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The Competitiveness of the Irish Dairy Industry in the Global Market: Farm to Trade

Thesis presented by

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March 2023



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DECLARATION 1: PLAGIARISM

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism and intellectual property.

Lungelo Cele

March 2023

DECLARATION 2: PUBLICATIONS AND CONFERENCES

PUBLICATIONS

The following publications form part of the research presented in this thesis.

Publication Manuscript 1 (Chapter 3- **Published** December 2022)

Cele, L.P., Hennessy, T. and Thorne, F. 2022. Evaluating farm and export competitiveness of the Irish dairy industry: post-quota analysis. *Competitiveness Review: An International Business Journal* 32(7): 1-20. [1908 downloads as of 30 January 2023-7 citations]

- Cele, L.P., Hennessy, T. and Thorne, F. 2021. Competitive without quotas. *TResearch*, summer issue 16(2): 40-41. (Teagasc research magazine for the public)
- Shalloo, L., O'Connor, D., **Cele, L.**, Thorne, F. and Egan, M. 2020. *An analysis of the Irish dairy sector post quota*. Teagasc: Cork, Ireland.

Publication Manuscript 2 (Chapter 4- **Published** December 2022)

Cele, L.P., Hennessy, T. and Thorne, F. 2022. Regional technical efficiency rankings and their determinants in the Irish dairy industry: a stochastic metafrontier analysis. *Agribusiness: an International Journal* 00(00): 1–17. DOI: 10.1002/agr.21791

Publication Manuscript 3 (Chapter 5- **Accepted** July 2023)

Cele, L.P., Hennessy, T., Eakins, J. and Thorne, F. Price transmission analysis of Irish butter export prices in the world butter market. *International Food and Agribusiness Management Review*.

Publication Manuscript 4 (Chapter 6- **Conference Paper** December 2022)

Cele, L.P., Hennessy, T., Eakins, J. and Thorne, F. The competitiveness trends and impact of competitors on Irish butter competitiveness. *International Agricultural Trade Research Consortium*.

CONFERENCES

Cele, L.P., Hennessy, T. and Thorne, F. 2021. Farm and export competitiveness of the Irish dairy industry: post milk quota removal. *Agricultural Economics Society (UK)*, 94th Annual Conference 2021 (Online conference), 29-30 March. (**Poster presentation**)

- **Oral presentation** at *Teagasc*, Agricultural Economics and Farm Surveys (AEFS) Research Seminar, 10 March 2021.

Cele, L.P., Hennessy, T., Eakins, J. and Thorne, F. Price transmission analysis of Irish butter export prices in the world butter market. Selected presentation for the ***International Agricultural Trade Research Consortium (IATRC)***, 2022 Annual Meeting (hybrid), Sheraton Sand Key Resort in Clearwater Beach, Florida, USA, on December 11-13. Available at: <https://iatrc.umn.edu/2022-iatrc-annual-meeting/> (Session 3: Price Analysis in Global Commodity Markets - ***Oral presentation***)

Cele, L.P., Hennessy, T., Eakins, J. and Thorne, F. The competitiveness trends and impact of competitors on Irish butter competitiveness. Selected presentation for the ***International Agricultural Trade Research Consortium (IATRC)***, 2022 Annual Meeting (hybrid), Sheraton Sand Key Resort in Clearwater Beach, Florida, USA, on December 11-13. Available at: <https://iatrc.umn.edu/2022-iatrc-annual-meeting/> (Session 13: Aspects of Agricultural Export Competitiveness - ***Oral presentation***)

ABSTRACT

The removal of the EU milk quota in 2015 has increased the exposure of the Irish dairy industry to international competitors and has raised the question of how competitive is the Irish dairy industry in the global market. The purpose of this thesis was to measure Irish dairy sector – competitiveness by examining the interaction between the farming system and the trading system of processed dairy products in the global market. In the context of the removal of the EU milk quota in 2015, it examined the competitiveness trends and rankings of the Irish dairy sector at the farm and trade levels, relative to selected European Union (EU) Member States. In 2019, Ireland was the third-largest exporter of butter in the world butter market and Irish butter prices were more volatile than other Irish dairy products. Despite the significance of butter in the dairy industry, empirical research that examines the market price dynamics and international competitor behaviour in the butter market has remained scarce. The thesis contributed to the objectives of the Food Wise 2025 and the Food Vision 2030 policies by examining the dynamics between farm milk and butter prices (linking farm and trade levels) to ensure that there is a transfer of benefits from trade to farmers through price transparency.

Competitiveness indicators including partial productivity measures and accountancy-based indicators were used for farm competitiveness, and net export market share and normalised revealed comparative advantage were used for export competitiveness. A stochastic meta-frontier approach was adopted for comparing Irish regional farm technical efficiencies (proxy for farm competitiveness). The vector error correction (VEC) model was applied to test the extent to which changes in competitor prices and farm milk prices had an impact on Irish butter prices. The vector auto-regression (VAR) model was used to measure the competitiveness integration relationship between global butter competitors. Amongst the countries examined, Ireland had the highest growth in partial productivity indicators and was ranked first with the lowest total costs and cash costs per kg of milk solids post-quota amongst the main European competitor countries examined. The potential challenge for Irish dairy farmers is how to lessen the relatively high land and labour costs to come in line with the main European competitor countries, which can limit farm competitiveness in the long-run.

Based on the Irish regional farm technical efficiencies, the findings suggested that policies aiming to promote labor use and soil quality improvement in the East region would be useful for improving efficiency in that region post-quota. The findings also suggested that policies that related to discussion groups and management of herd size in the South region would also be useful for improving efficiency in that region post-quota. Some farms expanded beyond

their optimal scale leading to a reduction in efficiency levels, especially in a region like the South West. That pointed to the need to tailor farm advice and promote caution in relation to farm expansion decisions. The regional growth patterns and insights may be used for adapting the national policy frameworks to regions in policy dialogues, i.e. to achieve the Food Vision 2030 with ambitious targets set for expansion.

While Irish dairy products, such as butter and powders, have demonstrated growth potential in competitiveness post-quota, other products, i.e. cheese and liquid milk have declined. Despite the growing competition in the global butter market, Ireland became the second most competitive country in the world and was advancing rapidly at the time of analysis. Irish butter was the only Irish dairy product that had maintained a comparative advantage. Irish butter prices were more responsive to shocks in New Zealand butter prices and Irish farm milk prices in the long-run with positive bidirectional causality effects. Based on the findings, Irish dairy farmers and processors were more susceptible to pricing decisions made by international butter processors. Only New Zealand butter competitiveness had an impact or Granger-caused Irish butter competitiveness but not vice versa. Consequently, the key players in the Irish dairy industry can now better position themselves in the global dairy market, recognising the competitiveness dynamics of the different dairy products and their competitors. The thesis policy recommendations and areas for future research were presented in the conclusion section.

Keywords: Accountancy-based indicators, partial productivity, stochastic meta-frontier, country/competitiveness rankings, normalised revealed competitive advantage, price transmission, vector error correction model, farm and export competitiveness assessment, Irish butter competitiveness.

DEDICATION

I dedicate this thesis to my late brother (Dr. SR Cele) whom I made a pact with to become a “business” doctor as he was a medical doctor. I also dedicate it to my supportive family.

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I would like to thank my supervisors, namely, Dr. Fiona Thorne, Prof. Thia Hennessy and Dr. John Eakins, for their support during my PhD journey. This work would have not been possible without their wisdom or expertise and guidance which allowed me to gain confidence as an independent researcher. I have grown from your responsive and considerate mentorship approach in the course of this study.

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To my family and friends, thanks for always being there for me, especially during COVID lockdown where I could not travel back home to South Africa.

Doing this PhD has helped me to grow personally and professionally, I have significantly improved my project management, quantitative skills and communication skills. I appreciate all those who helped me along my journey.

All possible shortcomings in this study are my sole responsibility and should not be directed to any acknowledged person or organisation.

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
CAP	Common Agricultural Policy
CD	Cobb-Douglas
CSO	Irish Central Statistics Office
DAFM	Department of Agriculture, Food and the Marine
DEA	Data Envelopment Analysis
DII	Dairy Industry Ireland
DRS	Decreasing Returns to Scale
ECB	European Central Bank
ECM	Error Correction Models
EU	European Union
FADN	Farm Accountancy Data Network
FAOSTAT	Food and Agriculture Organisation Statistical Databases
ICOS	Irish Co-Operative Organisation Society
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
LU	Livestock Units
MT	Million Tonnes
NFS	National Farm Survey
NMA	National Milk Agency
NRCA	Normalised Revealed Comparative Advantage
NXMS	Net Export Market Share
OLS	Ordinary Least Squares
PP	Phillips-Perron
RC	Revealed Competitiveness
RCA	Revealed Comparative Advantage
RMA	Relative Import Advantage
RTA	Relative Trade Advantage
SFA	Stochastic Frontier Analysis
SMF	Stochastic Meta-Frontier
TE	Technical Efficiency
TL	Trans-Log
TT	Thousand Tonnes

VAR	Vector Autoregressive
VEC	Vector Error Correction
WID	Worldwide Inflation Data
WTO	World Trade Organisation

1. Introduction

Export-oriented sectors that have a huge interest in export expansion find themselves increasingly under the spotlight to ensure that their value chains are efficient. Such sectors are expected to demonstrate their competitiveness in global markets, to show that their primary producers are efficient in the production of raw materials and to ensure that there is price transparency from farm production to trade of dairy products. This is the contextual background of this thesis, the purpose of which is to measure Irish dairy sector competitiveness by examining the interaction between the farming system and the trading system of processed dairy products in the global market. The thesis seeks to achieve a better understanding of where Ireland stands, from production to trade in the global dairy market. This chapter presents an overview of the purpose of this thesis and the potential benefits of the research for academia, practitioners, industry stakeholders and policymakers. The following section outlines the key research questions examined in this thesis which are addressed in the various chapters using recent data and econometric models. The last section provides the structure of the thesis and offers a summary of the contribution of chapters to the literature (detailed contributions are provided in the specific chapters).

1.1. Purpose of the research and the benefits for policy and practice

1.1.1. Overview of the research purpose

With the shift by the European Union (EU) to a more market-oriented policy regime and liberal trading environment for agri-food products, especially dairy products, greater attention is now being given to the underlying competitiveness of agriculture in each Member State (Hennessy *et al.*, 2009; Läpple *et al.*, 2017). Research is required to examine how each Member State and their sectors might fare in the new policy and trade environment. The ending of the milk quota system in 2015 sparked an interest to industry stakeholders to understand the implications of this policy change on Irish dairy competitiveness (Läpple *et al.*, 2017). The removal of the milk quota regime was considered a “trend-breaker”, as it presented Irish dairy farms with significant growth opportunity in different regions within Ireland (Teagasc, 2016; Läpple *et al.*, 2017). The ambitious plans to improve the competitive position of the Irish dairy industry in the global market are set out in the Irish Government’s Agri-Food Strategies; Food Wise 2025 and Food Vision 2030. These strategies highlight the need for evidence on the competitiveness of the Irish agri-food sector to support export-led growth (DAFM, 2021).

The Irish dairy industry exceeded its objectives set in Food Harvest 2020, to increase milk production and dairy exports by 50% and 42%, respectively, from the 2007-9 base line to 2020. This has raised questions as to how and where this growth occurred, especially given the differences at the farm level across regions (Läpple *et al.*, 2017) and trade level across dairy products. The Food Wise 2025 and the Food Vision 2030 also call for growth in milk production and dairy exports using more domestic inputs and taking more environmental considerations to deliver sustainable growth and to support the industry's development for the decades ahead (DAFM, 2015; 2021). The analysis of the dairy industry across the value chain provides trade insights and mechanisms to track the progress of the sector for all stakeholders involved in the value chain and ensures that attention is focused where it is most needed. For example, Food Wise 2025 forecasts that exports have the potential to grow to €19 billion per annum by 2025 and Food Vision 2030 forecasts growth to be €21 billion by 2030, driven by expansion in dairy, beef, seafood and consumer food and drinks exports. However, the data and literature on Irish exports is often limited compared to the research data on farm level production, which is surprising given Ireland's focus on export-led growth for the dairy industry.

Bojnec and Ferto (2014) call for future research to include lessons drawn from case studies of successful EU-27 countries that have strengthened export competitiveness in milk production, milk processing, and dairy product marketing in global dairy markets. Analysing international trade at the industry level provides greater detail and a better understanding of the export competitiveness dynamics of nations (Fetscherin *et al.*, 2012). This is achieved by conducting an industry-specific analysis that can enable inter-country and intra-country comparisons of an industry's degree of specialization and the comparative advantages or disadvantages between and among national industries. The knowledge from the industry-specific analysis of specialization by nations can be extended further by analysing the level of integration or relationships between industries and nations via price transmission (Brown *et al.*, 2021). The literature on vertical integration (i.e. milk production to dairy product marketing) has almost exclusively been developed from a domestic perspective and the decision to integrate remains largely unexplored from an international trade perspective (Gaigne *et al.*, 2017). This lack of research interest has been surprising given the significant proportion of export-oriented firms that have chosen to integrate or bring together the downstream stages of their value chain, especially in the Irish dairy industry. Gaigne *et al.* (2017) found that processors were motivated

to use vertical integration as a business strategy to boost their export performance and reduce their global distribution costs via lower prices paid by customers and lower costs of exporting.

Against the backdrop of milk quota removal, the purpose of this thesis is to examine the competitiveness of Irish farm production and trade of Irish dairy products in the global market. The reality of an increasingly globalised market is that Irish producers are in greater direct competition for global market share with their counterparts in other agri-food producing countries (DAFM, 2015). By lowering trade barriers, regional integration may either enhance or impede the international competitiveness of industries, and different countries can experience very different outcomes of regional integration from farm to trade (Toming, 2007; Brown *et al.*, 2021). Yet, research in this direction is limited, especially research that considers how farm efficiency, price transmission and competitiveness have evolved as the policy has changed. The research presented here makes a contribution to the existing knowledge by analysing global developments and trends, regional competitiveness and competitiveness of national dairy products in global markets, and provides up-to-date information for the major traded dairy products. It considers for the first time, how the benefits or prices arising from the trade of dairy products accrue proportionately to Irish milk farms post-quota and uses empirical evidence to inform industry and policy decision-making. A model capable of informing strategic decisions is instrumental in determining the optimum product portfolio (Geary *et al.*, 2010). Previous studies on competitiveness have not analysed farm and trade performance simultaneously and do not investigate how the markets between farm production and trade of dairy products are integrated through prices (Fetscherin *et al.*, 2012; Bojnec and Ferto, 2014; Gaigne *et al.*, 2017). This study also contributes by conducting competition analyses between products and nations, as part of the evaluation of trade competitiveness. These are some of the novel components of this research.

1.1.2. Contributions of the thesis to policy

The nature of the Irish dairy industry as a net exporter puts it on the global stage and Irish food policies may be influential on the export performance of the Irish dairy industry in the global market. The Food Wise 2025 and Food Vision 2030 strategies have a global outlook for the Irish dairy industry and are aligned with the new EU CAP strategic plans of 2022 which seek to support competitiveness through sector-specific interventions and make the most of the opportunities offered by global markets. Based on the Food Wise 2025, the requirements for economies of scale at the producer level need to be addressed, and mechanisms that drive efficiencies against competitive benchmarks and maintain competitiveness on the domestic and

global markets for processors are also needed. The Food Wise 2025 tasks the Department of Agriculture, Food and the Marine (DAFM) to explore mechanisms to improve transparency around pricing and costs, and to review the possibility of developing a mechanism to minimise risk for processors and give farmers confidence regarding price. This includes establishing mechanisms to support market prioritisation strategies and market decision-making through the provision of market intelligence in specific regional and country markets. It also tasks DAFM to ensure that any future schemes and supports target those producers with the best potential for growth and competitiveness.

The Food Vision 2030 is considered to be unique compared to previous strategies because it adopts a ‘food systems approach’ which focuses on the role each part of the food chain has in delivering the 2030 vision. Similar to previous policies, it still aims to secure a premium price for as high a percentage as possible of Irish output and ensure that this premium is shared across the value chain, including the primary producer. For example, in 2021, the unfair trading practices directive to prohibit certain unfair trading practices was introduced for the supply of agricultural and food products. In cases where shocks to dairy product prices are not short-lived, then risk management policies and government intervention may be needed to help farmers cope with smoothing the shocks to their incomes and consumption as well as providing the necessary capital for maintaining production. The Food Vision 2030 adopted a concept of high-level missions (four) which are underpinned by a series of key goals (22) and actions or deliverables (about 200) (DAFM, 2021). For the dairy industry, the missions, goals and actions (only those relevant to this thesis and they are further discussed in the conclusions) are outlined in the Food Vision 2030 as follows:

Mission 2 (viable & resilient primary producers with enhanced wellbeing): Goal 1 (improve competitiveness and productivity of primary producers)

- Action 7: Explore the potential for the development of specific volatility and risk management measures or tools, within both the private and public sectors.
- Action 8: Opportunities exist to grow and develop new markets for value-added Irish dairy produce and the benefits should accrue proportionately to primary producers.
- Action 10: The stakeholders must continue to meet and engage strategically on all the key issues above in various fora, including the Dairy Forum.

Mission 2: Goal 2 (improve the creation and equitable distribution of value)

- Action 2: Ireland will engage fully with the Commission work and continue to develop new national initiatives on market and price transparency.

Mission 3: Goal 4 (develop market opportunities at home and abroad- export markets)

- Action 1: Prioritise markets and target segment(s) by continuing to conduct and use trade and market insights, at the company, sector and national level.
- Action 6: Carry out an update on the 2018 ‘Prioritising Markets: Opportunities for Growth’ exercise in 2022.
- Action 8: Further integrate primary producers into market engagement to keep them informed of market developments (research) and product requirements in their main export markets and to help them plan their business for the medium term.

1.1.3. Contributions of the thesis to practice

The empirical evidence and new metrics developed through this research will be critical in providing competitiveness insights at a farm and trade level which will aid in framing evidence-based public policy that seeks to maximise the contribution of the dairy sector to the agri-food sector in the Irish economy. Understanding the 'responsiveness' of the dairy industry to volatility or market changes and competitive performance can help ensure the sustainability of the Irish dairy industry in the long-term. The thesis seeks to support the work of dairy practitioners, industry stakeholders and policy makers, to improve the competitiveness of agriculture, food, and the wider bio-economy. This objective is set to be achieved by providing an economic analysis of market developments (i.e. price dynamics, trends in competition, engagement with international markets and the destination of exports) and regional farm management systems in the Irish dairy industry pre and post-quota. For example, it will address the changes in scale, changes in product specialisation and changes in the relationships between components of the dairy value chain.

The Irish national report (i.e. Teagasc Technology Foresight 2035) indicated that technological change stemmed from changes in the structure of the production process, for example, changes in scale, changes in specialisation, or changes in the relationships between components of the value chain (Teagasc, 2016). The report called for research on international comparisons of dairy product mix portfolios, especially in terms of increased production towards higher value products, supplying markets with higher margins, and facing less price competition from competitors. The results presented in this thesis can feed directly into the national or regional planning processes in a way that creates efficiency in achieving overall sectoral objectives for

policymakers and industry stakeholders in the agri-food industry (Ballas *et al.*, 2006). For the first time, the thesis will provide an up-to-date picture of the competitiveness of the Irish dairy sector beyond the farm gate, using trade-based indicators of competitiveness, which is a novel addition to the suite of competitiveness indicators measured by practitioners and academics.

The thesis will discover new facts and make new interpretations of existing knowledge on markets, competition, price transparency and trade of dairy products, and thus represent a real advance in the field of study. It develops a relative and multidimensional framework for measuring farm and industry export competitiveness, which could also be applied to other industries and countries. It discusses the changing trade patterns of competition in the dairy business worldwide and seeks to explore key industry-specific factors influencing the competitiveness of the Irish dairy industry. The findings of the thesis will enable policymakers to monitor progress in the achievement of policy objectives (i.e. Food Vision 2030 policy actions stated above) and facilitate informed policy-making by better understanding the farm and trade competitiveness.

1.2. The research questions

1.2.1. General question

- How competitive is the Irish dairy industry in the global market from farm to trade?

1.2.2. Farm-level questions (addressed in Chapters 3 and 4)

- How do Irish dairy farms compare with other dairy farms at the EU level in terms of total costs and partial productivity?
- What are the regional differences in terms of Irish farm performance or efficiencies and the determinants of regional farm efficiency?
- What impact do government programmes and policies, i.e. discussion groups and quota abolition, have on regional farm efficiency?
- To what extent does production expansion result in efficiency improvements and/or unit cost saving through economies of scale?

1.2.3. Trade-level questions (addressed in Chapters 3, 5 and 6)

- How competitive are Irish dairy products in the global market?
- How competitive is Irish butter relative to other dairy products and other countries?
- To what extent does specialisation in butter production by other international countries affect Irish butter competitiveness or trade performance in the global export market?

- To what extent do butter export prices for the Netherlands and New Zealand in the global market, influence or are integrated with Irish butter export prices (horizontal price transmission)?

1.2.4. Farm to trade level question (addressed in Chapter 5)

- To what extent are changes in Irish butter export prices integrated or transmitted to the Irish farm milk prices in the dairy value chain (vertical price transmission)?

1.3. Structure of the thesis and contributions to academia

The thesis is organised as follows. Chapter 2 offers the background to the Irish dairy industry and the main theoretical frameworks applied in the thesis, i.e. competitiveness, technical efficiency and price transmission are also introduced which gives context and scope to research questions addressed in this thesis. The overview of trends in dairy products produced and destination of exports are presented, taking a value chain approach, i.e. from farm to trade. Chapter 2 also provides the conceptual framework for the thesis which highlights how the concepts and chapters of the thesis are linked.

Chapter 3 provides a descriptive statistical analysis of the Irish dairy farm and export competitiveness pre and post-quota. The changes occurring in the external and internal environment are identified and proactive responses to them are initiated, such as improving sales of competitive products and the extension of market positions in new market segments. This is necessary for achieving market expansion and improving the competitive performance of Irish dairy products. Competitiveness assessment can be an important tool to enable all firms and nations (i.e. policymakers, practitioners and industry stakeholders) to make data-informed strategic decision-making (Fetscherin *et al.*, 2012; Bojnec and Ferto, 2014).

The findings presented in Chapter 3 inform the research presented in Chapters 4 to 6. For example, the findings presented in Chapter 3 indicate that Ireland had the highest growth in partial productivity and was ranked first with the lowest total costs and cash costs per kg of milk solids post-quota compared to selected key competitor EU countries. The analysis of Irish farm performance needs to be interpreted with caution given that previous literature (i.e. Läßle and Hennessy, 2012; Läßle *et al.*, 2012) reported that there are technological differences between the Irish farms by region. This motivates the further investigation of farm efficiency in Chapter 4. The findings presented in Chapter 3 also indicated that Ireland was most competitive in butter compared to other Irish dairy products and other countries in the world. For example, in 2019, Ireland was the third-largest exporter of butter in the world butter market

and Irish butter prices have been more volatile than other Irish dairy products making Irish dairy an interesting case study. Given the importance of butter to Ireland's product mix and overall international competitiveness, it warrants further investigation. To date, empirical research that examines the market price dynamics to provide price transparency in the value chain and international competitor behaviour in the global butter market is scarce. Hence, the motivation for pursuing price transmission in Chapter 5 and export competitiveness in Chapter 6.

The research presented in Chapter 4 extends the analysis in Chapter 3 by analysing farm technical efficiency rankings and their determinants in Ireland. A regional approach is adopted to identify the regions where better and poorer performing farms are located. This analysis is conducted using a stochastic metafrontier approach which takes into account the technological differences between regions, based on panel data. Such a methodological approach has not been applied to Irish data previously. The purpose of conducting a regional farm analysis is to inform better policy design and to avoid the risk of having just one efficient region while others are not or are struggling to remain efficient. The analysis helps to identify potential areas of intervention by the government (i.e. need to tailor farm advice or support) at the regional level. Efficiency improvement is an important indicator that reflects the potential of a sector to survive in an environment that is characterized by both domestic and international competition. Increasing farm and processor efficiencies does not just allow the sector to achieve economic viability and international competitiveness, but it also allows the sector to achieve environmental sustainability.

Chapter 4 contributes to the literature on spatially locating farming systems by applying, and validating a methodology to add a spatial dimension to the FADN sample farms. It provides insights into how regional farms responded to uncertainty by evaluating the efficiency and expansion capacity of farms in different regions (Hennessy *et al.*, 2009). Technical efficiency is a key factor for dairy farm survival, as more efficient farms are likely to be well-positioned to continue operating (Dong *et al.*, 2016). Studying farm efficiency and the potential sources of inefficiency is therefore important from a practical and policy point of view. On the one hand, farmers could use this information to improve their performance. On the other hand, policymakers could use this knowledge to identify and target public interventions.

Arising from the findings presented in Chapter 3, the vertical and horizontal price transmission in the Irish dairy industry and in particular butter are examined in Chapter 5. Chapter 5

addresses the issue of price linkages or transparency in dairy product markets, i.e. for different products within the same market and the same product in different markets, given the market liberalization and structural adjustment efforts undertaken by several countries (especially in the EU) in recent years. The degree to which markets are integrated or prices are transmitted across products has been used as a yardstick in assessing the impact or success of policy reforms (Baffes and Ajwad, 2001). Chapter 5 links farming to trade of dairy products through price transmission analysis.

Chapter 6 focusses on analysing the competitiveness of butter as one of the main dairy products in Ireland and international competitor behaviour (i.e. New Zealand and the Netherlands). This Chapter makes significant contributions to the literature pertaining to the Irish dairy industry in the global context by using the normalised revealed comparative advantage (NRCA) to measure the competitiveness of Irish dairy products which has not been done before for the dairy industry. In the long term, the economic sustainability of the dairy sector largely depends on the role of revealed comparative advantages and the differentiated abilities of dairy product chains to survive in the global market (Bojnec and Ferto, 2014). For example, to protect or promote certain industries and sub-industries, it is important to direct scarce resources to where they may count the most (Fetscherin *et al.*, 2012).

Chapters 5 and 6 use time series data and adopt the vector error correction (VEC) and vector auto-regression (VAR) models for the analysis of price transmission and export competitiveness dynamics, respectively, in the international markets. A principle innovation of these Chapters is the adaptation of the recently developed methods for measuring changes in the production of dairy products into price transmission models associated with the global dairy market. The research aims to provide supporting evidence for the overall impact of this measure on markets and price dynamics for milk and dairy products. This analysis will also be relevant to other countries with differentiated milk production channels for the production of different dairy products.

Chapters 5 and 6 contribute to the objectives of the Food Wise 2025 and the Food Vision 2030 by examining farm milk and butter prices to help minimise risks for processors and give farmers confidence regarding price transmission. Milk pricing is one of the only methods of communication between the milk processor and the producer to increase the overall efficiency of the dairy industry (Geary *et al.*, 2010). The changes in price volatility that took place in the Irish dairy industry in the past decade may have resulted in steep changes in competitiveness

of Irish dairy farms and processors. Examining this issue can reveal important information concerning the way that farmers and processors reacted to shocks. More broadly, the chapters provide one of the first detailed trade level studies and they inform current discussions of the transmission of supply and demand shocks across nations. It is important to strengthen dairy industry integration across the entire value chain from on-farm practices, processing milk, and marketing to consumers for a competitive dairy industry in global markets (Bojnec and Ferto, 2014).

Finally, Chapter 7 provides general conclusions and policy implications of the thesis. The chapter starts by providing a summary of the whole thesis and the overall contributions of the thesis. Then the next section offers policy implications starting from general to specific recommendations. The final section highlights the areas for future research. The thesis has both theoretical (first to apply stochastic metafrontier model and NRCA in the Irish dairy industry) and practical or managerial implications (policy and stakeholder recommendations).

Table 1.1 indicates peer-reviewed articles (and chapters) and the international academic journals targeted. The candidate (Cele, L.P.) is first author on all publications and was responsible for article conception, review of literature, data curation, data analysis and interpretation, and preparation for submission to different international journals. The co-authors (supervisors) were responsible for providing direction on data analysis, reviewing and editing of articles.

Table 1.1. The articles and the academic journals targeted

Chapter	Paper Title	Author(s)	Journal (*) [#]
3	Evaluating dairy farm and export competitiveness- Post-quota analysis	Cele, L.P., Hennessy, T. and Thorne, F.	Published-06/2021 Competitiveness Review: An International Business Journal. [2.8]
4	Regional farm technical efficiency rankings and their determinants- A stochastic metafrontier analysis	Cele, L.P., Hennessy, T. and Thorne, F.	Published-11/2022 Agribusiness: an International Journal. [2.7]
5	Price transmission analysis of Irish butter export prices in the world butter market.	Cele, L.P., Hennessy, T., Eakins, J. and Thorne, F.	Accepted-07/2023 International Food and Agribusiness Management Review. [1.7]
6	The competitiveness trends and impact of competitors on Irish butter competitiveness.	Cele, L.P., Hennessy, T., Eakins, J. and Thorne, F.	Conference Paper-12/2022 International Agricultural Trade Research Consortium.

* Publisher. # Impact factor as of July 2022.

2. Background and conceptual framework

To give context to the overall thesis, this chapter presents an overview of the Irish dairy industry in the global market through the value chain approach, i.e. from farm to trade. It highlights the economic importance of the industry and an overview of the implications of the change in the policy framework such as milk quota abolition in the Irish dairy industry is presented. The overview of trends in dairy products and export destinations are also discussed. It provides definitions of key concepts adopted in this thesis, their scope and significance for the dairy sector, i.e. competitiveness, technical efficiency at a regional level and price transmission. Lastly, it highlights how these concepts are linked through the conceptual framework that forms the basis of this thesis.

2.1. Background of the Irish dairy industry in the global market

2.1.1. Overview of the policy context

The dairy industry in the European Union (EU) has undergone significant structural adjustments over the years due to changes in factors such as prices, markets, and policies (Giles, 2015; Läpple and Sirr, 2019). Government policies are important as they can influence the choice of strategy that farms and firms pursue (Martin *et al.*, 1991). One of the more prominent policy changes in recent years was the abolition of the EU milk quota system in 2015, which impacted the strategic direction of many farmers and processors in different EU countries, especially those producing above their allocated quota. For example, farmers and processors saw an opportunity to put a milk production and processing capacity expansion plan in place for the next period, to create better returns for farmers and improved products for customers.

The milk quota system was introduced in 1984 to contain the growth of milk production, limit public expenditure on the dairy sector, stabilize milk prices and ensure that the EU would be able to continue to fund the growing cost of the price support framework (Donnellan *et al.*, 2011; Groeneveld *et al.*, 2016). This ensured that the EU dairy market would have little or no surplus in the EU public storage for products such as butter and skimmed milk powder, which on occasion had exceeded 1 million tonnes for both products (Giles, 2015). While the policy was beneficial in the beginning, it later became a constraint in the development of the industry because the demand for dairy exports was growing much faster than the supply (Bouamra-Mechemache *et al.*, 2008; Donnellan *et al.*, 2011; Donnellan *et al.*, 2015), especially in Ireland (for more information see Donnellan *et al.*, 2015). The European Commission increased the

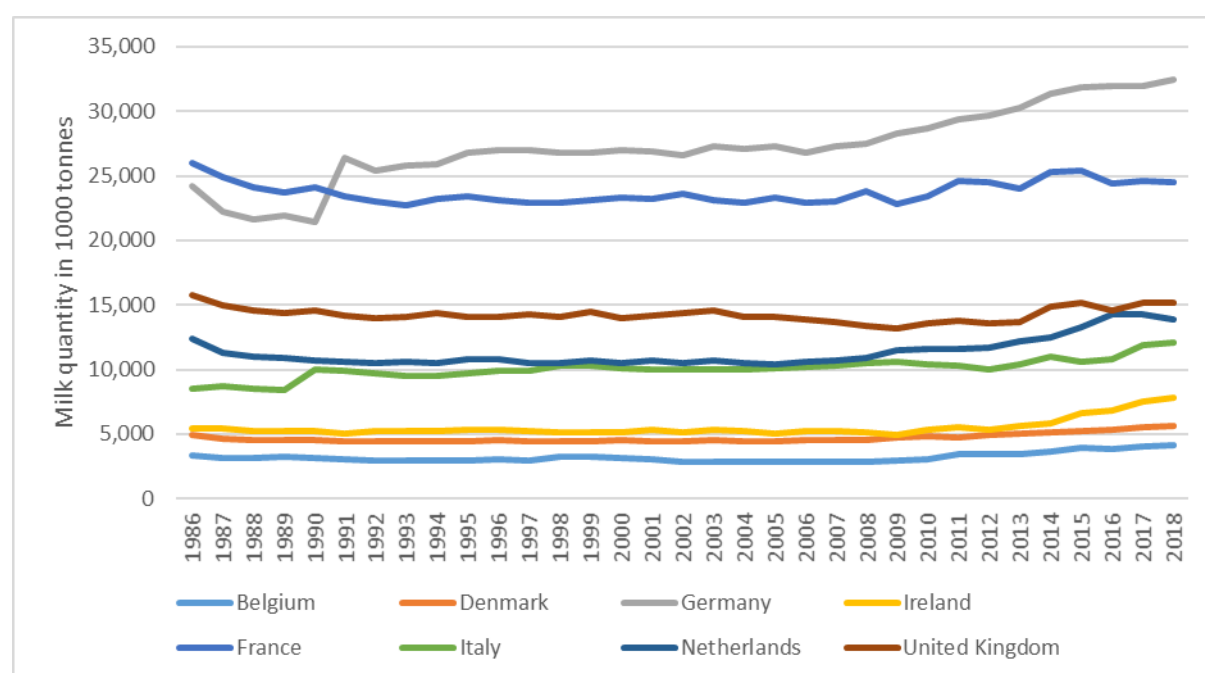
milk quota by 2% in 2008 and gradually increased it by 1% per annum thereafter until 2013 to allow for a “soft-landing” scenario or a smooth transition to eventual removal in 2015.

2.1.2. Trends in dairy cows’ milk deliveries, livestock units & farm information

The removal of the milk quota led to structural changes in milk production across the EU. Figure 2.1 illustrates the trends in raw cows’ milk delivered to dairies by selected EU countries. In 2017, Germany (21%), France (16%), the United Kingdom (UK) (10%), the Netherlands (9%), Poland (8%), and Italy (7%) collectively provided over two-thirds (70%) of the raw cows’ milk produced on farms and collected by dairies in the EU (EU-28 total of 154.8 million tonnes- MT), Ireland contributed 5% (Eurostat, 2019). In 2019, Irish milk production was at a record high at 7.99 billion litres and whole milk imports were about 640 million litres which is equivalent to 8% of the milk produced domestically. As noted by the IFA (2021), milk production had increased by 67% by 2020 from 2007-9, with associated downstream benefits to the broader economy. Läpple and Sirr (2019) noted that a year after the quota removal, milk production in Ireland increased by 18.5%, the fastest rate in the EU, compared to an average growth rate of 4.5% across the EU. Ireland had the highest growth rate of 25% in raw milk deliveries post-quota (2015-17) compared to other EU countries, from 5.6 to 7 MT supplied to creameries and pasteurisers.

The analysis of dairy policy reforms relies on the integrated use of a model which takes into account the whole dairy chain, starting upstream from primary milk production and ending downstream with consumer demand for processed dairy products (Bouamra-Mechemache *et al.*, 2008). According to DAFM (2015), some 140,000 farm families were involved in the production of output valued at more than €7 billion, and together the beef and dairy sectors accounted for almost 70% of this output value. The indirect jobs in processing, haulage, sales and services, associated with the dairy sector were approximately 40,000 in 2020 (IFA, 2021). In 2020, the dairy farm population consisted of 16,146 farms which were 17% of the total farm population and these farms were responsible for 50% (€1,199 million) of the total farm income generated (Teagasc, 2021).

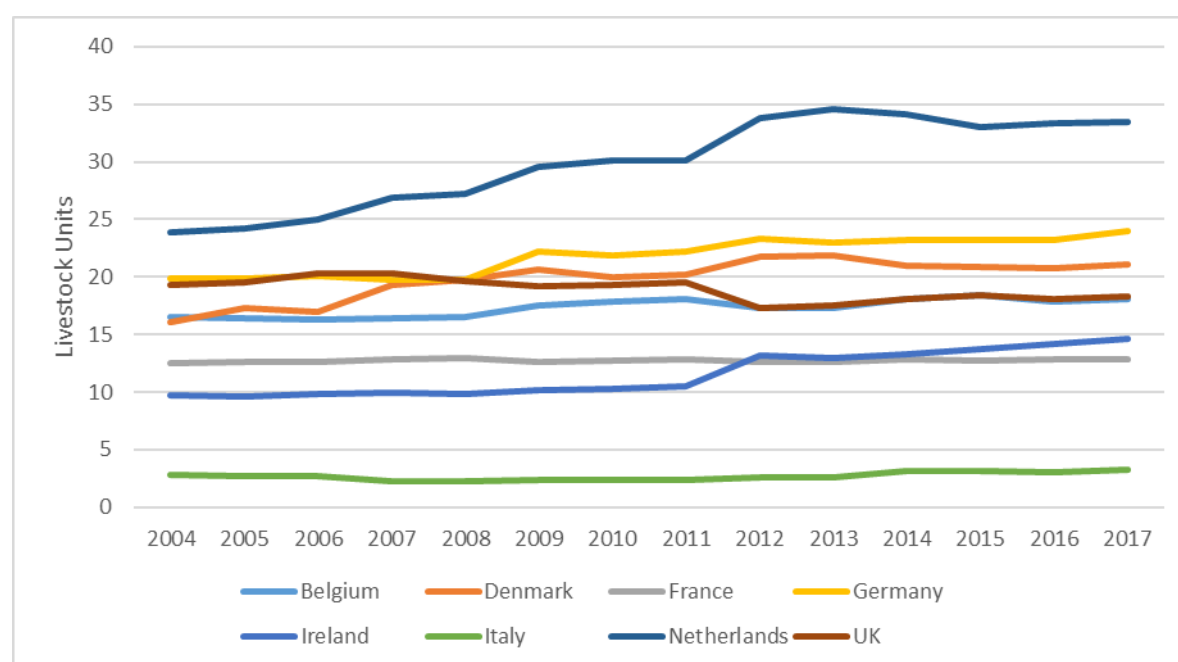
Figure 2.1. The trends in raw cows' milk delivered to dairies by selected EU countries



Source: Authors' calculations based on the Eurostat database

Figure 2.2 shows the trends in dairy cow livestock units (LU) for the selected EU countries over the years. The Irish growth rate of average dairy cows per farm was the highest at 51% from 2004-2017, followed by the Netherlands and Denmark at 40% and 31%, respectively. According to Teagasc (2021), dairy farm structures vary by region and substantial structural change took place on Irish dairy farms ahead of and after the abolition of the EU milk quota in 2015. Following the milk quota removal in 2015, investment in dairy farms was the highest of all farm types, at an average spend of €31,289 per farm accounting for almost half of the total farm investment in 2020 (Teagasc, 2021). From 1995 to 2013, Irish dairy farmers collectively invested approximately €1.4 billion in the purchase of milk quota to help meet the demand of processors (Donnellan *et al.*, 2015). Since 2015, over €2.2 billion was invested by dairy farmers and over €1.3 billion invested by milk processors in the sector, which has had broader economic benefits to the Irish economy, both in terms of employment and net foreign earnings associated with the processing sector, and the economic activity generated from the on-farm investment (IFA, 2021). Investment in the development of new technologies that create more sustainable production systems must be a cornerstone of achieving future growth at primary production (DAFM, 2015).

