

Secondary Publication



McLaughlin, Eoin; Sharp, Paul; Tsoukli, Xanthi; u. a.

Ireland in a Danish mirror : A microlevel comparison of the productivity of Danish and Irish creameries before the First World War

Date of secondary publication: 02.12.2025

Version of Record (Published Version), Article

Persistent identifier: urn:nbn:de:bvb:473-irb-111956x

Primary publication

McLaughlin, Eoin; Sharp, Paul; Tsoukli, Xanthi; u. a. (2025): Ireland in a Danish mirror: A microlevel comparison of the productivity of Danish and Irish creameries before the First World War, in: Business History, London: Taylor & Francis, pp. 1–17, doi: 10.1080/00076791.2025.2486643

Legal Notice

This work is protected by copyright and/or the indication of a licence. You are free to use this work in any way permitted by the copyright and/or the licence that applies to your usage. For other uses, you must obtain permission from the rights-holders.

This document is made available under a Creative Commons license.



The license information is available online:

<https://creativecommons.org/licenses/by/4.0/legalcode>

Ireland in a Danish mirror: A microlevel comparison of the productivity of Danish and Irish creameries before the First World War

Eoin McLaughlin^a, Paul Sharp^b , Xanthi Tsoukli^c and Christian Vedel^b

^aHeriot-Watt University, Edinburgh, UK; ^bUniversity of Southern Denmark, Odense, Denmark; ^cUniversity of Bamberg, Bamberg, Germany

ABSTRACT

The relative success of the Danish and failure of the Irish dairy industries before the First World War is often contrasted. The traditional narrative assumes that the Irish failed because they were unsuccessful at adopting cooperative ownership, and that Irish cooperatives were not as efficient as their Danish counterparts, despite having been explicitly modelled on them. This is, however, untested at the 'firm' level. We rectify this through the analysis of a large microlevel database of creameries in both countries over the period 1898–1903. Using Stochastic Frontier Analysis (SFA), a standard methodology in modern productivity studies, we find that Irish creameries were in fact slightly more efficient on average than their Danish counterparts, although with a larger variance. This nuances the idea that the Irish were unable to establish cooperatives successfully, although some creameries were certainly laggards, and the reputational cost of this might have impacted the industry.

ARTICLE HISTORY

Received 17 March 2025
Accepted 25 March 2025

KEYWORDS

Dairying; Denmark;
Ireland; microdata;
productivity

JEL CODES

N13; N53

1. Introduction

The success of Danish agriculture before the First World War owed much to a rapid spread of butter factories and the capture of a sizable share of the important British market (Lampe & Sharp, 2014, 2015, 2019). This is often contrasted with the case of Ireland which, at that point a constituent of the UK, with greater access to coal (Henriques & Sharp, 2016)¹ and as a country with a long tradition of butter production and export, seemed well-placed to enjoy a similar trajectory. Thus, Irish campaigners, notably the Irish Agricultural Organisation Society (IAOS), explicitly aimed to copy the Danish model, which relied on peasant supplier-owned cooperatives and a new technology, the steam-powered automatic cream separator. However, after 30 years of mechanisation and 20 years of dairy cooperatives, the share of Irish butter on the British market had declined from 46.6 per cent in 1860 to just 11.9 per cent in 1910. Denmark's share, by contrast, increased from 0.6 to 35.2 per cent over

CONTACT Paul Sharp  pauls@sam.sdu.dk

© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

the same period (Henriksen et al., 2015). We ask: what explains this relative failure of Irish dairying?

A number of reasons have been given in the existing literature. As we will discuss more below, it has been suggested that for various reasons Irish cooperative creameries per se constituted the problem, for example due to less efficient management, and in general lower levels of productivity and quality of produce. But industry averages and anecdotal evidence might conceal a more complex story. Thus, the present work seeks to shed light on this through a large, novel database on microdata for the two countries. We employ Stochastic Frontier Analysis (SFA), a standard tool for the analysis of firm-level efficiency, and find that the Irish creameries were not on average less productive than those in Denmark, although they did suffer from greater variance. This has the important implication that it was not the organisation, or the technology employed by the Irish cooperatives, which explains their relative failure, but rather the failure of certain outliers and potentially a reputational effect on the entire industry. Indeed, we find evidence that the butter price received by less productive creameries, an indicator of quality, was lower for those which were less productive.

The present work contributes to at least three important debates at the core of business history. First, we contribute to the factors explaining the relative success of (exporting) firms. There is an abundant literature within economics and economic history on the determinants of international trade on the macroeconomic level, see for example Lampe and Sharp (2019), where in the past two decades we see a shift from country- and/or industry-level analysis to firm-level (Bernard et al., 2018). The key findings of this new empirical literature are that not all firms export; exporters tend to be more productive than non-exporters; and trade liberalisation tends to see aggregate industry level productivity increases (Bernard et al., 2018).² Second, we contribute to understanding the determinants of relative efficiency in the use of an organisational form, specifically in this case the milk-supplier owned dairy cooperative, and to the debate about the reasons for the relative success of Danish cooperative creameries compared to their Irish counterparts on the UK market. Lampe and Sharp (2019) conclude that Danish success owed more to the long-run improvements in agriculture rather than the cooperatives as such, thus making it more difficult to place the blame for Ireland's relative failure on its less than enthusiastic embrace of the cooperative form. Others have noted that there were certain institutional barriers to forming cooperatives in Ireland, such as conflict (O'Rourke, 2006, 2007); and difficulties in enforcing vertically binding contracts between the milk suppliers and the cooperative, with a deleterious impact on quality (Henriksen et al., 2012a, 2015), as well as a far more competitive (and hostile) proprietary sector in Ireland (McLaughlin & Sharp, 2021). Third, we link our findings to recent developments in the comparative study of cooperative enterprises, for example Boone and Özcan (2014) on the U.S. ethanol industry from 1978 to 2013, Higgins and Mordhorst (2015), on British and Danish organisational structures in bacon production; and Medina-Albaladejo and Menzani (2017), on cooperative wineries in Italy and Spain.

Finally, we contribute to at least two growing debates within business history where scholars have argued for the importance of international comparisons (Chandler, 1976; Webster & Walton, 2012), as well as the quantification of business history. Henriques et al. (2024) present some of the data used in the present work, but also provide a survey of the debate regarding a 'new business history' and some arguments for the relevance of large datasets for the field allowing for the exploration of industries and small firms which might otherwise be ignored (see also Balleisen, 2020).

In sum, the literature in economics, economic history, and in business history suggest no obvious reasons why Danish cooperatives fared better on the British market than their Irish counterparts. What the present work is doing is to exclude the trivial explanation of the innate inferiority of Irish cooperative creameries, as measured by their productivity. In the following section we provide a brief historical overview of Danish and Irish dairying over the relevant period; in [Section 3](#) we present our data and empirical specification, and in [Section 4](#), we give the results of our analysis. [Section 5](#) concludes.

2. An historical overview of Danish and Irish dairying

The roots of the success of the Danish dairy industry go back more than a century before the foundation of the first peasant cooperative creamery in 1882. Enlightened elites from northern Germany bought up large estates in Denmark from the second half of the eighteenth century and, after introducing new agricultural techniques, including a centralised dairy facility, participated in and in part initiated a radical programme of reform (Boberg-Fazlić et al., 2023; Lampe & Sharp, 2019). This included the abolition of serfdom (Gary et al., 2022) and a more general agrarian reform which established the medium-sized peasant farmers who would go on to found the cooperatives (Boberg-Fazlić et al., 2022). Over the course of the nineteenth century, educational establishments and extension services teaching best practice, including sophisticated accounting techniques, were founded (Lampe & Sharp, 2017, 2019), as dairying expanded behind protectionist tariff barriers (Henriksen et al., 2012b). When the centrifugal separator was invented in the 1870s, Danish peasant farmers were well-placed to embrace this technology in order to centralise production similarly to how larger producers had for a century.

