared, the data published by the National Institute of Statistics have underlined that sheep, cows, and horses predominate in Icelandic animal husbandry. Poultry farming is primarily concentrated in the Capital region, in the Southwest, and in the South Peninsula, which is the region with the greatest concentration of animal rearing in general, while in the northern Icelandic regions there is a significant concentration, in particular, of sheep breeding. Dairy farming is predominantly concentrated in the South and Northeast regions, even if other regions also have scattered small-scale dairy farming enterprises with a modest endowment of animals.

The percentage of Icelanders employed in agriculture is 3.56%, with a total of 12,000 people actively engaged in agriculture on a full-time basis. The total output in the primary sector for the 2017 year in constant prices equals 59,023 million Icelandic króna (ISK). The labour costs have been calculated considering the cost of each unit of labour for each Icelandic region in terms of average values. The leasing costs represent those expenses that farmers have borne in order to be able to access goods and/or activities not otherwise found in farms, also assessed in constant prices.

The findings of technical efficiency estimated in all Icelandic regions for 2008 have revealed that the highest results close to the optimal threshold of 1, both in Constant Returns to Scale (CRS) and also in Variable Returns to Scale (VRS), were found in dairy farms in the North-West, Southern, and Westfjords regions (Table 1). In sheep farms, the highest levels of technical efficiency were found in the Capital

Table 1: Values of technical efficiency in constant returns to scale (CRS) and variable returns to scale (VRS) assessed in Icelandic regions in 2008.

Region	Dairy CRS	Dairy VRS	Sheep CRS	Sheep VRS
Capital and Southern Peninsula	0.31	0.31	1.00	1.00
Eastern	0.82	0.85	1.00	1.00
North-eastern	0.85	1.00	0.82	0.83
North-western	1.00	1.00	0.87	1.00
Southern	1.00	1.00	1.00	1.00
Western	0.80	0.81	0.77	0.78
Westfjords	1.00	1.00	1.00	1.00

Source: own calculations based on Statistics Iceland (2019) data

Table 2: Values of technical efficiency in constant returns to scale (CRS) and variable returns to scale (VRS) assessed in Icelandic regions in 2017.

Region	Dairy CRS	Dairy VRS	Sheep CRS	Sheep VRS
Capital and Southern Peninsula	0.62	0.64	0.42	1.00
Eastern	0.75	1.00	1.00	1.00
North-eastern	0.63	1.00	0.88	0.94
North-western	0.68	0.93	0.95	1.00
Southern	0.79	1.00	0.82	1.00
Western	0.91	1.00	0.83	0.90
Westfjords	1.00	1.00	1.00	1.00

Source: own calculations based on Statistics Iceland (2019) data

and Southern Peninsula, Eastern, Southern, and Westfjords regions. In contrast, the lowest values of technical efficiency were found in the Capital and Southern Peninsula region in dairy farms, and in the Western region for sheep farms.

In 2017, the technical efficiency, in terms of both CRS and VRS, in the investigated dairy farms showed the best results in the Westfjords region, while the worst results were found in the Capital and Southern Peninsula region (Table 2). Sheep farms have shown the highest levels of technical efficiency in the Westfjords and Eastern regions of Iceland.

The differences in technical efficiency among Icelandic regions are due, in large part, to differences in their orographic and pedological features, considering that many parts of Iceland have soils that are created by magmatic processes and are more or less unproductive. In fact, in some regions there are permanent pastures that can be used during the spring and the summer months to rear animals in the wild and provide forage without the need to buy feed. The age or gender of the farmer are not the only variables able to act on technical efficiency, since more farms have tried to diversify their activities through the introduction of agritourism or other types of agricultural activities. Furthermore, in many cases, agriculture is linked to fishing, which is the main primary sector activity in Iceland.

In Icelandic sheep farms, findings for the gain in inputs reveal that only the 5 out of 7 regions have seen zero change and they need to increase or reduce the allocated input (Table 3); in contrast, the worst results in terms of the reduction of inputs have been found in the North-eastern and Western regions, where farms must reduce their labour capital, assets and liabilities in 2008. In 2017, the sheep farms located in the North-eastern region have to reduce labour input, assets and liability.

As regards Icelandic dairy farms, only 4 regions out of 7 in 2008 have achieved the optimal level of input, while the Capital, Western and Eastern regions reveal the worst results in terms of needing to decrease all inputs and in particular labour, assets and liabilities (Table 4). In 2017 the Capital of Iceland and North-western regions have pointed out a significant decrease in labour input, assets and liability.