Figure 2.2. The trends in dairy cows livestock units for the selected EU countries

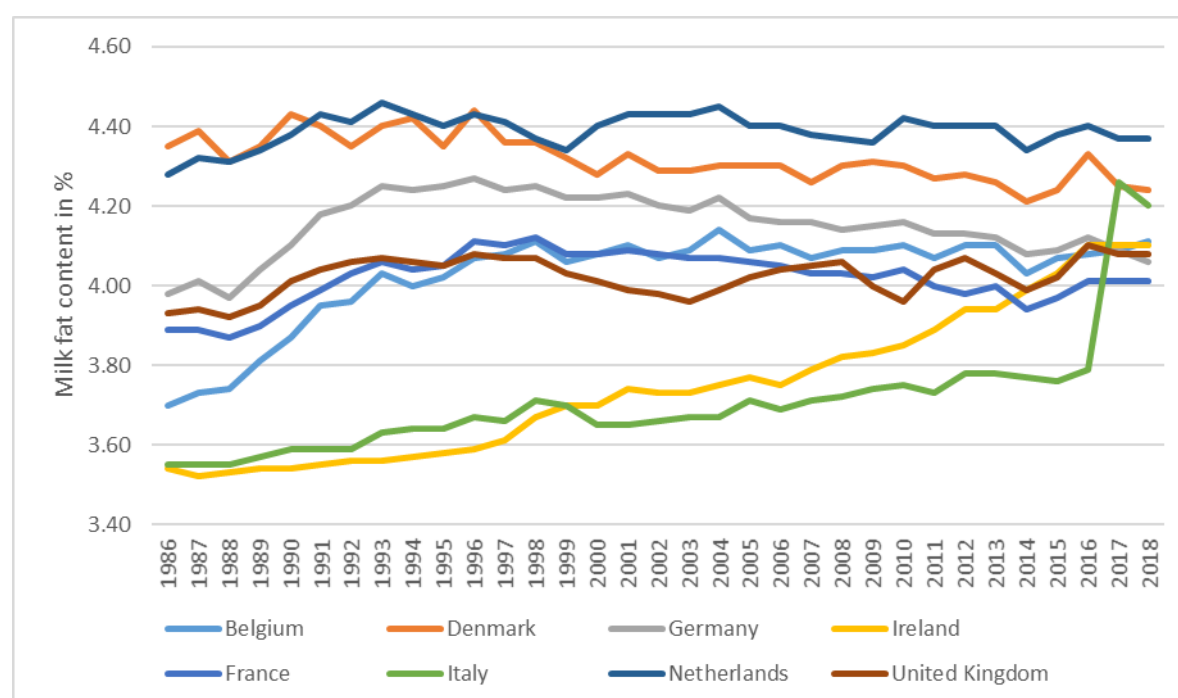


Source: Authors' calculations based on the Farm Accountancy Data Network (FADN) database

2.1.3. Trends in milk fat and production of dairy products for export

Milk is valued through the value of its two main components (fat and protein) in the final dairy commodities and the underlying technology is consistent with milk availability (Bouamra-Mechemache *et al.*, 2008). Milkfat is mainly used for making butter. For much of the milk quota era, about 60 percent of Irish whole milk was used in butter production, making butter a dominant milk product (Donnellan *et al.*, 2015). The content of milk fat and protein in milk could affect both the efficiency and competitiveness of farms and the processing industry (Geary *et al.*, 2010; Viira *et al.*, 2015). Geary *et al.* (2010) suggest that for each additional kilogram of fat or protein, the overall milk revenue is increased depending on product portfolio, product values, and processing costs. Figure 2.3 shows a significant increase from 1997 in average milk fat content as a % of product weight (0.56% point increase from 1986 to 2018). Viira *et al.* (2015) noted that between 2003 and 2013, Ireland witnessed one of the largest increases (by 0.21 percentage points and 5.6%) in milk fat content in the EU.

Figure 2.3. The trends in average milk fat content as a % of product weight



Source: Authors' calculations based on the Eurostat database

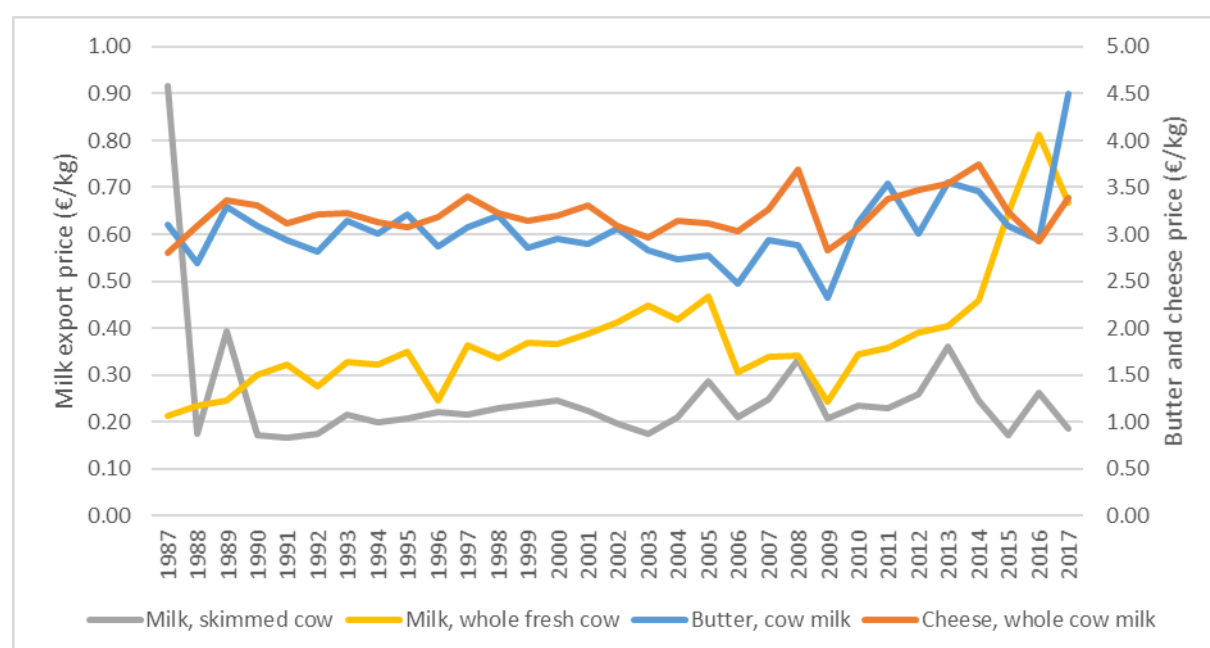
Bojnec and Ferto (2014) suggest that most of the EU-27 countries have diverse product portfolios and for a country exporting a wider product portfolio, the probability of losing competitiveness can be greater, even though this could be done in the spirit of diversification or risk reduction. Nonetheless, the global dynamic industries, i.e. those growing faster than other industries and having a high degree of specialization, are the export champions of a nation (Fetscherin *et al.*, 2012). In Ireland, the strategic focus for dairy stakeholders remains on the production of dairy products such as butter, cheese and powders. Milk processing is highly complex with many variables changing throughout the year. For example, the volume of milk, milk composition, product portfolio, product compositions, and labour requirements vary throughout the year. Of those, a large component that affects milk returns is the product portfolio (Geary *et al.*, 2010).

The dairy sector contributed about €5.2 billion to the Irish food and drink export industry worth about €13 billion which made it the most significant food export category in the country in 2020 (Bord Bia, 2020). According to O'Callaghan *et al.* (2021), through restructuring, mergers and cooperation, the Irish milk processing industry has changed from 20 individual milk plants processing butter in 1991 to 11 butter plants by 2001 and the majority of raw milk transportation for milk processing is now managed by nine large primary processors who

operate multiple milk processing sites distributed throughout the country. The three largest processors, Glanbia, Dairygold and Kerry, have five processing plants and processed approximately 70% of the total milk pool in 2014 (Donnellan *et al.*, 2015). However, there are variations in product portfolios for each processor.

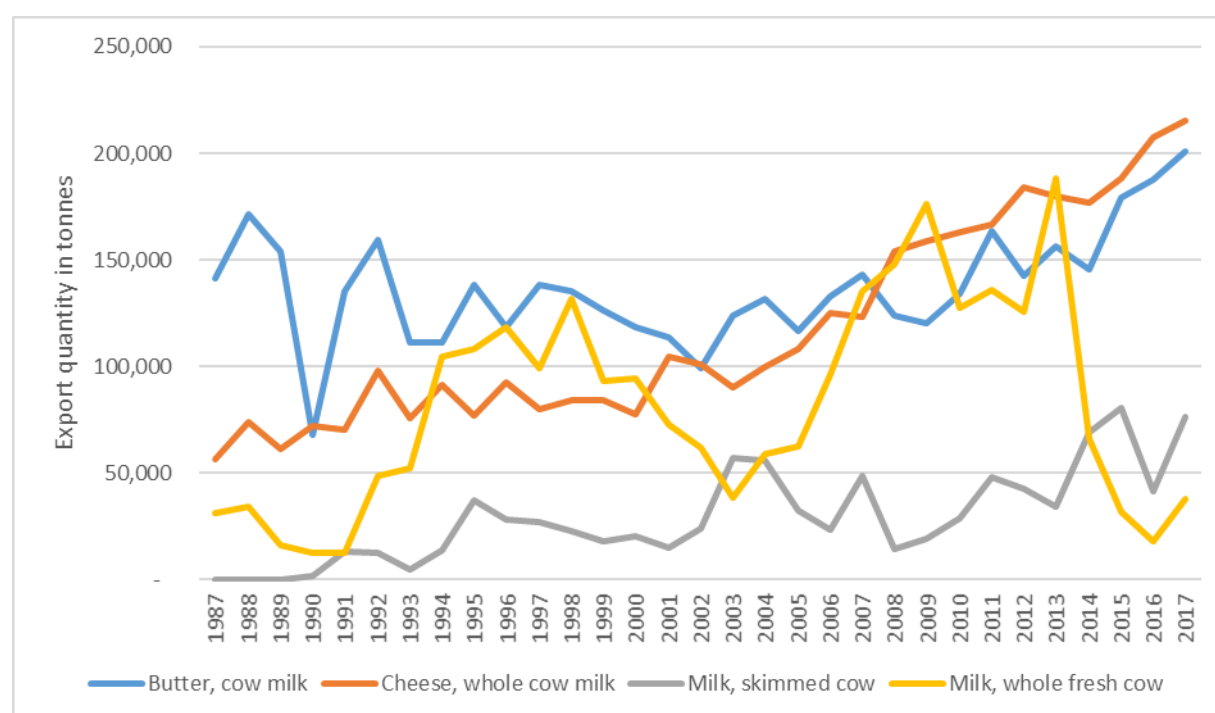
Figures 2.4 and 2.5 show the trends in Irish dairy products' export prices and quantity, respectively. The Irish export quantity post-quota (2015-17) comprised of cheese, butter, skimmed dried milk, skimmed cow, whey, whole dried, and whole milk at 30%, 28%, 11%, 10%, 10%, 8%, and 4%, respectively, of 680 thousand tonnes (TT). While cheese export prices remained relatively stable over the years, the export quantity was steadily increasing from about 57 TT in 1987 to about 215 TT in 2017 (279% increase). From 2009 to 2017, there was a significant increase in export prices for fresh milk and butter at 179% and 93%, respectively. On the other hand, export quantity declined by 79% for fresh milk and increased by 67% for butter in that same period. Bouamra-Mechemache *et al.* (2008) argued that an increase in butter price induced an increase in the milk price as well as an increase in the price of other dairy products (i.e. cheese, liquid milk).

Figure 2.4. Trends in Irish dairy products export prices



Source: Authors' calculations based on the FAOstat database

Figure 2.5. Trends in Irish dairy products export quantity

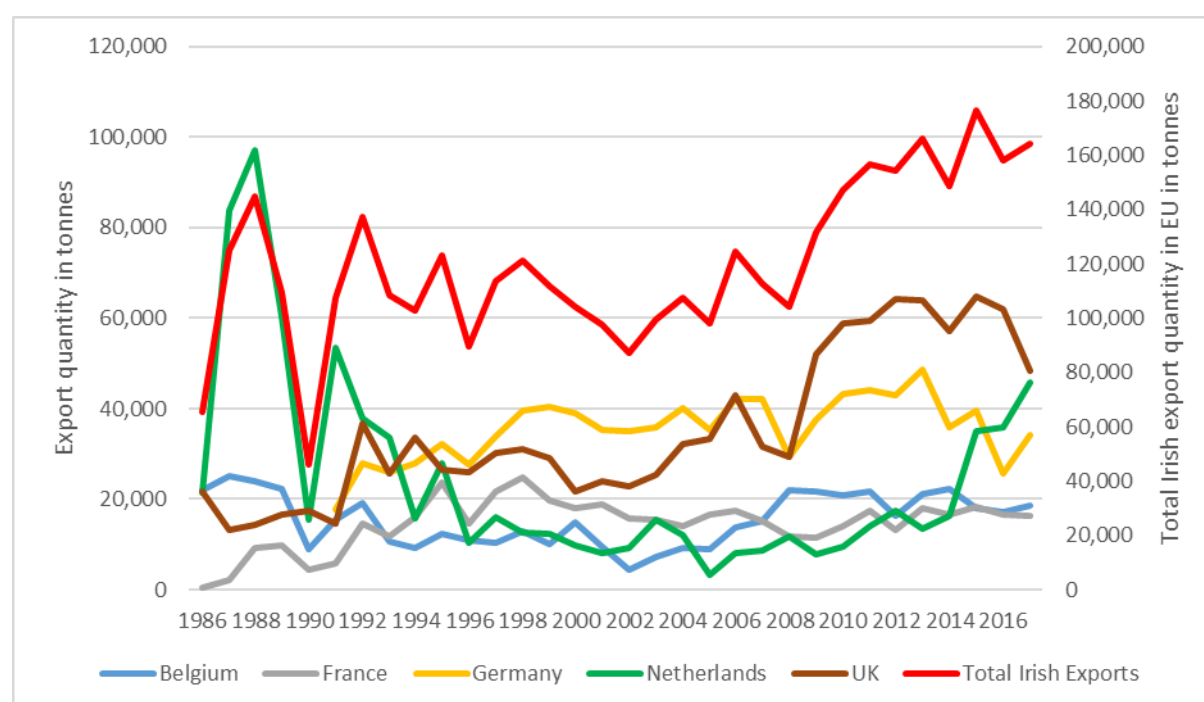


Source: Authors' calculations based on the FAOstat database

2.1.4. Trends of Irish butter exports in the top five EU destinations

According to Bord Bia (2019), the key drivers of dairy export performance were due to an increase in milk availability and buoyant butter commodity price shaping output. Irish butter prices were more volatile compared to other high-value dairy products in recent years (Ornua, 2019). Butter exports were worth €961 million in 2020, the most valuable of all the dairy sub-categories, in value terms (Bord Bia, 2020). Ireland is one of the most prominent exporters in the EU, making it crucial that the dairy sector maintains and strengthens its competitiveness in external markets to sustain the leading role in the agri-food (dairy) value chains. In 2019, Ireland exported €1.1 billion worth of butter, making it the 3rd largest exporter of butter in the world after NZ (€2.2 billion) and the Netherlands (€1.4 billion) (OEC, 2019). The top five destinations of Irish butter exports, in value terms, were the Netherlands (27%), the United States (US) (18%), the UK (18%), Germany (11%), and Belgium (9%) (Bord Bia, 2020). Figure 2.6 illustrates the trends of Irish butter exports in the top five EU destinations. From 2005 to 2017, Irish butter exports to the Netherlands significantly increased by 1,287%.

Figure 2.6. The trends of Irish butter exports in the top five EU destinations



Source: Authors' calculations based on the FAOstat database

2.1.5. *Current opportunities and threats for the Irish dairy industry*

Ireland plays a significant role in the dairy export market within the EU and enjoys the benefits of being a member of the EU which provides ease of access (i.e. common rules governing customs duties or tariffs, rules governing quantitative restrictions or quotas, and rules governing other non-tariff barriers such as technical regulations and standards) and protection in the EU market. Other benefits include low exchange rate risks, transportation costs, and adaptability to market conditions (Miljkovic, 1999). Competition from non-EU members, such as New Zealand and the UK, does not enjoy the same benefits that EU members enjoy. However, Ireland has embarked on the diversification of its markets outside the EU to markets such as the US (i.e. for Irish butter) and China (i.e. for Irish powdered milk), especially in the post-quota period whereby competition has intensified. The market diversification strategy has become a priority in Ireland due to the fluctuations in demand and supply conditions for various markets of Irish dairy products.

The declining trade barriers, intensification of competition, and innovations in milk processing have necessitated access to raw material components on a global scale including via imports (Fousekis and Trachanas, 2016; Bord Bia, 2020). This can be viewed as a way to secure comparative advantage where demand and supply for butter continue to increase and

competition for farm milk is high. Donnellan *et al.* (2015) argue that the convergence of Irish milk prices over time with those of the EU is due to greater diversification in the Irish product mix in recent years. This creates interest in market adjustments and the need for greater insights into the dairy product mix in Ireland. In the post-quota removal period, the EU milk sector is expected to be more integrated with the global dairy market and to have more volatile prices (Jansik *et al.*, 2014). Trade linkages do not evolve randomly but depend on the structure of existing connections (Fertő *et al.*, 2021). Over time, countries have to respond to changes in trade agreements and market dynamics, i.e. facilitated by the Common Agriculture Policy (CAP) and World Trade Organization. According to Bojnec and Fertő (2012), the EU's CAP set up in 1957 to guarantee food security via the dairy policy regime in post-war Europe and was subsequently updated to compete in the global market, has caused distortions to specialisation in agri-food trade in the long-run.

The more competitive other Irish dairy products are relative to Irish butter and other countries relative to Ireland in the global butter market, the less competitive Irish butter will be due to scarcity of inputs and competition in global butter markets. The interdependencies between butter competitors and dynamic aspects of the Irish butter economy have not yet been studied, especially in the post-quota period. For example, how would changes in decisions by other countries to allocate more resources to produce butter influence the Irish butter market and what are the implications for growth rates of other Irish dairy products? The Food Vision 2030 highlights the need for market and price transparency (oversight and monitoring mechanisms) in the agri-food value chains, including in dairy, to achieve sector resilience and to preserve international competitiveness from farm to trade. More market and price transparency can assist in strengthening the bargaining power of primary producers, alongside regulation to ensure fair trading practices (DAFM, 2021). The patterns of trade between countries are often ignored in justifying industrial policies. Part of a strategic business planning process should be the evaluation of the overall market trends (i.e. pricing trends, market position, how quickly the industry is growing, and how are competitors moving), which are often considered before the next planning cycle begins. Hence the need for more research on competitiveness, efficiency and price transmission.

2.2. Competitiveness

2.2.1. Definition of competitiveness in this thesis and its significance

The concept of competitiveness holds many definitions in the literature due to its complex and dynamic nature, which can vary by industry. Various authors have chosen definitions that

match their areas of interest (Latruffe, 2010; Viira *et al.*, 2015) and the type of data they have available to compute their measures. Competitiveness in this thesis is defined as the combined relative measure for comparing countries based on their performance within and across dairy farm production and international trade of various dairy products over a defined period (Thorne and Fingleton, 2006; Latruffe, 2010; Bojnec and Fertő, 2014). A country can be considered competitive when it can increase its performance by reducing its production costs and inefficiencies at the farm-level, and grow or maintain its market share and comparative advantage in the domestic and global markets at trade-level (Thorne and Fingleton, 2006; Latruffe, 2010; Bojnec and Fertő, 2014).

Many of the factors mentioned in the next section can be influenced by economic policy and regulations of the home country and foreign countries. For countries to take advantage of expanding trade opportunities in an increasingly complex global environment, they need to conduct or carry out an assessment of their competitiveness. As noted by Porter (1998) and Viira *et al.* (2015), to maintain competitiveness, it must be periodically analysed and respective corrective actions must be taken. This requires the development of a range of market analysis tools and methodologies via strategic and operational research, assessing national farm and trade performance. This can be done by analysing and presenting statistical data from diverse sources on global dairy markets to provide farm, trade and market intelligence, i.e. emerging issues and trends. This thesis aims to develop such tools to provide an overview of Ireland's competitiveness and some insights on how it may be improved.

2.2.2. Factors affecting competitiveness from farm to trade level

At the farm level, the competitiveness definition tends to lean towards productivity and profitability with these often regarded as leading performance indicators under the strategic management theory which emphasises cost leadership and product differentiation (i.e. brand identification and customer loyalty) (Boyle, 2002; Thorne and Fingleton, 2006; Latruffe, 2010). Competitiveness, at the micro or farm-level, is affected by the farm/firm's operations and strategy, market structure, quantity and quality of production factors, price changes, economies of scale (unit costs reduction), the environment, animal welfare, scale of the enterprise, technology, and innovations (Dillon *et al.*, 2008). For example, Donnellan *et al.* (2011) projected that there would be an increase in milk production, farm sizes, and processing facilities in Ireland post-quota, which would help drive competitiveness. According to DAFM (2015), at a micro level, the sector faces several competitiveness challenges in particular labour

and utility costs, access to finance, lack of scale, insurance and legal costs, regulatory costs and lack of investment in innovation and research.

At the trade-level, the definition leans towards industrial organisation theory or international trade theory for increasing profits and maintaining market share (Martin *et al.*, 1991; Thorne *et al.*, 2017), and the concept of comparative advantage (country's relative cost-efficiency based on the inputs into the production process) (Porter, 1998; Fetscherin *et al.*, 2012; Bojnec and Fertő, 2014). At the macro or trade-level, competitiveness is influenced by monetary and fiscal policy, the rule of law, and the quality of social and political institutions (Latruffe, 2010; Viira *et al.*, 2015) which are essential for farmers and processing firms to make decisions on long-term investments. Previous references focus on market demand and supply for firm products and their influencing factors. Traditional trade theory of competitiveness focused on the cost structure of the firm or supply-side approach and industrial organisation theory focused on the market demand for firm products (Viira *et al.*, 2015; Thorne *et al.*, 2017). Viira *et al.* (2015) suggested that an ideal combination of competitiveness indicators will provide a good overview of the competitiveness of an industry or country.

Porter (1998) identified other factors for both micro and macro level such as the intensity of rivalry among existing competitors, capital requirements, favourable access to raw materials, favourable locations, changes in the exchange rate, and government policy or support. Any given industry may gain a competitive advantage, relative to competitors, based on the exploitation of only one or two of the Porter factors, but this is unlikely to be sustained for any long period. In the case of low value-added and bulk products such as dairy products, price is the most decisive factor of demand, and for high value-added (processed) products (especially niche products), product traits such as quality, brand name, innovation, product differentiation and after-purchase services are more important. These strategic management factors can be captured qualitatively and quantitatively. The qualitative factors, i.e. customer perceptions, are normally not readily available as secondary data compared to the quantitative data. The lack of secondary data available for some measures that capture quality (innovation and product differentiation) and customer perceptions limit the possibility to test the relationship between the drivers and the state of competitiveness. However, the condition of the drivers across countries at different points in time can be used to indicate, or as indicators of, the state of competitiveness of the industry.

2.2.3. Competitiveness measures: competitive potential, performance and process

The competitiveness factors mentioned above provide indicators that focus on determining the state of competitiveness of an industry (Martin *et al.*, 1991). Buckley *et al.* (1988) classified competitiveness measures into three categories, namely, competitive potential, performance and process.

- The potential measures describe the inputs going into operation e.g. comparative advantage, cost competitiveness, productivity, price competitiveness, and access to resources. Most studies on competitiveness have focused on price competitiveness, directly or indirectly, through cost competitiveness and profitability. For an industry in a small country with a limited domestic market like Ireland for dairy, the ability to export products with high value-added is a key to long-run sustainable growth and profitability. This ability depends on managing price factors (such as costs), on the one hand, and managing non-price factors (such as product quality and reputation), on the other. Efficiency improvement is an important indicator that reflects the potential of a sector to survive in an environment that is characterized by both domestic and international competition.
- The performance measures are focused on the outcome of the operation e.g. export market share, balance of trade, export growth, and profitability. The performance measures help to indicate how the management and industry stakeholders have been operating and performing (e.g. government policies, commitment to international business and management relations).
- The competitive process is the mechanism whereby competitive potential is translated into competitive performance (Viira *et al.*, 2015; Thorne *et al.*, 2017). The process measures require a qualitative study of management processes (i.e. the effectiveness of corporate and divisional decision-making) at the firm level and government management of the economy at the national level, which is beyond the scope of this thesis (Thorne *et al.*, 2017; Pascucci, 2018). Alternatively, it requires detailed micro-firm data which is not readily accessible for the selected countries.

2.3. Technical efficiency at a regional level

2.3.1. Definition of technical efficiency and its relevance

The analysis of farm efficiency can deliver significant insights into the competitiveness of farms and their potential for improving resource use (Abdulai and Tietje, 2007; Carroll *et al.*,

2011; Latruffe *et al.*, 2012; Chavas *et al.*, 2022). The concepts of efficiency and competitiveness are interlinked through their measures or performance indicators, and similar to competitiveness, efficiency is a relative concept that can be used to benchmark the performance of farms (a proxy for competitiveness in this thesis) (Latruffe, 2010). Countries often seek to promote competitiveness through policies and reforms that encourage efficiency improvements (Kumbhakar *et al.*, 2015). Efficiency improvements need to be continuously pursued against competitive benchmarks and based on discussions around future development policies (DAFM, 2015). Technical efficiency is defined as the ratio of the observed output to the corresponding maximum potential output (given inputs and technology) relative to the estimated production frontier (Kumbhakar *et al.*, 2015; Dong *et al.*, 2016). It refers to the ability to minimise input use in the production of a given output vector, or the ability to obtain maximum output from a given input vector (Kumbhakar *et al.*, 2015). A producer is deemed technically inefficient if they operate below the production frontier and technically efficient if they operate on the production frontier. The level of access to inputs, technology, investments, extension services, management and location are critical factors that determine where the producer will be located in the production frontier. A producer's efficiency level can only be compared to either a group of similar producers or to same producer efficiency level over time (Carroll *et al.*, 2011).

Technical efficiency reflects whether a firm uses the best available technology and scale efficiency considers whether firm size minimizes average cost (Latruffe *et al.*, 2012; Chavas *et al.*, 2022). Given a production frontier displaying variable returns to scale (decreasing, increasing or constant), a producer operating on the production frontier may be able to further increase their productivity by changing their scale of operations. Technical efficiency is regarded as one of the components of Total Factor (multifactor) Productivity (TFP) which is considered to be the most complete approach to measuring productivity since it involves all factors of production simultaneously (Kumbhakar *et al.*, 2015). However, the consideration of the TFP index built as a ratio of distance function measure goes beyond the scope of this thesis. Instead, the focus is on the decomposed TFP growth sources such as technical change, returns to scale and efficiency changes which capture productivity in a way that allows for comparison among producers. If a firm is technically inefficient, then its productivity can be improved by eliminating inefficiency but it is difficult to compare the productivity and profitability of two technically inefficient firms. The goal of efficiency analysis is to quantify a decision-making unit's ability to convert input(s) into output(s), in effect, to measure management ability.

Technical efficiency requires the implementation of methodologies that allow for the estimation of the effects of exogenous factors i.e. policy impact. Carroll *et al.* (2011) suggested that three factors contribute to competitive positioning: relative productivity growth rates, relative changes in costs and relative changes in the price of output. All of which are indicators of competitiveness. In this thesis, we consider farm level efficiency at a regional level.

2.3.2. *Justification for a regional rather than a national approach*

Technical efficiency estimates of a country are often used as a key performance indicator for improving production processes and farm performance (O'Donnell *et al.*, 2008). In countries where there are regional differences, farms in poor-performing regions may struggle to be viable in the long run which can threaten the competitiveness of the value chain and stakeholders in those regions (Shrestha and Hennessy, 2008; Hennessy *et al.*, 2009). Even though Ireland is a small country, regional disparities still apply (Läpple *et al.*, 2017). Ahikiriza *et al.* (2021), noted that dairy advisory services often relied on 'one-size-fits-all' solutions because insights into variability and benchmarks were lacking. Technology differences may exist at a regional level, suggesting that aggregate estimates of technical efficiency and productivity at a country level could be misleading in terms of the adjustments or support required by farms in different regions (Abdulai and Tietje, 2007). There are often gaps in regional planning and policy processes that help to define regional targets, especially when empirical data on farm performance for regions is limited or not well coordinated (Alem *et al.*, 2019). This suggests a need for appropriate allocation of resources across regions matched with rigorous programmes for auditing regional farm performance and existing regional policies (Tsekeris and Papaioannou, 2018).

Ireland makes an interesting case study within the EU, given the differences in regional technology (Läpple and Hennessy, 2012; Läpple *et al.*, 2017; Chavas *et al.*, 2022) and differences in regional constraints posed by policies such as the milk quota policy (Shrestha and Hennessy, 2008; Hennessy *et al.*, 2009; Gillespie *et al.*, 2015). Understanding the location of winners and losers from policy reforms is paramount if we are to analyse the impacts of such reforms on regional development (Ballas *et al.*, 2006). According to Dong *et al.* (2016), regional concentration among marginal farms may create the political environment for a specific policy response to adverse shocks that marginalize producers. Irish dairy farms increased milk production by 54% from 2005-2018, and the building of regional milk processing facilities played a key role in this expansion (Kelly *et al.*, 2020). Yet, the regional challenges and the effects of farm growth policies or schemes on efficiency are not well-

researched. Regional growth patterns and insights that can be used for adapting the national policy frameworks to regions in policy dialogues are needed, i.e. to achieve the Food Vision 2030 with ambitious targets set for expansion.

2.4. Price transmission

2.4.1. Definition of price transmission

Price transmission refers to a process through which information is transmitted between participants in a market and measures comparative static or dynamic price relationships (Vercammen, 2011; Lloyd, 2017). The transfer of prices can occur horizontally (or spatially) which is concerned with how prices of the same good relate to one another at different regions or markets (influenced by a range of macroeconomic factors and government policy intervention), and vertically which focuses on the value chain from farm to trade, such as how the price of a processed product impacts on the farm-level raw material price (farmer behaviour) and vice versa (McCorrison, 2015). Price transmission is concerned with competition and the behaviour of price dynamics. Price transmission can be symmetric or asymmetric in terms of differences in transmission speed and/or magnitude between markets. For example, if a price increase or decrease is completely and rapidly transmitted from one market to another, the transmission is symmetric; otherwise, it is asymmetric. Therefore, the assumption in this thesis is that, the more symmetrical the prices, the more competitive the sector or country (with rapid and complete price transmission as a proxy measure of competitiveness in this thesis). Thus, asymmetry and lack of information can lead to poor integration (price shocks in one market evoke responses in other markets) in some market segments and between some market actors (Brown *et al.*, 2021).

Firms/countries take advantage of their market power by marking up the price above their marginal cost of production and market power influences the degree of price transmission (McCorrison, 2015). In an integrated market system, the price in the country-buyer should be equal to the price in the country (symmetric) seller plus transportation and transaction costs (the law of one price) (Vercammen, 2011; Lloyd, 2017; Brown *et al.*, 2021). The convergence of prices in the long-run does not necessarily imply efficient allocation of resources unless the setting in which trade takes place is competitive (Baffes and Ajwad, 2001; Vercammen, 2011). In markets that are not integrated by the price mechanism, price movements across those countries will be independent. For example, the pattern and strength of price linkages provide useful information on whether a given set of spatial markets are integrated or segmented (Serra and Goodwin, 2003; Liu *et al.*, 2019). The effective distribution of benefits in the food value

chain is crucial for competitiveness and ensuring that various economic actors fully benefit from agricultural policy reforms toward greater market orientation (McCorriston, 2015).

2.4.2. *Significance of price transmission*

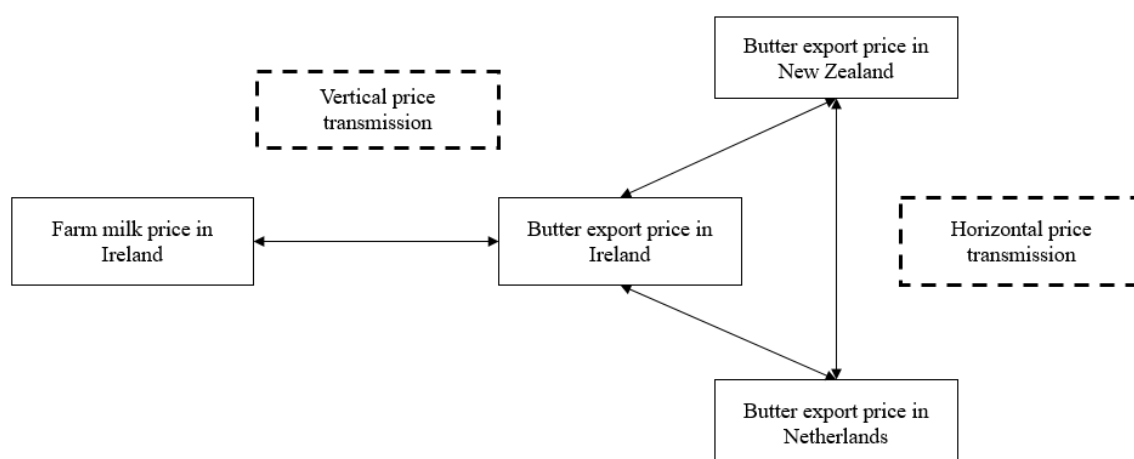
There are several reasons why studying price transmission is important. Price transmission provides price transparency and risk management along the value chain and across markets (Baffes and Ajwad, 2001; McCorriston, 2015), especially when pricing issues are high on the list of concerns of stakeholders and policy-makers in the food chain. A high degree of pricing integration is a standard feature of competitive global commodity markets and a measure of relative price performance (Vercammen, 2011; Ramsey *et al.*, 2021). Economists that study market competition, performance, efficiency, and integration, are interested in the price transmission processes, i.e. for improved perception of the link between domestic and foreign market developments or uncertainty, and between farm to trade or in the value chain (Vercammen, 2011; Ramsey *et al.*, 2021). Price transmission demands an industry to be brought directly into the analysis, rather than assuming away the price relationships that exist (McCorriston, 2015; Lloyd, 2017). Price transmission provides a yardstick with which to measure the functioning of markets, and a brief review of the micro and macro dimensions uncovers a unifying theme, namely the importance of competition in the value chain. The level of efficiency at each marketing stage and the nature and extent of market shocks transmitted through the various stages of the value chain or horizontally related markets can significantly influence commodity price behaviour. For example, it is important to study the impact of the performance of agri-food markets on commodity prices i.e. milk via the transmission of shocks between markets (Von Cramon-Taubadel, 1998; Baffes and Ajwad, 2001; Vavra and Goodwin, 2005). Milk pricing is one of the only methods of communication between the milk processor and the producer to increase the overall efficiency of the dairy industry (Geary *et al.*, 2010). In the short-run, substitutability between the channels of milk use is expected to be possible but limited and in the long-run, milk prices are expected to be interlinked and react to each other because farmers can adjust their production techniques (e.g., feeding practices) and adapt to new market conditions (McCorriston, 2015).

2.4.3. *Price transmission and its significance in the Irish dairy industry*

In Ireland, the production of butter absorbs the highest percentage of whole milk fat and protein content (Donnellan *et al.*, 2015) which raises the question of price transmission between the prices of those two commodities. In some cases, the relationship between butter and milk prices has been discussed but has not been empirically tested in the literature (Chavas and Mehta,

2004; Xue *et al.*, 2018), especially in the post-milk quota period for Ireland. Figure 2.7 indicates the horizontal and vertical price transmission framework for the Irish dairy industry (i.e. farm milk and butter). It illustrates how symmetric transmission can be used to send signals from the global market to the farm level (McCorriston, 2015). Vertical price transmission looks at the bidirectional link between Irish farm milk prices and Irish butter prices. Horizontal price transmission focuses on the multidirectional link between Irish butter prices with New Zealand and the Netherlands' butter prices as major global competitors. The trade of dairy commodities has become an increasingly important component of international food trade due to the general drive for trade liberalisation and innovations in milk processing (Fousekis and Trachanas, 2016). For example, the volatility of the US market prices for butter and the growth in Irish butter imports in the US post-2014 led to an ad valorem tariff rate of 25% in 2015 instituted by the US (Newton, 2016). Traditional indicators of competitiveness generally focus on export growth and market shares, but price competitiveness (proxy by export price) for homogenous goods like butter is also important for tracking and understanding the market price dynamics and competitor behaviour (Bakucs *et al.*, 2014).

Figure 2.7. Price transmission framework for the Irish dairy industry



Source: Authors' creation

The butter price dynamics or competitiveness of different exporters can be linked to each other due to the substitution effects and market integration in the global market (McCorriston, 2015; Xue *et al.*, 2018). Prices reflect equilibrating forces in a market setting and provide vital signals for the allocation of resources by economic agents (Meyer and Von Cramon-Taubadel, 2004). Both demand and supply of a commodity are affected by the change in the price of the commodity and vice versa. By depicting and analysing the paths of adjustment and/or the

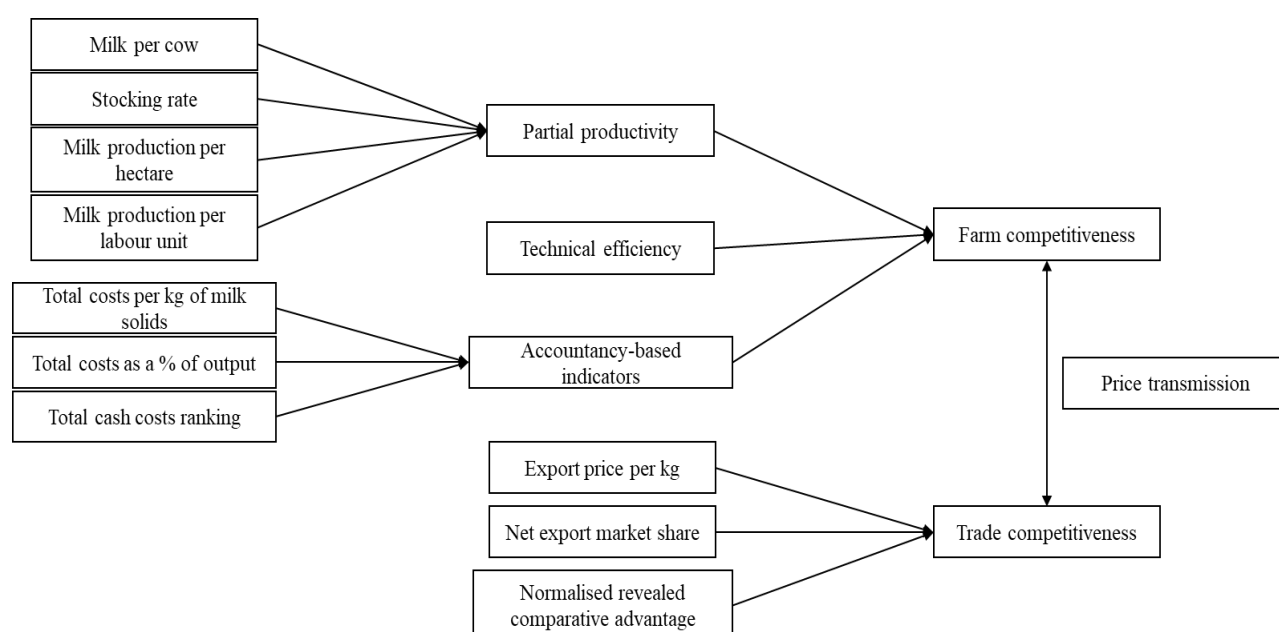
duration of the disequilibrium following initial positive or negative disturbances in prices, useful conclusions about the long- and short-run patterns of asymmetry can be made (Fousekis and Trachanas, 2016). The information on asymmetric price transmission allows processors to make some inferences about the behaviour of different competitors in the market, particularly as their actions impact links across different market levels (Bakucs *et al.*, 2014). It also assists butter industry stakeholders to draw lessons from butter price responses and influence trade expectations more precisely. The price information is useful for setting up new trade policy instruments and informing the need for public subsidies to keep domestic food prices low (McCorrison, 2015). The dairy price and trade interventions that are designed to insulate domestic dairy prices have had an impact on spatial price arbitrage, i.e. different prices in different markets for the same product (Zhang *et al.*, 2017). Moreover, the EU policies are also expected to influence spatial prices for butter in the global market.

The milk market is considered to be among the most protected agricultural markets in the world (Hockmann and Voneki, 2006). One of the major concerns about the asymmetries in milk price transmission within the dairy value chain is that farmers might not reap any benefits from price increases (Liu *et al.*, 2019; Ramsey *et al.*, 2021). Butter and skimmed milk powder are the main dairy products monitored by the EU's Common Agricultural Policy (CAP) to regulate the dairy market. The CAP rules for market management were put in place to limit distortion in international competition and to ensure the competitive price positioning of these products in the international market. The information on butter and skimmed milk powder production, price, and the volumes traded including raw cows' milk was essential for the milk market stakeholders in the EU to be able to react effectively to the market signals and risks in the world food market (Xue *et al.*, 2018). Some of the factors that disrupt the supply of Irish dairy produce (i.e. butter) and its prices include policy changes such as tariffs and quotas, changes in the sustainable supply of raw materials, economic and environmental shocks, and international trade disputes which may result in a loss of revenue growth momentum (McCorrison, 2015; Ornuu, 2019). The removal of market interventions encourages policymakers to rely on specialised past information for countries and dairy products to contribute to the discussions on national policy measures in the long-term. As the world dairy markets liberalise, Ireland's product mix makes processors and farmers more vulnerable to milk price volatility, given that most of the Irish dairy products are exported (Geary *et al.*, 2010).