Inspired by the Danish example, the Irish Agricultural Organisation Society (IAOS) was established in 1894 by Horace Plunkett to promote the formation of rural cooperatives that were owned by the farmers themselves as in Denmark. Irish dairy farmers seemed however to have been reluctant to do so; for the most part, they only established cooperatives when there was no other satisfactory alternative and were not keen on actively participating in cooperative governance even if one was established. Thus, while Denmark had over 500 cooperative creameries by 1888, Ireland had under one hundred, but twice as many proprietary creameries. On a per capita basis, the Danes had 10.6 times as many creameries as Ireland. However, by the First World War Ireland had caught up to a certain extent, with 458 cooperatives and 251 proprietary creameries in 1920, compared to over 1000 cooperatives (and very few private creameries) in Denmark (Breathnach, 2012); on a per capita basis the Irish had narrowed the gap to half that of Denmark.

This implies that the IAOS had some success, but there were major differences in the way cooperatives were established in the two countries. Those in Denmark arose as a spontaneous, bottom-up affair which required little support from outside agencies, contrasting with a lack of spontaneity in the Irish case; around one fifth of the cooperative creameries established up to 1920 were conversions of pre-existing private operators. This proportion was much higher in the south – 33.2% compared to just 7% in the north, which was outside the traditional heartland of Irish dairying and consequently there were fewer creameries to be converted. The spatial pattern of the private and cooperative creamery sectors provides further evidence that, to a large extent, cooperatives were established where there were no alternatives to private creameries. Private investors were attracted to locations where a

plentiful supply of milk offered prospects of high profitability. Milk availability was the key determinant of the location of private creameries, but seemed to have had only a minor influence on the location of cooperatives (Breathnach, 2006).

Over time, farmers developed a more positive attitude towards forming, or becoming members (and therefore owners) of, cooperatives (Doyle, 2019). According to Breathnach (2012), this was because they were considered to be better run than their private counterparts, and more prepared for periods of economic downturn. Cooperatives rarely changed hands in the period up to 1920, were more successful at curbing rogue behaviour (e.g. hygiene and milk adulteration) among suppliers, and paid better prices for milk. Moreover, they were not driven solely by profit and thus could provide a credit system where the payment was extracted over time from a monthly milk cheque. A particular issue in Ireland, however, seemingly was that neighbouring cooperatives were more likely to be bitter rivals competing for suppliers in overlapping territories rather than working together. In addition, the IAOS was under constant financial pressure which limited the level of service that it could provide. This was reflected by the small subscriptions that the cooperatives paid to the organisation.

The worldview of the Irish farmers was profoundly shaped by the socio-economic structures and systems in which they operated. Key to the success of the Danish creamery cooperatives was the restructuring of the Danish landholding system. In the late nineteenth century, most Danish farmers were free of debt and had gained more than a hundred years of experience in developing the productive capacity of their farms. A result of the centralised nature of Danish land reform was the absence of major inequalities in the size of the farms created, which were larger on average than the Irish.³ This produced a strong sense of common identity, while in Ireland there were deep social divisions created by inequality in farm size. The high level of education of the Danish farmers and a wide range of community-based organisations, such as farmers' associations, credit unions, parish councils and socio-cultural activities, also contributed to their success. In Ireland, most farms were still held in tenancies in the late nineteenth century, while the tradition of inheriting farms on the death of the incumbent, coupled with the linking of marriage to inheritance, inhibited innovation in the farming community. The occupiers of holdings generally had little education and few resources, and frequently were indebted to local shopkeepers and moneylenders. In addition, farmers incurred substantial debts with state funded mortgages, over 68 years, that commenced at scale with the 1903 Wyndham Land Act (Foley-Fisher & McLaughlin, 2016).

Jenkins (2004) examined the activities of two groups involved in the establishment of creameries: private capitalists (mainly from the former butter trade or butter retailers based in Britain) and agricultural reformers, organisers and supporters of the Irish Agricultural Organisation Society. He argues that cooperatives worked not purely because of economics but because of culture. The creameries, with their centrifugal separators, had a big impact on the rural economy and social life in Ireland. The adoption of the creamery system was a cultural novelty undertaken by private capital and cooperative interests. He differentiates between 'foreign' capitalists with a 'free hand' and concerns that strove for 'Irish' self-help and cooperation. The creameries became accepted due to micro political conditions but resulted in discussions around issues of cultural identity, economic power, the welfare of rural communities, and wider colonial relationships. The attitudes towards creameries and their legitimacy as 'Irish' and 'local' businesses were contested, but finally resolved when the Irish Free State chose cooperatives as a way to

deliver on the new independent government's stated goal of democratic empowerment of farmers. This is something, however, which Moulton (2017) argues the cooperatives were never designed to do, having been founded by local elites: landlords, politicians and Catholic clergymen. Indeed, following independence, some of the Anglo-Irish landlords who had been involved in the cooperative movement left Ireland, including Plunkett himself, who moved to England and devoted himself to the cause of cooperative agriculture around the world.

3. Data and empirical specification

We combine two novel datasets of Danish and Irish cooperative creameries from 1898 to 1903. For Denmark, our data are collected by the Committee for Creamery Statistics and published as *Dansk Mejeri-Drifts-Statistik* (MDS, 'Operational Statistics for Danish Creameries'). Apart from basic characteristics such as location, year of establishment, number of shareholders etc., the reports also include information on inputs and outputs as well as the technologies employed in the production of mainly butter (Henriques et al. (2024)). The MDS data are combined with data published as *Annual Reports of the Irish Agricultural Organisation Society* (IAOS) that have similar detailed information on Irish cooperative creameries (McLaughlin et al., 2024). The result is an unbalanced panel of 2,391 observations for 712 cooperative creameries: 541 in Denmark and 171 in Ireland, covering the years 1898 to 1903.⁴ Table 1 reports summary statistics, and Figure 1 overlays histograms for milk/butter ratios for Danish and Irish creameries. The milk/butter (MB) ratio is a simple measure of productivity used at the time, describing how many kilograms of milk it took to produce 1 kg of butter; by definition, the lower the more productive. It should be noted here that the Irish creameries were on average more productive than their Danish counterparts, although with a larger variance.⁵ This turns out to be potentially important for our empirical analysis and thus we explore this a little more below, where we employ a method inspired by Hadri et al. (2003) and Battese and Coelli (1993,1995), allowing the mean and variance of technical efficiency to depend on observables (Dakpo et al., 2022). Otherwise, the Danish creameries processed more milk, and thus produced more butter, than their Irish counterparts. On the other hand, the former had fewer 'shareholders' (farmer owners of the cooperatives), an average of 156 per creamery, relative to 194 in Ireland.

Table 1. Summary statistics.