In general, it is important to focus attention on the difference in technical efficiency between the two types of livestock farming. In fact, sheep farms show the best results in terms of technical efficiency, due both to their greater ability to convert modest-quality feed into meat, and to a lower level of inputs such as labour and leasing costs compared to dairy farms, owing to the fact that the animals are predominantly reared in the wild. This is clearly not the case in dairy farms, and this has an influence on their level of technical efficiency. Furthermore, the fact that dairy farms received a different level of quotas and state subsidies in the past could have had an effect in reducing their level of technical efficiency.

The metafrontier analysis, crucial to estimating and comparing different clusters of DMUs in Iceland, has corroborated the observation that, when measuring input-oriented variable returns to scale for both types of specialised farming studied in Iceland, namely dairy and sheep, a higher level of technical efficiency can be found in sheep than dairy farms. In fact, the average values of CRS, VRS, and Scale Efficiency in dairy farms were equal to 0.881, 0.946 and 0.932 respectively, while in sheep farms the values were equal to 0.949, 0.974 and 0.974.

Conclusions

A brief review of the available literature has highlighted that studies and research aimed at estimating the technical efficiency in specialised farms in Iceland using a non-parametric approach are not so common.

The findings of this study have revealed that lower levels of technical efficiency have been detected in dairy farms

Table 3: Gains, in percentage, in some investigated inputs in Icelandic sheep farms in 2008 and in 2017.

year 2008					
Region	**Operating expenses**	**Goods and raw material**	**Labour costs**	**Assets**	**Liabilities**
Capital and Southern Peninsula	0	0	0	0	0
Western	-14.26	-8.33	-12.37	-21.37	-36.31
Eastern	0	0	0	0	0
North-eastern	-8.83	-3.54	-13.26	-16.53	-19.54
North-western	0	0	0	0	0
Southern	0	0	0	0	0
Westfjords	0	0	0	0	0
year 2017					
Region	**Operating expenses**	**Goods and raw material**	**Labour costs**	**Assets**	**Liabilities**
Capital and Southern Peninsula	0	0	0	0	0
Western	2.21	3.96	2.08	-9.95	-9.95
Eastern	0	0	0	0	0
North-eastern	5.23	0.39	-1.44	-7.96	-5.11
North-western	0	0	0	0	0
Southern	0	0	0	0	0
Westfjords	0	0	0	0	0

Source: own calculations based on Statistics Iceland (2019) data

Table 4: Gains, in percentage, in investigated inputs in Icelandic dairy farms in 2008 and 2017.

Region	Operating expenses	Goods and raw material	Labour costs	Assets	Liabilities
year 2008					
Capital and Southern Peninsula	-30.64	-19	6.07	-86.8	-68.69
Western	-5.96	-15.94	-7.07	-20.67	-19.14
Eastern	-0.43	-8.77	2.72	-14.41	-14.41
North-eastern	0	0	0	0	0
North-western	0	0	0	0	0
Southern	0	0	0	0	0
Westfjords	0	0	0	0	0
year 2017					
Region	**Operating expenses**	**Goods and raw material**	**Labour costs**	**Assets**	**Liabilities**
Capital and Southern Peninsula	7.73	5.54	-0.6	-41.26	-35.51
Western	0	0	0	0	0
Eastern	0	0	0	0	0
North-eastern	0	0	0	0	0
North-western	-2.34	0.24	-6.09	-6.54	-20.7
Southern	0	0	0	0	0
Westfjords	0	0	0	0	0

Source: own calculations based on Statistics Iceland (2019) data

compared to sheep farms, largely due to a greater use of inputs such as labour, suggesting that labour-saving techniques should be introduced in dairy farms, in particular with regard to milking activities. In fact, in dairy farms, it is not so common to find the livestock left in the wild, and the main activities are predominately located in stalls; in contrast, sheep farms rear animals in wild pastures, with farmers generally leaving sheep to roam freely from the Spring to the end of the Summer. The main result of this are consequently higher costs for managing herds in terms of labour, feed, and management inputs for dairy farms compared to sheep farms. In dairy farms, the introduction of greater automation, particularly in the milking process, could be useful for reducing labour costs, although the modest size of herds often means that it is not economically viable to introduce innovative technologies that are capable of significantly minimising the level of inputs.