2.5. Conceptual framework

Figure 2.8 illustrates the competitiveness conceptual framework of performance indicators for the Irish dairy industry adopted in this study and indicates the scope of the thesis. It highlights the interconnections between competitiveness, efficiency and price transmission concepts that have been adopted in this thesis to make an analysis of the Irish dairy industry in the global market. This helps to provide a holistic picture of the Irish dairy industry. Partial productivity, technical efficiency, accountancy-based measures and price transmission are used to assess farm competitiveness (Boyle, 2002; Abdulai and Tietje, 2007; Carroll *et al.*, 2011; Vercammen, 2011; Thorne *et al.*, 2017). Efficiency measurement is important for better resource allocation and for the evaluation of particular policies and farm characteristics that could affect their competitiveness. Comparative advantage, export price and market share are useful measures for evaluating the trade or export competitiveness of a country relative to other countries (Buckley *et al.*, 1988; Porter, 1998; Thorne and Fingleton, 2006; Fetscherin *et al.*, 2012; Bojnec and Fertő, 2012; 2014; 2017). The integration between farm (price) and trade (price) competitiveness is tested by using price transmission (see illustration of price transmission in Figure 2.7 above) (Serra and Goodwin, 2003; Vercammen, 2011; Ramsey *et al.*, 2021). The use or application of these competitiveness measures is important for enhancing decision-making and managing commodity risks (i.e. demand, supply and price risk management) for industry bodies. For example, they can be used to identify business growth opportunities and track competitive activity from market and industry trends to build collective knowledge and increase the speed of reaction. Also, they can be used for understanding the structural changes happening in the dairy value chain.

Figure 2.8. Competitiveness conceptual framework for the Irish dairy industry



Source: Authors' creation

The thesis measures competitiveness and examines the interaction between the farming system of farm milk and the trading system of processed dairy products. Following the approach of Bouamra-Mechemache *et al.* (2008), to deal with the downstream part of the dairy chain, the thesis models the processing of milk into final commodities and the model is spatial and disaggregated at the product and country level. This facilitates the modelling of farming systems across regions and trade between and within countries. As the majority of Irish dairy products are exported, this warrants a need to understand the link between farm and trade relationship or integration (the performance of export markets and its impact on farm performance). Analysing how fundamental drivers and market trends affect trade flows and consequently dairy product prices or price relationships, which in turn impact farm performance, can help to inform strategies relating to the dairy product portfolio. According to DAFM (2021), factors influencing the competitiveness and resilience of the agri-food sector include responsiveness to market and price signals, the development of the scale, investment in innovation, access to finance and liquidity, the reduction of business operating costs, enhanced productivity, and the overall business environment. However, the effects of trading in international markets through the value chain have received very little attention to date in the empirical literature.

3. Evaluating dairy farm and export competitiveness: Post-quota analysis

Abstract

This chapter aims to examine the competitiveness trends and rankings of the Irish dairy sector at the farm and trade levels, relative to selected European Union (EU) Member States, in the context of the removal of the EU milk quota in 2015. Competitiveness indicators including partial productivity measures and accountancy-based indicators were used for farm competitiveness, and net export market share and normalised revealed comparative advantage were used for export competitiveness. Amongst the countries examined, Ireland had the highest growth in partial productivity indicators and was ranked first with the lowest total costs and cash costs per kg of milk solids post-quota. However, the total economic cost sub-components showed that Irish dairy farmers had high opportunity costs for owned land and labour. The challenge for Irish dairy farmers is how to mitigate relatively high land and labour costs, which can limit farm competitiveness in the long run. While Irish dairy products such as butter and powders have demonstrated growth potential in competitiveness post-quota with Irish butter and whey ranked in the top three relative to other countries, other products, i.e. cheese and liquid milk have declined in competitiveness according to key export competitiveness indicators used. The key players in the Irish dairy industry can now better position themselves in the global dairy market, recognising the competitiveness dynamics of the different dairy products and their competitors.

Keywords: Accountancy-based indicators, country/competitiveness rankings, normalised revealed competitive advantage, partial productivity, farm and export competitiveness assessment.

3.1. Introduction

The dairy industry in the European Union (EU) has undergone significant structural adjustments over the years due to changes in factors such as prices, weather, environment, and policies (Giles, 2015; Läpple and Sirr, 2019). Of particular importance to this thesis is the removal of the EU milk quota regime in 2015. The milk quota system was introduced in 1984 to contain the growth of milk production and to ensure that the EU would be able to continue to fund the growing cost of the price support framework (Donnellan *et al.*, 2011; Groeneveld *et al.*, 2016). This ensured that the EU dairy market would have little or no surplus in the EU public storage for products such as butter and skimmed milk powder. While the policy was beneficial in the beginning, it later became a constraint in the development of the industry

because the demand for dairy exports was growing much faster than the supply (Donnellan *et al.*, 2011; Donnellan *et al.*, 2015), especially in Ireland. The European Commission increased the milk quota by 2% in 2008 and gradually increased it by 1% per annum thereafter until 2013 to allow for a “soft-landing” scenario or a smooth transition to eventual removal in 2015.

The most efficient EU dairy-producing countries depended on the easing of the quota restrictions to maintain and improve their competitive position in the global market. Viira *et al.* (2015) conducted research in the pre-quota abolition period using partial productivity and accountancy-based indicators and classified dairy farmers in countries such as Germany, Italy, Netherlands, and Ireland as competitive milk producers with a high impact on the EU dairy market. Likewise, Bojnec and Fertő (2014) found that Belgium, Denmark, France, Ireland, and the Netherlands had a competitive advantage in the global market based on the revealed comparative advantage index. Based on that, Jansik *et al.* (2014) noted that Ireland, the Netherlands, Germany, and Denmark were most constrained by the milk quota system. According to Giles (2015), countries that had high growth potential post-quota were those countries with a comparative advantage in the international market, e.g. Ireland, Denmark, and the Netherlands. Therefore, the milk quota abolition prompted dairy farmers in those countries to evaluate their short-term positions regarding milk production and to decide whether to expand, remain static or exit milk production altogether to survive in the evolving market situation. According to Porter (1998), there is a need to periodically conduct a competitiveness assessment for industries, using the latest data and relevant indicators.

Previously, Donnellan *et al.* (2015) found that the average milk production growth rate in Ireland was about 10% per year between 1970 and 1984, whilst in France, Germany, Denmark, and the United Kingdom (UK) it averaged at about 2%. Recently, Läßle and Sirr (2019) noted that a year after the quota removal, milk production in Ireland increased by 18.5%, the fastest rate in the EU, compared to an average growth rate of 4.5% across the EU. Ireland opposed the introduction of the milk quota system and welcomed its abolition (Donnellan *et al.*, 2015). Therefore, it remains an appealing area of study to review how the Irish dairy industry has performed following the policy change relative to other EU countries such as the Netherlands, Germany, France, Italy, Belgium, Denmark, and the UK. According to Martin *et al.* (1991), government policies can influence the choice of strategy that the farms or firms pursue. Given this context, some questions remain, how has the Irish and EU dairy industry evolved at the farm- and trade-level? How was Ireland positioned (competitiveness ranking) pre (2012-14)

and post (2015-17) quota relative to other EU countries? Where or in which dairy products did trade grow or diminish?

Previous studies such as Viira *et al.* (2015) analysed the competitiveness of the Hungarian dairy industry from farm to trade, and Bojnec and Fertő (2014) analysed EU dairy export competitiveness. However, these studies were limited in the following ways. The data analysed in these studies ended in 2014, before the quota abolition. The main measure used, e.g. the revealed comparative advantage (RCA), prevented the comparison of countries at the trade-level (Yu *et al.*, 2009). Dairy products were analysed as one homogenous group, even though they have significant differences. The probability of a country losing its RCA position is high when it has a broad product portfolio, even though this may be maintained for risk management. This is based on competitiveness theory, which states that countries must direct their resources to products that share similar resources and that they are good at producing (Boyle, 2002; Suwannarat, 2017). This means that a country can have a comparative advantage over a group of processed dairy products but have a competitive disadvantage in products within the same group. This makes it difficult to compare across countries, as one country could have a comparative advantage in butter but not in cheese and vice versa.

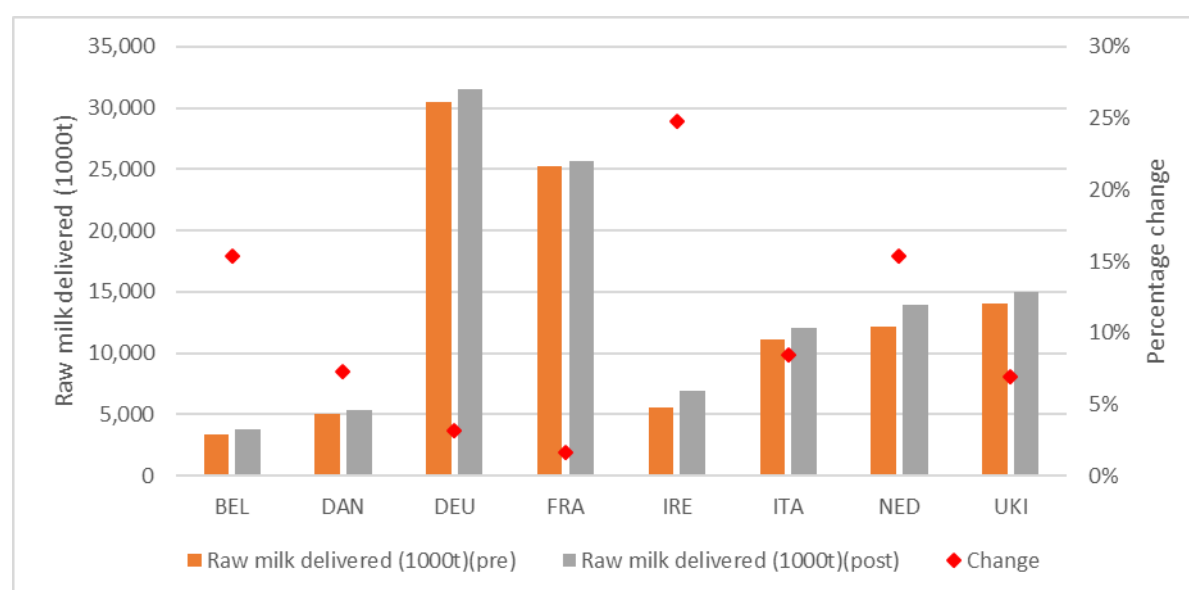
This chapter contributes to the existing literature by identifying industry trends, ranking, and comparing countries based on their competitiveness in dairy farm production and international trade of different dairy products. The competitiveness assessment provides insights that can assist decision-makers in the Irish dairy industry to identify which dairy products to prioritise for production, improvement, and promotion (Fetscherin *et al.*, 2012). According to Martin *et al.* (1991), it is important to separate the web of causality between public policy, private management strategy, and the food industry's competitiveness state. In the following sections, this chapter will provide the contextual background of the Irish and EU dairy industry. It will then review relevant literature on previous studies of competitiveness in agriculture or the dairy industry which will help to guide the direction of this chapter. The methodology for farm- and trade-level measures will then be provided. This will be followed by the results section. The penultimate section will provide a discussion of the results and the policy implications that arise from the application of the competitiveness assessment. Lastly, a conclusion will be made by restating the main arguments or contributions.

3.2. Background of the Irish and selected EU countries' dairy industry

3.2.1. Production of raw milk delivered to processors

In 2017, Germany (21%), France (16%), the United Kingdom (UK) (10%), the Netherlands (9%), Poland (8%), and Italy (7%) collectively provided over two-thirds (70%) of the raw cows' milk produced on farms and collected by dairies in the EU (EU-28 total of 154.8 million tonnes- MT), Ireland contributed 5% (Eurostat, 2019). While the Irish contribution was relatively low in terms of quantity produced. Figure 3.1 demonstrates that Ireland had the highest growth rate of 25% in raw milk deliveries post-quota, driven by exports, from 5.6 to 7 MT supplied to creameries and pasteurisers. The growth was significant for a relatively small country like Ireland. This is in line with the Food Wise 2025 for Ireland which advocated for growth in production and export expansion. The Food Wise 2025 strategy was published in 2015, which coincided with the milk quota abolition. It outlined expansion goals for the Irish agri-food sector with the dairy industry featuring prominently.

Figure 3.1. Changes in raw milk delivered pre (2012-14) and post (2015-17) quota



Source: Authors' calculations based on Eurostat database

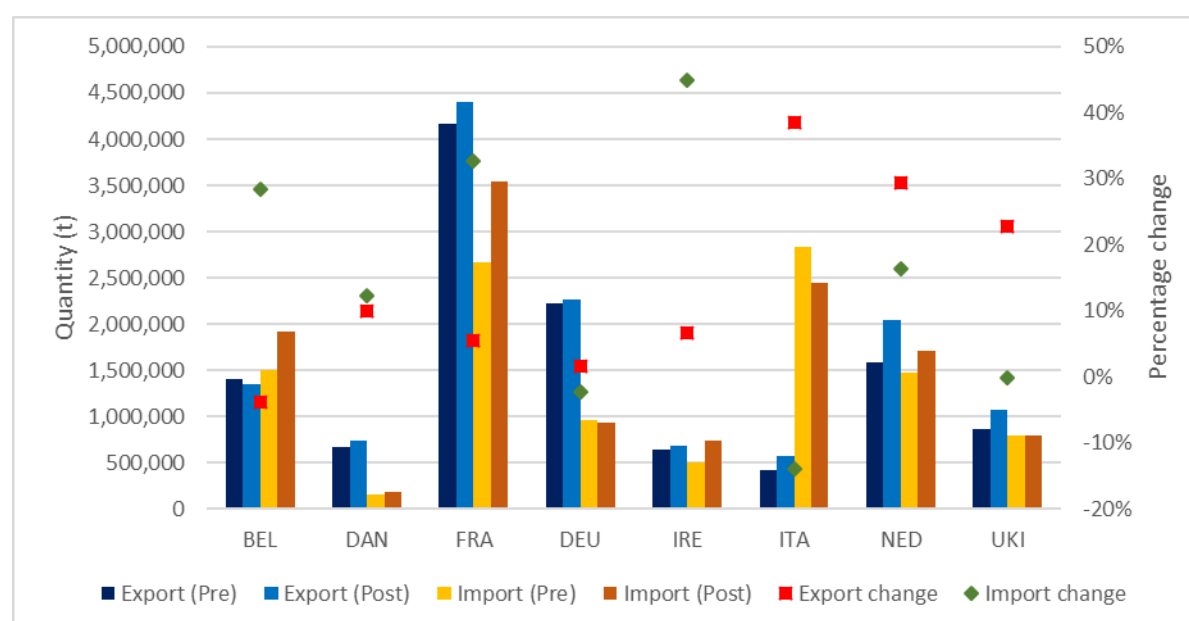
3.2.2. Trends in dairy products' exports and imports

In 2019, the exported edible Irish food and drinks industry contributed €12.9 billion to the economy, and the dairy industry had the highest contribution of 34% (National Milk Agency [NMA], 2019), making it one of the most significant industries. According to DAFM (2021), Ireland's success in gaining and retaining access to international markets is directly related to

Ireland's excellent reputation for food safety and our enviable national herd health status. Ireland is one of the most prominent exporters in the EU. For example, Ireland contributed 4% to the total EU export quantity in 2017 compared to 20% for Germany, 10% for France, and 3% for Italy, of 20.6 MT. For total dairy products, Irish export quantity grew by 7% and had the highest rise in export price/kg of 3%, while import quantity growth was the highest at 45% with the highest decline in import price/kg of 24% post-quota. This is illustrated in Figure 3.2 for quantity and 3.3 for price/kg. The rise in Irish export price/kg slowed the growth in export quantity. Italy had the largest reduction in export price/kg of 13% and the highest growth in the export quantity of 39%. This is due to the different profiles of dairy products per country.

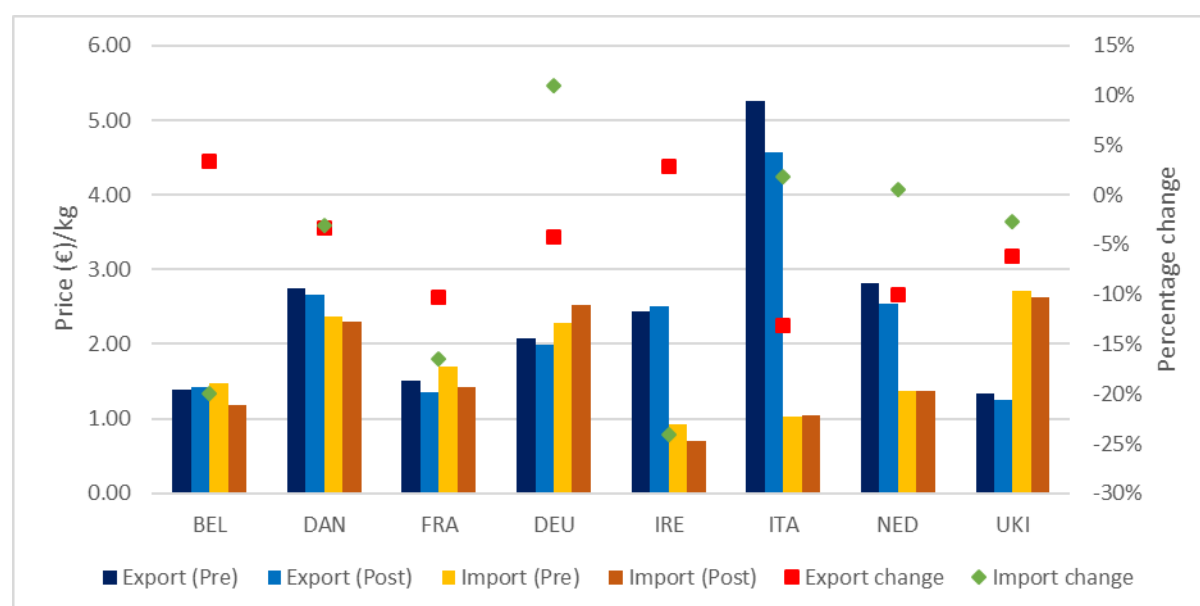
The Irish export quantity post-quota comprised of cheese, butter, skimmed dried milk, skimmed cow, whey, whole dried, and whole milk at 30%, 28%, 11%, 10%, 10%, 8%, and 4%, respectively, of 680 thousand tonnes (TT). For Ireland, the highest export quantity growth came from skimmed dried milk, while the largest decline was in whole fresh milk. The growth in Irish imports was mostly due to the importation of raw milk which grew by 56% to 587 TT (see Figure A1 in Appendix A), and constituted 80% of the total quantity imported post-quota. According to NMA (2019), from the 651 TT of imported milk, excluding imports of fresh milk in consumer packs, 92% was for processing into manufactured dairy products and 8% was for processing into liquid/fresh milk for consumption. In 2019, the Irish fresh milk market was worth about €514 million in retail value (for 578 TT), the largest consumer market in domestic milk and milk products at 118 litres per capita per annum, the highest in the world (NMA, 2019).

Figure 3.2. Total dairy products export and import quantity pre- and post-quota



Source: Authors' calculations based on the FAOstat database

Figure 3.3. Total dairy products export and import price (€) per kg pre- and post-quota



Source: Authors' calculations based on the FAOstat database

3.3. Literature review on competitiveness

3.3.1. Definition of competitiveness from farm- to trade-level in the dairy industry

Policy changes in domestic and international markets continue to be the primary driver of competitiveness research (Jansik *et al.*, 2014; Thorne *et al.*, 2017). Research on the

implications of the changes in price-distorting support systems is expected to grow as more countries become engaged in and exposed to global markets where productivity and profitability are essential for the survival of an industry (Boyle, 2002; Bojnec and Fertő, 2014). The concept of competitiveness holds many definitions in the literature due to its complex and dynamic nature, which can vary by industry. Various authors have chosen definitions that match their areas of interest (Latruffe, 2010) and the kind of data they have available to compute their measures. According to Fetscherin *et al.* (2012), an industry-level analysis enables inter-country comparisons of a given industry, which provides greater detail and a better understanding of the export competitiveness dynamics of countries. At an industry level, such as the dairy industry, competitiveness measures can be analysed at three sub-levels, namely, farm and firm (processing) production levels, and trade-level in international markets, i.e. country's trade balance. However, the competitiveness assessment of the dairy industry in this chapter excludes firm-level competitiveness due to a lack of data on public data sources. Therefore, competitiveness is defined as the combined measure of farm and trade performance of dairy products over a period. A country can be considered competitive when it can increase its performance and reduce its production costs at the farm-level and grow or maintain its market share in the domestic and global markets. Improving and promoting the quality of exports while protecting the domestic industry from unrestrained imports in the country, can also be considered as a measure of competitiveness.

3.3.2. Measures of competitiveness at the farm-level

In the previous literature, farm-level competitiveness papers have used indicators such as partial productivity measures, namely, milk yield per cow (kg), milk solids per cow (kg), stocking rate (LU/ha), milk production per hectare (kg), milk solids per hectare (kg), milk production per labour unit (tonne) and accountancy-based indicators. These partial productivity measures help to track the input costs (total costs per kg of milk solids) and profitability (total costs as a percentage of dairy output) (Boyle, 2002; Groeneveld *et al.*, 2016; Thorne *et al.*, 2017). In these studies, Ireland was considered as a competitive milk producer based on cash costs as a percentage of output or per kg of milk solids but was ranked in the bottom three when it came to partial productivity indicators and total economic costs of production. The high seasonality of milk production in Ireland has limited efficiency in the processing industry, which requires a constant supply of milk throughout the year to maximise efficiency (NMA, 2019). Donnellan *et al.* (2011) projected that there would be an increase in milk production, farm sizes, and processing facilities in Ireland post-quota, which would help drive

competitiveness. On the other hand, Viira *et al.* (2015) found that Ireland was the most significant country within the EU in 2014 with the highest import of raw milk, which was processed, i.e. 6% of the processed raw milk.

3.3.3. Measures of competitiveness at the trade-level

Previous export competitiveness studies have computed indicators such as export and import price growth rates, export-to-import ratio, net export market share (NXMS), revealed comparative advantage (RCA), relative import advantage (RMA), relative trade advantage (RTA), or revealed competitiveness (RC) and normalised revealed comparative advantage (NRCA) (Yu *et al.*, 2009; Viira *et al.*, 2015; Suwannarat, 2017). Price and quality competitiveness were used to analyse the industry or product performance and potential in the market (Buckley *et al.*, 1988). If the quality of the product is a crucial component in the market as in the dairy industry, the price may be considered as an approximate indicator of quality because there is no quantitative data on product quality. Low prices would indicate low-quality products.

There has been an increasing number of export competitiveness studies in other industries, using the RCA as the primary indicator. Examples include; the agriculture and manufacturing sector in Pakistan (Abbas and Waheed, 2017), the tuna industry in Thailand (Kuldilok *et al.*, 2013), the wine industry in the EU (Balogh and Jámbo, 2017), and the coffee roasting industry in Italy (Pascucci, 2018). In the dairy industry, Bojnec and Fertő (2014) used the RCA measure and found that Ireland was one of the few countries that had a competitive advantage in the global market for total dairy products from 2000-2011. However, previous research has focused on exports only and was narrow on the measures that considered imports. Import competitiveness is very broad and has aspects beyond the scope of this chapter, i.e. import processes and their management. It requires data that is not readily available.

3.4. Data sources and methodology

3.4.1. Data sources

3.4.1.1. Farm-level

For the analysis presented here, the data sources were the European Commission's Farm Accountancy Data Network (FADN) [i.e. Type of farming (45)- specialist dairy farms], and Eurostat for fat and protein content, to analyse the largest EU specialist milk producers (i.e. Belgium, Germany, France, Denmark, Italy, Netherlands and United Kingdom) and to

calculate partial productivity and accountancy-based indicators. The countries were selected based on the findings of studies such as Thorne and Fingleton (2006), Bojnec and Fertő (2014), Giles (2015), and Thorne *et al.* (2017). Moreover, these countries compete with Ireland in terms of production and trade in the global market. They also play a significant role in the agricultural policy arena (Boyle, 2002). The data was obtained from the European Central Bank (ECB) for the annual nominal interest rate and Worldwide Inflation Data (WID) for the annual inflation rate, which was used to calculate the annual real interest rate.

3.4.1.2. Trade-level

The data was gathered from FAOstat for trade competitiveness indicators (2012-2017) which included dairy products (butter, cheese, skimmed milk, dried skimmed milk, dried whole milk, and whole fresh milk) and agricultural imports and exports within the EU and in the world. The data for the exchange rate was also secured from FAOstat.

3.4.2. Methods

3.4.2.1. Farm-level

An average of three years (short-term) pre (2012-14) and post (2015-17) quota was calculated for all variables. Farm-level data was used to compute partial productivity measures and accountancy-based indicators, following Thorne *et al.* (2017). Total cash costs include all specific costs directly incurred in the production of a given commodity (e.g. fertiliser, feedstuffs, seeds, etc.), external factors (e.g. wages, rent, and interest paid), and farming overheads (e.g. machinery and building current costs, energy and contract work, etc.). The total economic costs include all cash costs plus depreciation and imputed opportunity costs for family labour, equity capital, and owned land. Total costs and cash costs were expressed as per kg of milk solids to account for the differences in milk fat and protein, and as a percentage of dairy output to account for differences in milk prices, which depicts the variation in profitability across countries or resilience of countries to changes in milk prices (Boyle, 2002; Thorne *et al.*, 2017). According to Buckley *et al.* (1988), costs enable comparison between firms/farms using different methods of foreign market servicing.

3.4.2.2. Trade-level

Based on the theory of comparative advantage, a country specialises and exports products for which it has a comparative advantage (Viira *et al.*, 2015; Abbas and Waheed, 2017). According to Latruffe (2010), Revealed Comparative Advantage (RCA), which is Vollrath's modified

version of the Balassa index, is based on exports only. RCA measures a country's export market share of a commodity relative to its total agricultural exports in the global markets. An RCA index greater than one indicates that the country has a comparative advantage in exports of dairy products and has higher competitiveness in the world agricultural market. The revealed comparative import advantage (RMA) is based on imports only, and an RMA index of less than one indicates a comparative advantage and thus higher competitiveness as the country can meet its domestic demand with minimal or no dairy imports relative to other agricultural imports in that country. A country is considered to have import competitiveness when it is not dependent on imports (net exporter) to meet domestic demand or when it can keep its imports minimal.

In the literature, the RCA indicator has been criticised for three main reasons (Yu *et al.*, 2009; Suwannarat, 2017). Firstly, countries cannot be compared to each other using the RCA, and it can only compare the trends over a period for each country. Secondly, the RCA index is not symmetric (between -1 to 1) and the mean is not fixed, hence the RCA index can range from one to infinity, making it difficult to compare countries. Even though some studies have used the revealed competitiveness (RC) index, which is the difference between log RCA and RMA. This has a limitation as the outcome is not always symmetric, for example, if RCA is 3 and RMA is 0.2 the result is 1.2 which is outside that range. Thirdly, the RCA does not account for the size of the country and commodity market in the world. To address the limitations of the RCA, the Normalised Revealed Comparative Advantage (NRCA) indicator is used.

According to Yu *et al.* (2009), the NRCA index measures the degree of deviation of a country's actual exports from its comparative-advantage-neutral situation in terms of its relative scale concerning the world export market. An NRCA index greater than zero (comparative-advantage neutral point) (or $NRCA < 0$) indicates that the country has a comparative advantage (or disadvantage). The index shows the dairy products that the country specialises in and how it competes in those products with other countries. The higher (or the lower) the NRCA score is above zero, the greater the comparative advantage (or disadvantage) for a country. The country with the highest NRCA score is the most competitive. No country can have a comparative advantage (or disadvantage) in all products based on the relative nature of comparative advantage or the assumption that the available resources which are shared across products are limited or held constant. Therefore, the sum of a country's and the sum of a product's NRCA scores equals to zero, which means that when a country gains a comparative

advantage in producing a dairy product, other countries lose a comparative advantage in that dairy product.

The NRCA calculates competitiveness from the comparative-advantage neutral point for each country which enables country and dairy products comparisons and ranking. The NRCA considers both the country's market share of all commodities in the world export market and the specific commodity's market share in the global market. The size of the country and dairy product markets is important for distinguishing specialisation or competitiveness in big and small countries and their comparable dairy products. For example, it could be expected that more prominent countries may favour diversification because of the economies of scale, and smaller countries may choose to specialise more in a few products with more focus on niche markets. Export competitiveness measures such as the NRCA index face a common criticism which is that they ignore the import indicators and as a result, the net export market share (NXMS) indicator is used (Martin *et al.*, 1991; Fetscherin *et al.*, 2012; Pascucci, 2018). The market share indicator looks at the absolute performance of an industry vis-à-vis its European or world competitors. Therefore, the use of the net export market share indicator complements the NRCA indicator.

Table 3.1 specifies the indicators used in this chapter to enrich the export competitiveness analysis and augment the NRCA indicator. Given that countries do not use similar technologies and factors of production, this may influence trade patterns and specialisation. Hence, the value rather than the quantity approach is considered suitable for this chapter to calculate the NRCA index. The export and import price and quantity changes or growth rates were calculated to capture the significance of the trends. According to Fetscherin *et al.* (2012), Suwannarat (2017), and Pascucci (2018), export growth in each industry and country implies a greater degree of competitiveness. The export-to-import ratio is used for assessing product quality. A ratio greater than one indicates that exports are more expensive, and thus of higher quality than imports. The net export market share shows the difference between the export and import market share of dairy products. It reveals the competitive position of a country in the international market for a given sector (Martin *et al.*, 1991; Suwannarat, 2017). A higher index suggests a higher potential of that country in that industry and a negative value indicates that the country is a net importer in that sector or product.

Table 3.1. The indicators for trade competitiveness in the dairy industry

Measure	Calculation/equation
Export [or import] price €/kg	$\frac{\text{Export [or import] value}}{\text{Export [or import] quantity}} \quad (3.1)$
Export-to-import ratio (export quality)	$\frac{\text{Export Price(€)/kg}}{\text{Import Price(€)/kg}} \quad (3.2)$
Relative change or growth rate	$\frac{\text{Export [or import] price (post-pre)}}{\text{Export [or import] price pre}} \times 100 \quad (3.3)$
Export [or import] market share (EMS) [or IMS]– value terms	$\left(\frac{\text{Country dairy exports [or imports]}}{\text{World dairy exports [or imports]}} \right) \times 100 \quad (3.4)$
Net export market share (NXMS)	Export market share (%) – Import market share (%) (3.5)
Normalised revealed comparative export advantage (NRCA)- value terms*	$\left(\frac{\text{Country total dairy products exports}}{\text{World agricultural exports}} \right) - \left(\frac{\text{Country agricultural exports}}{\text{World agricultural exports}} \right) \left(\frac{\text{World total dairy products exports}}{\text{World agricultural exports}} \right) \quad (3.6.1)$
	$\left(\frac{\text{Country dairy product exports}}{\text{World total dairy products exports}} \right) - \left(\frac{\text{Country total dairy products exports}}{\text{World total dairy products exports}} \right) \left(\frac{\text{World dairy product exports}}{\text{World total dairy products exports}} \right) \quad (3.6.2)$

*For total dairy products, the first equation (3.6.1) is used and for individual dairy products (i.e. butter, cheese, skimmed milk, skimmed dried milk, whole dried and whole fresh milk), the second equation (3.6.2) is used.

These measures are used to rank the country's positions and trends. Two short-term periods were used to examine relative performance pre and post-policy change. According to Fetscherin *et al.* (2012), using longitudinal data enables one to look at the historical change in export competitiveness for various industries and countries. This helps to overcome the need for analysing the predictive values by focusing on trends instead, which are useful for strategic decision-making (Pascucci, 2018). Whilst the change in performance indicators does not prove causality with the policy change. The change in position would suggest a significant impact in the period examined, during which the policy change was a significant structural event.

3.5. Results

3.5.1. Farm-level competitiveness

Table 3.2 presents productivity measures such as milk yield and solids per cow and stocking rate per hectare. Ireland had the lowest milk yield per cow pre- and post-quota, but it had the second-highest growth rate at 6.9%. The situation with milk solids was similar, Ireland had the

lowest level but had the highest growth rate of 10%. The UK declined the most in both milk yield (1.5%) and solids (0.2%) per cow post-quota. Growth in milk solids, which is influenced by farming practices, leads to improvements in the efficiency of the dairy processing industry (Viira *et al.*, 2015) as milk pricing models tend to place value on fat and protein content. Ireland had the highest stocking rate increase of 5% and Italy had the highest decline of 11%.

Table 3.2. Yield and stocking productivity indicators pre- and post-quota

Country	Milk yield/cow (kg)			Milk Solid/cow (kg)			Stocking rate (LU/ha)		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
BEL	7131	7501	5.2%	533	563	5.6%	2.3	2.4	4.3%
DAN	8926	9563	7.1%	691	745	7.9%	2.2	2.3	4.6%
DEU	7536	7597	0.8%	567	582	2.6%	1.9	1.9	1.7%
FRA	6840	6856	0.2%	504	507	0.6%	1.4	1.5	3.4%
IRE	5365	5735	6.9%	394	435	10.2%	2.0	2.1	5.0%
ITA	6072	6163	1.5%	434	458	5.5%	3.4	3.0	-11.4%
NED	7969	8334	4.6%	630	660	4.9%	2.5	2.5	-0.3%
UKI	7327	7219	-1.5%	535	533	-0.2%	2.1	2.1	0.3%

Source: Authors' calculations based on FADN, Eurostat, ECB, and WID dataset

Table 3.3 provides the land and labour partial productivity indicators pre- and post-quota. Ireland had the highest growth rate at 12% for milk production per hectare, 16% for milk solids per hectare, and 19% for milk production per labour unit. Thorne *et al.* (2017) also found similar partial productivity results in a more limited period post-quota. Generally, most countries improved their partial productivity indicators post-quota as highlighted in Tables 3.2 and 3.3, with Ireland showing the most growth potential. Italy was the only country among the countries examined to exhibit negative growth rates post-quota for milk production (10%) and solids (7%) per hectare.

Table 3.3. Land and labour productivity indicators pre- and post-quota

Country	Milk production (kg/ha)			Milk solids(kg/ha)			Milk production/labour unit		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
BEL	16187	17753	9.7%	1210	1331	10.1%	337645	378299	12.0%
DAN	19398	21753	12.1%	1502	1695	12.9%	779605	805361	3.3%
DEU	14415	14778	2.5%	1084	1131	4.4%	333101	353362	6.1%
FRA	9675	10031	3.7%	713	741	4.0%	294940	305551	3.6%
IRE	10764	12075	12.2%	791	915	15.6%	320612	382377	19.3%
ITA	20874	18776	-10.1%	1492	1395	-6.5%	230587	250155	8.5%
NED	20261	21110	4.2%	1601	1673	4.5%	491773	518113	5.4%
UKI	15237	15064	-1.1%	1112	1113	0.1%	451124	476691	5.7%

Source: Authors' calculations based on FADN, Eurostat, ECB, and WID dataset

Milk prices are a critical influencing factor in dairy farmer behaviour which can influence investments to increase production and improve productivity. Donnellan *et al.* (2011) noted

that the Irish farm milk price is primarily determined by dairy commodity prices on the EU market. Post-quota, milk prices declined for all countries, in Ireland prices fell by 13% compared to the UK which fell the most by 15%. The price decline in France was the smallest at 7%. Irish dairy farmers had the second-highest net farm income on average (after Italy) post-quota, with the highest growth rate of 18%. This was significant given that income declined in most countries except for Germany and Italy as demonstrated in Table 3.4. Dairy farmers in the Netherlands experienced the largest net income decline (28%). Ireland had the highest growth in dairy cows at 9% with the Netherlands declining the most by 1.6%. Groeneveld *et al.* (2016) argued that in the Netherlands, the policy change would lead to no detrimental changes in the number of cows kept by the smallest farm type. The Irish total utilised agricultural area growth rate remained stagnant, compared to Italy which increased the most by 13%, and the Netherlands which fell the most by 5%.

Table 3.4. Raw milk price and farm income pre- and post-quota

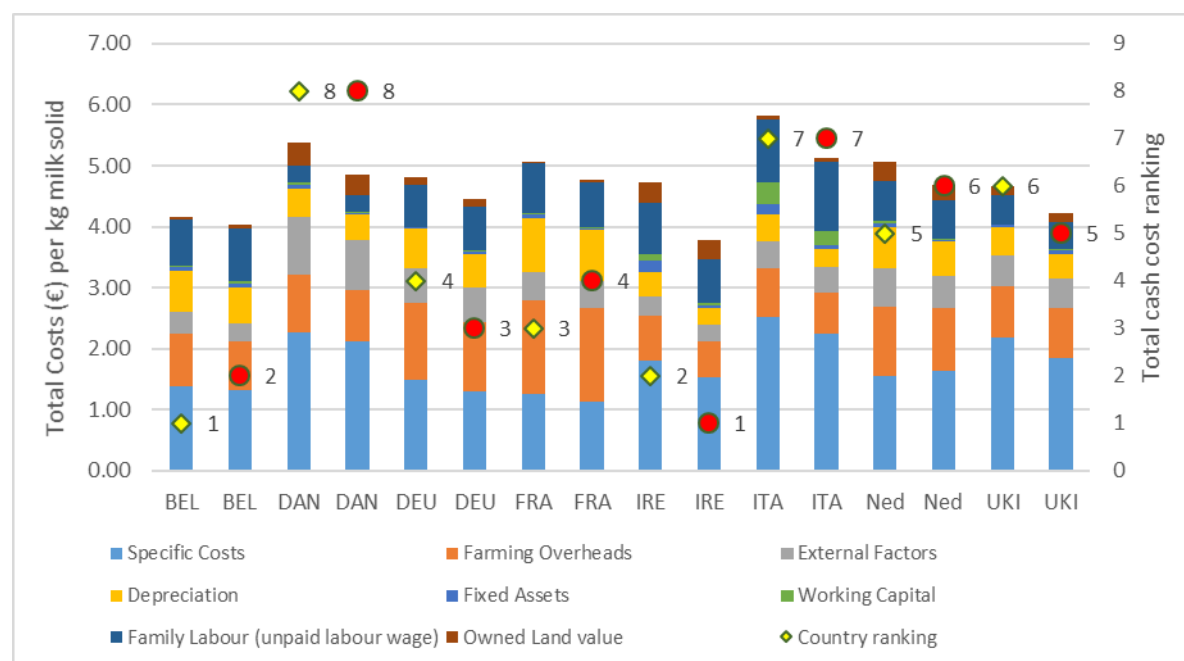
Country	Milk price (€/100 kg)			Total utilised agric. area (ha)			Dairy cows (LU)			Farm net income (€)		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
BEL	34.5	29.9	-13%	53.6	54.1	0.9%	66.6	72.3	8.6%	65,025	55,828	-14%
DAN	37.4	32.3	-14%	159.9	158.5	-0.9%	168.3	166.4	-1%	57,355	45,710	-20%
DEU	34.8	31.1	-11%	72.1	72.1	0.1%	61.2	63.2	3%	47,287	47,498	0.4%
FRA	34.4	31.8	-7%	91.5	91.5	0.1%	57.1	59.5	4%	36,968	32,432	-12%
IRE	36.1	31.4	-13%	59.4	59.4	0%	67.3	73.5	9%	61,808	73,092	18%
ITA	38.5	34.6	-10%	29.5	33.3	13%	53.7	55.8	4%	88,625	89,812	1%
NED	37.6	32.3	-14%	53.9	51.3	-5%	93.5	92.0	-1.6%	72,304	51,991	-28%
UKI	36	30.5	-15%	109.5	112.7	3%	130.9	135.4	3.5%	77,866	57,940	-26%

Source: Authors' calculations based on FADN, Eurostat, ECB, and WID dataset

According to Buckley *et al.* (1988), the lower the costs a firm/industry incurs, the more competitive it will be. Figure 3.4 shows the total costs (cash and economic) per kg of milk solids pre and post-quota and country rankings based on total cash costs. Similarly, Figure 3.5 provides the total costs as a percentage of market-based dairy output pre and post-quota and total cash cost rankings. In general, total costs for milk solids fell for all the countries. The results for total costs as a percent of dairy output were mixed, which is expected given the change in milk price post-quota. Total costs and total cash costs for milk solids fell the most in Ireland by 20% and 16%, respectively, moving from third to first position and second to first position, respectively. The lowest total costs and total cash costs recorded post-quota were in Ireland at €3.78/kg and €2.39/kg, respectively. By contrast, Italy and Denmark had the highest total cost (€5.13/kg) and total cash cost (€3.79/kg) post-quota, respectively. Consequently, Ireland was ranked first as the most competitive country post-quota for both total costs and total cash costs per kg of milk solids, and Belgium lost its rank to Ireland becoming second.