	Observations	Mean	St. Dev.	Min	Q25	Median	Q75	Max
Denmark (N = 1815)								
MB ratio	1881	26.07	0.69	24.10	25.60	26.00	26.50	29.60
Butter	1884	79427	34130	5024	54489	74867	99580	269366
Milk	1881	2067072	879340	132653	1413589	1961401	2599944	6841896
Shareholders	1817	155.96	73.39	4	104	142	201	541
Ireland (N = 508)								
MB ratio	511	25.26	1.65	20.75	24.48	25.21	25.93	53.01
Butter	556	56343	36990	1764	28349	46830	79364	282946
Milk	509	1410144	928846	42076	701784	1180370	1970387	7073491
Shareholders	1126	166.46	183.82	5	66	113	187	1620
Total (N = 2323)								
MB_ratio	2392	25.90	1.03	20.75	25.40	25.90	26.40	53.01
Butter	2440	74167	36118	1764	47624	70483	95982	282946
Milk	2390	1927166	929686	42076	1247333	1831327	2498028	7073491
Shareholders	2943	159.97	127.56	4	88.5	134	200	1620

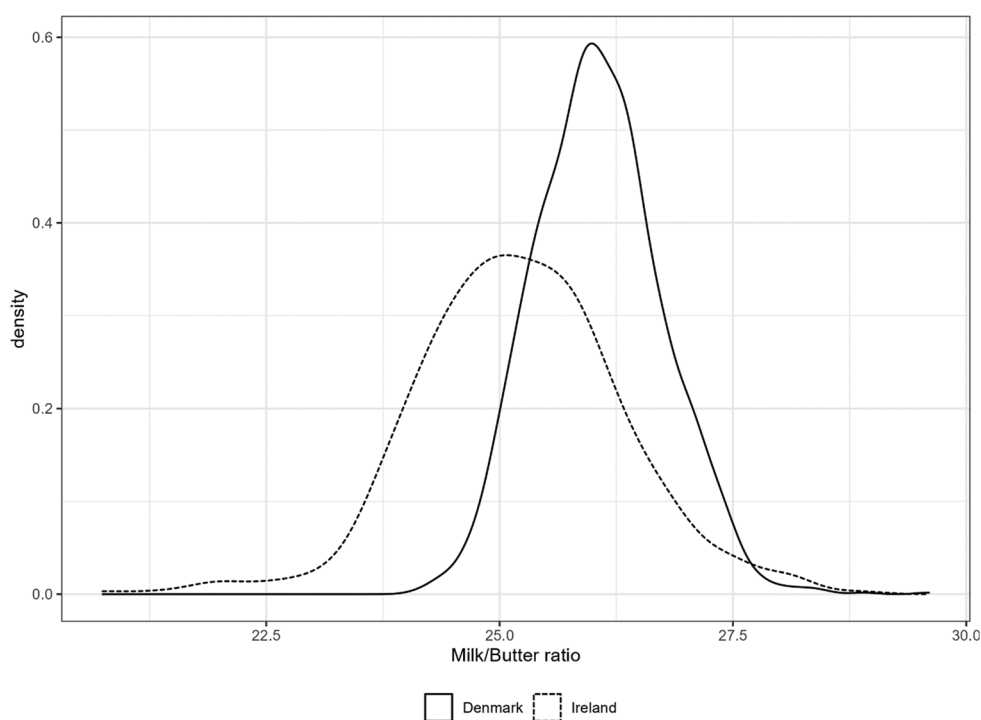


Figure 1. Milk/butter ratios for Danish and Irish creameries, 1898–1903.

Notes: This figure shows the percentage of creameries in the full distribution of creameries (on the y-axis) by the kg of milk required to produce 1 kg of butter, for Denmark and Ireland separately. The density is estimated using the Gaussian kernel as implemented in the ggplot2 library (Wickham, 2016).

Source: Henriques et al. (2024); McLaughlin et al. (2024).

Unfortunately, comparable data was not published by the IAOS between 1904 and 1912, and we decided to exclude the period from 1913 onwards. Interference during the First World War meant that cooperative creameries lost their close association with constructive unionism and began to be linked instead with nationalist politics, especially in comparison with British-owned proprietary creameries. Then, during the War of Independence, creameries were targets of reprisal attacks by Crown Forces who perhaps saw them as local gathering-places for a population into which Irish Republican Army members seemed to blend seamlessly. According to one report, some 42 creameries had been damaged by November 1920, a testament to their significance as community gathering places in the eyes of the British forces (Bolger, 1977).

The methodology we employ is Stochastic Frontier Analysis (SFA), which has already been used in the Danish context, although for earlier years and other data, by Henriksen et al. (2011) and Lampe and Sharp (2015).⁶ In short, the idea is to estimate a production possibility frontier (PPF), the maximum output (which in our case is butter) given a certain quantity of inputs (which in our case is milk). The econometric procedure provides an estimate of the slope of the PPF based on the most productive firms, i.e. those with the lowest milk/butter ratio, but also provides firm (and in some specifications year) level estimates of the distance between what is actually produced, and what might have been produced on the PPF (corresponding to ‘best practice’). Firms, our creameries, might typically be expected to aim to increase output without increasing the inputs used. Equivalently, they would aim to increase

efficiency. In [Section 4](#), we provide an illustration of the estimated PPF and some sample deviations from this (shown in [Figure 2](#)). Somewhat counterintuitively, firms can also be observed to produce above the PPF, but this is due to the fact that SFA is based on separating the standard error term from regression analysis into a standard stochastic error and an inefficiency term (Kumbhakar & Lovell, 2000; Kumbhakar et al., 2020a,2020b), and thus allows for the deviations of observed choices from the optimal ones due to two factors: a failure to optimize, i.e. inefficiency, but also random elements including measurement error.

In modern studies, the estimated inefficiencies can be used to identify which firm needs intervention and then corrective measures can be taken – a large part of the motivation for publishing the statistics we use in the first place, although contemporaries did not have the same statistical tools to draw from. While the creamery-level estimates might have some interest, our focus here is the average national performance to assess whether Danish or Irish cooperatives were more efficient. We then go one step further and extend the analysis by modelling the inefficiency term to understand the determinants of inefficiency. We use the procedure developed by Battese and Coelli (1995) and Hadri et al. (2003). The new implementation by Dakpo et al. (2022) allows for the inefficiencies (both the mean of the inefficiencies and the variance ‘risk’ of the inefficiencies) to be explained by specific factors, more pertinently whether the cooperative is Danish or Irish, but we also include the number of members (shareholders) of the cooperative as an indicator of size, which is common in related studies. We have no particular expectation about whether larger or smaller creameries might be more or less efficient.