Summing up, it is important to underline that it is crucial to reduce certain inputs such as labour and other costs directly related to the rearing of animals. In fact, considering the prevailing climatic conditions and the typology of soils, the production of pasture represents one of the main cost items for Icelandic farms, and proper and efficient management strategies to reduce this cost input is essential in order to improve the technical efficiency in farms. At the same time, an increase of new innovative labour-saving technologies, in particular in dairy farms, represents a good opportunity for increasing technical efficiency. Furthermore, a reduction of steps in the supply chain, even if it not directly correlated to technical efficiency, is crucial to increasing the level of income in farms without necessarily raising the level of output, consequently reducing the buyer power of the specialised firms downstream of the farms by mainstreaming Icelandic food production from small localised markets to a broader domestic one. In general, small farms in Iceland have had a lower level of output price compared to larger farms, and have had a more limited ability to diversify their productions and activities in order to supplement their incomes. If small farms are able to sell their productions in the local market, they will be able to increase the prices and therefore their level of income. This is becoming a greater possibility for small Icelandic farms, particularly in the wake of increasing touristic flows and the consequently growing demand, both for the supply of local foods and for the provision of in situ venues (such as agritourisms) in which to eat it.

Comparing the findings for technical efficiency in this study to those carried out in other European countries, the estimation of technical efficiency in sheep farms that has been made using a different approach to the Stochastic Frontier Analysis has pinpointed which inputs have acted on the inefficiency of farms (Theodoridis *et al.*, 2014). The findings from this research have shown very similar levels of technical efficiency found in other specialised zootechnical farms, corroborating the view that the variable labour represents one of the main inputs that must be minimised in order to maximise technical efficiency in livestock farming (Bojnec and Latruffe, 2009). Furthermore, comparing this research to other studies carried out in many countries belonging to the European Union, it has not been possible to assess what the direct impact of a public policy to support dairy and sheep farming would have in Iceland, as some authors have argued in relation to other EU countries (Zhu *et al.*, 2012). In fact, dairy farms in Iceland have shown broadly the same levels of technical efficiency as those assessed in similar studies of other European countries during the phases of enlargement of the European Union for farms characterised by equally modest levels of land capital, numbers of sheep and cows, and a relatively small economic dimension (Bojnec and Latruffe, 2008).

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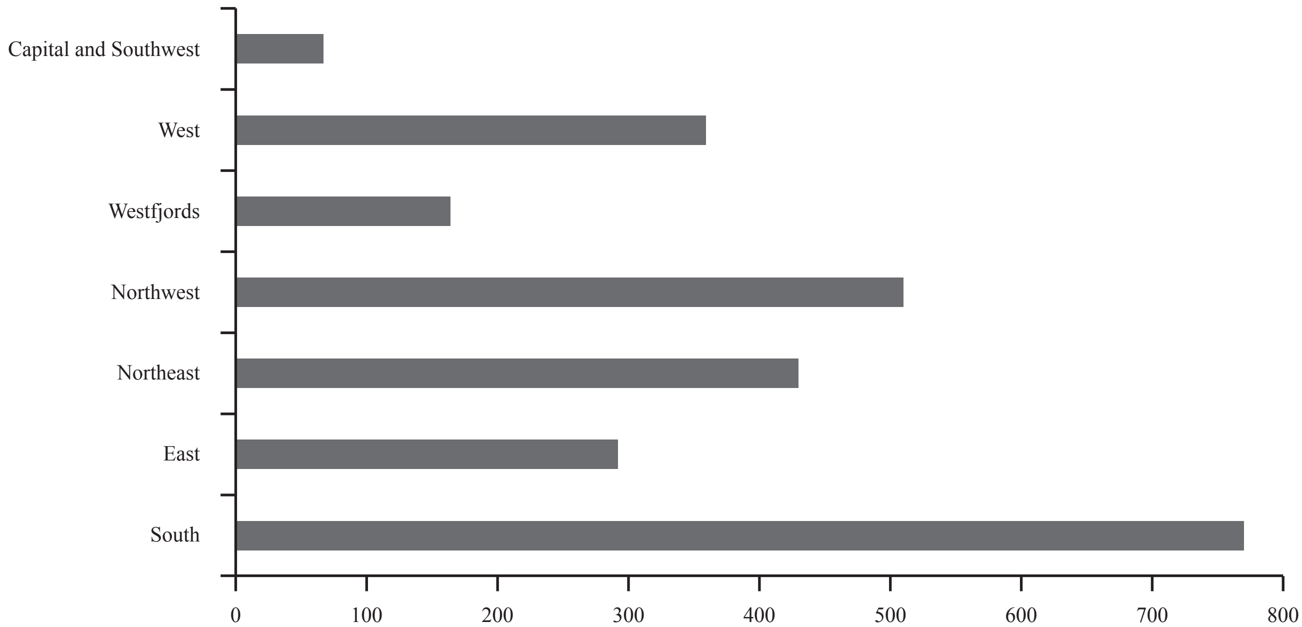
Appendix

Appendix 1: Main Icelandic regions investigated from 2008 to 2017

Source: GoogleMaps (2019)

Appendix 2: Number of farms in Iceland in 2010



Source: own calculations based on Statistics Iceland (2019) data