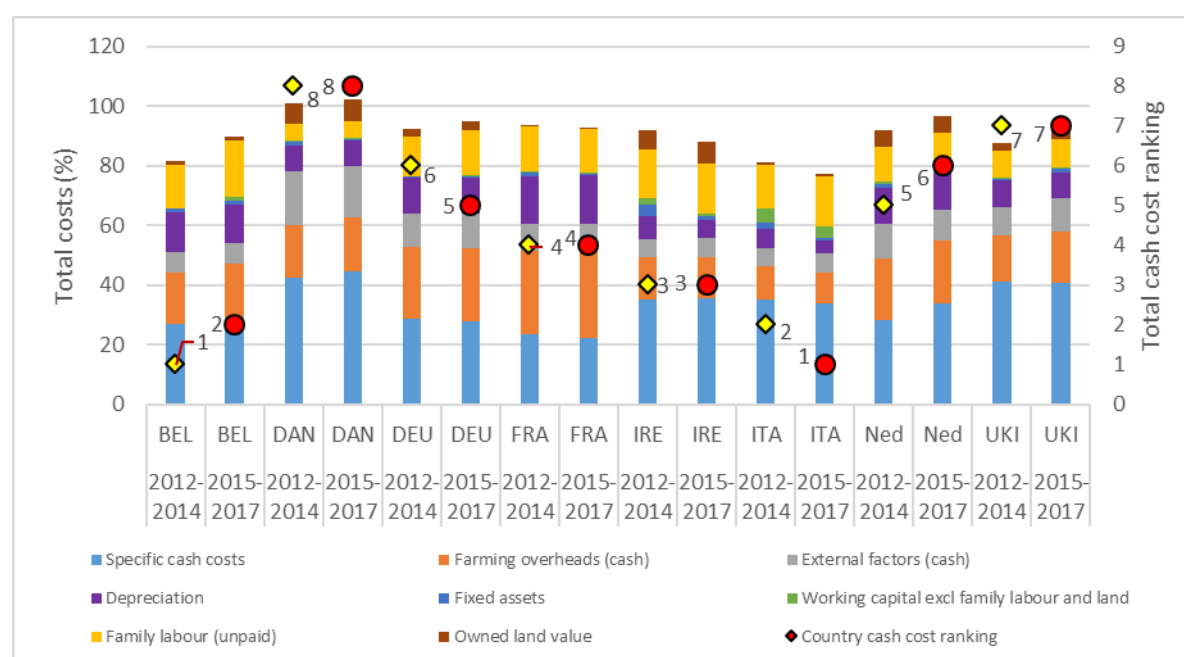
Ireland ranked third, pre (55%) and post (56%) quota, for total cash costs as a percentage of dairy output with the third-lowest growth in total cash costs of 0.5%. Belgium (51%) and Italy (50%) (declined the most by 3.7%) ranked first, respectively, pre- and post-quota. Ireland had the second-highest drop of 4.4% in total costs, which led to a rise from fourth to the second position with total costs of 88% post-quota after Italy (78%). Denmark had the highest total cost (102%) and total cash costs (80%) post-quota. The Irish land and family labour costs per kg of milk solids slightly declined post-quota, which was important for the dairy farmers' ability to adapt and expand milk production efficiently. Despite that, Ireland continued to have the third-highest family labour costs as a percent of dairy output and milk solids post-quota. Donnellan *et al.* (2011) also observed that Ireland relied more on family labour than hired labour which kept the imputed costs high.

Figure 3.4. Total costs per kg of milk solids and total cash cost ranking pre- and post-quota



Source: Authors' calculations based on FADN, Eurostat, ECB, and WID dataset

Figure 3.5. Total costs as a percentage of dairy output and total cash cost ranking



Source: Authors' calculations based on FADN, Eurostat, ECB, and WID database

3.5.2. Trade competitiveness based on NRCA ranking

The strength of the dairy sector in a country is demonstrated by the Normalised Revealed Comparative Advantages (NRCA) (Bojnec and Fertő, 2014) and the market share which are proxies to competitiveness. The NRCA captures the comparative advantage a country has in producing a particular product in the global market and it assumes that the less specialised a country is in producing a particular product, the less competitive it is or will be. Figure 3.6 depicts the competitiveness ranking across countries and dairy products based on the NRCA index pre- and post-quota. Overall, the rankings for countries changed in most dairy products except powders and whole fresh milk. Based on total dairy products, Ireland has ranked number five amongst the countries examined pre- and post-quota. Its competitiveness remained relatively unchanged at just 0.01 points. The Netherlands increased the most by 4.9 points and Germany declined the most by 4.7 points.

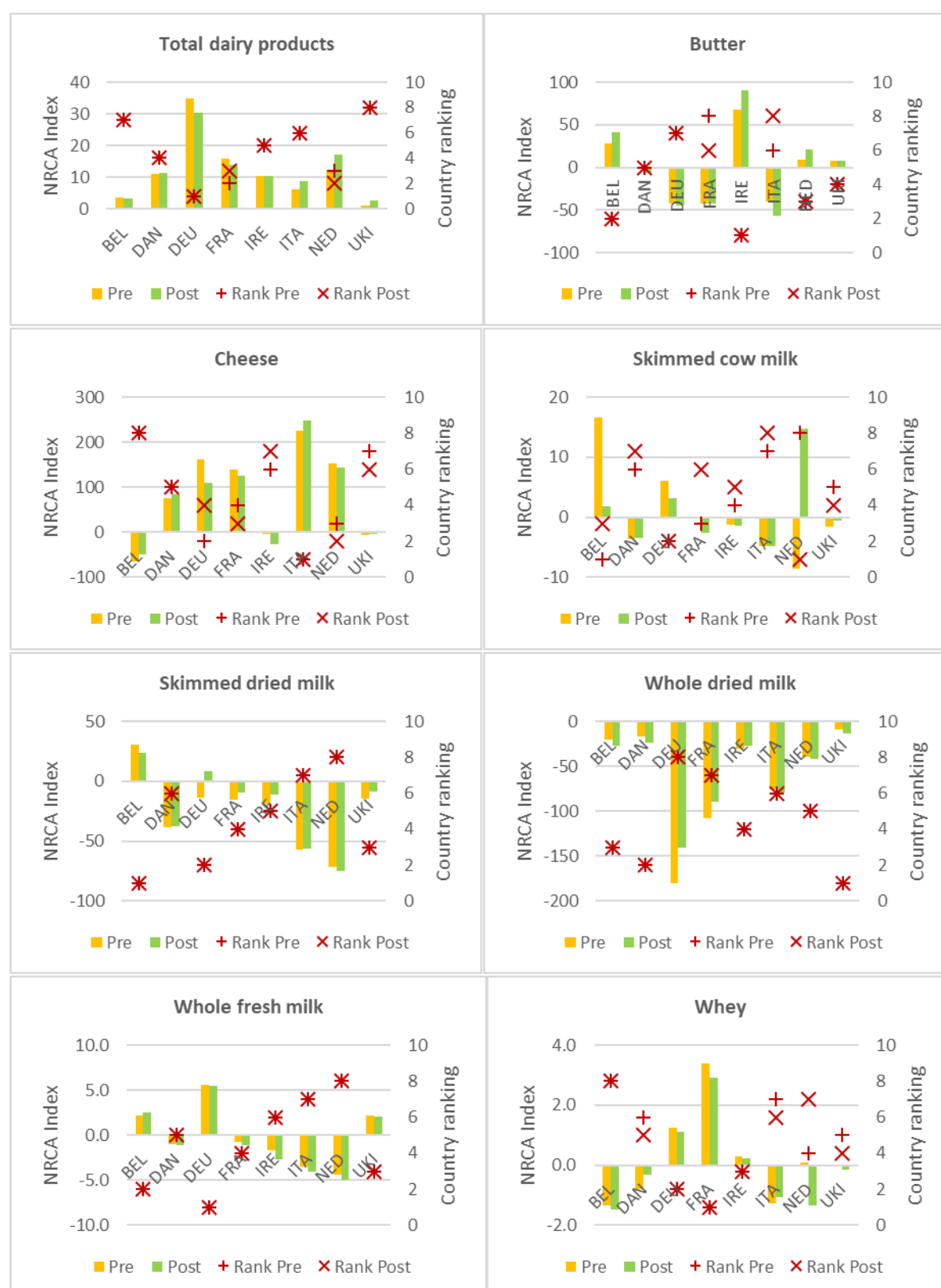
Focusing on individual dairy products, Ireland was ranked first in butter pre- and post-quota and showed the strongest growth of 22.7 points in competitiveness followed by Belgium at 12.7 points. Italy declined the most by 17.5 points and lost its sixth position to France. Ireland had the highest net export market share (NXMS) of 10.6% for butter post-quota, but the growth rate was the fourth highest at 10.9% (see Figure A2 in Appendix A). The butter prices indicated that Ireland was exporting (€3.51/kg) very high-quality butter compared to what was imported

(€2.86/kg). Moreover, Irish butter was the only dairy product that did not experience a shift in the supply curve, but it was the only product that had a shift (rightward) in the demand curve (see Figure A1 in Appendix A). There was a rightward shift in the supply curve for most Irish dairy products except whole fresh milk which had an opposite shift. In this case, the supply shifts can mainly be attributed to the changes in policy and prices of factors of production, amongst other factors.

Based on the NRCA index, whey from Ireland was ranked third pre- and post-quota and was the second most competitive dairy product within Ireland, even though it slightly dropped in competitiveness by 0.4 points. Denmark increased the most by 4.8 points and the Netherlands declined significantly by 14.6 points. Compared to other Irish dairy products, whey had the greatest reduction of 33% in export (€1.47/kg) to import (€1.56/kg) quality ratio and lost its third position for net export market share post-quota to Denmark. In Ireland, the NRCA index fell for most dairy products such as cheese (23.3 points- second highest fall in this category after Germany at 52.5 points), skimmed cow milk (0.2 points), whole fresh milk (10.1 points- with the most significant decline in this category), and whey. Whereas it increased in products such as butter, skimmed (7.6 points) and whole (3.8 points) dried milk post-quota. Germany had the highest rise in competitiveness for skimmed (22.1 points) and whole (39.7 points) dried milk. Ireland had the highest growth rate in quantity exported for skimmed (59%) and whole (44%) dried milk compared to other countries, even though they still operate at a comparative disadvantage.

The general ranking position of Irish products remained unchanged post-quota, except for cheese and skimmed cow milk which lost their competitiveness positions to the UK. The least competitive dairy products from Ireland compared to other countries were cheese (7th) and whole fresh milk (6th) post-quota. The competition in the cheese market was much stronger than it was in butter. The net export market share for cheese was the least positive at 2% post-quota. However, Ireland had the highest quantity of cheese produced compared to butter post-quota. For whole fresh milk, Ireland had the highest reduction (77%) in export quantity and a further deficit in net export market share of 3.5% post-quota. Irish whole fresh milk was more valuable abroad (€0.71/kg) than it was domestically (€0.31/kg). This resulted in high growth in imports by processors/creameries.

Figure 3.6. NRCA competitiveness ranking across countries and dairy products



Source: Authors' calculations based on FAOstat dataset

3.6. Discussions and policy implications

3.6.1. Farm-level competitiveness

The decline in Irish milk prices coupled with the growth in the number of cows and the high growth in net farm income suggests that the quota abolition shifted the supply curve towards a new equilibrium point. After quota abolition, the Irish farmers produced more and reduced costs of production through economies of scale. As noted by Boyle (2002), high productivity may compensate for relatively low output prices. Ireland had been producing above the imposed quota before 1984 and was not producing at its most effective level during the quota phase (Jansik *et al.*, 2014; Donnellan *et al.*, 2015; Läßle and Sirr, 2019). Farmers adjust their practices regularly to improve productivity and to remain resilient to negative price effects. For example, Ireland improved its cost competitiveness ranking post-quota and was ranked first with the lowest total costs and total cash costs per kg of milk solids. Despite reductions in milk prices, Ireland retained its position of third place for total cash costs as a percentage of dairy output post-quota. Furthermore, Ireland had the second-lowest total costs post-quota with the second-highest reduction in total costs as a percentage of dairy output. This has positive implications for the potential of Irish farms in the future, even in comparison to the competitor countries.

Based on the partial productivity indicators, it can be argued that Ireland exploited the opportunity to expand production post-quota more than other countries. This expansion was achieved through productivity gains. However, despite the significant expansion, there were only marginal changes in land and labour size, suggesting that farms may be approaching their productive limit. If production continues to increase in Ireland, the demand for more land will also increase in the long run. Government intervention will be required to ensure proper land regulation policies. According to Dillon *et al.* (2008), if land access and fragmentation challenges remain unchanged, more dairy farmers will be likely to consider a combination of grazing and indoor high-input farming systems to expand their farming operations and remain competitive. The demand for feed will more likely increase as well because more land may not be available. Therefore, the increase in the number of cows may have severe environmental implications if not monitored accordingly in the future. The need for the Irish government and dairy stakeholders to increase the availability of farm labour and their efficiency to replace family labour remains justified post-quota, as outlined in the Food Wise 2025. Improved availability and productivity of factors of production, such as land and labour, can further

enhance the competitiveness position of Ireland in the long run. This is necessary under volatile milk prices and stringent environmental regulations.

3.6.2. Trade-level competitiveness

Whilst Irish dairy products like butter and powders indicated growth potential in competitiveness, other dairy products such as cheese, whey, skimmed and whole cow milk became less competitive post-quota. Post-quota, Ireland had the highest quantity of cheese produced compared to butter, but there was high competition from other countries for cheese. Cheese had a lower value compared to butter in Ireland. This resulted in a drop in cheese ranking and specialisation for Ireland post-quota. However, low net market share and poor competitiveness ranking do not always imply low profitability, this depends on the country's strategic positioning. The strategic goals that promote innovation for expansion of the sector in the Food Wise 2025 suggest that Ireland seeks to be a unique player in the international market. This may be more sustainable in the future for a small country (Yu *et al.*, 2009). According to Porter (1998), some countries want to be the best or number one and some want to be unique in the market. Countries with the same products compete by imitation and market share, which is a zero-sum game. In contrast, countries pursuing a unique strategy focus on profits and compete using innovation, which is a positive sum.

According to Buckley *et al.* (1988), strategic access to a key input for processing, i.e. raw milk, may be a source of competitiveness. The decline in whole fresh milk exports was motivated by the focus on the value creation strategy which promotes exporting high-value products and importing low-value products. This trend has left the Irish raw milk market susceptible to international competitors. The need for sustainable growth of the processing industry for Ireland to remain competitive in the global market is difficult to question. Nonetheless, how that growth is achieved needs to be monitored. The lack of a monitoring system could present a challenge for local dairy farmers because processors could start offering lower prices for raw milk in the future, on par with global markets, especially if world prices continue to drop (Jansik *et al.*, 2014). The location of Northern Ireland where raw milk is imported from is an advantage to Ireland due to its proximity which reduces the transport costs and trading rigidities. However, in the long run, the cheap imports can undermine the benefit of the cost competitiveness of Irish milk at the farm level delivered to processors. This highlights the importance of evaluating farm and trade-level data simultaneously by policymakers to ensure that Irish farmers are protected and rewarded for improving their productivity.

There is a need for ensuring secure access to raw materials within the value chain to contribute to the economies of scale for the country. Given the land limitations at the farm level, better technology and trade agreements will be needed to improve and maintain competitiveness in the long run. The rise in raw milk imports used to produce Irish dairy products may eventually raise some ethical issues such as the rules of origin (traceability) which will need to be addressed by policymakers to protect the “produced in Ireland” brand image (Pascucci, 2018). Product differentiation is essential for Ireland to compete and reach new markets. The growth in competitiveness of powders was in line with the Food Wise 2025 objectives to reach developing countries and diversify their markets. However, more growth is still needed to ensure that Ireland has a comparative advantage in powders. According to Buckley *et al.* (1988), in a short time horizon, highly competitive products earning high margins may compensate for uncompetitive products. The ability of the Irish dairy industry to generate and maintain competitive advantages and net export market shares highlights the strong competitiveness position that it has relative to its competitors.

3.7. Conclusions

The unique feature of this study was the use of the competitiveness assessment approach to provide insights for value chain decision-making in the dairy industry. This was achieved by identifying trends and rankings, and comparing Ireland’s competitiveness position to other countries pre- and post-quota. The analysis of different dairy products, which allowed for the comparison of countries, provided a deeper understanding of the dairy industry. The findings are useful for all the selected countries in the EU. The evidence suggested that Ireland had the most significant rates of farm production expansion, overall, relative to other countries post-quota. However, this farm-level expansion was insufficient to meet the growing demand for the export of dairy products, even domestic demand. This led to strong growth in liquid milk imports post-quota, highlighting the interdependence between farm and trade-level competitiveness. Chapter 4 analyses the differences in technical efficiencies in farm milk production at the regional level in Ireland.

To date, trade-level analysis for the dairy sector has been relatively limited, as previous analyses have typically aggregated processed dairy products despite the high variation in price, quantity, markets, and strategies used per product. This aggregated approach has not been particularly useful for comparing countries or for informing decision-making. Despite Ireland being a small country, it remained competitive for dairy products such as butter and whey in

terms of EU rankings, and butter and powders in terms of competitiveness growth. Hence, the differences in the competitiveness of dairy products highlighted the importance of disaggregating dairy products to allow for specialised cross-country analysis. Research on individual dairy products is essential given the changes in specialist country behaviours. This study has been the first of its kind in this direction. Chapters 5 and 6 provide a deeper analysis of the competitiveness of Irish butter in the global market.

4. Regional farm technical efficiency rankings and their determinants

Abstract

The chapter aims to evaluate regional farm efficiency rankings for Ireland which seeks to be a leader in the global dairy industry. It conducts a within-country analysis based on the technical and scale efficiency of dairy farms to explore how regional constraints imposed by the milk quota may have affected Ireland's regional farm efficiency levels. The stochastic meta-frontier approach is adopted because of its usefulness in comparing regional technical efficiencies. The findings suggest that policies aiming to promote labor and soil quality improvement in the East region, and that relate to discussion groups in the South region, in addition to management of herd size, would be useful for improving efficiency post-quota. Moreover, some farms expanded beyond their optimal scale leading to a reduction in efficiency levels, and this points to the need to tailor farm advice and promote caution and prudence in farm expansion decisions, especially in a region like the South West.

Keywords: Farm efficiency rankings, technical efficiency, scale efficiency, stochastic meta-frontier, EU milk quota policy.

4.1. Introduction

In the European Union (EU), emphasis has been placed on the promotion of agricultural practices that are economically viable for farmers and less harmful to the environment. The Irish dairy industry seeks to be a strong competitor in the global market with sustainable and efficient farming practices in line with the Common Agricultural Policy. In 2019, Ireland was ranked the seventh largest dairy producing country in the EU based on the volume of milk produced and had the highest growth rate of milk produced post-quota from 2015-2019 (see Chapter 3). Ireland was also identified as having the lowest total costs and cash costs per kg of milk solids post-quota, amongst top EU countries, exhibiting its cost competitiveness (see Chapter 3). Irish dairy farms increased milk production by 54% from 2005-2018, and the building of regional milk processing facilities played a key role in this expansion (Kelly *et al.*, 2020). Given the competitiveness and growth of Irish farms at an EU level, understanding within-country or regional efficiency rankings becomes critical. Farms in poor-performing regions may struggle to be viable in the long run which can threaten the value chain and stakeholders in those regions (Shrestha and Hennessy, 2008). Even though Ireland is a small country, regional disparities may still apply. According to Abdulai and Tietje (2007), the analysis of farm efficiency can deliver significant insights into the competitiveness of farms

and their potential for increasing productivity and improving resource use. Therefore, comparing regional performance may provide insights into the regions that need more support, labour, and capital investment to ensure sustainable growth and enhanced efficiency levels, thus improving the average farming profits and the living standards of farmers.

According to Kelly *et al.* (2012) and Kelly *et al.* (2013), the key to reducing overall unit costs of production is to maximise the efficiency of resource endowments, innovation, and productivity. Technical efficiency estimates of a country are often used as a key performance indicator for improving production processes and farm performance (O'Donnell *et al.*, 2008). Läpple and Hennessy (2012) noted that there is scope for the application of knowledge and technologies gained through extension and education to help improve productivity. Ahikiriza *et al.* (2021), also noted that dairy advisory services often rely on 'one-size-fits-all' solutions because insights into variability and benchmarks are lacking. Technology differences may exist at a regional level, suggesting that aggregate estimates of technical efficiency and productivity at a country level could be misleading in terms of the adjustments or support required by farms in different regions (Abdulai and Tietje, 2007). There are often gaps in regional planning and policy processes that help to define regional targets, especially when empirical data on farm performance for regions is limited or not well coordinated (Alem *et al.*, 2019). This suggests a need for appropriate allocation of resources across regions matched with rigorous programmes for auditing regional farm performance and existing regional policies (Tsekeris and Papaioannou, 2018). Tsekeris and Papaioannou (2018) advocated for decentralisation of management to regional authorities which can undertake institutional arrangements suitable to their comparative advantages and prioritise the allocation of investment resources where they can provide efficiency gains. According to DAFM (2015), efficiency improvements must be continuously pursued against competitive benchmarks and based on discussions around future regional development policies of the Irish dairy industry.

Ireland makes an interesting case study within the EU, given the differences in regional technology (Läpple and Hennessy, 2012) and differences in regional constraints posed by policies such as the milk quota policy (Shrestha and Hennessy, 2008; Gillespie *et al.*, 2015). Some questions remain in the Irish dairy industry that other countries can learn from, especially those with regional technology differences. For example, did production expansion result in efficiency improvements and/or unit cost saving through economies of scale? Put differently, have the farms at a regional level converged to the industry or meta-frontier, or have their relative inefficiencies remained unchanged, taking into account the changes introduced by the

policy-makers? Which region(s) performed the best and what were the factors that influenced the adjustments? Did the government programs and policies, i.e. discussion groups and quota abolition, have an impact on efficiency? According to O'Donnell *et al.* (2008), governments can change the characteristics of the production environment by deregulating markets, i.e. quota abolition, and modifying land and labor laws. These questions have not yet been addressed in the literature using long-term data that includes both the pre and post-quota periods and using a meta-frontier approach to compare regions in the Irish dairy sector. This is a unique feature of this study, especially within the EU context. The findings will inform industry leaders and policy-makers about the regional challenges and the effects of farm growth policies or schemes on efficiency. It will provide regional growth patterns and insights that can be used for adapting the national policy frameworks to regions in policy dialogues, i.e. to achieve the Food Vision 2030 with ambitious targets set for expansion.

The rest of the chapter is organised as follows: Section 4.2 reviews previous studies of technical efficiency modelling applied to Irish farms. A more in-depth review of methodological approaches to efficiency modelling was presented, i.e. data envelopment analysis, stochastic frontier analysis, and stochastic meta-frontier. Section 4.3 describes the empirical model, i.e. stochastic meta-frontier, applied in this study. Section 4.4 outlines the information on the data and variables used from 2010–2018 for 280 Irish farms per annum, on average, specialised in dairy production in four regions of Ireland, namely, the East, South, South-West, and Rest. Section 4.5 offers the findings of the study. A discussion of the results and policy implications follows in Section 4.6. Finally, a conclusion is made and areas for future research are suggested in Section 4.7.

4.2. Literature review

4.2.1. Empirical estimation of technical efficiency in Irish dairy farms

Many studies have analysed the technical efficiency of Irish dairy farms at a national level. They provide context for this study and identify gaps that exist in the literature for regional performance. For example, Newman and Matthews (2006) analysed the productivity performance of Irish dairy farms in the long run, from 1984-2000. They used the trans-log output distance function to find technical efficiency (TE) estimates (72%). They found that the best-performing farms were adopting more efficient technologies at an increasing rate due to structural changes (i.e. introduction of milk quota). Moreover, Carroll *et al.* (2007) employed the stochastic frontier analysis (SFA) to estimate Irish dairy farm TE, from 1996-2005. They

found that the average efficiency score was 80%, and soil type and extension service had a statistically significant influence on efficiency, whilst the household size and the presence of an off-farm job did not. Kelly *et al.* (2012) applied a data envelopment analysis (DEA) to measure TE on Irish dairy farms for 2008, and compared inefficient farmers to higher performers. They found statistically significant variation across farmers. Similarly, a study by Kelly *et al.* (2013) used DEA to measure TE for Irish dairy farms in 2008 and found that there was potential to increase technical and scale efficiency on Irish dairy farms. However, both these studies were limited to one year and they suggested an interesting area for future research would be to look at efficiency over a longer period, including post-quota period, which has been done in this study. The various studies in Ireland have used both parametric and non-parametric approaches. Each of these approaches offers some advantages which are outlined in the next section and which inform the approach adopted in this chapter.

4.2.2. Advantages of using parametric and non-parametric models

The DEA (non-parametric) is often favoured over the SFA (parametric) because it does not require a prior determination of a production function or make an assumption about the inefficiency term. However, according to Ray *et al.* (2015), the DEA approach has its own set of limitations, i.e. it is deterministic and attributes all the deviation from the frontier to inefficiencies. It is also sensitive to measurement errors or other noise in the data. The SFA approach accounts for random or stochastic noise and allows for statistical tests of hypotheses concerning production structure and degree of inefficiency through a composite error term (Kumbhakar *et al.*, 2015). Carroll *et al.* (2007) argue that this approach is appealing in the agricultural setting as output levels fluctuate with factors that are outside the farmer's control and ignoring such stochastic influences would bias the true performance of farms. The SFA approach is often criticised because it requires the imposition of a parametric functional form for the underlying technology, and a distributional assumption for the inefficiency term (Ray *et al.*, 2015). Nonetheless, in addition to the dairy sector studies that have already been mentioned, other recent studies examined the Irish beef sector using SFA. For example, Cillero *et al.* (2019) and Cillero *et al.* (2021) applied the SFA approach which provided a flexible representation of the production technology in the Irish beef sector, due to its advantages over the DEA, which took into account the purpose of their studies i.e. to evaluate farm performance and estimate inefficiency drivers. Therefore, previous research is useful for setting prior determination of a production function.

4.2.3. Estimation of technical efficiency using stochastic meta-frontier

The TE of farms from a specific production technology is not comparable with those of farms operating under different technologies in the SFA (Huang *et al.*, 2014). On the other hand, the stochastic meta-frontier (SMF) model takes into account technology differences across groups and is useful for making group comparisons (Battese *et al.*, 2004; O'Donnell *et al.*, 2008). According to Battese *et al.* (2004), the SMF model incorporates deterministic components of the SFA approach for the farms that operate under the different technologies involved. It handles technological differences by exploiting exogenous sample separation information (Kumbhakar *et al.*, 2015). In the dairy industry, recent studies have used the SMF model to study the differences in TE and technological gaps between regions, and to compare regional performance, e.g. in New Zealand (Jiang and Sharp, 2015) and Norway (Alem *et al.*, 2019; Alem, 2021). Jiang and Sharp (2015) found large differences between regional production frontiers, due to technological differences. Alem *et al.* (2019) found that factors such as farming experience, contact with the advisory service, size of the farm, and local off-farm contacts had a positive impact on TE in all regions, whereas government support had a negative impact. They found slight regional differences in TE and technological gap ratios, which supported the assumption about joint underlying technology across regions as a reasonable one to make for the dairy industry in Norway. So far, the SMF model has not been applied in Ireland or any other EU country, hence the unique contribution of this chapter.

4.3. Empirical approach

This study uses the meta-frontier production function which envelops the stochastic production functions for different groups employing different technologies (Battese *et al.*, 2004).¹ A production frontier is defined in terms of the maximum output that can be achieved from a set of inputs given the technology available to the farm. According to Tran and Tsionas (2015), the specification of the reduced equations in SFA provides more efficient estimates of the frontier parameters as well as an improvement in predicting inefficiency terms. Inefficiency is measured as the extent farms are using more resources to produce a given level of output relative to the best practice farms in the sample (Kumbhakar *et al.*, 2015). Previously, Huang *et al.* (2014) proposed a two-step SMF to estimate the group-specific frontiers and decompose the efficiency scores of various groups into meta-TE and technology gaps. Alem *et al.* (2019)

¹ Unlike Olley and Pakes (1996), this study was not particularly concerned with accounting for entry and exit of farms through the control function approach.

and Alem (2021) applied this approach and a similar approach is followed in this study. The trans-log (TL) and Cobb-Douglas (CD) functions are adapted and estimated from previous empirical models in the literature i.e. Huang *et al.* (2014), Jiang and Sharp (2015), Alem *et al.* (2019), and Cillero *et al.* (2021).

The models are estimated in two steps as follows.

$$\text{Step 1: } \ln y_{it}^k = f^k(x_{it}^k, \beta^k) + v_{it}^k - u_{it}^k, i = 1, 2, \dots, N_k; t = 1, 2, \dots, T \quad (4.1)$$

$$\begin{aligned} \ln y_{it}^k = & \beta_0^k + \sum_{j=1}^J \beta_j^k \ln x_{jit} + \frac{1}{2} \sum_{j=1}^J \sum_{l=1}^L \beta_{jl}^k \ln x_{jit} \ln x_{lit} + \delta_t^k t + \frac{1}{2} \delta_{tt}^k t^2 + \\ & \sum_{j=1}^J \delta_{jt}^k \ln x_{jit} t + \theta_i^k + v_{it}^k - u_{it}^k \end{aligned} \quad (4.1.1)$$

$$TE_{it}^k = e^{-u_{it}^k} \leq 1 \quad (4.2)$$

Where y_{it}^k denotes the output level for farm i in the k^{th} region in the t^{th} time, x_{jit} is a vector of inputs ($j = 1, \dots, J$) by farms ($i = 1, \dots, N$) over time ($t = 1, \dots, T$) and the Greek letters (beta and delta) are parameters to be estimated for the k^{th} region. Similar to Alem *et al.* (2019) and Cillero *et al.* (2021), these parameters were estimated using the “true” random-effect model of Greene (2005) to account for the farm effect (unobserved heterogeneity) within the region, given that the data used is unbalanced panel data and the variables have low correlation with farm effects. According to Abdulai and Tietje (2007), the ‘true’ random-effects model is a random-constant frontier model that is obtained by combining a conventional random-effects model with a skewed stochastic term representing inefficiency. The trend variable, t , is introduced to capture the effect of technological change. The stochastic error term, v_{it}^k , is assumed to be distributed independently and identically (iid) as $v_{it}^k \sim N(0, \sigma_{vk}^2)$ and it captures the data that cannot be explained by the regression model. The one-sided error term represents time-varying technical inefficiency (changes over time and across individuals), u_{it}^k , is distributed as $u_{it}^k \sim N^+[\mu^k(z_{git}^k), \sigma_{vk}^2]$, where z_{git}^k denotes farm-specific inefficiency or production environment and farm-management strategies. θ_i^k is a farm-specific component for capturing time-invariant unobserved heterogeneity, which is assumed to have an independently and identically distributed normal distribution. It captures shocks to production that are observed by firms but not by the econometrician. However, as noted by Cillero *et al.* (2021) this approach should give an idea of the potential endogeneity bias in the estimates obtained using the standard stochastic meta-frontier approach and future research could look at how this bias can be solved for meta-frontiers using unbalanced panel data. Technical efficiency for the technology of a

region or regional frontier, TE_{it}^k , is the measure of performance of the individual farm relative to the regional group frontier [$f^k(x_{it}^k, \beta^k)$].

$$\text{Step 2: } \ln \hat{f}_t^k(x_{it}^k, \beta^k) = f^M(x_{it}^k, \beta) + v_{it}^M - u_{it}^M \quad (4.3)$$

$$MTR_{it}^k = e^{-u_{it}^M} \leq 1 \quad (4.4)$$

$$TGR_{it}^k = 1 - MTR_{it}^k \quad (4.5)$$

$$MTE_{it} = MTR_{it}^k \times TE_{it}^k \quad (4.6)$$

Where $\hat{f}_t^k$ represents the predictions or estimates of the region-specific frontier over time calculated from the first step (4.1) and the individual vectors of group frontier predictions are stacked together as one vector for the whole sample. Region-specific technical inefficiency is independently distributed as $u_{it}^M \sim N^+[\mu^M(z_{it}^M), \sigma_{vM}^2]$, where z_{it}^M denotes regional determinants for the technology-gap component. The truncated-normal distribution of u_{it} is assumed (Huang *et al.*, 2014). The maximum likelihood estimates (slope coefficients) of the farm efficiency determinants are not very informative when the effects of the determinants are the focus, but the coefficient signs and statistical significance are informative (Kumbhakar *et al.*, 2015). The relationship between efficiency and the effects of its determinants is non-linear. Consequently, the observation-specific marginal effects of the exogenous determinants were estimated with a truncated-normal model based on the Wang model cited in Kumbhakar *et al.* (2015). The computation of the marginal effects of the z_{it} variables is useful for empirical purposes. The marginal values show how much the variable influences efficiency and negative values imply a positive (or negative) impact on the uncertainty of (in)efficiency. Furthermore, according to Cillero *et al.* (2021), the meta-frontier allows the exploration of potential heterogeneous effects of the variables in z_{it} on the efficiency of farms within each region. This feature implicitly relaxes, to a certain extent, the constraints imposed by the common production technology assumption for farms in each region.

MTE_{it} can be defined as the firm's technical efficiency concerning the meta-frontier production technology [$f^M(x_{it}^k, \beta)$] or the total distance of each farm to the meta-frontier. The unrestricted ratio in (4.3) differentiates the meta-frontier approach that uses the SFA by accounting for the random noise component. The distance of the k^{th} region's production frontier to the meta-frontier is defined as the meta-technology ratio, MTR_{it}^k . It shows the difference (or gap) in the technology available to a given (k^{th}) region relative to the technology available to the industry

or country. The higher the MTR in equation 4.5, the lower the technology gap between the group/regional frontier and the meta-frontier (O'Donnell *et al.*, 2008). A value of 1 is equivalent to a point where the individual regional frontier coincides with the meta-frontier. The technology gap component is region, firm, and time-specific. To determine the region with the most productive technology the MTR is used. The MTE allows regions to be compared based on how closely their farms operate relative to the meta-frontier (Cillero *et al.*, 2021). The national model is based on aggregated data for all regions. The regional frontier captures the technology of a region and the meta-frontier captures the technology of the nation.

4.4. Data and variable description

The unbalanced panel data was collected from the Irish Teagasc, National Farm Survey (NFS) for the years 2010–2018, i.e. pre (2010–14) and post (2015–18) quota. The entry and exit of farms into the panel was random (unbalanced panel data) for a period of nine years and the selection bias issue was not a concern in this study.² According to Kumbhakar *et al.* (2015), a key advantage of panel data is that it enables the researcher to take into account some heterogeneity that may exist beyond what is possible to control using a cross-sectional data. The NFS is collected as part of the Farm Accountancy Data Network (FADN) of the European Union, providing a representative sample of Irish farms. The study focuses on farms classified as specialist dairy farms with dairy products as the main output (Latruffe *et al.*, 2016). There were, on average, 280 observations per annum which represents, on average, a weighted national population of 14,919 farms per annum, with 207 farms in 2010 and 298 farms in 2018. The NFS data can be disaggregated into regions to provide a representative view of each region.

In this chapter, we used four regions as classified by Läpple and Hennessy (2012) and Läpple *et al.* (2012), namely, the East, South, South-West, and Rest. The map of Ireland can be found in Appendix E (see Figure E1). The regions are comprised as follows, East: Kildare, Wicklow, Laois, Carlow, Kilkenny, and Wexford; South: Waterford and Cork; South West: Kerry, Clare, Limerick, and Tipperary; Rest: Louth, Leitrim, Sligo, Cavan, Donegal, Monaghan, Galway, Mayo, Roscommon, Longford, Offaly, Meath, Westmeath and Dublin. All monetary figures were deflated according to the annual Irish agricultural price indexes (base=2011) which are available from the Irish Central Statistics Office (Carroll *et al.*, 2011). Each input variable in

² According to Kazukauskas *et al.* (2010) and Lapple *et al.* (2013), a selection-bias problem occurs due to unobserved factors that affect participation and the outcome variable of interest (i.e., probability of exit). As noted by Carroll *et al.* (2011), for unbalanced panels, it is likely that some producers become less efficient through time before leaving the sample entirely or shutting down. However, farms were allowed to exit and enter the sample (no distinction between new and old farms) without affecting the overall objective of this study.

the original data was normalised by dividing by the geometric mean of the sample and the first-order coefficients were output elasticities.

The gross output (€) was used as the output variable (y_{it}^k) of the dairy enterprise only, which includes the value of calf and milk sales. Using revenues for total output rather than quantity output has the advantage that it takes milk quality (i.e. fat and protein content) and price differences into account (Abdulai and Tietje, 2007; Huang *et al.*, 2014; Alem *et al.*, 2019; Cillero *et al.*, 2021). The inputs used in this study are standard in the SFA literature for the dairy industry, i.e. Carroll *et al.* (2007), Jiang and Sharp (2015), and Alem *et al.* (2019). The first input was land (owned and rented) (x_{1it}) which measured farm total utilised agricultural area in hectares allocated to the dairy enterprise. The second input was labor (unpaid and paid) (x_{2it}) which measured the total labor units working on the dairy farm. The third input was dairy direct costs (€) (x_{3it}) which measured purchased feeds, winter forage, veterinary costs, artificial insemination (AI), service fees, seeds, fertilizers, plant protection products, and transport expenses. The fourth input was dairy overhead costs (€) (x_{4it}) which measured the costs that cannot be directly allocated to a specific farm enterprise. Overhead costs for dairying were not directly available from NFS data but were calculated based on the proportion of farm gross output originating from the dairy enterprise, while ensuring that there was no double counting of land and labour by also estimating correlation tests, following Carroll *et al.* (2007) and Läßle *et al.* (2012).

Table 4.1 outlines the farm-specific variables and their expected sign or impact on technical efficiency at a regional level based on previous research. The determinants included in the efficiency specification were based both on previous research and their effect on the estimation model. The farm characteristics include the average dairy herd size, farmer's age, number of members in the farmer's household, quality of the soil, membership in a dairy discussion group, farmer's work status, and access to extension advisory service (Carroll *et al.*, 2007; Kelly *et al.*, 2012; Jiang and Sharp 2015; Alem *et al.*, 2019). The farm characteristics included in Table 4.1 help to account for observed heterogeneity following Abdulai and Tietje (2007). Kumbhakar *et al.* (2015) argue that if the technology is known, i.e. based on previous research, then the issue of endogeneity can be limited. Fortunately, Table 4.1 outlines the numerous literature sources which have examined the technology on dairy farms in Ireland, which counteracts to some extent the issues of endogeneity which is often cited in the literature. As noted by Latruffe *et al.* (2016), endogeneity arises if farmers adjust input use to stochastic events affecting their production process and/or to conditions prevailing on their farms.

Table 4.1. Farm-specific variables and their expected impact on technical efficiency

Variables	Description	Sign*	Reference
Herd size (z_{1it}^k)	Average dairy herd size. It is used as a proxy for the measurement of farm capital investment on TE (Kelly <i>et al.</i> , 2012).	+	Carroll <i>et al.</i> (2007); Alem <i>et al.</i> (2019); Jiang and Sharp (2015)
Age (z_{2it}^k)	Farmer's age	+/-	Abdulai and Tietje (2007)
Household members (z_{3it}^k)	Number of members in the farmer's household	+	Kelly <i>et al.</i> (2020)
Quota** (D_{1it}^k)	2008-2014 describes the quota abolition period during which gradual production increases were allowed (1=pre 2015)	-/+	Shrestha and Hennessy (2008); Kelly <i>et al.</i> (2013); Lapple <i>et al.</i> (2021)
Soil type (D_{2it}^k)	The quality of the soil or land quality for the farms. (1=very good soils)	+	Carroll <i>et al.</i> (2007); Kelly <i>et al.</i> (2012)
Discussion Member (D_{3it}^k)	Member of a dairy discussion group i.e. participatory peer extension (1=yes)	+	Kelly <i>et al.</i> (2020); Lapple <i>et al.</i> (2012)
Full-time (D_{4it}^k)	A farmer that works on the farm full-time (1=yes)	+	Carroll <i>et al.</i> (2007); Abdulai and Tietje (2007)
Advisory service (D_{5it}^k)	Farm contact with extension advisory service (1=yes)	+	Carroll <i>et al.</i> (2007)

Notes: * The positive expected sign on efficiency is equivalent to a negative sign on inefficiency. ** In that period ‘soft landing’, tradable milk quota operated almost on a regional level and there was only limited movement of quota between regions. Further information about the EU milk quota has been described in the cited studies.

According to Amsler *et al.* (2016), if the endogenous variables are correlated with inefficiency in addition to (or instead of) with noise, we need to model the joint distribution of inefficiency and the reduced form errors. Moreover, they argued that if we observed more data on farm characteristics and if we had a better behavioural model of the farmer, we would have less apparent endogeneity. Tran and Tsionas (2015) also noted that there is the potential difficulty of implementing these approaches, i.e. SFA, when there is no outside information available to construct the appropriate instruments. Therefore, the observed heterogeneity helps to deal with the endogeneity problem. According to Jiang and Sharp (2015) and Kumbhakar *et al.* (2015), judgment on the relevant variables to include in the model vary based on a combination of dairy production knowledge, review of past literature, balancing between reality and simplicity, as well as compromises on data availability. If variables forced the model not to converge and/or have a high correlation coefficient (multicollinearity) from spearman and/or variance inflation factor tests with other variables, they were excluded (see Tsekeris and Papaioannou, 2018). As noted by Kumbhakar *et al.* (2015), it can sometimes be difficult to get the model to converge given the flexibility and complexity of its form.