We estimate the PPF using three specifications. The first and simplest, is an Ordinary Least Squares (OLS) model (column 1 of [Table 2](#)). The second and third specifications use a

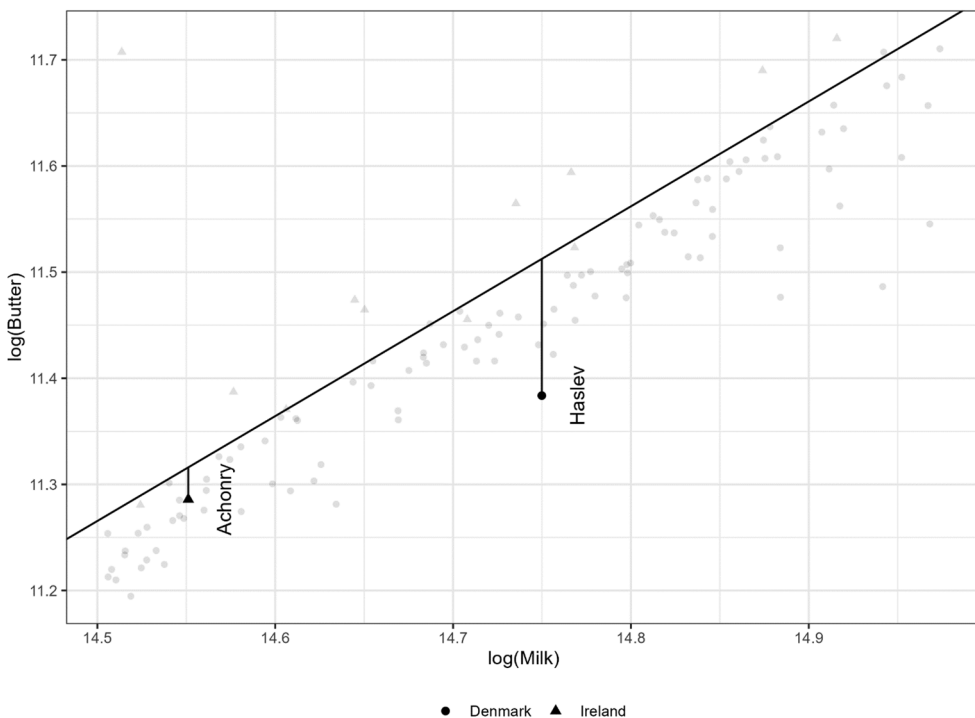


Figure 2. Estimated PPF with examples from the sample.

Stochastic Frontier Analysis (SFA) model, assuming the distribution of the estimated inefficiencies (intuitively the distance between the observed output and the PPF) can be modelled by half normal (column 2) and log normal (column 3) distributions respectively. These three specifications help to explore the differences in variance in the milk/butter ratios presented in [Figure 1](#) and understand better their sources and implications.

The standard OLS specification is included to demonstrate that similar results follow from a method which is more widely used than SFA. We estimate the following specification:

$$\ln(\text{Butter}_{it}) = \alpha_t + \ln(\text{Milk}_{it})\beta_1 + \log(\text{Shareholders}_{it})\beta_2 + 1[\text{Nation}_i = \text{Ireland}]\delta_1 + \varepsilon_{it} \quad (1)$$

Here, $\ln(\text{Butter}_{it})$ is the log of butter in creamery i at time t . α_t gives year fixed effects. $\ln(\text{Milk}_{it})\beta_1$ models the production function with β_1 assumed to be positive, i.e. more milk, more butter. $\log(\text{Shareholders}_{it})\beta_2$ controls for the effects of the size of the creamery, as measured by the number of owner-farmers ('shareholders'). Finally, $1[\text{Nation}_i = \text{Ireland}]$ is an indicator function for whether a creamery is in Ireland or Denmark. Here δ_1 is our parameter of interest. It captures the approximate percentage increase in butter production which should be expected in Ireland rather than Denmark for the same butter input and the same number of shareholders.

However, the average might not be the interesting difference here. A fable of unknown origin but well known in some academic circles is that of the statistician who drowned while trying to cross a river. He believed it would be safe since it was only half a metre deep *on average*. But as most of the river was shallow but a small portion was much deeper, he drowned. In a similar way, and suggested by the different distributions of milk/butter ratios, it might just be that we are missing some important details; in particular, we suspect, a difference in the distribution of inefficiencies. That would explain the larger spread in the milk/butter ratio observed in Ireland in [Figure 1](#) and [Table 1](#).

We start with the following specification to model the production function, which describes the PPF, and the inefficiency term for each firm:

$$\ln(\text{Butter}_{it}) = \beta_0 + \ln(\text{Milk}_{it})\beta_1 + \log(\text{Shareholders}_{it})\beta_2 + \text{Trend}\beta_3 + v_{it} - u_{it} \quad (2)$$

Where the main input $\ln(\text{Milk}_{it})$ in the production function is the amount of milk used in kg and *Trend* captures average yearly changes in butter production, for example due to technological advancements at the industry level. v_{it} is the noise error term, while u_{it} is the inefficiency term. We start by simply modelling this inefficiency distribution based on a half-normal distribution:

$$u_{it} \sim \mathcal{N}^+(0, \sigma_u) \quad (2')$$

This gives us an estimate of the inefficiency of each creamery, and enables comparisons between them. However, it might also implicitly impose a strong restriction on the variance of the inefficiency term, which matters since the model is estimated using maximum likelihood which is only valid when it is plausible to assume a specific given probability distribution. We can however explicitly model the inefficiencies in more detail, and do so by including explanatory variables for the mean level of inefficiency μ_u and the variance of inefficiency the 'risk' in production, $\sigma_{u'}$ for the individual firm and time (indicated by subscript *it*):

$$\ln(u_{it}) \sim \mathcal{N}(\mu_{u,it}, \sigma_{u,it})$$

$$\mu_{u,it} = \delta_0 + \ln(\text{Shareholders}_{it})\delta_1 + 1[\text{Nation}_i = \text{Ireland}]\delta_2 \quad (2'')$$

$$\sigma_{u,it} = \exp(\theta_0 + \ln(\text{Shareholders}_{it})\theta_1 + 1[\text{Nation}_i = \text{Ireland}]\theta_2)$$

where the inefficiency term now includes the number of shareholders, and the dummy for whether the creamery was located in Denmark or Ireland, which is our main coefficient of interest. We model the effect to both the variance and the mean of the inefficiencies, giving us the two δ_2 parameters of interest δ_2 and θ_2 respectively. If δ_2 is large, this corresponds to a large effect to efficiency of being in Ireland rather than Denmark. If θ_2 is large this corresponds to greater variation in productive efficiency in Ireland rather than Denmark.

4. Results

Table 2 reports the results of our estimates. Column (1) contains basic OLS results (Equation (1)). Column (2) contains estimates using the half-normal inefficiency distribution (Equations (2) and (2')). Column (3) contains results using the log normal distribution, and where the inefficiency is modelled – both the mean inefficiency and the variance of inefficiency – by number of shareholders and whether production was in Ireland or Denmark (Equations (2) and (2'')).

Table 2. Results.

Specification/dependent variable	(1) OLS ln (Butter)	(2) SFA half-normal ln (Butter)	(3) SFA log normal ln (Butter)
Production function			
Intercept		−3.080*** (0.0190)	−3.1494*** (0.0202)
ln(Milk)	1.0006*** (0.0032)	0.9882*** (0.0013)	0.9973*** (0.0016)
Ireland	0.0357*** (0.0028)		
Trend		0.0054*** (0.0004)	0.0062*** (0.0004)
Technical inefficiency			
Intercept			−2.2757*** (0.1201)
ln(Shareholders)			−0.0130*** (0.0160)
Ireland			−0.5471*** (0.0958)
Inefficiency variance			
Intercept			−11.444*** (0.0157)
ln(Shareholders)			−2.5013*** (0.0339)
Ireland			21.934*** (0.0157)
Year FE	Yes	–	–
R ²	0.9967		
σ_u		0.0011	0.2831
σ_v	0.0011	0.0009	0.0007
γ		0.5531	0.9976
Average efficiency		0.9745	0.9076
Observations	2323	2323	2323
Creameries	933	933	933

Notes: Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ The years included are 1898–1903.
Source: MDS and IAOS.

For illustrative purposes, [Figure 2](#) provides an example of the estimated inefficiency of two creameries, Achonry in Ireland and Haslev in Denmark, based on the specification given in column 3. The slope of the PPF is estimated to be 0.9973, and gives the optimal production of (log of) butter for a given quantity of (log of) milk. There are (slightly) diminishing returns to milk, so that a 1 per cent increase in milk processed leads to a less than one per cent increase in butter produced. Both Achonry and Haslev produce below the PPF, although the former is closer to producing optimally, but on a smaller scale.

From column 1 of [Table 2](#), it should be noted how Irish creameries on average produce around 3.6 per cent more butter for any input of milk, but [Figure 1](#) seems to suggest that the distribution might be very different. Thus, the other columns decompose this result. The efficiency estimates based on the half-normal distribution and [Equations \(2\) and \(2'\)](#) can be compared across borders. We do this in [Table 3](#) and [Figure 3](#) that show Irish creameries to be slightly more efficient than Danish creameries – though with a higher variance. However, this very fact breaks the assumption of homoscedasticity, which is necessary to estimate the SFA in the first place. As such, we proceed to a more ‘formally correct’ estimate in column 3

Table 3. Technical efficiency by nation, 1898–1903.

Sample	Mean	St.D.	Min	Median	Max
Denmark	0.9735890	0.0082060	0.9218957	0.9750350	0.9890289
Ireland	0.9793739	0.0177693	0.6523875	0.9822707	0.9958285
Full sample	0.9748541	0.0112814	0.6523875	0.9762538	0.9958285

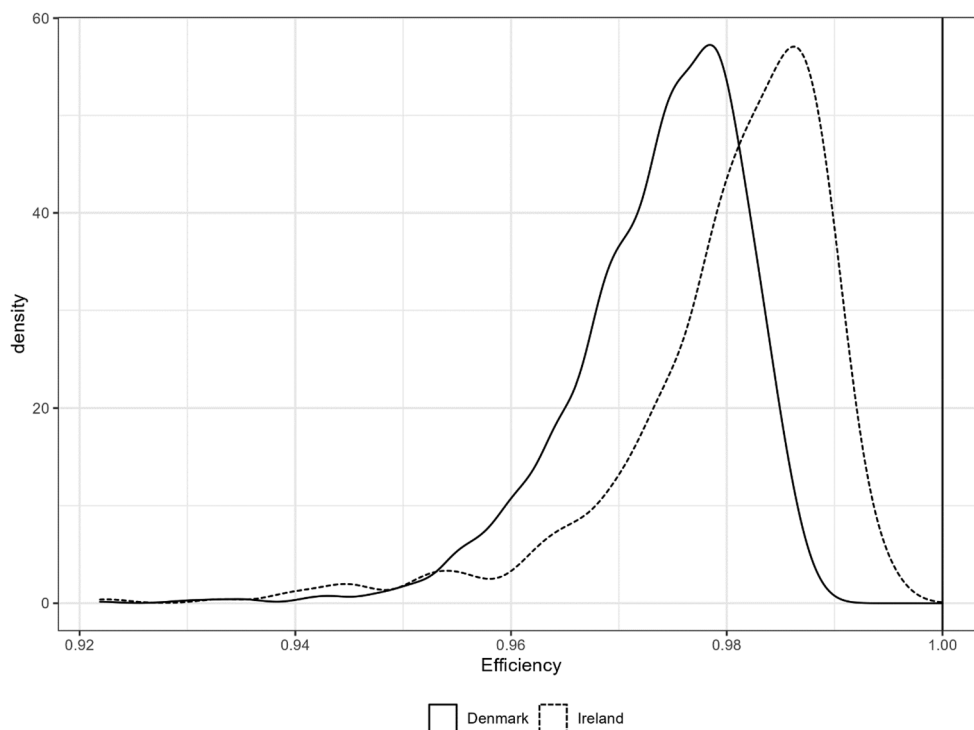


Figure 3. Technical efficiencies for Danish and Irish creameries, 1898–1903.

Notes: The results are as reported in specification 3 of [Table 2](#). We have filtered away efficiencies below 0.9 (only 1 observation). The density is estimated using the Gaussian kernel as implemented in the `ggplot2` library ([Wickham, 2016](#)).

(Equations (2) and (2')).⁷ Here, we model how the number of shareholders and more importantly, the country of production influences the technical efficiency of production. The parameter estimate of -0.5471 in column (3) suggests that the technical efficiency is higher on average in Ireland (or equivalently inefficiency is lower).⁸ That is, less is lost in production compared to our estimated production possibility frontier. However, as Figures 1 and 3 already suggested, the variance of the inefficiency is higher, by 21.934.⁹ Thus, although Irish creameries, in their full distribution, were on average slightly more efficient (have lower milk/butter ratios) than their Danish counterparts in terms of milk/butter ratio which contradicts what we might have expected given the traditional narrative, there were many, well below the mean efficiency (having higher milk/butter ratio).

Nothing so far explains why the Irish lost market share to the Danish, but the large variance in the Irish sample is striking. As an obvious next step, we consider whether this relates to quality of output in some way: for example, low efficiency might reflect poor management which might also reveal itself in the quality of the final product. In fact, it is well known that Danish butter was of exceptionally high-quality, with a uniformity of taste and appearance, and Denmark reacted quickly to the threat posed by the invention of margarine through legislation allowing consumers to differentiate it from real butter. By contrast, the uneven quality of Irish produce has been recognised by contemporaries as well as subsequent scholars, see e.g. Faber (1918), Ó Gráda (1977) and Lampe and Sharp (2014). Already in 1901, a common 'Lur brand' was created to signal the national origin and quality of Danish export butter, whereas Kerrygold was only launched in Ireland in the 1960s. In order to consider the quality angle, we use the price received by the individual Irish creamery for their butter, and we correlate it with the milk/butter ratio. Figure 4 reveals a striking relation between efficiency and quality, as measured by the price of butter. If buyers were prepared to pay more for large quantities of a homogenous product, or if the poor quality of some producers had a negative impact on industry-level reputation, then such variance in quality might be able to explain the relative failure of Irish dairying.

Finally, we consider whether productivity differed within Ireland. As McLaughlin and Sharp (2021, p. 330) noted, the IAOS soon discovered that competition with proprietary enterprises made it more attractive to establish cooperatives in the north of Ireland. Figure 5 illustrates this point very clearly, with a surge in the number of cooperatives in Ulster from around 1896 onwards. Figure 6 demonstrates that these were also more productive than their southern counterparts.¹⁰ Indeed, outside of Ulster, the average productivity of cooperatives was not greatly different from those in Denmark (although as we have seen, the variance was still greater). This could be because they were established later, and had less depreciated capital equipment. But given that the year of establishment only differed by a few years, this seems unlikely. However, the pernicious impact of competition on the industry seemed to be more important. As Henriksen et al. (2015) explain, the difficulty of enforcing vertically binding contracts in Ireland, together with often belligerent competition from proprietary incumbents, might have reinforced poor social capital in the Irish countryside and had a pernicious effect on quality. Creameries were sometimes forced to accept poor quality milk out of fear of a loss of supply, and IAOS attempts to promote quality control measures fell foul to rivals undercutting policies. In Denmark, by contrast, contracts were enforced and farmers would face large fines if they ceased supplying a cooperative.