4.5. Results

4.5.1. Specification tests and model justification

To test the appropriateness of the models used in this study, several specification tests were conducted. Initially, the generalised likelihood ratio (LR) test for the null hypothesis of no one-sided error, or validity of the use of SFA specification, was constructed based on the log-likelihood values of the ordinary least squares (OLS) (restricted) and the SFA (unrestricted) (Ray *et al.*, 2015). The estimated log-likelihood at 353 was statistically significant at 1% and the null hypothesis was rejected. Thus, we could proceed to estimate an SFA. In addition to the F-test which showed differences in regional variables, the LR-test was used to test the null hypothesis that dairy farms in the four regions operate on the same production frontier (Battese *et al.*, 2004). $L(H_0)$ is the value of the log-likelihood function for pooled SFA data for all groups at 772 and $L(H_A)$ is the sum of the values of the log-likelihood functions from the individual SFA at 866. Hence, the null hypothesis that all regions share the same technology was rejected at the 1% confidence level and the MF was deemed the appropriate approach to use for different regions.

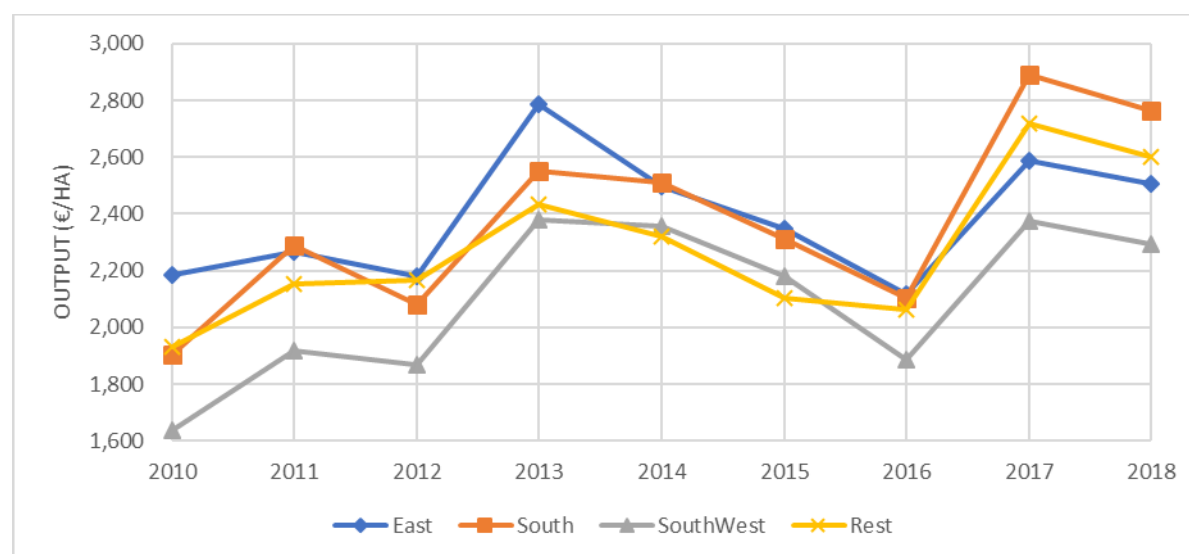
Lastly, the LR-test was used to test the null hypothesis that TL is preferred over CD. $L(H_0)$ is the value of the log-likelihood function for the pooled TL at 1,292 and $L(H_A)$ is the value of the log-likelihood function for the pooled CD at 772. We failed to reject the null hypothesis and the TL was the preferred model at the 1% confidence level. However, the findings of the two models were very similar and this was demonstrated by the high correlation between the outputs from the two models (see Table D4 for correlation results in Appendix D). A similar approach was followed by Jiang and Sharp (2015). The technical efficiency measures did not appear to be largely affected by the choice of functional form. According to Carroll *et al.* (2007) and Cillero *et al.* (2021), multicollinearity can be a concern for production functions assuming a TL functional form. Therefore, the focus of the chapter will be on the CD which can achieve the objectives of this study with relatively fewer collinearity issues. The TL findings are presented in Appendix D (i.e. Table D1, D2, and D3).

4.5.2. Descriptive statistics

Figure 4.1 shows the trends in output per hectare from 2010-2018 which takes into account milk price (see Figures B1 and B2 in Appendix B for trends in regional output and milk production per hectare, respectively). The South region had the highest output per hectare and milk production per hectare post-quota and the South West region was the lowest. This is

consistent with the prediction by Laple and Hennessy (2012). Over nine years, on average, the East region had the highest output, overhead and direct costs, and land and herd size per farm, followed by the South region as shown in Table 4.2. The South West region had the lowest averages, below the national averages. The South region had the highest labor units and the highest proportion of farmers with very good soils and a high discussion group participation rate. Laple *et al.* (2012) found that over 60% of the farms in the South region were on very good soils and strip graze their cows, but farms in the East region were larger in land size than farms in other regions. They also found that 35% of farmers in the South region participated in discussion groups, which was the highest amongst the regions examined. Based on the F-test in Table 4.2, there were statistically significant differences across regions. These results highlight the importance of taking account of differences that exist in different regions which can have implications for policy making. It is important to note that production was increasing before the quota removal, i.e. due to the soft landing period during 2008-14, and hence, quota removal as an event might not be statistically significant for some regions in the results.

Figure 4.1. Trends in regional output per hectare



Source: Authors' calculations based on National Farm Survey (NFS) data

Table 4.2. Descriptive statistics on regional differences, from 2010-2018.

Variables	IRL	East	South	South West	Rest	F Test
Sample farms	2,517	599	788	565	565	
Weighted population	134,273	20,478	40,808	43,602	29,385	
Output (€)	128,108	148,109	134,579	112,682	128,072	29.8 ***
Farm inputs						
Overhead costs (€)	33,818	39,323	34,222	28,914	36,697	23.9***
Direct costs (€)	49,492	55,630	50,399	42,885	53,760	18.8***
Land size (ha)	57.7	63.5	58.6	55.6	55.4	22.3***
Labor units	1.2	1.13	1.22	1.21	1.21	6.5***
Farm-specific variables						
Herd size (cow)	70	79	72	65	69	26.8***
Age	52	51	51	53	52	2.2*
Household members	3.52	3.51	3.58	3.50	3.47	0.2
Full Time (D)	0.96	0.97	0.96	0.96	0.95	1.1
Discussion member (D)	0.35	0.37	0.38	0.32	0.34	6.3***
Advisory services (D)	0.84	0.83	0.83	0.84	0.84	0.5
Soil (D)	0.55	0.72	0.73	0.39	0.45	73.6***

Note: East = Kildare, Wicklow, Laois, Carlow, Kilkenny and Wexford. **South** = Waterford and Cork. **South West** = Kerry, Clare, Limerick and Tipperary. **Rest** = Louth, Leitrim, Sligo, Cavan, Donegal, Monaghan, Galway, Mayo, Roscommon, Longford, Offaly, Meath, Westmeath and Dublin. ***P<0.01; **P<0.05; *P<0.10

4.5.3. SFA input elasticities on output

For sustainable expansion to take place, both efficiency and returns to scale must be optimal (Kelly *et al.*, 2013). Tables 4.3 and 4.4 show the influence of inputs on output and the returns to scale, overall, for the pre and post-quota periods, respectively. All the variables in Table 4.3 were positive and statistically significant at 1% with decreasing returns to scale (DRS) or sub-optimum scale for the country at 1% away from optimal scale operation, but not all variables were significant at a regional level. Similarly, Kelly *et al.* (2013) found that the country was operating at 95% scale efficiency with DRS. The overall returns to scale for all regions were close to optimal scale, i.e. DRS, with the Rest region having the least scope for improvement, and the South and South West regions with more scope for improvement, i.e. by 15% post-quota. Post-quota, the East and the Rest regions were the most efficient, and producers could generate a 3% additional efficiency level by becoming more scale efficient, but the East region had the highest scale growth rate of 15% from pre to post-quota, suggesting that it benefited most from quota removal. The Rest region had an increase in scale efficiency and a decrease in technical efficiency. As noted by Kumbhakar *et al.* (2015), scale improvement is not always positively correlated with technical efficiency. The South West region was the only region that

declined in scale efficiency by 4% and had the highest potential to improve scale efficiency by 18%, post-quota.

In the East region, all inputs were positive and statistically significant at 1%. Labour became statistically significant at 1% post-quota. Other inputs were statistically significant for both periods with adjustments to the production process which resulted in economies of scale or the unit costs minimisation being realised from higher volume production. As noted by Läpple and Hennessy (2012), unit costs decrease as scale increases but then they begin to rise again beyond a certain herd size due to farm expansion costs, i.e. cost for expanding bulk tank facilities and additional labor required to stock a dairy rather than a beef animal. Läpple *et al.* (2012) predicted that the highest cost savings for farms would likely be achieved in the East region post-quota due to an extended grazing season which leads to additional days for labor. In the South West region, most of the inputs, except labor, were positive and statistically significant at 1%, and 10% for land. Land and technology change or adoption of new production practices were not statistically significant post-quota. These factors, or their misallocation, potentially explain the loss of efficiency and scale in the production process, even when production expanded.

Table 4.3. Estimates for the long-run parameters of the SFA by regions on output

Elasticity	IRL	East (E)	South (S)	South West (SW)	Rest (R)
Land (x_{1it})	0.11***	0.14***	0.14***	0.04*	0.05*
Labor units (x_{2it})	0.03***	0.06***	0.01	0.01	0.07***
Direct cost (x_{3it})	0.48***	0.41***	0.47***	0.50***	0.50***
Overhead cost (x_{4it})	0.27***	0.29***	0.23***	0.3***	0.32***
Time trend (t)	0.01***	0.01	0.01**	0.01***	0.01**
Constant	0.09***	0.2***	0.13	0.01	-0.02
<i>Returns to scale</i>	0.9	0.9	0.85	0.85	0.95
<i>Mean TE</i>	0.90	0.87	0.90	0.93	0.92
<i>Log Likelihood</i>	772	232	249	212	173
<i>N</i>	2,517	599	788	565	565

Note: ***P<0.01; **P<0.05; *P<0.10

Table 4.4. Determinants of regional output pre (2010-14) and post (2015-18) quota

Output	E Pre	E Post	S Pre	S Post	SW Pre	SW Post	R Pre	R Post
Land	0.13***	0.15***	0.18***	0.12***	0.05*	0.03	0.07*	0.04
Overhead cost	0.26***	0.36***	0.18***	0.29***	0.29***	0.31***	0.27***	0.36***
Direct cost	0.43***	0.37***	0.48***	0.41***	0.49***	0.51***	0.53***	0.47***
Labor units	0.04	0.09***	0.02	-0.01	-0.003	0.04	0.05*	0.11***
Time trend	0.01	0.004	0.01*	0.04***	0.03***	0.01	0.01	0.03**
Constant	0.22	0.15*	0.14***	-0.13*	-0.02	-0.02	0.003	-0.16*
Return to scale	0.82	0.97(+15%)	0.85	0.86(+1%)	0.86	0.82(-4%)	0.92	0.97(+5%)
Mean TE	0.86	0.9 (+4%)	0.89	0.91 (+2%)	0.94	0.93 (-1%)	0.92	0.91 (-1%)
Log Likelihood	134	108	152	111	120	95	101	79
N	294	305 (+3%)	455	333 (-37%)	303	262 (-16%)	308	257 (-20%)

Note: ***P<0.01; **P<0.05; *P<0.10

4.5.4. Determinants of technical efficiency and their mean marginal effects

Tables 4.5 and 4.6 show the marginal effects of farm-specific variables on technical inefficiency for the overall period and split for the quota period, respectively. The marginal effects obtained from SFA output can be meaningfully interpreted (Ray *et al.*, 2015). In the national model, four variables, namely, herd size, quota, soil quality, and discussion group membership, had a positive impact on technical efficiency as expected, but there were variations in the regions. Herd size had the highest influence on efficiency in the East region compared to other regions, *ceteris paribus*. For example, if farms in the East region increased herd size by 1%, on average, the efficiency level increased by 17%, *ceteris paribus*. Herd size was statistically significant pre and post-quota for all regions. Farms in the South West region were, on average, 5% more efficient pre-quota than post-quota. This was consistent with the findings by Newman and Matthews (2006). Shrestha and Hennessy (2008) and Gillespie *et al.* (2015) suggested that farms with very low-efficiency levels would find it more profitable to exit production, leading to more quota transfers to more efficient producers, and that would increase the overall efficiency.

Farms with very good soils in the East and South West regions were, on average, 7% and 3% more efficient, respectively. Soil quality was only statistically significant in the East region post-quota and it was not statistically significant in the South and Rest regions post-quota. Läpple and Hennessy (2012) and Kelly *et al.* (2012) found that poor soil quality led to reduced grass production and capacity for maximum stocking density, which ultimately resulted in a reduction in TE. The farms that participated in the discussion groups in the South West, East, and South regions were, on average, more efficient by 14%, 5%, and 4%, respectively, compared to those that did not participate. Post-quota, only the South region was statistically

significant and in the East region, the difference was not significant. The findings suggest that the ‘Dairy Efficiency Programme’ for peer discussion groups, which offered grassland and financial management sessions before undertaking significant expansion, had more impact in the South region post-quota and South West region in the long run. However, given that previous research has confirmed that discussion groups are voluntary schemes and self-selection bias is at play, these findings must be interpreted with caution (Läpple and Hennessy, 2012). Läpple *et al.* (2012) found that participating farms were extending their grazing season based on the knowledge and technology they received from the discussion groups.

Table 4.5. Marginal effects of farm-specific variables on technical inefficiency

Technical Inefficiency	IRL	East	South	South West	Rest
Herd size (z_{1it}^k)	-0.14***	-0.17***	-0.15***	-0.12***	-0.12***
Age (z_{2it}^k)	0.0003	0.0005	0.0002	-0.0002	0.001
Quota (D_{1it}^k)	-0.03***	-0.03	-0.02	-0.05***	-0.03*
Soil type (D_{2it}^k)	-0.03***	-0.07***	-0.02	-0.03*	-0.02
Discussion member (D_{3it}^k)	-0.04***	-0.05***	-0.04***	-0.14*	-0.02
Fulltime (D_{4it}^k)	0.01	0.01	-0.02	0.03	0.03
Advisory service (D_{5it}^k)	-0.01	0.01	-0.01	-0.02	-0.01
Household members (z_{3it}^k)	0.001	0.001	0.0001	0.001	-0.001

Note: ***P<0.01; **P<0.05; *P<0.10

Table 4.6. Determinants of regional efficiency pre (2010-14) and post (2015-18) quota

Technical inefficiency	E Pre	E Post	S Pre	S Post	SW Pre	SW Post	R Pre	R Post
Herd size	-0.2***	-0.13***	-0.18***	-0.14***	-0.1***	-0.13***	-0.11***	-0.14***
Age	0.0003	0.001	-0.0002	0.0004	-0.0003	-0.0004	0.001	0.001
Soil type	-0.06***	-0.08**	-0.03*	0.02	-0.03	-0.03	-0.05**	-0.01
Discussion member	-0.04**	-0.09	-0.04**	-0.09*	-0.1	-0.14	-0.03	-0.02
Fulltime	-0.03	0.04	-0.004	-0.03	0.03	0.06	0.02	0.04
Advisory service	0.01	0.005	0.01	-0.01	-0.02	-0.02	-0.03	0.03
Household members	-0.002	0.01	0.001	-0.004	-0.001	0.002	-0.002	0.003

Note: ***P<0.01; **P<0.05; *P<0.10

4.5.5. Technical efficiency estimates within the meta-frontier

Table 4.7 shows the average technical efficiency and meta-technology estimates for the different regions. There were statistically significant differences between the regional estimates as shown by the F-test. The results from the regional frontier (TE) and MTR are not directly comparable across regions (see trends over time in Appendix C), but the combination of the two (MTE) allows for regional performance comparison. The low TE estimates below MTR estimates suggest that the primary source of inefficiency comes from managerial inefficiency,

rather than the technology undertaken (Huang *et al.*, 2014). Inefficiencies in the East and South regions were more likely to be from managerial inefficiencies. The average farms in the South West region operate the closest to the best-performing farms in that region or have the highest TE. The average farms' average technical efficiency estimates in the East have more scope to improve their efficiency at a regional level, as evidenced by the lowest TE. However, the technology of the best-performing farms in the East region, i.e. MTR of 92%, was the closest to the meta-frontier or technology of the best-performing farms in Ireland. According to Huang *et al.* (2014) and Cillero *et al.* (2021), the existence of the technology gap is caused by factors that affect the accessibility to and adoption of the meta-frontier production technology.

Table 4.7. Average technical efficiency and meta-technology estimates

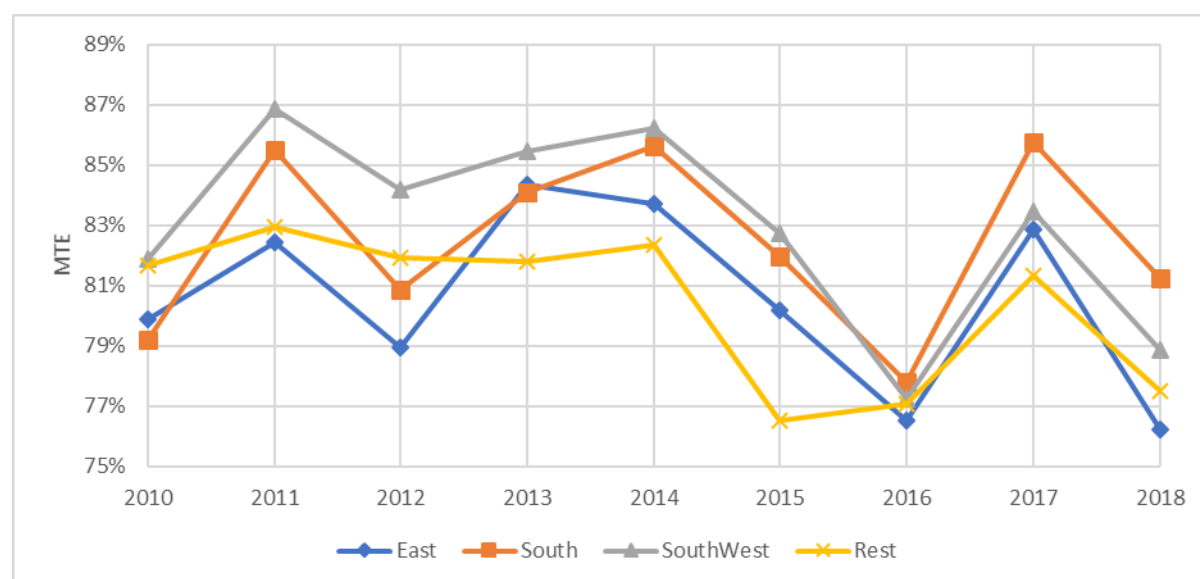
Regions	East	South	South West	Rest	F test
<i>TEs to the regional frontier (TE_{it}^k)</i>					
Mean	0.87	0.90	0.93	0.92	53.2***
SD	0.10	0.08	0.08	0.07	
Min	0.48	0.46	0.53	0.57	
Max	0.98	0.99	1	0.99	
<i>Meta-technology ratio (MTR_{it}^k)</i>					
Mean	0.92	0.91	0.89	0.87	51.6***
SD	0.07	0.07	0.09	0.10	
Min	0.60	0.52	0.51	0.55	
Max	0.99	0.99	0.98	0.99	
<i>TEs to the meta-frontier (MTE_{it})</i>					
Mean	0.81	0.83	0.83	0.80	6.1***
SD	0.14	0.13	0.14	0.15	
Min	0.30	0.24	0.27	0.31	
Max	0.96	0.97	0.98	0.98	

Note: ***P<0.01; **P<0.05; *P<0.10

Previous studies in Ireland found that overall efficiency was, on average, 72% from 1984-2000 by Newman and Matthews (2006), and 91% from 1979-2012 by Gillespie *et al.* (2015), but these statistics are not directly comparable. From 2010-2018, the average farms in the South and South West regions were both ranked first, as evidenced by the MTE estimates which are comparable across regions taking into account technology differences. They could increase their efficiency by 17% without influencing output, to be on par with the best-performing farms in the country. According to Kumbhakar *et al.* (2015), in the long run, firms in a competitive industry can be expected to have similar efficiency estimates which are close to 100 percent. Figure 4.2 displays the trends in MTE estimates across regions (see Figures C1 and C2 for trends in TE and MTR, respectively). The South West region lost its regional efficiency ranking to the South region post-quota. This is consistent with the forecast by Laple and Hennessy

(2012) that the South region will improve performance post-quota. The influence of the quota removal can be observed from 2013/14 when the policy abolition was agreed upon for 2015 with a significant decline in efficiency until 2016 for all regions. This is consistent with Tsekeris and Papaioannou (2018) who found that institutional and political factors may lead to differences in regional efficiency. According to Carroll *et al.* (2011), highly uncompetitive sectors can be characterised by highly fluctuating efficiency trends.

Figure 4.2. Comparison of MTE estimates across regions over time



Source: Authors' calculations based on NFS data

4.6. Discussions and policy implications

Farmers' resources and capabilities are essential for sustainable dairy expansion (Abdulai and Tietje, 2007; Kelly *et al.*, 2020). The results from this chapter have shown that the responses to quota removal varied across the regions of Ireland. Based on previous research i.e. Kelly *et al.* (2013), there was an expectation that quota removal would enhance technical efficiency. Based on the findings presented here, this was true only for the East and South regions which experienced growth in both technical and scale efficiency, with the East region having the highest growth rate in both technical and scale efficiency post-quota. It was noted that the inefficiencies that existed in the East and South regions were managerial-related (i.e. $TE < MTR$) rather than technological, in a context of a restrictive policy. An interesting difference between the East and South regions from a managerial perspective was that labor was statistically significant only in the East region post-quota which potentially relates to the growth in scale efficiency. The East region had the highest-performing farm technology in the

country based on MTR but the South region had the best-performing farms in the country based on the overall MTE measure, along with the South West region. In other words, farms in the East region were less efficient compared to farms in the South region. According to Ray *et al.* (2015), efficiency rankings are important for setting tougher future cost reduction targets for the more inefficient firms, to ensure that consumers do not pay for management inefficiency. Therefore, policies aiming to promote labor efficiency and investment in soil quality improvement would be important for farms in the East region, and policies that relate to discussion groups in the South region, in addition to other inputs like management of herd size, could improve the overall efficiency rankings for the regions and ensure the sustainable expansion of farms post-quota.

The South West region was the only region that had a decline in both technical and scale efficiency post-quota, farms were more efficient pre-quota than post-quota. Shrestha and Hennessy (2008) found that regionally tradable quotas reduced inefficiency through structural changes but led to a geographical concentration of milk production. In unbalanced panels, it is likely that some producers become less efficient over time and leave the sample entirely, and the surviving firms cluster around the fully efficient level (Carroll *et al.*, 2011; Kumbhakar *et al.*, 2015). Forcing the remaining farmers to improve their efficiency by encouraging the adoption of innovative management or technological practices (Gillespie *et al.*, 2015). The findings indicated that inefficiencies in the South West and Rest regions were technological (i.e. $TE > MTR$) rather than managerial, suggesting that investments in research and technology for the adoption of new production practices would be useful in the South West and Rest regions. It was also observed that land or farm size and technology adoption were not statistically significant post-quota in the South West region which potentially explains the decline in efficiency. Kelly *et al.* (2013) found that land was central to increasing scale, but issues such as the cost of land and land fragmentation may hinder it. Therefore, policies that can support the ability of farms to invest and procure new resources to expand their size and minimise the unit costs associated with their growth are essential. The results from the South West region suggest that the national policy approach to support dairy expansion was not a “good fit” for all farms and all regions which can be expected given the technological differences. The evidence presented here suggests that some farms expanded beyond their optimal scale leading to a reduction in efficiency levels and this points to the need to tailor farm advice and promote caution and prudence in farm expansion decisions, especially in a region like the South West.

4.7. Conclusions and future research areas

This chapter examined the regional efficiency rankings and their determinants in the pre and post-quota periods. The findings are important for informing future regional policy, farm advice and promotion, and industry development. Farm advisors must understand the needs of the regions post-quota and provide specialised services to the different regions. Understanding what has driven past performance is critical for policymakers and industry leaders to avoid setting challenging or under-ambitious targets, especially in the context of new sustainable intensification targets that have been set for the Irish dairy industry. The findings support recommendations on how regional policy, such as resource allocation and technological innovation, can be more effective in improving the productive capabilities of farms based on their locational advantage. Quota removal had varying impacts on the regions of Ireland and lessons can be drawn from regions that improved both technical and scale efficiency, i.e. East and South regions. To influence the efficiency rankings of regions through policy for sustainable national efficiency levels and growth, having regional performance monitoring mechanisms for farms such as those applied in this chapter may be useful to ensure more efficient farms in all regions.

In this chapter, it was assumed that inputs (i.e. inter-regional capital, labor flows, and technology) are not shared across regions. Moreover, non-price and non-trade factors like the degree of institutional embeddedness of farms in regional planning and governance structures in regions were not considered due to a lack of data. Future studies that capture such factors can help to provide nuance to the study of regions in the Irish dairy industry. A further evaluation challenge relates to estimating the target points for inputs that may affect how much resource allocation by farms is required to reach optimal regional efficiency rankings. Lastly, regional efficiency rankings were evaluated from a farm-level perspective and the implications for the rest of the value chain have not been addressed. Future research could investigate this relationship between farms and processors at a regional level, including the efficiency rankings of Irish processors.

5. Price transmission analysis of Irish butter export prices in the world market

Abstract

In 2019, Ireland was the third-largest exporter of butter in the world butter market but Irish butter prices have been more volatile compared to other Irish dairy products. Yet, empirical research that examines the market price dynamics and international competitor behavior in the butter market remains scarce. The Vector Error Correction Model was applied to data from 1970-2019, to test the extent to which changes in competitor butter prices and Irish farm milk prices had an impact on Irish butter prices. The results provide evidence of asymmetric price transmissions, Irish butter prices were more responsive to shocks in New Zealand (NZ) butter prices and Irish farm milk prices in the long-run. Declining world milk prices over time, related to milk supply, perishability and storability factors, may prevent symmetric response of Irish milk prices to changes/shocks in Irish butter prices. Moreover, different target markets and EU/NZ policies for Ireland and NZ butter may prevent symmetric response of Irish butter prices to changes/shocks from NZ butter prices. Essentially, the take home message for the butter industry is that Irish butter prices must not be studied in isolation, NZ is a major butter competitor to Ireland in the world market and NZ butter prices play a significant role on how Irish butter prices change.

Keywords: Horizontal and vertical price transmission, butter export prices, farm milk prices, vector error correction model.

5.1. Introduction

In 1973, Ireland joined the European Union (EU) and this helped to open new markets for Irish agricultural exports outside the United Kingdom (UK) market which was the main importer of Irish butter. During that time, the price received for Irish butter exports was low in the UK market due to competition from New Zealand (NZ) (Donnellan *et al.*, 2015). The situation has changed significantly since that time. The top five destinations of Irish butter exports in 2019, in value terms, were the Netherlands (27%), the United States (US) (18%), the UK (18%), Germany (11%), and Belgium (9%) (Bord Bia, 2020). In 2019, Ireland exported €1.1 billion worth of butter, making it the 3rd largest exporter of butter in the world after NZ (€2.2 billion) and the Netherlands (€1.4 billion) (OEC, 2019). The dairy exports sector (€4.4 billion) had the highest contribution to the total food and drinks exported (€12.2 billion) by Ireland in 2019 and butter exports were worth €961 million in 2020, the most valuable of all the dairy sub-categories, in value terms (Bord Bia, 2020). Irish butter prices were the most volatile compared

to other high-value dairy products in recent years (Ornua, 2019). All these facts make Irish butter an interesting sector for this study. A recent study by Cele *et al.* (2022) also found that Irish butter was the most competitive compared to other dairy products in the country and compared to other countries producing butter. Prices reflect equilibrating forces in a market setting and provide vital signals for the allocation of resources by economic agents. According to Xue *et al.* (2018), the butter price dynamics of different exporters can be linked to each other due to the substitution effects and market integration in the global market. Traditional indicators of competitiveness generally focus on export growth and market shares, but price competitiveness (proxy by export price) for homogenous goods like butter is also important for tracking and understanding the market price dynamics and competitor behaviour (Bakucs *et al.*, 2014).

Based on the trends of a time series, the convergence of prices in the long-run would suggest that cointegration exists between the prices which is what is referred to as the Law of One Price (LOP). For example, butter prices in similar countries should be cointegrated and shouldn't diverge indefinitely (Bergmann *et al.*, 2016). They may be separated by transaction costs i.e. transfer costs (i.e. freight, insurance, tariff rates, etc.) and other costs of trade (Serra *et al.*, 2006). If prices are not equalized through the law of one price, arbitrage may occur which leads to exporters buying identical products at low prices and selling at high prices to other countries, taking advantage of the price difference (Chavas and Mehta, 2004; Newton, 2016). The equilibrating role of spatial arbitrage does not come into play when prices differ by less than transfer costs (Norwood and Lusk, 2008). As noted by Miljkovic (1999), institutional factors also influence price settings or linkages in different markets but costs of arbitrage may be high in the short-run for markets that are strongly influenced by international trade agreements.

The pattern and strength of price linkages provide useful information on whether a given set of spatial markets are integrated (price shocks in one market evoke responses in other markets) or segmented (Serra and Goodwin, 2003; Liu *et al.*, 2019). That information is useful for setting up new trade policy instruments and informing the need for public subsidies to keep domestic food prices low (McCorriston, 2015). According to Fousekis and Trachanas (2016), the trade of dairy commodities has become an increasingly important component of international food trade due to the general drive for trade liberalisation and innovations in milk processing. For example, the volatility of the US market prices for butter and the significant growth in Irish butter imports in the US post-2014 leading to an ad valorem tariff rate of 25% in 2015 (Newton, 2016), suggested a need to provide insights on the price trends and growth of the Irish butter

exports. According to Zhang *et al.* (2017), dairy price and trade interventions that are designed to insulate domestic dairy prices have had an impact on spatial price arbitrage, i.e. different prices in different markets for the same product. The EU policies are also expected to influence spatial prices for butter in the global market. Many factors can disrupt the supply of the Irish butter industry and its prices, namely, policy changes such as tariffs and quotas, changes in the sustainable supply of raw materials, economic and environmental shocks, and international trade disputes which may result in a loss of revenue growth momentum (McCorriston, 2015; Ornuu, 2019). Therefore, a need exists for a deeper understanding of the Irish butter price transmission or market integration within the value chain (vertical price transmission) and across different markets for geographically separated dairy producing regions (horizontal or spatial price transmission).

According to Hockmann and Voneki (2006), the milk market is considered to be among the most protected agricultural markets in the world. Butter and skimmed milk powder are the main dairy products monitored by the EU's Common Agricultural Policy (CAP) to regulate the dairy market. The CAP rules for market management were put in place to limit distortion in international competition and to ensure the competitive price positioning of these products in the international market. The information on butter and skimmed milk powder production, price, and the volumes traded including raw cows' milk was essential for the milk market stakeholders in the EU to be able to react effectively to the market signals and risks in the world food market (Xue *et al.*, 2018). Post-removal of CAP market interventions, policymakers have to rely on specialised past information for countries and dairy products to contribute to the discussions on the national policy measures in the long-term which will be provided in this study. According to Liu *et al.* (2019) and Ramsey *et al.* (2021), one major concern of the asymmetries in milk price transmission within the value chain is that retailers can benefit from retail price lags in response to decreases in the farm price, but farmers might not reap those benefits. In Ireland, the production of butter absorbs the highest percentage of whole milk fat and protein content (Donnellan *et al.*, 2015) which raises the question of price transmission between the prices of the two commodities. In some cases, the relationship between butter and milk prices has been discussed but has not been empirically tested in the literature (Chavas and Mehta, 2004; Xue *et al.*, 2018), especially in the post-milk quota period for Ireland.

The chapter contributes to knowledge of the global butter markets by documenting the complex nature of price dynamics and assessment of the degree of integration, more specifically for Ireland. By addressing the following questions: To what extent are changes in butter export

price behaviour transmitted to the farm milk price behaviour in the value chain and vice versa? To what extent are spatial butter export prices for the Netherlands and New Zealand in the global market, integrated with Irish butter export prices and vice versa? These questions are addressed by taking into account the size of the shock causing changes in the long-run prices (*magnitude*), the significant lags of the adjustment (*speed*), and the extent to which adjustments are asymmetric. According to Fousekis and Trachanas (2016), depicting and analysing the paths of adjustment and/or the duration of the disequilibrium following initial positive or negative disturbances in prices adds useful information about the long- and short-run patterns of asymmetry. The findings may assist butter industry stakeholders to draw lessons from butter price responses and influence trade expectations more precisely. The information on asymmetric price transmission allows processors to make some inferences about the behaviour of different competitors in the market, particularly as their actions impact links across different market levels (Bakucs *et al.*, 2014). The flexibility of the Irish butter market to absorb domestic- and foreign-origin shocks is of paramount importance. According to Vercammen (2011) and Ramsey *et al.* (2021), a high degree of pricing integration is a standard feature of competitive global commodity markets and a measure of relative price performance. Therefore, the study seeks to provide price transparency along the value chain. It addresses some concerns that may exist about farm milk prices and butter export prices, i.e. the idea that farmers may not see the full benefits of higher export prices.

The chapter is organised as follows: In Section 5.2, the literature review on price transmissions within the dairy industry is provided. In Section 5.3, the data sources are provided for farm milk (1975-2019) and butter (1970-2019) prices. Section 5.4 provides trends in butter and milk prices and production in the global market relative to Ireland. Section 5.5 outlines the empirical econometric methods applied in this chapter. Section 5.6 presents results and discussions about horizontal and vertical price transmission in the dairy value chain. In the final section, conclusions are drawn and areas for future research are suggested.

5.2. Literature review

In recent years, there has been an increase in the literature seeking to understand the price transmissions within the dairy industry which were mainly driven by globalisation and policy changes. A recent study by Zhang *et al.* (2017) argued that EU dairy prices were more likely to be affected by international demand and supply developments than before, due to the abolition of the milk quota, reduction of export subsidies, and the expansion of dairy

production. According to Vercammen (2011), the storage capacity of stocks and production uncertainty are key determinants of price for many of the world's major agricultural commodities. In addition, according to Abeysinghe and Yeok (1998), export prices can be decomposed into four components, namely: (i) cost of raw materials and intermediate goods, which are domestically produced or imported, (ii) labor cost at the firm level for processed products, (iii) rentals and utilities, and (iv) profit mark-up. The pattern of price transmission in the dairy industry is often considered to be asymmetric because of the positive price shocks that are transmitted with higher intensity compared to negative price shocks (Olipra, 2020). Although a country may be unable to influence the global economic conditions that influence prices (price-taker), an analysis of the dynamics and factors that influence it may help to provide a certain level of understanding of a sector, especially for mitigating risks (Vercammen, 2011; Zhang *et al.*, 2017). According to Xue *et al.* (2018), price fluctuations can hinder the viability of agricultural producers and processors through vertical price transmission whereby sudden price changes in inputs and commodities can flow through the chain. For example, Chavas and Mehta (2004) found evidence of asymmetric price transmissions in the US butter market between wholesale and retail prices and argued that price volatility varies with market conditions.

Previous studies that have analysed price shocks and the long-run price relationships in the dairy industry have been from an international perspective (horizontal price dynamics) for different sectors within dairy. For example, Newton (2016) for all major dairy product markets, Hockmann and Voneki (2006), O'Connor *et al.* (2007) and Xue *et al.* (2018) for butter markets, Fousekis and Trachanas (2016) for skimmed milk powder markets and Zhang *et al.* (2017) for whole milk powder markets. Most studies have used the vector autoregressive (VAR) and vector error correction (VEC) models to examine price transmission effects in dairy markets or the relationship between national milk prices and dairy product prices in international milk markets. In the US, Newton (2016) argued that international dairy commodity prices influence the US commodity prices which then influence the US national milk price. A similar trend is tested for Ireland in this study, including the post-quota period, whereby New Zealand and Netherlands butter prices are expected to influence Irish butter prices which then will influence farm milk prices. Hockmann and Voneki (2006) found that international butter prices in the EU and Oceania are integrated and their response to shock corresponded with theoretical reasoning that higher prices on the global market for one region lead to higher prices in the second region. However, the regional analysis for butter often fails to capture the nuances that

exist within the regions and assumes that countries within a region are homogenous, and ignores the specialisation of countries in different dairy products. For example, countries such as the Netherlands and Ireland may respond differently to policy and market changes because of the differences in their portfolio mix for dairy products and the strategic objectives they have for different markets or products, even though they are both in the EU.

5.3. Data sources

The annual time series data for farm milk (1975-2019) and butter (1970-2019) prices were collected from Irish Central Statistics Office (CSO) and Food and Agriculture Organization Statistical Databases (FAOSTAT). The monthly time series data (January 2005-October 2021) for farm milk and butter was also collected from CSO for vertical price transmission. The farmers are paid monthly for their milk and the annual time series for vertical price transmission was considered too short for reliable estimation (Bakucs *et al.*, 2014). The length of the data sample was determined by the availability of the data. The study uses the latest price data, accounting for the pre and post-milk quota period that led to structural changes which could have influenced the degree to which price shocks were regionally transmitted (Serra *et al.*, 2006). There was no aggregation of data for different countries, which has been the case for previous studies. The selection of countries, i.e. Ireland, Netherlands ([proxy for EU - similar market conditions](#)), and New Zealand ([proxy for world - different market conditions](#)), was motivated by their significance in the world trade of dairy products ([Juchniewicz and Łukiewska, 2021](#)). The annual data was used for horizontal price transmission and was more appropriate to show the long-run price adjustments before, during, and after the milk quota policy which was introduced in 1984 and officially abolished in 2015. Bergmann *et al.* (2016) found that a dummy variable for the abolishment of the EU milk quota was not statistically significant in their regression model. In our case, the dummy variable for the milk quota policy was not included in the VEC models due to collinearity issues it has with both the milk and butter prices, since they already account for its effects.

The prices were adjusted from USD to EURO based on historical exchange rates from FAOSTAT. Product selection was based on product homogeneity and trading volumes leading to volatile export unit values, which is important for price transmission modelling (Norwood and Lusk, 2008). Milk and butter are relatively homogenous goods which makes them useful for comparability. An important note to make is that for vertical price transmission, farm milk was a single major input to the production process that also includes labor and capital

equipment but information on these other two inputs is scarce. Therefore, farm milk is considered to be a sufficient proxy of butter input for this study, especially since there is a lack of transparency or data available at the processing level. Consequently, the exact causes of imperfect price transmission in vertical markets are difficult to identify solely based on the model results, but the findings from existing data are still worth presenting and discussing (Ramsey *et al.*, 2021).

5.4. Trends in butter and milk prices and production

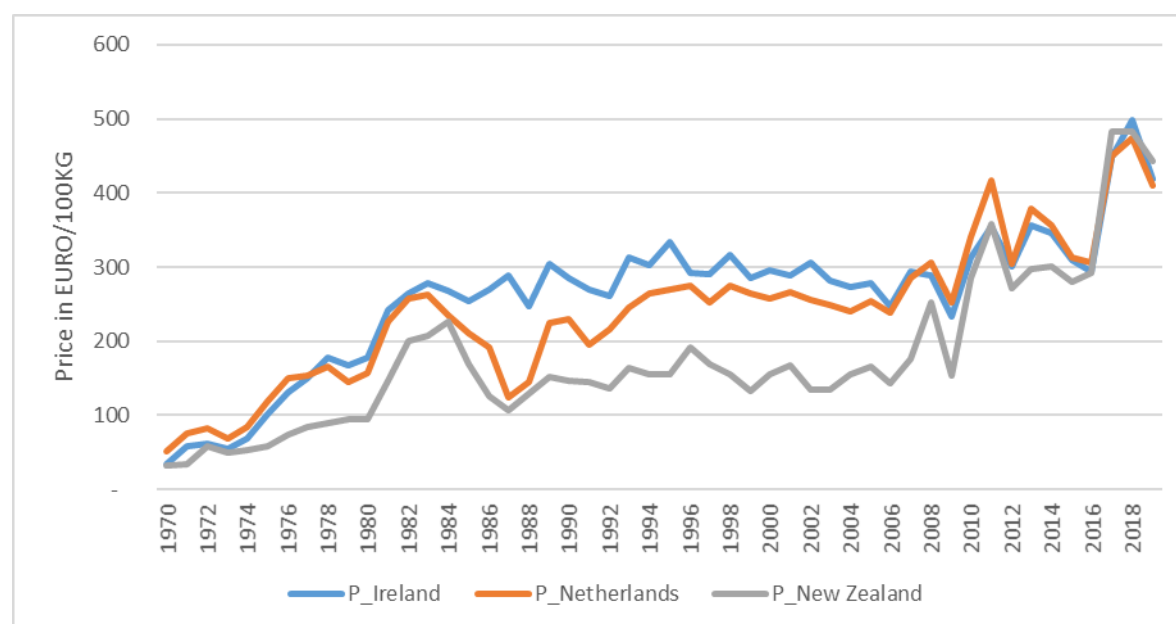
Ireland is ranked among the top three exporters of butter in the world. Figures 5.1 and 5.2 illustrate the export butter prices and quantity exported, respectively, by NZ, the Netherlands, and Ireland. The prices fluctuated around each other (converged) pre-1973 between Ireland and NZ, pre-1983 between Ireland and the Netherlands, and post-2006 for all countries. This pattern suggests a long-run relationship exists between the selected spatial prices (Fousekis and Trachanas, 2016). Ireland and NZ export prices started drifting apart post-1973 after Ireland joined the EU. Moreover, Ireland and the Netherlands' export prices started drifting apart post-1983, which was a year before the milk quota was introduced in the EU.