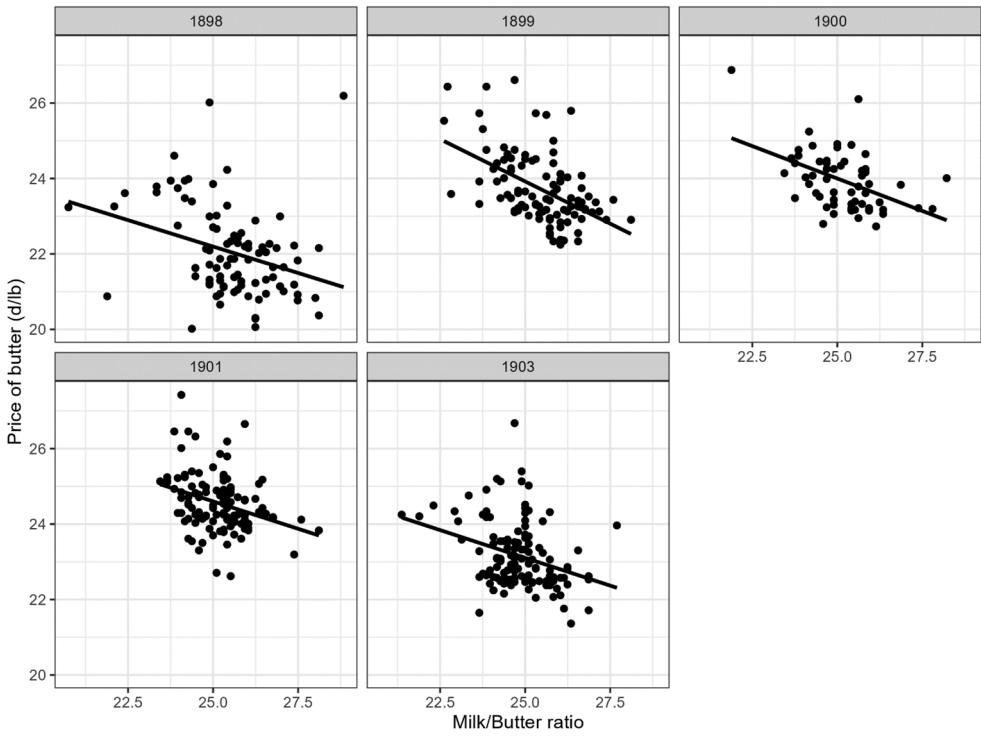


Figure 4. Milk/butter and prices for Irish Creameries, by year, 1898–1903.

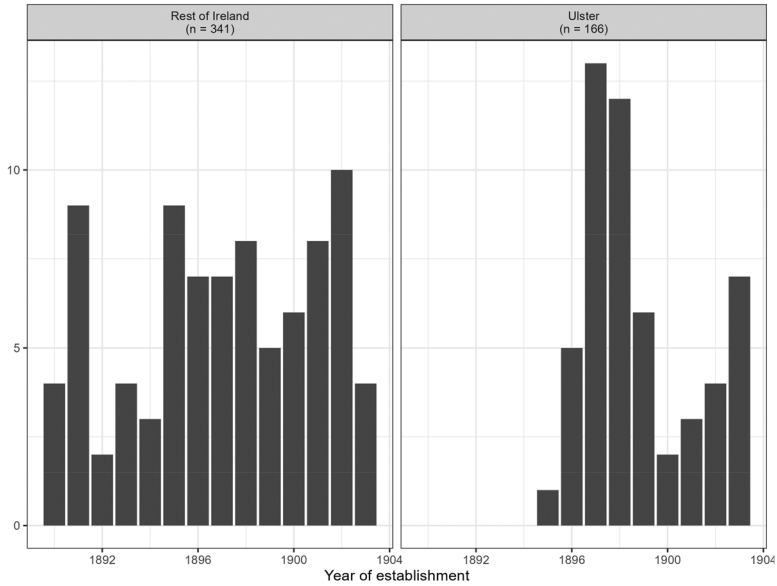


Figure 5. Number of Irish creameries established per year, Ulster vs. the rest of Ireland, 1898–1903.

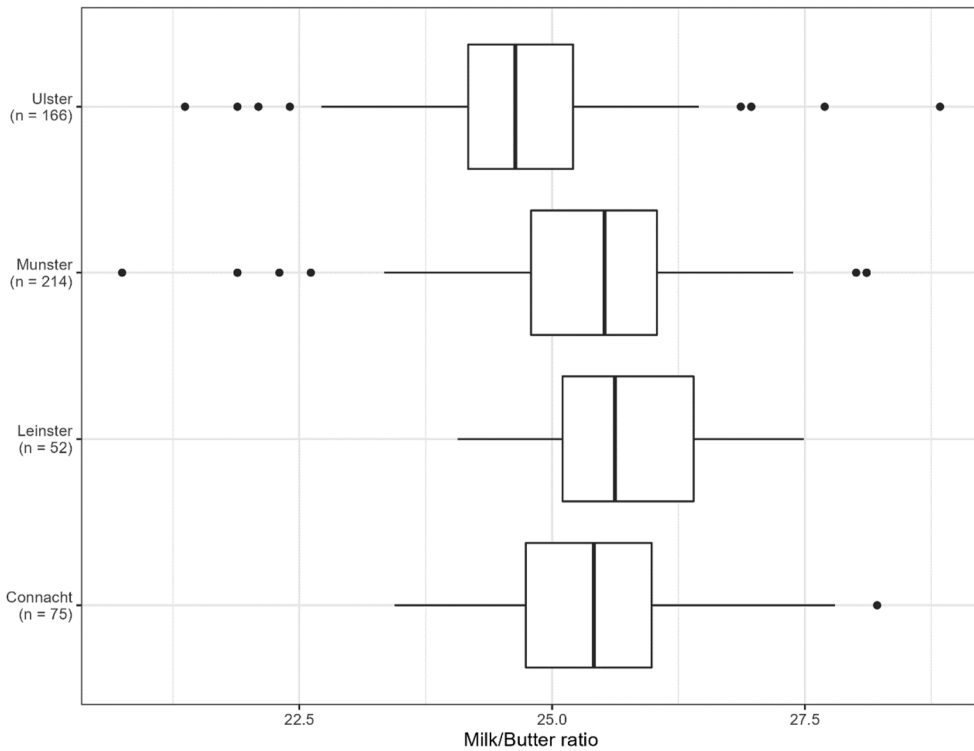


Figure 6. Milk/butter ratios by Irish Province, 1898–1903.

5. Conclusion

Using a detailed microlevel database of Danish and Irish creameries, we demonstrate that there was little statistical difference between the productivity of the cooperatives in the two countries. In fact, if anything on average Irish creameries were slightly more efficient, although they suffered from a greater variance in productivity. This is apparent both from simple milk/butter ratios, but also when we apply more advanced statistical methods. A tentative conclusion based on this might be that the relative Irish failure was not due to an inability of Irishmen to employ the cooperative institution or the new technology – at least on the very local level we have considered here – although it seems that they were unable to do this as consistently as the Danes. A clear limitation to our analysis is that we do not have information on the important proprietary sector in Ireland, which was perhaps more efficient, although competition for milk supplies with cooperatives might have led to inefficiencies.

Our findings suggest that future work should consider reasons for the relative failure of Irish dairying beyond a simple inability to use efficiently the cooperative form, such as legal or competitive barriers to the spread of Irish cooperatives, or simply that Irish farmers considered other activities, such as rearing cattle for live export or condensed milk manufacturing for the military to be a more profitable enterprise. For example, Ireland benefitted from (non-tariff) protective barriers to the British market for live cattle imports from 1869 onwards (McLaughlin, 2015, p. 88), and thereafter Irish farmers consistently held a dominant share of British cattle imports (Perren, 1971). Thus, according to official

statistics, livestock exports constituted 42.33 per cent of all exports from 1924–28, whereas butter exports were a mere 9.28 per cent. In contrast, Denmark faced tariff and non-tariff barriers on live cattle exports to Germany, its traditional market, from 1879 (O'Rourke, 2017, p. 44), coinciding with both the Danish reorientation towards Britain and towards dairying.