The decline of export prices from the Netherlands in 1983 and NZ in 1984 to about 1987 was followed by a significant spike in quantity exported from 1986 to 1988 for the Netherlands and Ireland. According to WTO (1990), this was during a period where there was a rise in world milk production which was not accompanied by an increasing demand and low retail prices. The accumulation of surplus stocks of butter and skimmed milk powder was high (with a large part of exports consisting of deliveries under derogations), then led to a depressive impact on the prices of all dairy products until 1986-87. Through the milk quotas and agreed minimum export prices, the dairy industry continued to pursue the objective of reducing the proportion of milk used to manufacture butter due to reduced access to traditional markets (i.e. notably in Western Europe and North America) and the lack of secure alternative markets. During that period, depressed market prices for butter were feared because of their adverse effects on sales and prices of other dairy products, notably powders.

Prices were stable from 1989 to 2008 for all three countries, but the quantity for NZ was steadily increasing in that period and significantly surpassed the Netherlands and Ireland. New Zealand had the lowest prices over the years and has been significantly increasing its quantity since 1991, suggesting significant technology advancements or structural adjustments at the processor (and farm) level. Ireland generally had the highest prices from 1978 to 2006, and had

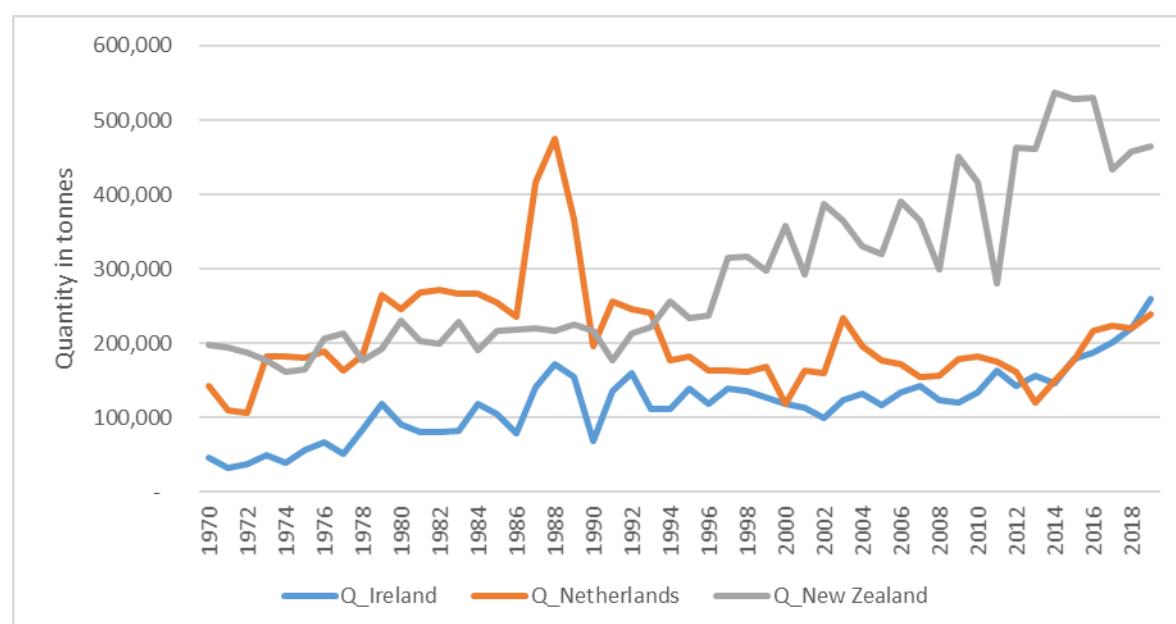
the lowest quantity exported amongst the selected countries but has experienced a significant increase from 2014. According to Hockmann and Voneki (2006), the EU domestic prices were significantly higher than prices on the global market due to the high protection of dairy production in the EU. Through the 90s and 00s, there were export subsidies paid by the EU to bridge the difference between Ireland and NZ prices and these have now been largely removed.

Figure 5.1. Export butter price for the top three butter exporters in the world



Source: Food and Agriculture Organization Statistical Databases (FAOSTAT)

Figure 5.2. Export butter quantity for the top three butter exporters in the world



Source: Food and Agriculture Organization Statistical Databases (FAOSTAT)

Table 5.1 presents the annual butter price (Euro/100kg) trends in means and standard deviations pre-quota: 1970-1983, during: 1984-2009 and post-quota: 2010-2019. The butter prices have increased significantly from the pre- to post-quota period for all countries. Ireland had the highest average butter price during quota with the lowest standard deviation, suggesting relatively minimal price fluctuations. New Zealand maintained competitive prices in all periods, but the standard deviation was highest post-quota, highlighting the need for price adjustments due to the rise in competition and policy changes, especially from the EU countries. According to Liu *et al.* (2019), the existence of a pricing regulation slows down the adjustment speed or responsiveness of prices back to the long-run equilibrium. EU policies allowed for higher EU prices above the world price, by preventing competitors from penetrating their markets which was not the case for the US where Ireland was able to outperform the US domestic producers based on price. For example, Newton (2016) argued that an arbitrage opportunity was unlocked in 2015 by the lifting of the EU milk quota system leading to additional world butter supplies and lower international butter prices which had a negative impact on the US domestic butter market. The combined effect of high US domestic prices and low world prices led to a surge in US imports of butter and butter substitutes in 2015 triggering WTO-authorised butter safeguards to protect US markets. Ireland was and has been amongst the countries that have targeted the US for its butter exports in recent years, especially post-quota.

Table 5.1. Annual butter price trends pre, during and post-quota

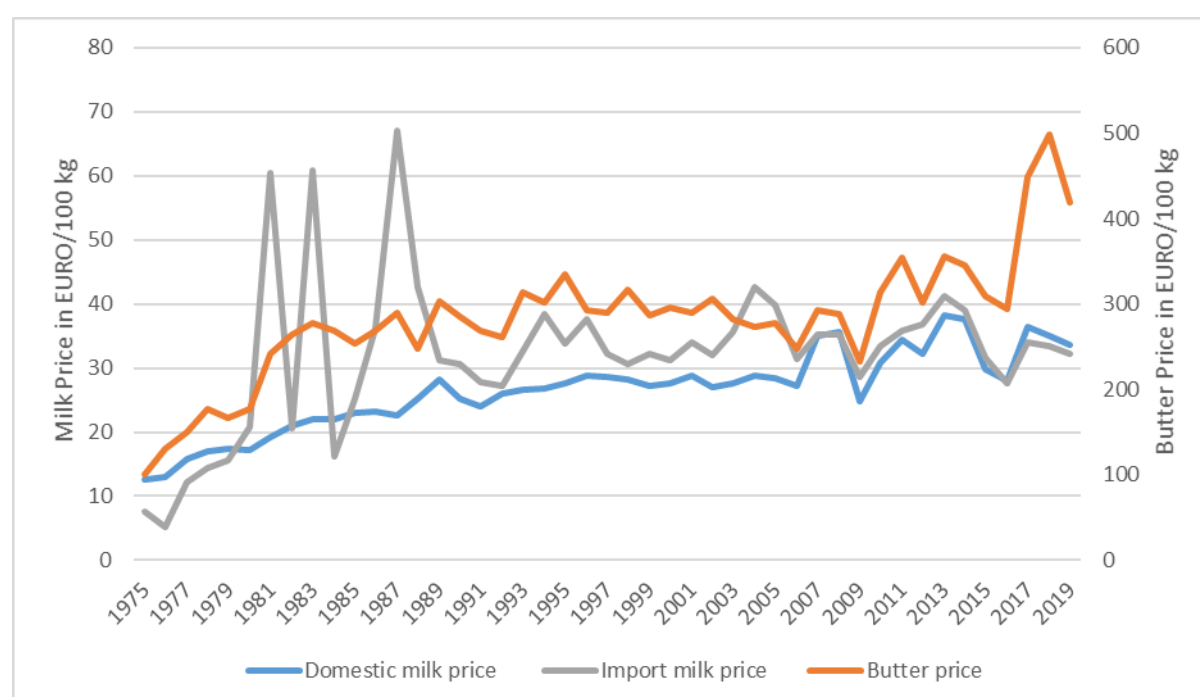
Quota		Pre: 1970-1983	During: 1984-2009	Post: 2010-2019
XP _{IRL}	Mean	140	283	364
	STD	82	23	69
XP _{NED}	Mean	143	240	375
	STD	69	41	61
XP _{NZ}	Mean	91	158	349
	STD	56	30	87

Source: Food and Agriculture Organization Statistical Databases (FAOSTAT)

In Ireland, a strategic focus for dairy stakeholders is on the production of high-value dairy products. Donnellan *et al.* (2015) argue that the convergence of Irish milk prices over time with those of the EU is due to greater diversification in the Irish product mix in recent years. The declining trade barriers, intensification of competition, and innovations in milk processing have necessitated access to raw material components on a global scale including via imports which can be viewed as a way to secure comparative advantage where demand and supply for butter

continue to increase and competition for farm milk is high (Fousekis and Trachanas, 2016; Bord Bia, 2020). According to Newton (2016), dairy commodity imports increase when the difference between domestic dairy product prices and the prices for similar products produced in foreign markets exceed transaction costs. From 1995 to 2013, Irish dairy farmers collectively invested approximately €1.4 billion in the purchase of milk quota to help meet the demand of processors (Donnellan *et al.*, 2015). Figure 5.3 displays the price of milk delivered to processors and butter export prices from 1975 to 2019. The domestic milk price has had a steady increase over the years along with the butter export prices but the milk prices were less responsive to the fluctuations in butter prices from 1991 to 1999.

Figure 5.3. Domestic and imported milk and butter prices in Ireland

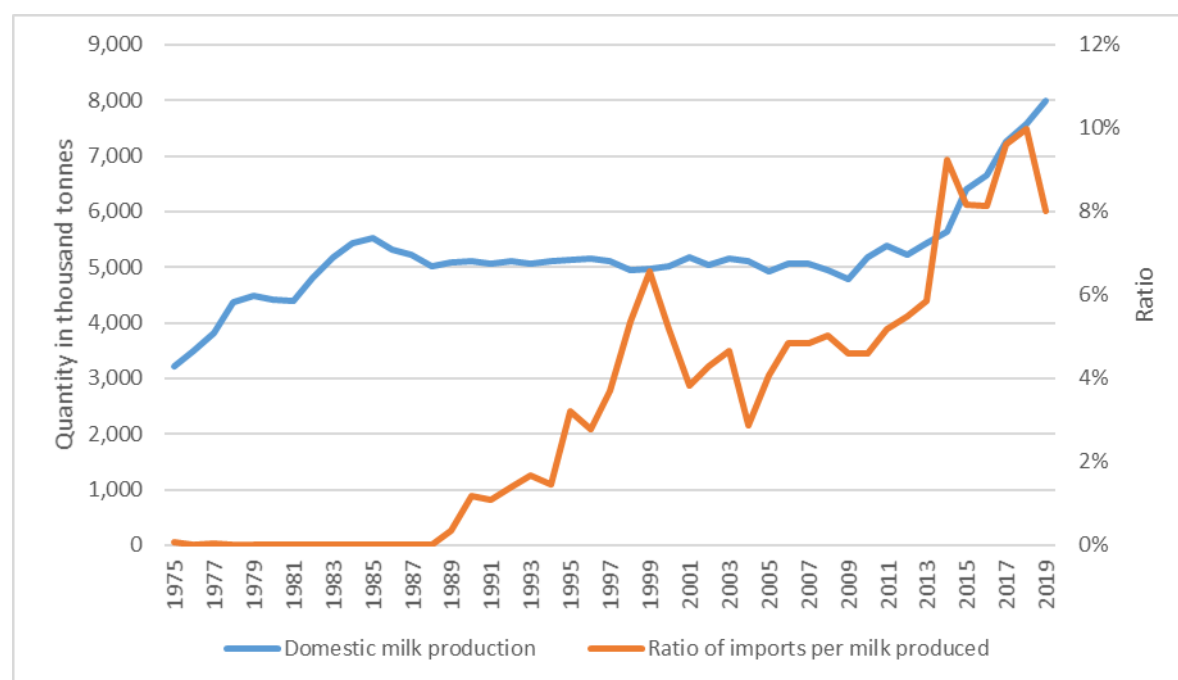


Source: Food and Agriculture Organization Statistical Databases (FAOSTAT)

Figure 5.4 shows Irish milk production and the ratio of imports to milk production. The quantity of milk produced was stable from 1985 to 2009 due to the milk quota which was introduced in 1984 and abolished in 2015. The discussions for its abolition were introduced in 2008 and from 2009 to 2015 there was a steady relaxation of the restrictions i.e. soft landing period. In 2019, Irish milk production was at a record high at 7.99 billion litres and whole milk imports were about 640 million litres which is equivalent to 8% of the milk produced domestically. The import price captures the cost of importing raw materials (Abeyasinghe and Yeok, 1998). Ireland mainly imported milk from Northern Ireland due to the way the processing industry has

developed. The rise in the quantity of milk imports coincided with the stabilisation of milk import prices which were very volatile before 1989. The significant rise in the quantity of milk imports from 1998 suggests that the milk quota of around five thousand tons for Ireland was not enough to meet the milk demand from processors which was expanding rapidly to meet the export demand for Irish dairy products.

Figure 5.4. Irish milk production and the ratio of milk imports in Ireland



Sources: Irish Central Statistics Office (CSO) and FAOSTAT

5.5. Empirical econometric methods

5.5.1. Stationarity tests for time series

The data was first transformed by using the (natural) log to help reduce heteroscedasticity and normally distributed errors as well as for ease of interpretation as log changes approximate growth rates and are additive through time (Zhang *et al.*, 2017). The logged variables were tested for the presence of unit roots or stationarity using the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests which deliver complementary results that help to minimise the probability of a type II error (Newton, 2016; Olipra, 2020; Ramsey *et al.*, 2021). The ADF and PP unit root tests, test the null hypothesis that a time series is non-stationary at level or stationary at first differences, and the KPSS stationarity test tests the null hypothesis that a time series is stationary at level. Where the test statistic is statistically significant for ADF and PP tests, the tested series is stationary. Where

the KPSS test is significant, it would be non-stationary. Non-stationary time series integrated of order one ($I(1)$) or stationary at first differences may have at least one cointegrating relationship. If the price time series are stationary, namely integrated of order zero ($I(0)$) or stationary at level, they can be studied using Autoregressive Distributed Lag models. However, price time series are often non-stationary as their statistical properties change over time. Non-stationary data cannot be predicted and modelled, because the model may be unreliable or spurious. For a consistent and reliable result, the original price time series needs to be transformed into stationary data for model construction, normally by differencing or if the data shows a deterministic trend by de-trending.

5.5.2. Selection of model between vector autoregressive and vector error correction

The choice of using the vector autoregressive (VAR) and vector error correction (VEC) models depends on the level of integration of variables and residuals in the model. If the variables are $I(1)$ and the residual or error term is $I(0)$, then at least one cointegrating relationship exists and the VEC model is preferred (Enders, 2015). The cointegration and the error correction models (ECM) are based on the idea of a long-run equilibrium, which disallows individual prices from drifting apart in long-term disequilibrium (Ghoshray, 2002; Liu *et al.*, 2019). The presence of asymmetries (i.e. due to quota policy) may invalidate the standard tests, such as the Dickey-Fuller test or the Johansen test for cointegration. When there are more than two $I(1)$ variables in the system, the maximum likelihood approach of Johansen and Julius can be used in addition to the residual-based approach of Engle and Granger (Zhang *et al.*, 2017). According to Levendis (2018), Engle and Granger's two-step procedure builds on regression, and Johansen's procedure builds on VARs and circumvents many of the problems in the two-step approach. The Granger causality test is undertaken to assess whether a unidirectional or a bidirectional relationship exists between the three main butter producing countries and within the value chain. However, Granger causality is not real causality, it is only statistical causality. The test results support the discussion about the predictive power of one price on another. The relationship derived from the Granger test is used to support the VEC model building that is to disentangle short- and long-run dynamics in price interdependence.

5.5.3. Key advantages of the VEC model and the estimation strategy

According to Asteriou and Hall (2011), there are four key advantages of using the VEC model. Firstly, it is a convenient model for measuring the correction from the disequilibrium of the previous period, which has a very good economic implications. Secondly, ECMs are formulated in terms of first differences, which helps to resolve the problem of spurious

regressions. Thirdly, the VEC model searches for the most parsimonious ECM model that best fits the given data sets with ease. Finally, the disequilibrium error term is a stationary variable. Therefore, the presence of cointegration implies that there is some adjustment process preventing the errors in the long-run relationship from becoming larger and larger.

The estimation strategy for this study can be summarised as follows (Asteriou and Hall, 2011; Enders, 2015; Levendis, 2018). The first step was to test whether the individual price series and residuals are stationary and their order of integration using statistical tests and line graphs. The second step was to estimate the long-run relationship and check for the order of integration of the residuals. A cointegrating relationship among the variables was estimated by ordinary least squares (OLS) and the error term was specified by using lagged residuals from the co-integrating regression. The third step was to estimate the long-run cointegrating equations based on economic theory, as well as the short-run adjustment terms. The results derived from these relationships feed into variables used to estimate a general Johansen multi-equation VEC Model. The fourth step was to estimate the orthogonalised impulse response functions to indicate how a shock or exogenous price impulse to one variable affects the other variables, or to describe the causal effects while ensuring that the ordering is justified based on economic theory (Zhang *et al.*, 2017). Lastly, the robustness checks (i.e. for autocorrelation and stability) were performed and several reasonable specifications were tried and compared before selecting the best models.

5.5.4. VEC model estimation for Irish butter prices

In the long-run, if the relationship between prices is cointegrated, we assume this relationship can be specified as follows (Johansen normalisation restriction imposed) using Ireland as the dependent variable.

$$\text{Horizontal (h) price transmission: } ECT_{IRLh,t} = LXP_{IRL,t} - \alpha_0 - \alpha_1 LXP_{NZ,t} - \alpha_2 LXP_{NED,t} \quad (5.1)$$

$$\text{Vertical (v) price transmission: } ECT_{IRLv,t} = LXP_{IRL,t} - \beta_0 - \beta_1 LFMP_{IRL,t} \quad (5.2)$$

This approach is adapted from previous literature, i.e. O'Connor *et al.* (2007); Hockmann and Voneki (2006); Newton (2016); Zhang *et al.* (2017); Liu *et al.* (2019) where ECT is the Error Correction Term, LXP is the logged butter export price for Ireland (IRL), New Zealand (NZ), and Netherlands (NED), LFMP is the logged farm milk price for Ireland, α and β are coefficients and t is for time. The negative sign of the coefficients of the error correction term means their short-term fluctuation can reverse or be pulled back by market forces when moving out of long-term equilibrium. The coefficients of the variables are elasticities and a value

greater than one indicates an elastic impact of the variable (Ramsey *et al.*, 2021) or price over adjustment. The sign and magnitude of the price transmission elasticity or responsiveness can be related to different underlying economic forces. According to Vavra and Goodwin (2005), price transmission might be asymmetric in its speed and magnitude and could differ depending on whether the price shock is positive or negative and is being transmitted upwards or downwards along the chain.

The VEC model for butter price in three countries with long-run and short-run relationships can be written as follows:

Horizontal price transmission based on annual data:

$$\Delta LXP_{IRL, t} = \phi + \sum_{b=1}^{k-1} \delta_b \Delta LXP_{IRL, t-b} + \sum_{j=1}^{k-1} \psi_j \Delta LXP_{NED, t-j} + \sum_{m=1}^{k-1} \rho_m \Delta LXP_{NZ, t-m} + \lambda_1 ECT_{IRLh, t-1} \quad (5.3)$$

$$\Delta LXP_{NED, t} = \sigma + \sum_{b=1}^{k-1} \delta_b \Delta LXP_{IRL, t-b} + \sum_{j=1}^{k-1} \psi_j \Delta LXP_{NED, t-j} + \sum_{m=1}^{k-1} \rho_m \Delta LXP_{NZ, t-m} + \lambda_2 ECT_{NEDh, t-1} \quad (5.4)$$

$$\Delta LXP_{NZ, t} = \vartheta + \sum_{b=1}^{k-1} \delta_b \Delta LXP_{IRL, t-b} + \sum_{j=1}^{k-1} \psi_j \Delta LXP_{NED, t-j} + \sum_{m=1}^{k-1} \rho_m \Delta LXP_{NZ, t-m} + \lambda_3 ECT_{NZh, t-1} \quad (5.5)$$

Vertical price transmission based on monthly data:

$$\Delta LXP_{IRL, t} = \beta + \sum_{q=1}^{k-1} \delta_q \Delta LXP_{IRL, t-q} + \sum_{s=1}^{k-1} \psi_s \Delta LFP_{IRL, t-s} + \lambda_4 ECT_{IRLv, t-1} \quad (5.6)$$

$$\Delta LFP_{IRL, t} = Q + \sum_{q=1}^{k-1} \delta_q \Delta LXP_{IRL, t-q} + \sum_{s=1}^{k-1} \psi_s \Delta LFP_{IRL, t-s} + \lambda_5 ECT_{IRLv, t-1} \quad (5.7)$$

Where Δ denotes changes in first differences, δ_b , ψ_j , ρ_m , δ_q , and ψ_s are short-run coefficients of the models' adjustment to long-run equilibrium. λ is the speed of adjustment parameter with a negative sign. ECT_{t-1} is the error correction termed lagged value of the residuals obtained from the cointegrating regression of the dependent variable on the regressors. It is based on the notion that the deviation from long-run equilibrium in the last period will influence its short-run dynamics. $k-1$ is the optimal lag length which is reduced by one. The lags can be due to contracts, imperfect information, sticky prices, long-term buyer-seller relationships, and inertia in consumer habits which may cause prices to deviate in the short run from equilibrium, but in the long-run these deviations should be eliminated (Ghoshray, 2002). The differences analysis removes the effect of standard cost components from the analysis.

5.6. Results and discussions

Table 5.2 presents the unit root tests (ADF and PP) and stationarity test (KPSS) statistics for butter prices in three countries and Irish farm milk prices. The unit root test results were generally consistent with each other, especially for first differences. The variables were all

stationary for first differences at a 5% significance level based on the KPSS test.³ The unit root tests were consistent with the stationarity test at first differences.⁴ Given the same order of integration (I(1)) based on the unit root and stationarity tests, the focus was on the logged variables which have coefficients that can be interpreted as elasticity. The OLS estimates of the cointegrating relationship regressions (for horizontal and vertical price transmission) indicated that the residuals were all stationary at a level or integrated of order zero (I(0)) at a 5% significance level, based on ADF and PP tests. The additional or full output of the residual statistics or results for horizontal and vertical price transmission cointegrating relationship regressions can be made available upon request. These findings suggested that there were cointegration or long-run economic relationships between prices both horizontally and vertically which implied that prices moved closer together in the long-run, although in the short-run pre quota abolition they may have drifted apart. Therefore, given the results of the stationarity tests, the estimation of the VEC models for price transmissions or causal relationships was warranted. The test statistics between the monthly butter and milk prices suggest that the butter prices were more stable than the milk prices which were relatively more volatile. This difference in volatility can be explained by the perishability of the product and opportunity to store the product for certain period until prices become favorable.

Table 5.2. Unit root and stationarity tests statistics for farm milk and butter prices

Logged	PP	ADF	KPSS
LXP _{IRL}	-5.2***	-4.23***	0.47**
ΔLXP _{IRL}	-7.5***	-7.46***	0.36
LXP _{NED}	-2.99**	-2.87***	0.57**
ΔLXP _{NED}	-6.95***	-6.81***	0.27
LXP _{NZ}	-1.89	-1.94	0.55**
ΔLXP _{NZ}	-6.95***	-7.7***	0.17
Monthly data			
LXP _{IRL}	-3.1**	-1.95**	0.07
ΔLXP _{IRL}	-7.87***	-7.73***	0.04
LFMP _{IRL}	-1.7	-1.73**	0.33***
ΔLFMP _{IRL}	-12.97***	-12.95***	0.04

Note(s): ***1% **5%; ADF critical values with drift were used with 2 lags. KPSS with no trend at a maximum lag of 10 as chosen by Schwartz criterion. Statistical significance for the KPSS test indicates the non-stationarity of the variable.

³ According to Hobbijn *et al.* (2004) and Kagalwala (2022), the challenge of KPSS in STATA is that it uses asymptotic critical values and does not consider the sample size which can be a problem for short time series (low power). One way to respond to this is to report results for the 5% significance level, especially for a time series below 50 (Ramsey *et al.*, 2021).

⁴ There was some disagreement between ADF and PP test at level for Irish FMP.

Table 5.3 shows VEC results of the horizontal and vertical price transmission effects or Granger causality effects between prices in the long-run (asymmetry in magnitude). For horizontal price transmission, the NZ prices had a positive elastic impact (elasticity is >1) at a 5% significance level, i.e. asymmetric price adjustment effects, on Irish prices in the long-run. For example, a 1% increase in NZ prices led to a 1.33% increase in Irish prices, *ceteris paribus*. This finding is not surprising since the quantity of butter exported for Ireland was capped at around one hundred thousand during the quota period, indicating an inelastic supply of Irish butter and an elastic supply of NZ butter. Consequently, to compete, Irish butter prices had to increase more to maintain or improve its profitability and to keep up with the increasing international demand for Irish butter. Liu *et al.* (2019) found that both market power and state pricing regulations contribute to the heterogeneity in asymmetric price transmission. There was a bidirectional causality relationship that occurred between NZ and Ireland for butter prices, but Irish prices had a positive inelastic impact on NZ prices. A study by Olipra (2020) found that exporting countries with the highest market shares in dairy products effectively set the world price while other exporters were adjusting their prices. The findings in our study suggest that this relationship is not always unilateral, even though the impact of smaller countries might be smaller on bigger countries. Hockmann and Voneki (2006) and Bergmann *et al.* (2016) found that the EU, as a region, was able to affect global market prices because of its subsidised exports and its high share of butter export. However, they did not specify which of the EU countries had an impact on NZ, as identified in this study. There was a unidirectional causality relationship that occurred from Ireland to the Netherlands. Irish prices had a negative inelastic impact at a 5% significance level on the Netherlands prices in the long-run, *ceteris paribus*.

For vertical price transmission in the long-run, in Ireland, there was a bidirectional causality relationship that occurred from butter prices to farm milk prices and vice versa. Butter prices had a positive inelastic impact on farm milk prices, significant at the 1% significance level, i.e., a 1% increase in butter prices resulted in a 0.62% increase in farm milk prices, *ceteris paribus*. Farm milk prices had a positive elastic impact on butter prices, significant at the 1% significance level, i.e., a 1% increase in farm milk prices resulted in a 1.66% increase in butter prices, *ceteris paribus*. Given the limitations in the quantity that could be produced for butter and farm milk, a lot of policy emphasis was on the price changes to ensure profitability for processors and farmers, and to help reduce risks for them while maintaining a competitive industry. Bakucs *et al.* (2014) found that limits imposed on the price competition between retailers may lead to stronger pressure to use a vertical pricing policy to increase market share.

The findings suggest that butter prices or processors derived more value from farm milk prices than they provided to farmers, potentially due to the higher risk that processors face from increasing input costs, especially with the presence of bigger international competitors for butter. This could also suggest the influence of other dairy commodities on-farm milk prices and their competition for farm milk. However, that influence might have been offset by the fact that farmers benefit from higher commodity prices through dividends from processors, since most Irish dairy farmers sell into a co-op structure. Therefore, it is not possible in this study to conclude that the “weaker” parties in the food chain incur most of the burden of adjustment without the assessment of the impact that other dairy commodities (with heterogeneity in their strategic behaviours) have on-farm milk price, even though the findings suggest that to be the case. As noted by McCorriston (2015), at best the time series approaches using pairs of price series represent a ‘first-pass’ test relating to the functioning of the food chain since it is difficult to ascertain from this framework what factors are likely to be driving the results.

Table 5.3. Price transmission effects in the long-run

Variables	LXP _{IRL, t}	LXP _{NED, t}	LXP _{NZ, t}	LFMP _{IRL, t}
Horizontal Price Transmission (annual)				
Constant	5.56	4.68	-4.18	
LXP _{IRL, t}		-0.84**	0.75*	
LXP _{NED, t}	-1.19		0.89*	
LXP _{NZ, t}	1.33**	1.12***		
ECT _{h, t} (χ^2)	7.39**	12.5***	91.25***	
Vertical Price Transmission (monthly)				
Constant	2.77***			-1.7***
LXP _{IRL, t}				0.62***
LFMP _{IRL, t}	1.63***			
ECT _{v, t} (χ^2)	47.57***			20.18***

Note(s): ***1% **5% *10%

Table 5.4 presents the horizontal and vertical price transmission for butter and milk prices in the short-run (asymmetry in speed) and cointegration equations. The coefficients of the error correction terms with a negative sign capture the short-term fluctuations being pulled back by market forces when moving out of long-term equilibrium and it directly measures the speed at which the price in one region reacts to deviations from long-run equilibrium after a price change in other regions (Asteriou and Hall, 2011). Focusing on horizontal price transmission, the growth rate of Irish butter prices tended to adjust to deviations from the equilibrium growth rate at a faster speed than the growth rate of the Netherlands butter prices, with average growth rate response or speed of adjustment to long-run disequilibrium of 17% and 12%, respectively.

The lagged growth rate of butter prices for the Netherlands and NZ had a positive impact at a 5% significance level and a negative impact at a 1% significance level, respectively, on the growth rate of Irish butter prices in the short-run, *ceteris paribus*. For vertical price transmission, the monthly growth rate of Irish butter prices tended to adjust to deviations from the equilibrium growth rates at a slower speed than the growth rate of milk prices, with an average growth rate response or speed of adjustment to long-run disequilibrium of 2% and 9%, respectively. The speed of adjustment was more rapid on horizontal than vertical price transmission. In other words, Irish butter prices were quicker to respond to international price changes than to local price changes which are expected since the bulk of Irish butter is mainly for the export market and commodity prices dictate milk prices. According to Serra and Goodwin (2003) and Liu *et al.*, (2019), policymakers can cause retailers or processors to be less responsive to farm price changes, even though their laws intend to protect farmers.

Table 5.4. Price transmission effects in the short-run

Variables	$\Delta LXP_{IRL, t}$	$\Delta LXP_{NED, t}$	$\Delta LXP_{NZ, t}$	$\Delta LFMP_{IRL, t}$
Horizontal Price Transmission (annual)				
Constant	-0.01	-0.002	0.03	
$\Delta LXP_{IRL, t-b}$	-0.24	-0.12	0.31	
$\Delta LXP_{NED, t-j}$	0.48**	0.24	0.25	
$\Delta LXP_{NZ, t-m}$	-0.35***	-0.18	-0.4**	
$ECT_h, t-1$	-0.17***	-0.12*	-0.05	
Vertical Price Transmission (monthly)				
$\Delta LXP_{IRL, t-q}$	0.03			0.21
$\Delta LFMP_{IRL, t-s}$	0.02			0.59***
$ECT_v, t-1$	-0.02***			-0.09***

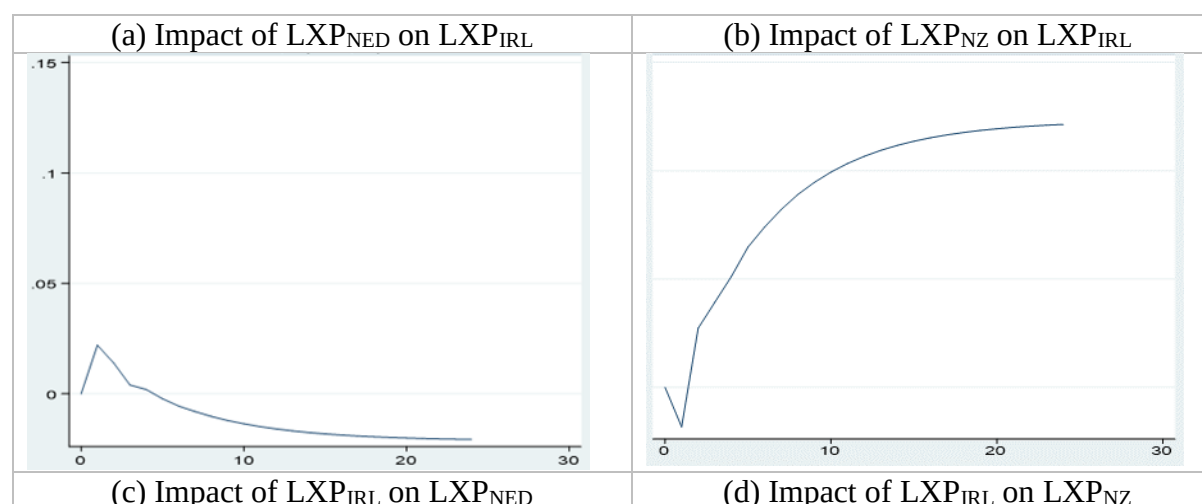
Note(s): ***1% **5% *10%

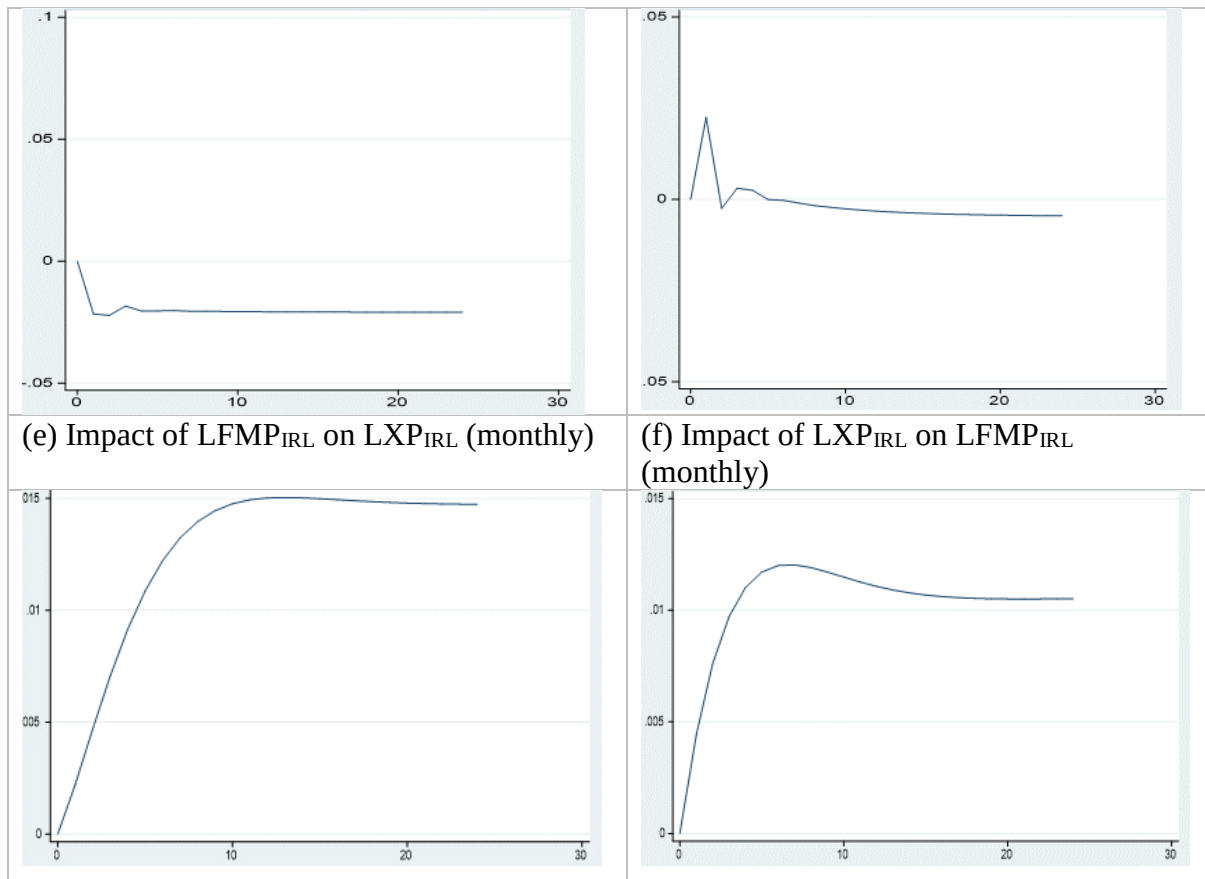
Figure 5.5 displays a visual representation of the effects of price shocks (impulse response) and their duration over time. Impulse response functions provide a visual overview of the dynamic price patterns associated with a one-time shock in a price series. In cointegrating VECM, it is expected that the impulse response functions or the effects of some shocks will not die out over time because the I(1) variables are not mean reverting as in VAR or reflecting the nonstationary nature of the price data (Serra and Goodwin, 2003). According to McCorriston (2015), the long-lasting change in prices matters for macroeconomic policy and may lead to governments prioritising actions to moderate the impact of price spikes on global markets. On the other hand, imposing a policy on transitory events may only result in output volatility. The graphs presented in Figure 5.5 are consistent with the findings in Tables 5.3 and 5.4, and the overall effects of the price shocks were permanent at different rates, except for figure 5.5(c) for the

impact of Irish butter prices on the Netherlands butter prices. The Netherlands prices had a positive short-term shock on Irish butter prices, but their impact slightly declined below zero in the long-run as shown in figure 5.5(a). According to Ghoshray (2002), countries exporting lower quality commodities may have to lower prices more rapidly than countries that export higher quality commodities, i.e. due to technological advances, economic investments, and government policies, to retain market share.

The NZ butter prices had a negative short-term shock on Irish butter prices, but their impact significantly increased way above 10% in the long-run as shown in figure 5.5(b). The opposite effects of the Netherlands and NZ on Irish butter prices can be explained by the nature of competition between the countries. For example, within the EU, the Netherlands and Ireland are governed by the same policies and trade in the international markets as a bloc. On the other hand, NZ remains the main competitor for Ireland as indicated by the significant influence on its prices. According to Fousekis and Trachanas (2016), when import demand and trade are booming and stocks are tight (i.e. due to quota restrictions in the EU), exporters have a stronger incentive to match a price increase from their competitors rather than a price decrease due to the increase in the intensity of competition. This was found to be true for Ireland in the long-run instead of short-run due to lags, concerning NZ butter prices.

Figure 5.5. The effects of price shocks





Note: X-axis is the period after a shock and Y-axis is the magnitude of the impulse response

5.7. Conclusion and areas for future research

The CAP policy was initially established to ensure the transmission of pricing benefits from the dairy commodity markets to farmers and to deal with external competitors within the EU. Given the high level of market integration and competitive pricing in the international butter market, Ireland was susceptible to spatial price arbitrage and was protected by CAP policy. During the quota period, Ireland had the highest butter prices and was limited in terms of being able to increase quantity which meant that it could not expand in existing and new markets by repositioning its products from existing markets such as the US. At the same time, NZ was able to significantly increase its quantity exported within the same price range. Ireland was limited to competing through prices in the international butter market, raising the significance of butter input prices, i.e. farm milk prices, on butter prices. The empirical results provide evidence of asymmetric price transmissions for the Irish butter market in the whole value chain.

The Irish butter prices were more responsive to NZ butter prices and farm milk prices in the long-run with positive bidirectional causality effects horizontally and vertically, respectively. Declining world milk prices and product age (perishability and/ storability of the product) may prevent symmetric response of Irish milk prices to changes/shocks in Irish butter prices.

Moreover, different target markets and EU or NZ policy for Irish and NZ butter may prevent symmetric response of Irish butter prices to changes/shocks from NZ butter prices. Irish dairy farmers and processors were more susceptible to pricing decisions made by international butter processors with asymmetric price transmission i.e. not realising the full benefit from changes in international butter prices as price takers. The farm milk prices were not insulated from the price shocks in the international butter markets but they were slow to respond to butter price changes. Ireland had a relatively lower market share compared to NZ and was restricted by the EU milk and butter regulations, but these dynamics could change in the future as Ireland continues to expand its butter production in the post-quota era.

Future policies and pricing strategies that seek to ensure competitive price positioning and risk management (price resilience) for Irish butter prices need to consider the long-run and short-run effects of international competitor prices and milk prices identified in this study. Considering the nuances that exist at the regional or EU level, a one size fits all approach might not be best for some countries or sectors that have different production mixes of dairy products. This chapter contributes to the objectives of the Food Wise 2025 policy by examining milk and butter prices to help minimise risks for processors and gives farmers confidence regarding price transmission. It will also help to enhance the engagement between processors, producers, and the government to make informed decisions. Our empirical findings present an opportunity for improving our conceptual understanding of the dynamic butter price adjustments within the value chain. Ireland was able to increase its butter prices above competitor prices due to EU regulations that governed the EU dairy market, suggesting their effectiveness in maintaining barriers to entry in the EU. However, the effects of this on the Irish butter competitiveness (without the protective regulations) and processor profitability remain an area for future research, i.e. linking prices to costs and profit margins for products at the various stages of the value chain. Future research can also analyse the impact of competitor butter prices in importing countries, i.e. the US, on Irish butter prices in those markets, and identify the forces driving competition in the butter market for importing countries, especially pre and post-quota. The approach followed in this chapter can be adapted for other sectors, i.e. cheese and/or powders.

6. Examining the impact of global competitors on Irish butter competitiveness

Abstract

This chapter seeks to analyse the extent to which Irish butter market dynamics are influenced by the competitiveness of global competitors, i.e. Belgium, the Netherlands, and New Zealand (NZ), to support market development, policy design, and improving competitiveness. An econometric model, i.e. vector auto-regression model, was used to test the competitiveness (normalised revealed comparative advantage) causal relationship between global butter competitors using data from 1970 to 2019. Despite growing competition in the global butter market, Ireland has become the second most competitive country in the world and is advancing rapidly. Irish butter is the only Irish dairy product that has maintained a comparative advantage, highlighting the strategic allocation of resources to this sector. Only New Zealand butter competitiveness had an impact or Granger-caused Irish butter competitiveness but not vice versa.

Keywords: Irish butter competitiveness, industry market assessment, international trade, trade competition, dairy sector, vector auto-regression model, normalised revealed comparative advantage.

6.1. Introduction

The dairy industry contributes significantly to the agriculture sector in the European Union (EU), making it an important industry for analysis (Fertő *et al.*, 2021). Ireland is one of the top three net exporters of butter in the world after New Zealand and the Netherlands, and the top two in Europe (see Chapter 3). Given the significance of Irish butter exports in the EU and the world, it is surprising that research on butter export competitiveness remains limited to date. Much of the research on the Irish dairy industry competitiveness has focused on the comparisons of EU Member States' performance at the farm rather than product level. For example, previous studies have not analysed how Ireland prioritises its dairy products portfolio mix for global export markets. This study is the first of its kind to test the law of comparative advantage of the global butter market with a special focus on market adjustments and insights into the dairy product mix in Ireland. The dairy sector contributed about €5.2 billion to the Irish food and drink export industry worth about €13 billion which made it the most significant food export category in the country in 2020 (Bord Bia, 2020). The competitiveness of the dairy industries concerns processors and farmers, especially in Ireland where butter is one of the main dairy products and farmers own or benefit from the processing and marketing firms.

The rationale to focus on product competitiveness has been amplified in the post-quota removal period, particularly when the EU milk sector is expected to be more integrated with the global dairy market and to have more volatile prices (Jansik *et al.*, 2014). It, therefore, becomes important to gain an understanding of the industry market dynamics and competitive position of Irish butter in the global butter market. For example, by providing empirical evidence of how changes in decisions by other countries to allocate more resources to produce butter may have on the Irish butter market and the implications of what that would do to the growth rates of other Irish dairy products. Over time, countries have to respond to changes in trade agreements and market dynamics, i.e. facilitated by the Common Agriculture Policy (CAP) and World Trade Organization, which impact prices in importing and exporting countries. Such changes can be captured through the analyses of a country's export competitiveness. Drescher and Maurer (1999), Jansik *et al.* (2014), and Cele *et al.* (2021) described competitiveness as a relative concept that can be defined relative to the position of a different historical point in time, or relative to an existing aggregate group of firms either of different nationalities or pursuing different policies. It can be analysed over time by observing export prices, comparative advantage, and market share trends.

Recent empirical studies (Sarker and Ratnasena, 2014; Narayan and Bhattacharya, 2019; Chen *et al.*, 2020) have adopted the use of the normalised revealed comparative advantage (NRCA) index proposed by Yu *et al.* (2009) as a proxy for export competitiveness. The assumption is that the more specialised a country is in a particular product or commodity the more competitive it becomes, especially for processed products that require high investment and innovation. Export flows of a country reveal its comparative (dis)advantage in trade sectors which is an outcome of relative factor endowments and various domestic and trade policies (Bojnec and Fertő, 2017). International competitiveness usually involves a cross-country comparison of a particular product and is sensitive to changes in macroeconomic variables (Bojnec and Fertő, 2017; Kea *et al.*, 2020). Relative prices, exchange rates, market share, and comparative advantage are common indicators of competitiveness in the literature (Hörl and Hess, 2017; Juchniewicz and Łukiewska, 2021). According to Abeyasinghe and Yeok (1998), as an economy or sector develops by increasing the domestic content of manufactured exports, exchange rate policies become increasingly intertwined with trade policies. Competitiveness can be measured at the farm, firm, industry, and/or national level. The success of the industry at the export level depends on the success of farms for raw material procurement through vertical integration (Jansik *et al.*, 2014; Kea *et al.*, 2020) and firms in developing unique value-

added products, ensuring the sustainability of the industry. According to Jansik *et al.* (2014), foreign trade performance indicators encompass the activities of companies across the value chain, from farmers and their cooperatives to dairy processors and traders. Latruffe (2010) argued that the assessment of competitiveness should be undertaken based on several indicators which are complementary.

This chapter seeks to address the following questions:

- How much focus is on butter production across different countries in the world?
- How has the competitiveness of Irish butter changed relative to other Irish dairy products, given the competition for scarce resources (i.e. raw milk)?
- Does prioritisation or specialisation in butter production by other international countries affect Irish butter competitiveness or trade performance in the global export market?

Addressing these questions is important for improving our understanding of the overall butter market and understanding the changing butter export relationships between countries. The more competitive other Irish dairy products are relative to Irish butter and other countries relative to Ireland in the global butter market, the less competitive Irish butter will be due to scarcity of inputs and competition in global butter markets. The interdependencies between butter competitors and dynamic aspects of the Irish butter economy have not yet been studied, especially in the post-quota period. According to Bojnec and Fertő (2012), the EU's CAP set up in 1957 to guarantee food security via the dairy policy regime in post-war Europe and was subsequently updated to compete in the global market, has caused distortions to specialisation in agro-food trade in the long-run. Whilst the development of the EU and global trade policy are beyond the control of the sector, countries often have their national industrial policies to promote strategic sectors in the global market. Understanding the industry market dynamics may provide industry stakeholders with key insights for their long-term strategic planning of firm operations and market selection. It may also help with lobbying policymakers to ensure that their plans align with the industrial policy, i.e. Food Vision 2030 which seeks to expand Irish agri-food exports from €14bn to €21bn by 2030. All of these factors are important for achieving sector resilience and preserving international competitiveness. The patterns of trade between countries are often ignored in justifying industrial policies. According to Fertő *et al.* (2021), trade linkages do not evolve randomly but depend on the structure of existing connections.

The chapter aims to analyse dairy industry data using econometric methods and to help improve strategic business planning processes based on industry trends, rankings, and competitiveness. Part of the strategic business planning process is the evaluation of the overall market trends (i.e. pricing trends, market position, how quickly the industry is growing, and how are competitors moving), which are often considered before the next planning cycle begins. The chapter is organised as follows: In Section 6.2, the theoretical basis of the empirical methods used in the study are described, i.e. normalised revealed comparative advantage (NRCA) and vector auto-regression (VAR) models. In Section 6.3, the data sources for dairy products and countries, and the descriptive analysis of Irish butter export performance (compared to other dairy products and countries and in importing countries) which provides some context to the research question are provided. Section 6.4 presents results and discussions about competitiveness trends and competitor effects on Irish butter competitiveness based on NRCA and VAR models. In the final section, conclusions are drawn, highlighting the contribution of the chapter and areas for future research.

6.2. Empirical methods

6.2.1. Normalised revealed comparative advantage (NRCA)

Following previous research, this study uses the normalised revealed comparative advantage (NRCA) index proposed by Yu *et al.* (2009) as a proxy for export competitiveness. The major advantage of using the NRCA is that it allows for symmetry of the data output which helps to preserve the normality assumption in regression analysis and comparability across countries for the same product or commodity. Thus, it is useful for examining changes in international competitiveness. By detecting possible variations in comparative advantage over time, we could assess the impact of drivers on trade and comparative advantage and thus derive possible policy implications. According to Yu *et al.* (2009), the NRCA index measures the degree of deviation of a country's actual export value from its comparative-advantage-neutral level and is presented on a relative scale. The higher (or the lower) the NRCA score is, the stronger the comparative advantage (or disadvantage) would be. Since comparative advantage is a relative concept, the interpretation of the magnitude of NRCA is more meaningful within a comparative context in terms of the relative strength of comparative advantage. The sum of a commodity's NRCA scores is equal to zero and a country's NRCA scores are also equal to zero. Therefore, the NRCA index indicates that each country or each commodity as a whole is comparative-advantage-neutral; and no country has a comparative advantage (or disadvantage) in all

commodities. This implies that if a country gains a comparative advantage in a commodity, some other countries must lose a comparative advantage in this commodity. This reflects the relative nature of comparative advantage. The reader can refer to Yu *et al.* (2009) for the derivation of the NRCA from the RCA by Balassa. This chapter only focuses on its empirical application as adopted by Sarker and Ratnasena (2014), Narayan and Bhattacharya (2019), and Chen *et al.* (2020).

The NRCA in value terms for Ireland's butter export market in the global dairy market was estimated using the following formula (adjusted by ten thousand units for ease of interpretation of the results) (see in Chapter 2):

$$NRCA_{\text{country}, t} = \left(\frac{\text{Country butter exports}}{\text{World dairy exports}} \right) - \left[\left(\frac{\text{Country dairy exports}}{\text{World dairy exports}} \right) \left(\frac{\text{World butter exports}}{\text{World dairy exports}} \right) \right] \quad (6.1)$$

$$NRCA_{\text{IRL}, t} = \left(\frac{\text{Irish butter exports}}{\text{World dairy exports}} \right) - \left[\left(\frac{\text{Irish dairy exports}}{\text{World dairy exports}} \right) \left(\frac{\text{World butter exports}}{\text{World dairy exports}} \right) \right] \quad (6.2)$$

Where dairy products are the total combination of butter, cheese, skimmed milk, skimmed dried milk, whole dried, and whole fresh milk in the global export market. The NRCA is captured over time (t). Based on this formulation, a country has a comparative advantage in butter (i.e. $NRCA > 0$) if it enjoys a larger butter export market share than that of total dairy commodities, and does not have a comparative advantage if otherwise (i.e. $NRCA < 0$). According to Sarker and Ratnasena (2014), unlike the RCA, the magnitude of NRCA provides a meaningful economic interpretation in a comparative context.

6.2.2. Vector auto-regression model based on NRCA

To investigate the effects of competitor countries' NRCA on Irish NRCA, the equations are estimated using a vector auto-regression (VAR) system approach which has also been used by Chavas and Mehta (2004) and Newton (2016) for butter price transmission. For example the VAR model for Ireland is as follows:

$$LNRC A_{\text{IRL}, t} = \alpha_0 + \alpha_1 LNRC A_{\text{NZ}, t-2} + \alpha_2 LNRC A_{\text{NED}, t-2} + \alpha_3 LNRC A_{\text{BEL}, t-2} + \alpha_4 LNRC A_{\text{IRL}, t-2} \quad (6.3)$$

The variables appear in the regression models in natural logarithmic form over time (t) and t-2 is a lagged value. Where $LNRC A_{\text{IRL}}$ is the logged NRCA for Ireland, $LNRC A_{\text{NZ}}$ is the logged NRCA for New Zealand, $LNRC A_{\text{NED}}$ is the logged NRCA for the Netherlands, and $LNRC A_{\text{BEL}}$ is the logged NRCA for Belgium. The estimation strategy or procedure for this study can be summarised as follows (Asteriou and Hall, 2011; Enders, 2015). To test whether the individual variables and residuals were stationary and their order of integration, the statistical tests such

as the unit root tests (ADF and PP) and stationarity tests (KPSS) were used. The robustness check of the VAR model was tested using the eigenvalue stability condition.

6.3. Data sources and descriptive analysis of export performance

The annual time series data were collected from the Food and Agriculture Organization Statistical Databases (FAOSTAT) available from 1970 to 2019 for export prices and export value for competitor countries (Belgium, the Netherlands, and New Zealand) and dairy products (i.e. butter, cheese, skimmed milk, skimmed dried milk, whole dried and whole fresh milk). Unlike fresh milk, value-added dairy products can be stored and sold when market conditions are more suitable during the year. The net export value of butter was calculated for the top three net exporting countries in the world, i.e. New Zealand, the Netherlands, and Ireland. The data for Irish butter market share in importing countries, i.e. Belgium, France, Germany, Netherlands, United Kingdom, and the United States of America, and country import prices were available from 1986 to 2019. No reasons were mentioned in the FAOSTAT database for the missing data from 1993 to 1997 in the US. The data for computing the NRCA was also available from 1970 to 2019 which included the value of Irish butter exports, Irish total dairy products exports, world butter exports, and world total dairy products exports. The data was sourced in US dollars (\$) from FAOSTAT and the exchange rate was collected from FAOSTAT.

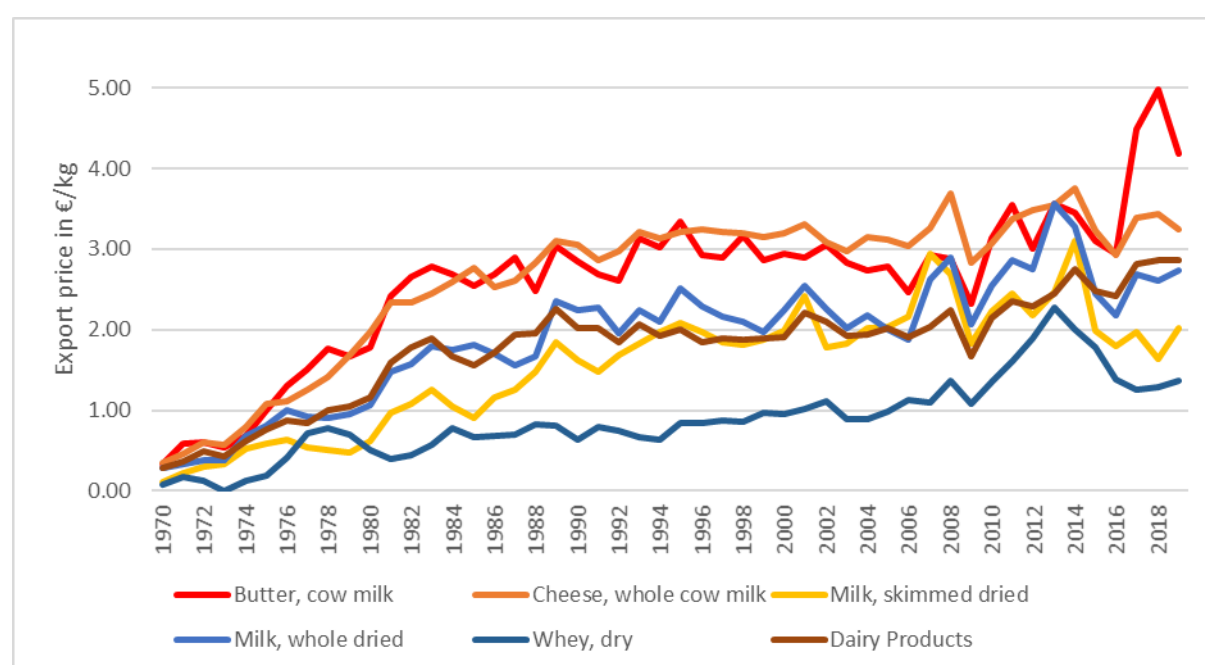
6.3.1. The descriptive analysis of the Irish butter export performance

6.3.1.1. Irish butter export performance compared to other dairy products and countries

The overall prices of Irish dairy products have steadily increased over the years before becoming more volatile in 2006 as shown in Figure 6.1. Among dairy products, butter and cheese have had the highest export prices over the years with butter having the highest export price increase of 79% from 2009 to 2019 as demonstrated in Figure 6.1, and export quantity increased by 45%. Most of the export value has been derived from butter and cheese as shown in Figure 6.2, and cheese, whey, and butter had the highest growth rate of 281%, 238%, and 209%, respectively, from 2000 to 2019. Cheese has different varieties which are aggregated to get the average measures, and the most significant variety of cheese was cheddar cheese. This makes it difficult to compare countries' NRCA based on cheese. The high value derived from butter and its homogeneity makes it an interesting case study. The net export value for butter increased by 268% and 216% for NZ and Ireland, respectively, from 2000 to 2019, and NZ had been increasing significantly since 2003 but Irish butter had significant growth from 2009. Irish

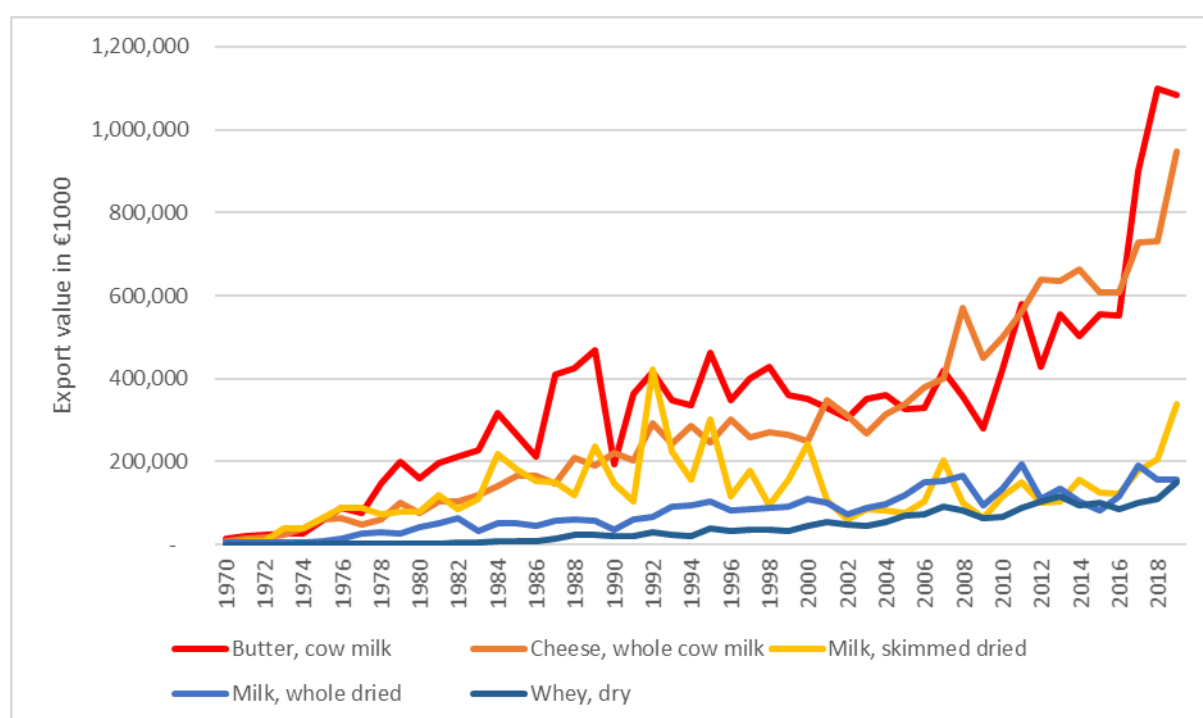
butter has the highest net export value in the EU and the second highest in the world which is shown in Figure 6.3, making it a significant player in the global markets. The Heckscher-Ohlin theorem states that with free trade, a country will primarily export the good that uses its relatively abundant production factor intensively i.e. raw materials and labor, and import the good that uses its relatively scarce factor intensively. According to Kea *et al.* (2020), higher domestic production costs and imports can reduce export competitiveness. Our focus for this study was only on exports for the NRCA and not imports, but the net export value in Figure 6.3 accounts for imports. Ireland is a net exporter of butter and the imports in terms of butter are minimal (see Chapter 3).

Figure 6.1. Export prices for Irish dairy products



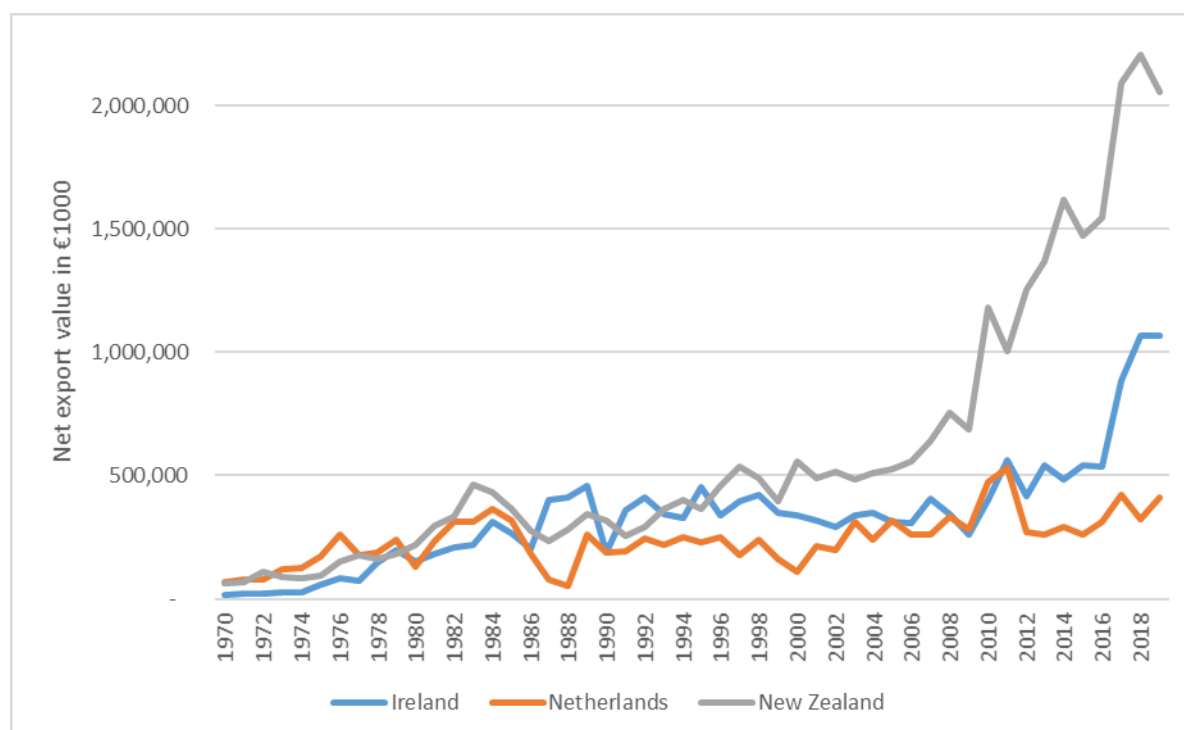
Source: Authors' estimates based on the FAOSTAT dataset

Figure 6.2. Export value for Irish dairy products



Source: Authors' estimates based on the FAOSTAT dataset

Figure 6.3. Net export value of butter from top 3 exporting countries in the world

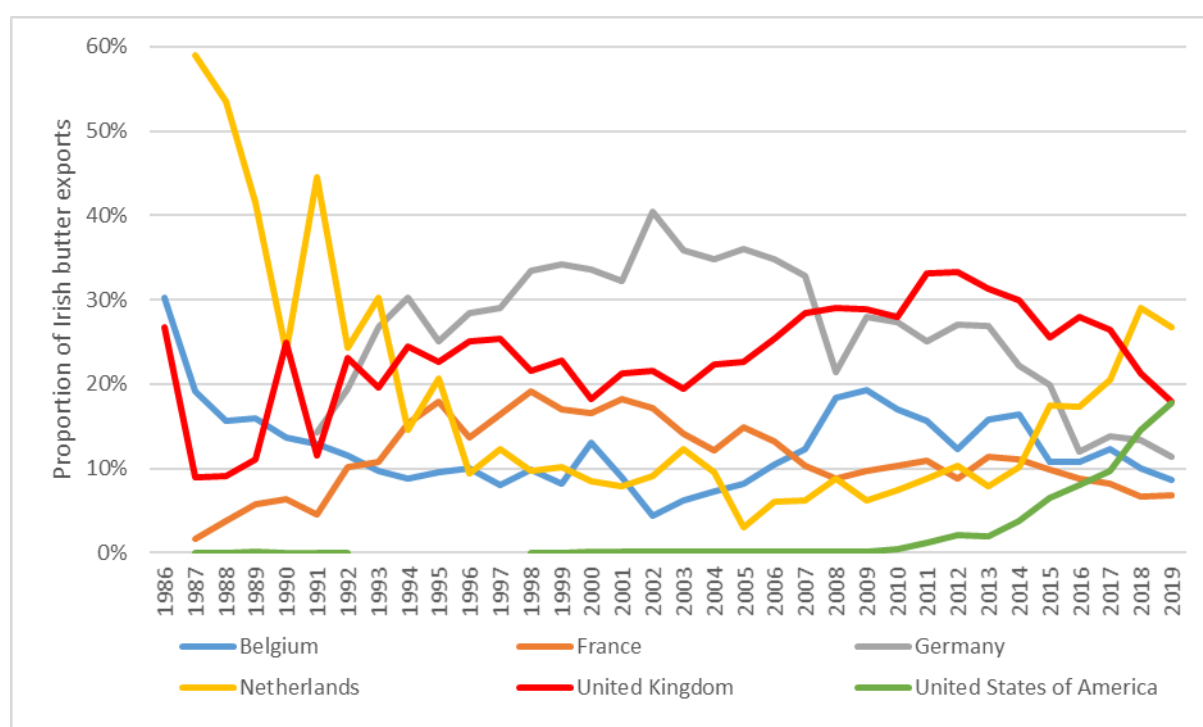


Source: Authors' estimates based on the FAOSTAT dataset

6.3.1.2. *Irish butter export performance in importing countries*

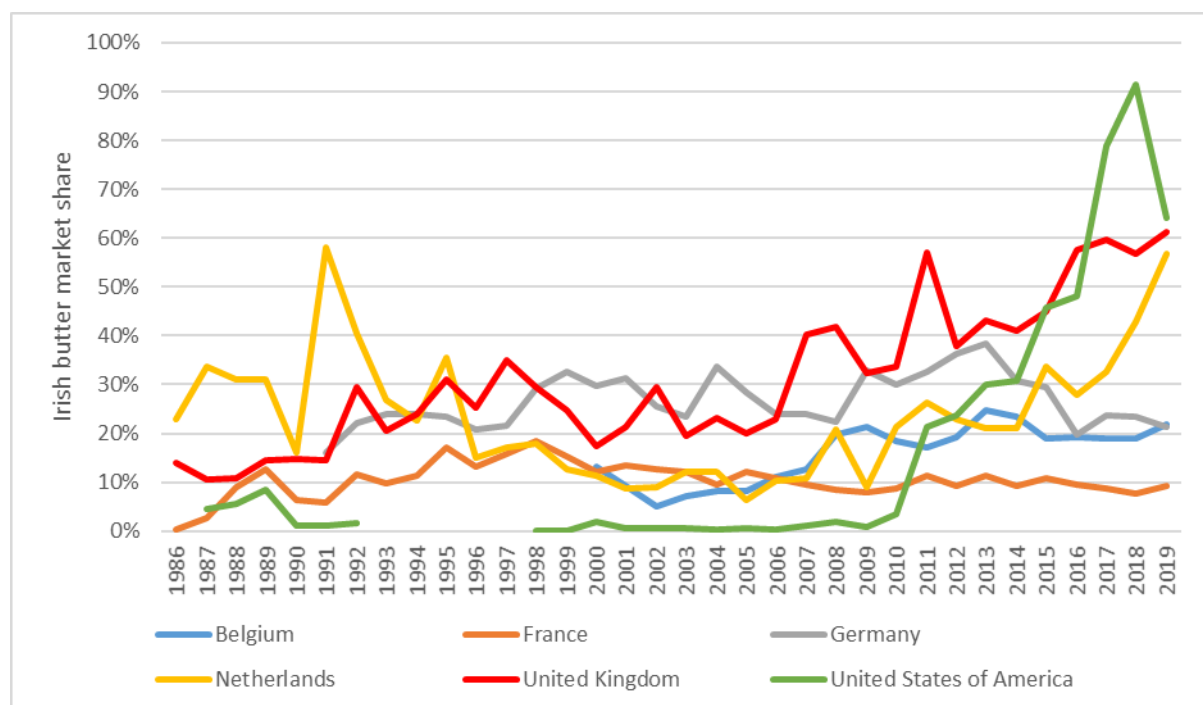
Figure 6.4 shows the top importers of Irish butter and the proportion of Irish butter exports directed towards those markets. The majority of the exports ranging from 70% to 95% over the years have been directed toward developed countries, namely, Belgium, France, Germany, Netherlands, United Kingdom (UK), and the United States of America (US). Since 2009, Ireland has significantly increased the proportion of butter exports to the US and the Netherlands, while it has reduced the proportion of butter exports to the UK and other developed countries. This suggests a strategic change that could be due to changes in the environment (i.e. technological change, policy, new competitors, and new markets) or internal management changes (i.e. new corporate vision, mergers, and acquisitions). As the Irish exports to the Netherlands were falling from the late 1980s, the Irish exports were increasing to Germany and the opposite effect was observed from 2005. Figure 6.5 also shows that the market share of Irish butter has been increasing significantly since 2009 in the UK, along with the Netherlands and the US. The Irish butter market share was the highest in the US followed by the UK from 2017 to 2019. The US Airbus ad valorem tariff imposed on Irish butter imports as a result of a WTO ruling from 2015-2019, led to a decline in Irish market share in the US from 2018. In 2019, Irish butter constituted 64% of the butter imports in the US, 61% in the UK, and 57% in the Netherlands. Figure 6.6 demonstrates the ratio of importing country's price of Irish butter relative to the Irish export price. The transaction costs and protective measures, i.e. tariffs, influence the importing country's prices of Irish butter to be above Irish export prices and their lack of subsidisation may influence prices to be lower. The importing country prices of Irish butter were the highest above the Irish butter export prices for Belgium from 2006 and the US from 2008, suggesting premium prices, i.e. due to transaction costs, or price protection that exist for Irish butter in those markets.

Figure 6.4. The proportion of Irish butter exports in different countries



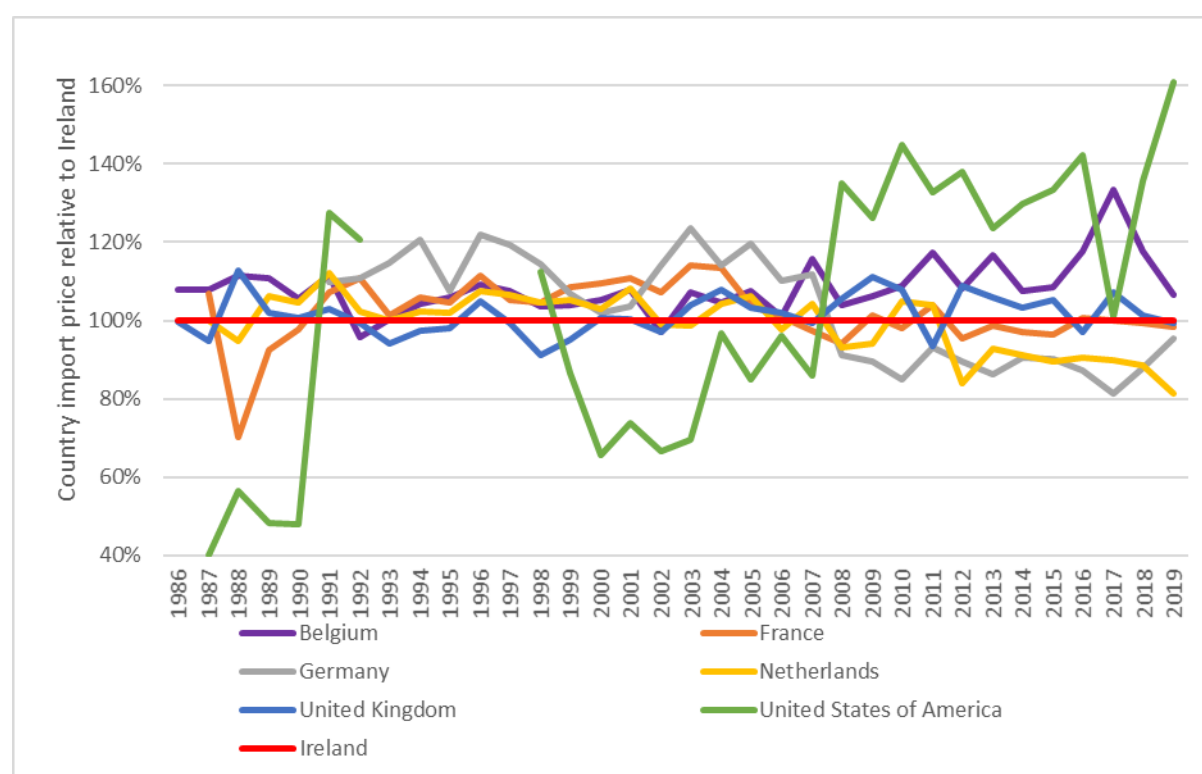
Source: Authors' estimates based on the FAOSTAT dataset

Figure 6.5. Market share held by Irish butter in major importing countries



Source: Authors' estimates based on the FAOSTAT dataset

Figure 6.6. Country import price of Irish butter relative to the Irish export price



Source: Authors' estimates based on the FAOSTAT dataset

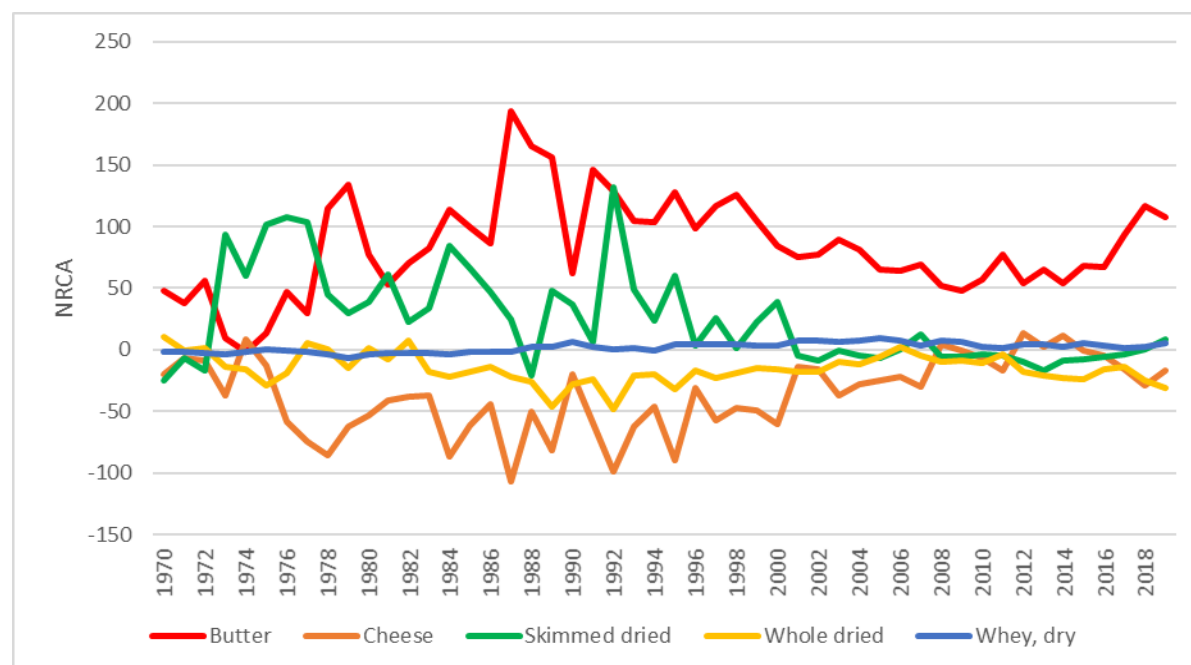
6.4. Results and discussions

6.4.1. Competitiveness trends based on NRCA

The national strategic plans often position the country to be the low-cost producer in an industry, to develop products that are considered different from the products of the competition, or focus efforts to better serve a narrow group of the market. Part of the strategic plan is to increase market share and/or profitability. The firm seeks to achieve a competitive advantage against its competitors, monitor its progress, and modify the production mix strategies based on changes in the environment (evaluation and control). Figure 6.7 shows the competitiveness of Irish dairy products in the global dairy market and it shows Ireland's strategic production mix over time. Irish butter is the only product that has maintained a comparative advantage over the years and Irish skimmed dried milk lost its comparative advantage from 2000. Irish cheese has improved its competitiveness since 2000 but has remained at a comparative disadvantage. As butter competitiveness increases, the competitiveness of cheese declines, which is consistent with the law of comparative advantage. On the other hand, as butter competitiveness increases, the competitiveness of skimmed dried milk also increases in most cases and the inconsistencies are likely due to the storage of the products. This is expected

since skimmed dried milk is a by-product of butter production. Butter and cheese compete for the same resources at the firm level.

Figure 6.7. NRCA for Irish dairy products in the global dairy market

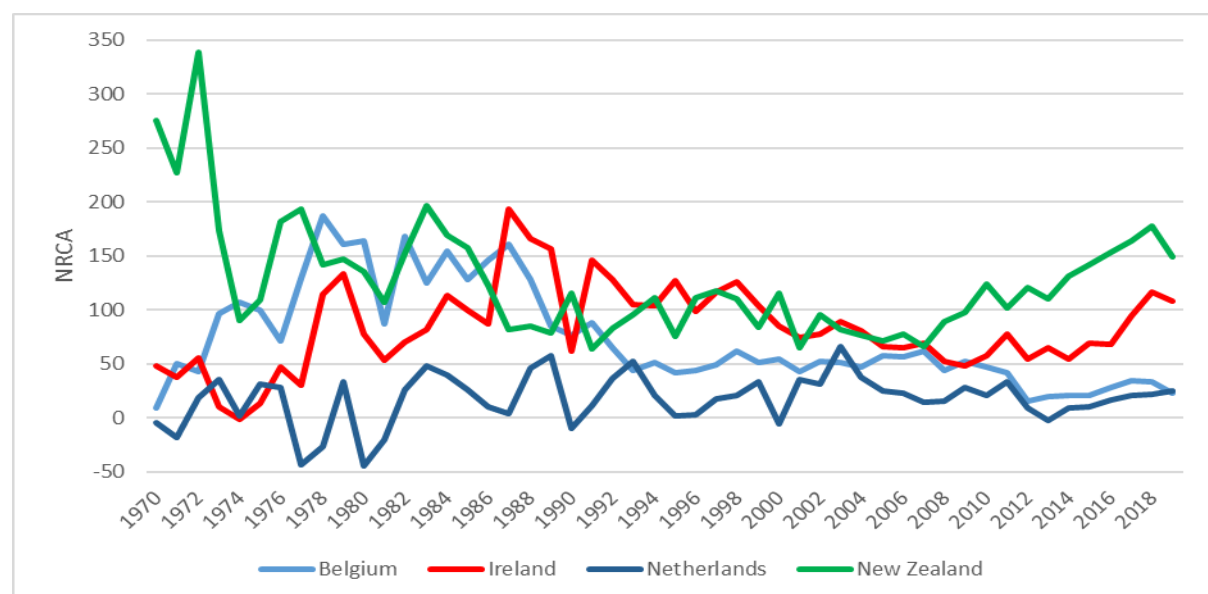


Source: Authors' estimates based on the FAOSTAT dataset

The competitiveness of a country over time demonstrates the ability to adjust and/or adapt to global economic changes or conditions. Figure 6.8 displays the trends in butter competitiveness for the countries that specialise or have the highest comparative advantage for butter in the global market from 1970 to 2019. Ireland reached its competitiveness peak in 1987 from its lowest point in 1974 and has been declining ever since, until 2014. As noted by Donnellan *et al.* (2015), before 1987, there had been no butter restriction which resulted in high stockpiles e.g. butter intervention reached 60 percent of EU production in 1986, and from 1987, a limit of 180,000 tonnes was introduced. There was strong competition between Irish butter and New Zealand (NZ) butter competitiveness from 1986 to 2007, with NZ being the most competitive post-2007 followed by Ireland. The findings show that despite the growing competition in the global butter market, Ireland became the second market leader in competitiveness and is advancing rapidly, suggesting a good allocation of resources in the sector. The shocks in Irish butter competitiveness were also observed in the Netherlands, suggesting causality and the results of the tests are presented in Tables 6.2 and 6.3. As noted by Bojnec and Fertő (2012), the competitiveness of countries change due to relative cost differences between trading partners and impacts of different sector-specific macroeconomic and market-related policy

distortions. Narayan and Bhattacharya (2019) and Chen *et al.* (2020) found that structural change or trade agreements and prices had a negative influence on commodity competitiveness. From 2007, the butter agreements and prices were less restricted. The competitiveness of NZ and Ireland grew by 126% and 64%, respectively, from 2007 to 2019.