Notes

1. However, this is contested. Bielenberg (2009) argues that Ireland suffered from a lack of access to coal due to high internal transport costs and that only Belfast was able to take advantage of lower shipping costs.
2. See also surveys on success on the microlevel: Haddoud et al. (2021, based on 82 papers) on "export entry" of firms, and Cefis et al. (2021, based on 142 journal articles) on the determinants of firm, specifically SME, exit.
3. Although Danish land reforms also created a class of losers, with little or no land, many of whom left for America, where they would often found (sometimes cooperative) creameries (Boberg-Fazlić et al., 2024; Boberg-Fazlić & Sharp, 2023).
4. In the analysis, a few creameries are dropped due to lack of data in all years. Note that 2,391 observations for 712 cooperative creameries over 6 years implies 3.6 years per cooperative and 399 observations per year on average, a result of the unbalanced nature of the panel data.
5. One technical issue we had to solve was the conversion from imperial to SI units. This is trivial for most variables. However, milk is measured by volume in IAOS and by weight in MDS. This requires a conversion based on the density of milk, which is not entirely constant. We used 1.035 kg/l, as suggested by Jones (2002). The density of milk varies slightly with the fat content and temperature. The range of feasible values is somewhere between 1.027–1.035 kg/l. This is all within a range which does not impact our results in any appreciable way.
6. For an accessible introduction to these models, which are widely used in economics and business studies, see Woltjer (2018).
7. No assumptions are violated in the OLS estimate. But it does not allow to understand the distribution of the production efficiencies.
8. This model is not linear, so we cannot directly interpret the coefficient. It is however possible to compute "average partial effects" (APEs). If we use the parameter estimates and change only whether the creamery was in Denmark or in Ireland, and let all remaining data for the creameries be the same, then we can estimate that the model implies an average difference in butter output of 0.04059, which is equivalent to around 4 per cent higher efficiency in Ireland.
9. We can also compute APEs here. Irish creameries had on average a standard deviation in production "risk", which was 0.56 standard deviations higher than the counterfactual Danish counterpart (counterfactual in the sense that it is implied by the model, when we use our parameters to predict, setting all creameries to have Ireland = 1 or all creameries to have Ireland = 0).
10. This was also noted by McLaughlin et al. (2024). However, this advantage did not persist beyond the First World War.

Acknowledgements

We would like to thank participants at seminars and conferences, as well as the editor and two anonymous referees, for helpful comments and suggestions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

We gratefully acknowledge support from the Danish Council for Independent Research (grant no. DFF-6109-00123).

Notes on contributors

Eoin McLaughlin is a professor of Economics at Edinburgh Business School, Heriot-Watt University.

Paul Sharp is a professor of Economic History at the University of Southern Denmark.

Xanthi Tsoukli is a postdoctoral research associate at the University of Bamberg.

Christian Vedel is an assistant professor at the University of Southern Denmark.

ORCID

Paul Sharp  <http://orcid.org/0000-0003-0679-0106>

References

- Balleisen, E. J. (2020). The prospects for collaborative research in business history. *Enterprise & Society*, 21(4), 824–852. <https://doi.org/10.1017/eso.2020.68>
- Battese, G. E., & Coelli, T. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, 20(2), 325–332. <https://doi.org/10.1007/BF01205442>
- Battese, G. E., & Coelli, T. J. (1993). *A stochastic frontier production function incorporating a model for technical inefficiency effects*. Working Papers in Econometrics and Applied Statistics No. 69, Department of Econometrics. University of New England. Armidale. https://www.researchgate.net/profile/George-Battese/publication/245083353_A_Stochastic_Frontier_Production_Function_Incorporating_a_Model_of_Technical_Inefficiency_Effects/links/5726935108aee491cb3f100f/A-Stochastic-Frontier-Production-Function-Incorporating-a-Model-of-Technical-Inefficiency-Effects.pdf
- Bernard, A. B., Jensen, J. B., Redding, S. J., & Schott, P. K. (2018). Global firms. *Journal of Economic Literature*, 56(2), 565–619. <https://doi.org/10.1257/jel.20160792>
- Bielenberg, A. (2009). *Ireland and the Industrial Revolution: The impact of the Industrial Revolution on Irish Industry, 1801-1922*. Routledge.
- Boberg-Fazlić, N., & Sharp, P. (2023). Immigrant communities and knowledge spillovers. *American Economic Journal: Macroeconomics* 16(1): 102–146.
- Boberg-Fazlić, N., Jensen, P. S., Lampe, M., Sharp, P., & Skovsgaard, C. V. (2023). Getting to Denmark: The role of elites for development. *Journal of Economic Growth*, 28(4), 525–569. <https://doi.org/10.1007/s10887-023-09226-8>
- Boberg-Fazlić, N., Lampe, M., & Sharp, P. (2024). The sleeping giant who left for America: Danish land inequality and emigration during the age of mass migration. *Explorations in Economic History*, 91, 101525. <https://doi.org/10.1016/j.eeh.2023.101525>
- Boberg-Fazlić, N., Lampe, M., Lasheras, P. M., & Sharp, P. (2022). Winners and losers from agrarian reform: Evidence from Danish land inequality 1682–1895. *Journal of Development Economics*, 155, 102813. <https://doi.org/10.1016/j.jdeveco.2021.102813>
- Bolger, P. (1977). *The Irish co-operative movement: Its history and development*. Institute of Public Administration.
- Boone, C., & Özcan, S. (2014). Why do cooperatives emerge in a world dominated by corporations? The diffusion of cooperative in the US bio-ethanol industry, 1978-2013. *Academy of Management Journal*, 57(4), 990–1012. <https://doi.org/10.5465/amj.2012.0194>

- Breathnach, P. (2006). *The diffusion of the co-operative creamery system in Ireland, 1889–1920: A spatial analysis* [PhD thesis]. Department of Geography, National University of Ireland Maynooth.
- Breathnach, P. (2012). Reluctant co-operators: Dairy farmers and the spread of creameries in Ireland 1886–1920. In Duffy, P. & Nolan, W. (Eds.), *At the Anvil: Essays in honour of William J. Smyth* (pp. 555–573). Geography Publications.
- Cefis, E., Bettinelli, C., Coad, A., & Marsili, O. (2022). Understanding firm exit: A systematic literature review. *Small Business Economics*, 59(2), 423–446. <https://doi.org/10.1007/s11187-021-00480-x>
- Chandler, A. (1976). Institutional integration: An approach to comparative studies of the history of large-scale business enterprise. *Revue Économique*, 27(2), 177–199. <https://doi.org/10.2307/3500540>
- Dakpo, K. H., Desjeux, Y., & Latruffe, L. (2022). *sfaR: Stochastic frontier analysis using R. R package version 0.1.1*. <https://CRAN.R-project.org/package=sfaR>.
- Doyle, P. (2019). *Civilising rural Ireland: The co-operative movement, development and the nation-state, 1889–1939*. Manchester University Press.
- Faber, H. (1918). *Co-operation in Danish agriculture*. Longmans, Green.
- Foley-Fisher, N., & McLaughlin, E. (2016). Capitalising on the Irish land question: Land reform and state banking in Ireland, 1891–1938. *Financial History Review*, 23(1), 71–109. <https://doi.org/10.1017/S0968565016000019>
- Gary, K., Jensen, P. S., Olsson, M., Radu, C. V., Severgnini, B., & Sharp, P. (2022). Monopsony power and wages: Evidence from the introduction of serfdom in Denmark. *Economic Journal*, 132(648), 2835–2872. <https://doi.org/10.1093/ej/ueac037>
- Gráda, C. Ó. (1977). The beginnings of the Irish creamery system, 1880–1914. *Economic History Review*, 30(2), 284–305.
- Haddoud, M. Y., Onjewu, A. K. E., Nowiński, W., & Jones, P. (2021). The determinants of SMEs' export entry: A systematic review of the literature. *Journal of Business Research*, 125, 262–278. <https://doi.org/10.1016/j.jbusres.2020.12.017>
- Hadri, K., Guermat, C., & Whittaker, J. (2003). Estimation of technical inefficiency effects using panel data and doubly heteroscedastic stochastic production frontiers. *Empirical Economics*, 28(1), 203–222. <https://doi.org/10.1007/s001810100127>
- Henriksen, I., Hviid, M., & Sharp, P. (2012a). Law and peace: Contracts and the success of the Danish dairy cooperatives. *Journal of Economic History*, 72(1), 197–224. <https://doi.org/10.1017/S0022050711002488>
- Henriksen, I., Lampe, M., & Sharp, P. (2011). The role of technology and institutions for growth: Danish creameries in the late nineteenth century. *European Review of Economic History*, 15(3), 475–493. <https://doi.org/10.1017/S1361491611000128>
- Henriksen, I., Lampe, M., & Sharp, P. (2012b). The strange birth of liberal Denmark: Danish trade protection and the growth of the dairy industry since the mid-nineteenth century. *Economic History Review*, 65(2), 770–788. <https://doi.org/10.1111/j.1468-0289.2010.00595.x>
- Henriksen, I., McLaughlin, E., & Sharp, P. (2015). Contracts and cooperation: The relative failure of the Irish dairy industry in the late nineteenth century reconsidered. *European Review of Economic History*, 19(4), 412–431. <https://doi.org/10.1093/ereh/hev012>
- Henriques, S., & Sharp, P. (2016). The Danish agricultural revolution in an energy perspective: A case of development with few energy resources. *Economic History Review*, 69(3), 844–869. <https://doi.org/10.1111/ehr.12236>
- Henriques, S., McLaughlin, E., Sharp, P., Tsoukli, X., & Vedel, C. (2024). A microlevel analysis of Danish dairy cooperatives: Opportunities for large data in business history. *Enterprise and Society*, 25(3), 669–697.
- Higgins, D. M., & Mordhorst, M. (2015). Bringing home the “Danish” bacon. *Enterprise & Society*, 16(1), 141–185.
- Jenkins, W. (2004). Capitalists and co-operators: Agricultural transformation, contested space, and identity politics in south Tipperary, Ireland, 1890–1914. *Journal of Historical Geography*, 30(1), 87–111. [https://doi.org/10.1016/S0305-7488\(02\)00145-7](https://doi.org/10.1016/S0305-7488(02)00145-7)
- Jones, A. N. (2002). Density of milk. In G. Elert (Ed.), *The Physics Factbook: An encyclopedia of scientific essays*. <https://hypertextbook.com/facts/2002/AliciaNoelleJones.shtml>
- Kumbhakar, S. C., & Lovell, C. A. K. (2000). *Stochastic frontier analysis*. Cambridge University Press.

- Kumbhakar, S. C., Parmeter, C. F., & Zelenyuk, V. (2020a). Stochastic frontier analysis: Foundations and advances I. In Ray, S., Chambers, R., & Kumbhakar, S. (Eds.), *Handbook of production economics*. Springer. https://doi.org/10.1007/978-981-10-3450-3_9-1
- Kumbhakar, S. C., Parmeter, C. F., & Zelenyuk, V. (2020b). Stochastic frontier analysis: Foundations and advances II. In Ray, S., Chambers, R., & Kumbhakar, S. (Eds.), *Handbook of production economics*. Springer. https://doi.org/10.1007/978-981-10-3450-3_11-1
- Lampe, M., & Sharp, P. (2014). Greasing the wheels of rural transformation? Margarine and the competition for the British butter market. *Economic History Review*, 67(3), 769–792. <https://doi.org/10.1111/1468-0289.12046>
- Lampe, M., & Sharp, P. (2015). Just add milk: A productivity analysis of the revolutionary changes in nineteenth-century Danish dairying. *Economic History Review*, 68(4), 1132–1153. <https://doi.org/10.1111/ehr.12093>
- Lampe, M., & Sharp, P. (2017). A quest for useful knowledge: The early development of agricultural accounting in Denmark and Northern Germany. *Accounting History Review*, 27(1), 73–99. <https://doi.org/10.1080/21552851.2016.1264985>
- Lampe, M., & Sharp, P. (2019). *A land of milk and butter: How elites created the modern Danish dairy industry*. University of Chicago.
- Lampe, M., & Sharp, P. R. (2019). Cliometric approaches to international trade. In *Handbook of cliometrics* (2nd ed., 295–330). Springer.
- McLaughlin, E. (2015). Competing forms of cooperation? Land league, land war and cooperation in Ireland, 1879 to 1914. *Agricultural History Review*, 63, 81–112.
- McLaughlin, E., & Sharp, P. (2021). Competition between organisational forms in Danish and Irish dairying around the turn of the twentieth century. *Business History*, 63(2), 314–341.
- McLaughlin, E., Sharp, P., Tsoukli, X., & Vedel, C. (2024). A firm level database of Irish Creameries, 1897–1921. *Irish Economic and Social History*, 51(1), 48–74. <https://doi.org/10.1177/03324893231161927>
- Medina-Albaladejo, F., & Menzani, T. (2017). Co-operative wineries in Italy and Spain in the second half of the twentieth century: Success or failure of the cooperative business model? *Enterprise & Society*, 18(1), 32–71. <https://doi.org/10.1017/eso.2016.17>
- Moulton, M. (2017). Not to nationalise, but to rationalise? Cooperatives, leadership and the state in the Irish dairy industry 1890–1932. *Irish Economic and Social History*, 44(1), 85–101.
- O'Rourke, K. (2006). *Late nineteenth-century Denmark in an Irish mirror: Land tenure, homogeneity, and the roots of Danish success* (pp. 159–196). McGill-Queen's University Press.
- O'Rourke, K. H. (2007). Culture, conflict and cooperation: Irish dairying before the great war. *Economic Journal*, 117(523), 1357–1379.
- O'Rourke, K. H. (2017). Independent Ireland in comparative perspective. *Irish Economic and Social History*, 44(1), 19–45. <https://doi.org/10.1177/0332489317735410>
- Perren, R. (1971). The North American beef and cattle trade with Great Britain, 1870–1914. *Economic History Review*, 24(3), 430–444. <https://doi.org/10.2307/2594053>
- Webster, A., & Walton, J. K. (2012). Introduction. *Business History*, 54(6), 825–832. <https://doi.org/10.1080/00076791.2012.706897>
- Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag New York. ISBN 978-3-319-24277-4. <https://ggplot2.tidyverse.org>.
- Woltjer, P. (2018). Frontier analysis. In Blum, M. & C. Colvin (Eds.), *An economist's guide to economic history*. Palgrave.