Figure 6.8. Trends in butter competitiveness in the global butter market



Source: Authors' estimates based on the FAOSTAT dataset

6.4.2. Competitor effects on Irish butter competitiveness based on the VAR model

Table 6.1 provides the unit root tests and stationarity test statistics for butter competitiveness in different countries in the global butter market. The variables were all stationary at level at a 5% significance level in Table 6.1. The unit root tests were consistent with the stationarity test.⁵ Therefore, given the results of the stationarity tests, the estimation of the VAR model for competitiveness transmissions or causal relationships was warranted. Moreover, all the eigenvalues were inside the unit circle and VAR satisfied the stability condition. The Akaike Information Criterion (AIC) was used and the VAR with two lags was estimated (Levendis, 2018).

⁵ There was some disagreement between ADF and PP test at level, especially for Irish NRCA. However, given that there was consistency in other variables and between ADF and KPSS, the VAR model was used.

Table 6.1. Unit root and stationarity tests statistics for butter competitiveness

	ADF	PP	KPSS
LNRC_{AIRL, t}	-2.81***	-2.72	0.19
LNRC_{ANZ, t}	-3.39***	-3.23**	0.27
LNRC_{NED, t}	-4.98***	-4.88***	0.13
LNRC_{BEL, t}	-2.94***	-3.09**	0.37

Note(s): ***1% **5%; ADF critical values with drift were used with 2 lags. KPSS with no trend at a maximum lag of 10 as chosen by Schwartz criterion. Statistical significance for the KPSS test indicates the non-stationarity of the variable.

The inter-country comparisons of competitiveness show the potential areas of improvement to structural changes, i.e. taking better advantage of the easing of the EU market restrictions, the degree of country openness, and competition. Tables 6.2 and 6.3 show the Irish butter competitiveness transmission effects or Granger causality effects from competitor countries in the long-run.⁶ The results indicated that New Zealand butter competitiveness had a positive impact or Granger-caused Irish butter competitiveness at 1% significance level. In other words, an increase New Zealand butter competitiveness is more likely to have a positive influence on Irish butter competitiveness, especially in the post-quota era or in the long-run (see illustration in Figure F1 in the appendix). On the other hand, both the Netherlands and Belgium butter competitiveness had a negative impact or Granger-caused New Zealand butter competitiveness at 5% significance level. Belgium butter competitiveness also had a positive impact or Granger-caused the Netherlands butter competitiveness at 10% significance level. Juchniewicz and Łukiewska (2021), found that Belgium had a relatively high trade surplus and share of exports on the world market.

Further investigation on the supply-side and demand-side factors of export competitiveness or diversification (given heterogeneity between competitors) may be useful for understanding this relationship between the competing countries (Bojnec and Fertő, 2017; Ferto *et al.*, 2021). Countries often have different trade relationships or agreements for dairy products which dictate whether countries are rivals or allies in the global dairy market. The processing companies have to make investments in the sector (to improve quality, i.e. product differentiation) to open up better export opportunities and enhance their competitiveness, and the role of patents as an approximation for innovativeness will be important in the future (Horl and Hess, 2017). According to Toming (2007), for an industry in a small country with a limited

⁶ As noted by Enders (2015), the goal of a VAR analysis is to determine the interrelationships among the variables, not to determine the parameter estimates.

domestic market, the role of foreign countries' policies is often decisive in determining its possible access to the export market and can affect the long-run sustainable growth and profitability of domestic firms or industry. Therefore, Ireland has to consider this outcome to improve its competitive position, especially since the EU no longer offers the support it did for butter.

Table 6.2. VAR transmission effects on Irish butter competitiveness

VAR	$\text{LNRC}_{\text{IRL}, t}$	$\text{LNRC}_{\text{NZ}, t}$	$\text{LNRC}_{\text{NED}, t}$	$\text{LNRC}_{\text{BEL}, t}$
$\text{LNRC}_{\text{IRL}, t-2}$	(+) ^{***}	(-)	(-)	(-)
$\text{LNRC}_{\text{NZ}, t-2}$	(+) ^{***}	(+) ^{***}	(-)	(+)
$\text{LNRC}_{\text{NED}, t-2}$	(-)	(-) ^{**}	(-)	(-)
$\text{LNRC}_{\text{BEL}, t-2}$	(+)	(-) ^{**}	(+) [*]	(+) ^{***}
Constant	(-) [*]	(+) ^{***}	(+) ^{**}	(-)
R-sq	0.7783 ^{***}	0.5858 ^{***}	0.1653	0.7321 ^{***}

Note(s): ***1% **5% *10%

Table 6.3. VAR Granger causality Wald tests

VAR-Granger	$\text{LNRC}_{\text{IRL}, t}$	$\text{LNRC}_{\text{NZ}, t}$	$\text{LNRC}_{\text{NED}, t}$	$\text{LNRC}_{\text{BEL}, t}$
$\text{LNRC}_{\text{IRL}, t}$		0.710	0.143	0.817
$\text{LNRC}_{\text{NZ}, t}$	0.001 ^{***}		0.110	0.280
$\text{LNRC}_{\text{NED}, t}$	0.314	0.021 ^{**}		0.951
$\text{LNRC}_{\text{BEL}, t}$	0.697	0.045 ^{**}	0.085 [*]	
All	0.004 ^{***}	0.006 ^{***}	0.165	0.656

Note(s): ***1% **5% *10%

6.5. Conclusions

The chapter aimed to analyse the trends of export performance and comparative advantage of the Irish butter industry relative to global competitors, which has not been done before. The Irish government has set a strategic focus on value-added dairy products and expanding agri-food exports as part of the Food Wise 2025 strategic plan and Food Vision 2030. The strategic business planning process in companies provides insights to better develop action plans that will help to operationalise key industry strategies, i.e. to operate more efficiently, expand into new markets and improve performance relative to competitors in the global market.

The chapter has displayed how Irish butter markets responded over time in an increasingly competitive environment, i.e. due to increased price volatility and policy changes or trade disruptions. The market and competitor analysis presented here serves to close critical gaps in the strategic planning process by identifying correlations and trends of competitive positioning. Policymakers and industry stakeholders need to identify macro-level imbalances based on the analyses of the dynamic aspects of the Irish butter performance and make long-term strategic plans to ensure international competitiveness and viability of the sector in global markets. For

example, data-driven risk management mechanisms can be developed for the next planning period by diversification or restructuring dairy product portfolios, relative to global trends. The findings in this chapter can be used by practitioners and researchers as a template to produce industry competitiveness updates or market assessments, i.e. for market intelligence and production planning.

The product mix between butter and cheese for developed markets and powders for developing markets resulted in the strong growth of the dairy sector. Based on the findings presented here, Irish butter was the only Irish dairy product that maintained a comparative advantage over the years, suggesting a good strategic allocation of resources in the sector. Only New Zealand butter competitiveness had an impact or Granger-caused Irish butter competitiveness but not vice versa. Research on trade relationships between countries for dairy products remains scarce. Future research could further explore how Irish firms' shortcomings and/or competencies, and beyond market forces translate into strategic challenges and/or opportunities across dairy product portfolios. Analysing the profitability of the different dairy products can help determine the extent to which comparative advantage is an advantage for processors. Moreover, future research can investigate the sustainability issues of Irish butter production.

7. General conclusions and policy implications

7.1. Summary of key findings and overall contributions of the thesis

The removal of the EU milk quota in 2015 has increased the exposure of the Irish dairy industry to international competitors and has raised the question of how competitive is the Irish dairy industry in the global market. In 2013/14, eight countries (Germany, the Netherlands, Poland, Ireland, Denmark, Austria, Cyprus and Luxembourg) exceeded quota and production moved to areas where there was a comparative advantage and away from areas where economics and/or geography meant that dairy production was more marginal (Giles, 2015). In the context where Europe is considered as a relatively high-cost dairy producer, Giles (2015) estimated that over the following 10 years (2015-2025), dairy processing capacity would focus on the best producing regions and other dairy support services would focus the resources to those high-density milk production areas. The potential for increased competition between milk producers within the EU means that more farmers will be looking for technologies, not least in breeding, that help them lower their costs and become more efficient. The strategy for export specialization in differentiated dairy products, adopted by most of the EU-27 countries, highlighted the significance of exploiting the comparative advantages of rich natural factors of production and dairy infrastructure to boost cost-competitive dairy products in global markets (Bojnec and Ferto, 2014). A need existed to evaluate where the Irish dairy industry ranked from farm to trade within the EU and in the global market, taking into account the removal of the milk quota. This thesis sought to measure Irish competitiveness and examined the interaction between farm milk and trade system of processed dairy products in the global market.

The thesis addressed knowledge gaps on dairy competitiveness starting from the farm level. Chapter 3 addressed the question of how do Irish dairy farms compare with dairy farms at the EU level in terms of total costs and partial productivity? To the best of the authors' knowledge, Chapter 3 was the first of its kind to use both farm and export competitiveness measures to analyse the Irish dairy industry relative to other countries in the context of milk quota abolition. Amongst the countries examined, Ireland had the highest growth in partial productivity indicators and was ranked first with the lowest total costs and cash costs per kg of milk solids post-quota. However, the total economic cost sub-components showed that Irish dairy farmers had high opportunity costs for owned land and labour post-quota. Research on where the competitive dairy farms in Ireland were located has been limited, especially in post-quota period.

Chapter 3 was also a scene setting chapter for Chapters 5 and 6, it addressed trade matters like how competitive are Irish dairy products on the global market in the pre and post-quota period? And how competitive is Irish butter relative to other dairy products and other countries? Unlike previous studies on dairy export competitiveness, Chapter 3 disaggregated the processed dairy products, which allowed for the ranking of countries and comparability across countries. It also developed key performance indicators of dairy products for evaluating and benchmarking the performance of Irish dairy products which helps dairy product companies understand their dairy products' overall performance level and relevant areas for continuous improvement, relative to other dairy products in the global market. The findings of Chapter 3 at trade level revealed that Irish dairy products such as butter and powders had growth potential in competitiveness post-quota with Irish butter and whey ranked in the top three relative to other countries. Other Irish dairy products, i.e. cheese and liquid milk, had declined in competitiveness according to key export competitiveness indicators used. The key players in the Irish dairy industry will be able to better position themselves in the global dairy market, recognising the competitiveness dynamics of the different dairy products and their competitors. The thesis will be used to produce industry competitiveness updates or industry market assessments which can be replicated in other jurisdictions, especially given the complex trade environment where volatility in dairy markets has increased and to adapt to changing industry needs. The thesis was the first of its kind to undertake an industry market assessment and competitor analyses to evaluate the dynamic Irish butter export performance in the global butter market for better strategic planning and resource allocation (i.e. raw milk) among Irish dairy products which were briefly analysed in Chapter 3 and further investigated using more analytical tools over a longer period in Chapters 5 and 6.

Chapter 4 analysed Irish farm efficiency at a regional level by addressing the following questions. What are the regional differences in terms of Irish farm performance or efficiencies and the determinants of regional farm efficiency? Do government programmes and policies, i.e. discussion groups and quota abolition, have an impact on regional farm efficiency? Does production expansion result in efficiency improvements and/or unit cost saving through economies of scale? Chapter 4 provided an analysis of the regional farm efficiency rankings (proxy for farm competitiveness) for Ireland which seeks to be a leader in the global dairy industry. The technical and scale efficiencies of dairy farms were used to explore how regional constraints imposed during the milk quota era may have affected Ireland's regional efficiency levels. The distinctive feature of Chapter 4, was the use of the stochastic meta-frontier approach

which was useful for comparing regional technical efficiencies. The findings suggested that Irish policies aiming to promote labor and soil quality improvement in the East region, to promote discussion groups in the South region, in addition to policies to support management of herd size, would be useful for improving efficiency post-quota. Moreover, some farms expanded beyond their optimal scale leading to a reduction in efficiency levels, and this emphasized the need to tailor farm advice and promote caution and prudence in farm expansion decisions, especially in a region like the South West. The findings can be used for adapting the national policy frameworks to regions in policy dialogues, i.e. to achieve the Food Vision 2030 with ambitious targets set for expansion. For example, to prioritise more farmer engagement and to offer advice tailored to the primary producers in their regions.

Chapter 5 addressed questions such as, to what extent do butter export prices for the Netherlands and New Zealand in the global market, influence or are integrated with Irish butter export prices (horizontal price transmission)? To what extent are changes in Irish butter export prices integrated or transmitted to the Irish farm milk prices in the dairy value chain (vertical price transmission)? Chapter 5 linked farming to trade of dairy products through price transmission analysis. The vector error correction model was used to test whether changes in New Zealand and the Netherlands butter prices and farm milk prices had a positive or negative impact on Irish butter prices. Chapter 5 provided an assessment of the degree of integration of Irish butter in the international butter market which will help industry stakeholders to set trade expectations or policies more precisely along the value chain. The results provided evidence of asymmetric price transmissions, Irish butter prices were more responsive to shocks in New Zealand butter prices and farm milk prices in the long-run. For example, the low world milk prices and time (perishability and/ storability of the product) may prevent a symmetric response of Irish milk prices to changes/shocks in Irish butter prices. The different target markets and EU/NZ policy for Irish and NZ butter may prevent symmetric response of Irish butter prices to changes/shocks from NZ butter prices. Essentially, the take home message for the butter industry is that Irish butter prices should not be studied in isolation, NZ is a butter competitor for Ireland in the world butter market and the NZ butter price has a considerable influence on Irish prices.

Chapter 6 addressed the question related to export competitiveness such as does specialisation in butter production by other countries or specialisation in other dairy products affect Ireland's butter competitiveness in the global export market? Chapter 6 showed how Irish butter markets responded to increased price volatility and policy changes or trade disruptions over time, which

is useful for restructuring dairy product portfolios in a highly competitive environment. The normalized revealed comparative advantage (NRCA) enabled a systematic measurement of export competitiveness and allowed for both an intra-country comparison for various products and an inter-country comparison for one industry. The findings indicated that despite growing competition in the global butter market, Ireland had become the second most competitive country in the world and was advancing rapidly. Irish butter was the only Irish dairy product that had maintained a comparative advantage, highlighting the strategic allocation of resources to this sector. Based on the analyses of the dynamic aspects of the Irish butter performance, industry stakeholders will make data-informed long-term national trade plans to ensure the international viability and competitiveness of the sector. This will be necessary to improve their rankings in terms of export specialization, growth, and size.

7.2. Policy implications

Through the global market research on dairy farm performance and on dairy products that have strong comparative advantages in global market, the findings of this thesis will help Irish policymakers to design policies that will benefit Irish dairy farmers and other dairy stakeholders. The market insights from the thesis will help dairy stakeholders to contribute to the national initiatives on market and price transparency in the value chain. It is expected that the findings from the thesis will provide insights to dairy stakeholders on farm performance in different Irish dairy producing regions to help facilitate the emergence of regional partnerships or enhance relations between region-wide institutions and farmers.

In particular, the research identifies key actions that can be taken to improve the efficiency of dairy farming in the various regions of Ireland. This thesis provides extensive research that will enable Irish dairy stakeholders to participate and support regional policy dialogues, especially on topics related to capacity development (i.e. improving the use of resources or efficiencies and managing the costs) and resource mobilization for agriculture in the regions of Ireland (i.e. Pillar II CAP funds to facilitate more regional development and improving the competitiveness of agriculture). This is important for maintaining and improving competitiveness along the food chain in Ireland to support the ambitions of farmers focusing on value creation of output or more equitable distribution of value along the value chain as noted in the Food Vision 2030.

Ireland provides an interesting case study for measuring dairy competitiveness in the global market, given the policy interventions (i.e. CAP) that took place over the last decades (see Chapter 3 on how competitiveness indicators for Ireland at farm level changed post-quota) and

given its strong export orientation. The findings and recommendations of this thesis will facilitate industry stakeholders and policymakers in identifying micro and macro-level imbalances based on the analyses of the dynamic performance of the Irish dairy industry (especially butter) and will support data-informed, long-term planning for the sector. The findings highlight the gains achieved by the Irish dairy industry over the last decades from farm to trade. The insights can also inform firm strategies, i.e. inform decisions on product differentiation and value chain integration, and market expansion decisions. Industry stakeholders may need to increase efforts to gain and maintain access to priority international markets for key products by using insights from the competition analyses and market intelligence which is necessary to enhance their competitiveness.

The specific recommendations that can be made from this thesis in line with the Food Vision 2030 for dairy, as noted in section 1.1.2 in the introduction, are as follows.

On farm development or competitiveness [(M2:G1:A10); (M3:G4:A6); (M3:G4:A8)]⁷

- The findings of Chapter 4 indicated that discussion groups had a positive impact on farm efficiency, especially in the South region, and may help to develop viable and resilient farmers as encouraged by the Dairy Forum which was formed by various stakeholders to meet and engage on issues of concern to them. The thesis recommended that policy should encourage farmer to farmer capacity building or discussion groups to cover topics such as improving labor efficiency, management of herd size and investment in soil quality improvement, and those topics need to be covered in Dairy Forums and should take into account the regional technology differences and needs identified in this thesis. (M2:G1:A10)
- The findings of Chapter 3 were supplemented by those in Chapters 5 and 6 which provided an industry competitiveness update or market assessment. The findings can be used by stakeholders to identify macro-level differences based on the analyses of the Irish butter performance and make data-informed national trade plans to ensure global competitiveness. This provided an update on market developments. This will be necessary to further integrate primary producers into market engagement to keep them informed of market developments and to help them plan their business for the medium term in line with the Food Vision 2030. (M3:G4:A6) (M3:G4:A8)

⁷ See section 1.1.2 for reference to Mission (M): Goal (G): Action (A).

On price transparency via price transmission (M2:G1:A7-8)

- Action 7 which seeks to explore the potential for the development of specific volatility and risk management measures or tools, within both the private and public sectors, has been addressed in Chapter 5. The approach developed in chapter 5 provided volatility and risk measures through the assessment of price transmission from farm milk to butter trade to ensure price transparency in the value chain. The approach and outcomes could be used in a data gathering exercise for development of specific measures or tools. Regular price analyses such as the one in Chapter 5 could be conducted as new data become available to monitor shifts in the relative importance of supply-related factors in trade partner and export competitor countries. The approach can also be replicated for other sectors. By improving market and price transparency, the industry can achieve more responsive value chains. (M2:G1:A7)
- The findings of Chapter 5 indicated that there was no symmetric price transmission from farm milk to butter trade. As noted in action 8, the benefits from new and existing markets for value-added Irish dairy products should accrue proportionately to primary producers. Therefore, it was recommended that policymakers ensure that the benefits are proportionate through monitoring price transmission to highlight transparency within the value chain and to improve the resilience of primary producers. (M2:G1:A8)

On trade development or competitiveness [(M2:G2:A2); (M3:G4:A1)]

Being an exporter requires specific knowledge to manage multiple destinations with heterogeneous demands and informational barriers create obstacles to achieving efficient markets, accurate prices and well-integrated markets (Brown *et al.*, 2021). Moreover, the high level of competition in foreign markets creates more damaging market inefficiencies resulting from contractual relationships that may exist between the trading nations (Gaigne *et al.*, 2017) which then trickles down to farmers.

- Chapters 5 and 6 evaluated market and price transparency which can be used to inform how value is shared across the supply chain. This responds to the Food Vision 2030 objective to develop new national initiatives on price transparency. The findings provided insights into where there are strengths and opportunities. This can be used by policymakers to develop national initiatives to improve market and price transparency within the country and across markets. The thesis recommended that Irish dairy industry

stakeholders needed to consider levels of market integration with export competitor countries in its engagement with other stakeholders. (M2:G2:A2)

- The findings in Chapter 6 provided trade and market insights for the Irish dairy industry and also provided a competitor analysis to help determine priority markets and products. This was in line with the Food Vision 2030 objective to develop market opportunities at home and abroad in export markets. The thesis recommended the use of the analytical approach adopted in this study to achieve this objective in other sectors as well. The butter sector was the most competitive in the Irish dairy industry and it was recommended that policymakers ensure that this sector is not hindered by any trade related barriers. (M3:G4:A1)

7.3. Areas for future research

The thesis has provided a thorough investigation of the Irish dairy value chain, generating several important findings and policy implications. There are a number of areas for future research which can build on the work carried out and presented in this thesis.

In Chapter 3, the significance of disaggregating dairy products and taking a value chain approach to evaluate the competitiveness of the sector was highlighted. Future research could use the methodologies applied in this chapter (and other Chapters) to other sectors. The farm-level regional efficiency rankings were estimated in Chapter 4, comparing efficiency rankings at the processor level would be an interesting area of study, should appropriate data be available. Stochastic metafrontier analysis can be applied in other sectors. Future research could investigate the relationship between farms and processors at a regional level.

Ireland was able to increase its butter prices above competitor prices as indicated in Chapter 5. However, the effects of this on Irish butter competitiveness and processor profitability remain an area for future research, i.e. linking prices to costs and profit margins for dairy products. Future research can also analyse the impact of competitor butter prices in importing countries, i.e. the US, on Irish butter prices, and identify the forces driving competition in the butter market for importing countries, especially pre and post-quota. The approach followed in this chapter can be adapted for other sectors, i.e. cheese and/or powders.

Future research can utilize the same approach adopted in Chapter 6 for other sectors that have export exposure and has other competing products within the country and across countries. As indicated in Chapter 6, research on trade relationships between countries remains scarce in the literature due to limited data on industry competitiveness. Given the competitiveness of Irish

butter, future research investigating the effects of the increasingly stringent environmental regulations imposed on Irish dairy and the consequences of increasing environmental compliance costs on Irish dairy competitiveness must be considered worthwhile. To the authors' knowledge, this work has been the first of its kind to analyse export competitiveness of the Irish dairy products and future research can benefit from doing further analysis on export competitiveness of Irish butter.

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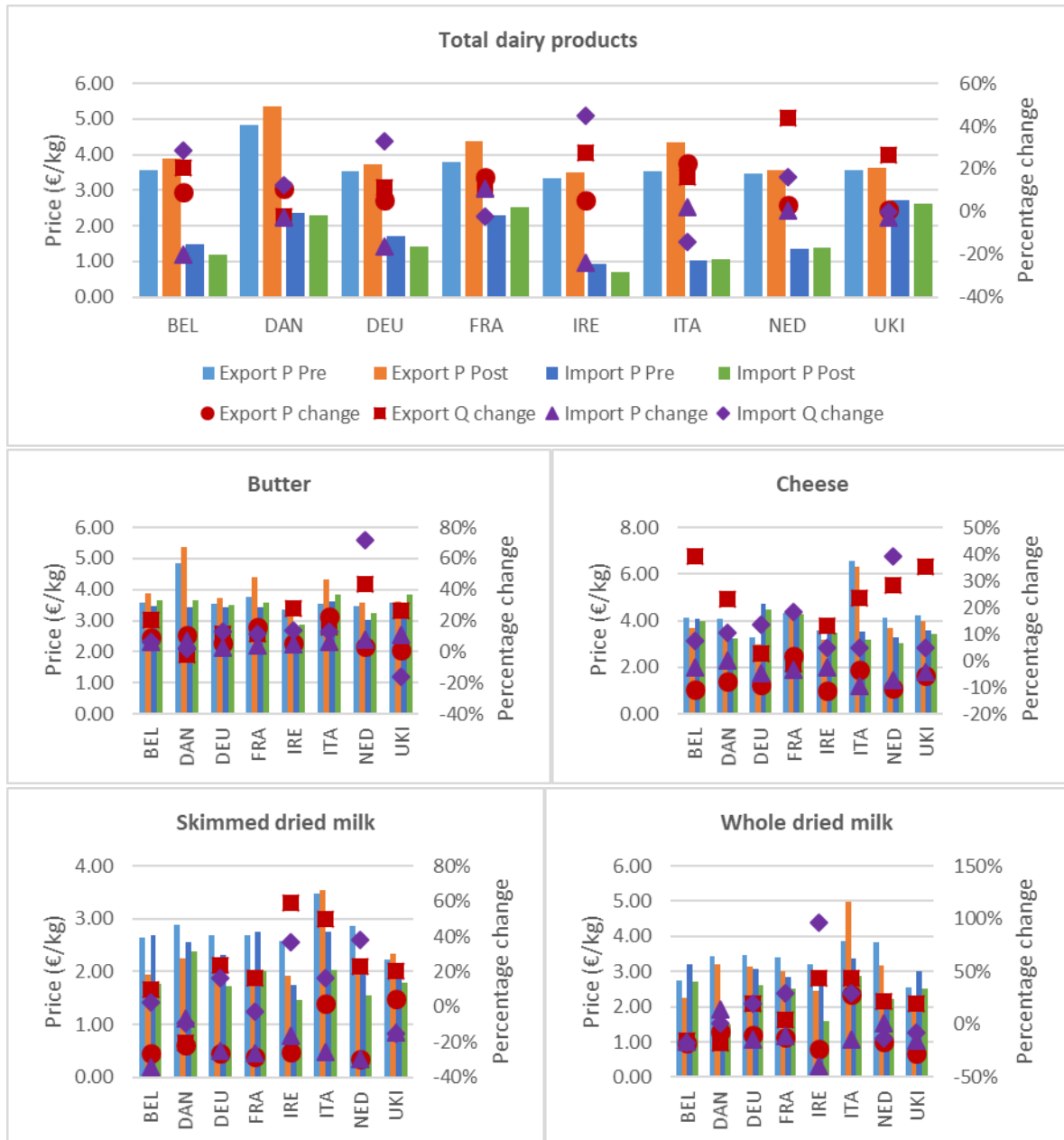
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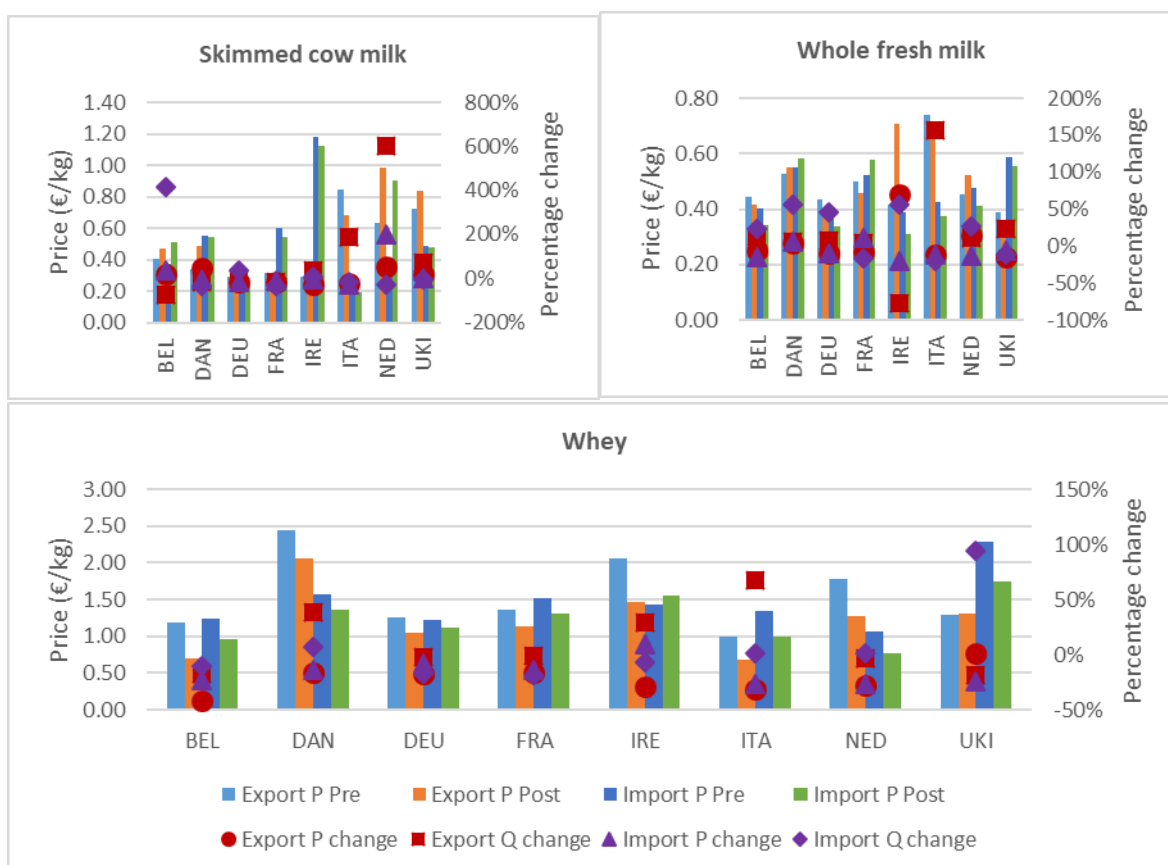
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9. Appendix

9.1. Appendix A (Chapter 3)

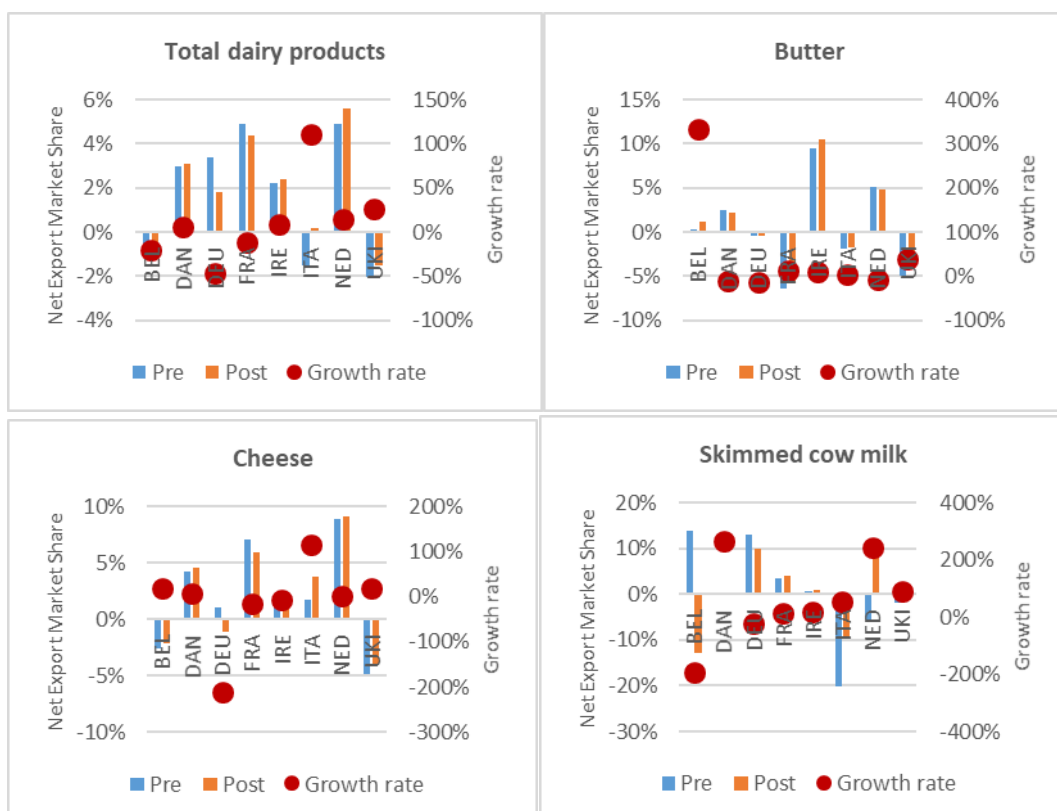
Figure A1. Dairy products export and import price and quantity growth rate pre and post-quota

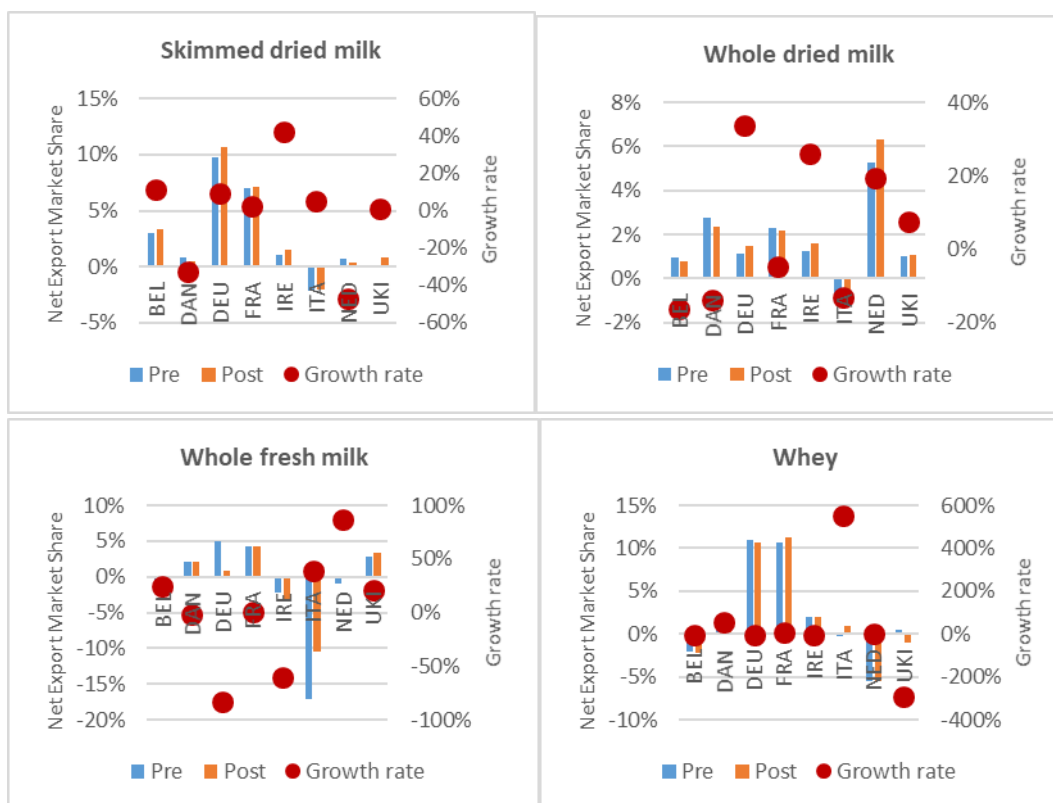




Source: Authors' calculations based on FAOstat dataset

Figure A2. Dairy net export market share (%) in the world pre and post-quota



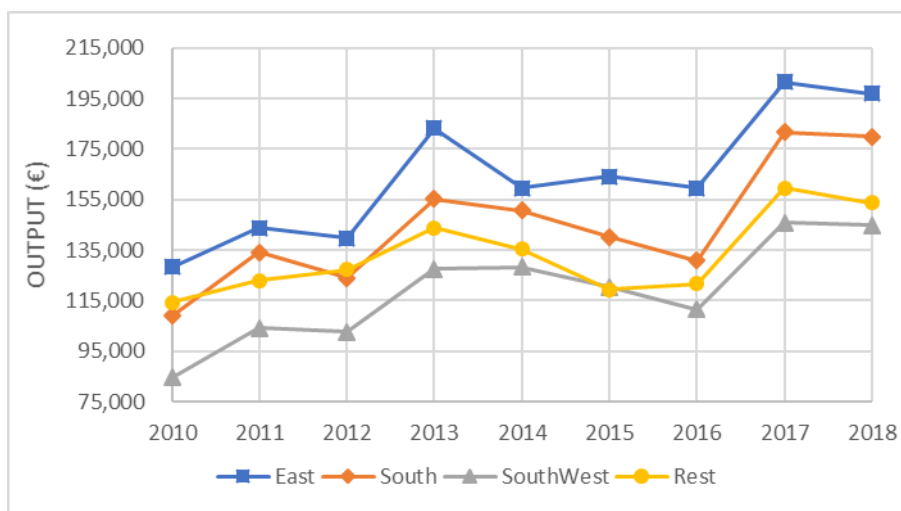


Source: Authors' calculations based on FAOstat dataset

9.2. Appendix B-E (Chapter 4)

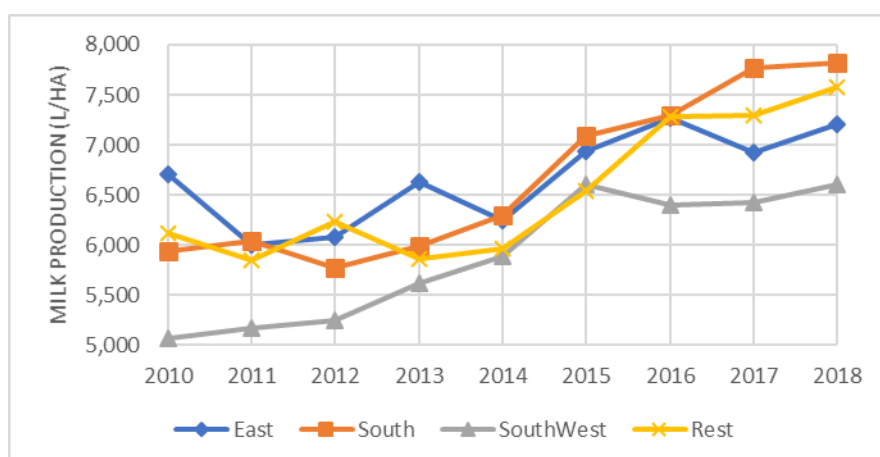
9.2.1. Appendix B: Farm-specific variables and descriptive statistics trends

Figure B1. Trends in regional output in Ireland



Source: Authors' calculations based on National Farm Survey (NFS) data

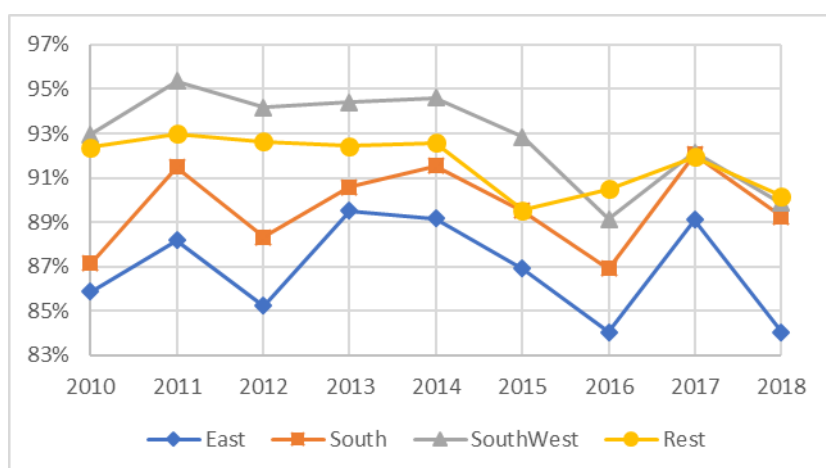
Figure B2. Trends in regional milk production per hectare



Source: Authors' calculations based on National Farm Survey (NFS) data

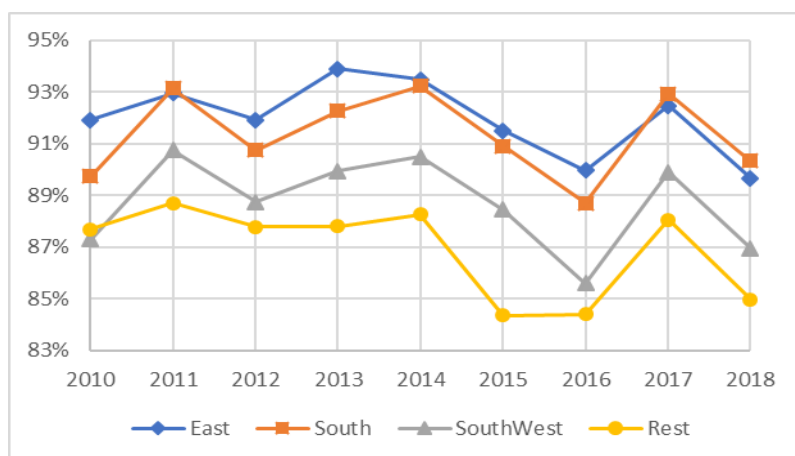
9.2.2. Appendix C: Additional results

Figure C1. Trends of Technical efficiency estimates to the regional frontier over time



Source: Authors' calculations based on National Farm Survey (NFS) data

Figure C2. Trends of Meta-technology ratio (MTR) over time



Source: Authors' calculations based on National Farm Survey (NFS) data

9.2.3. Appendix D: TL results

Table D1. Estimates for the parameters of the TL by regions

Elasticity	IRL	East	South	South West	Rest
Land (x_{1it})	0.40***	0.09***	0.13***	0.06***	-0.05
Overhead Cost (x_{2it})	0.19***	0.27***	0.23***	0.28***	0.36***
Direct Cost (x_{3it})	0.31***	0.46***	0.46***	0.50***	0.51***
Labor units (x_{4it})	0.03***	0.08***	0.04*	0.01	0.07***
Time trend (t)	0.01	0.01	-0.004	0.03**	-0.01
(t) (t)	0.0001	-0.001	0.003	-0.003	0.003
(x_{1it}) (x_{1it})	-0.29***	-0.10	-0.13*	-0.20*	-0.61***
(x_{2it}) (x_{2it})	-0.10**	-0.13	-0.11	-0.03	-0.32**
(x_{3it}) (x_{3it})	-0.03	-0.16	0.09	0.18*	0.19
(x_{4it}) (x_{4it})	-0.12***	-0.26***	-0.15**	-0.02	-0.15**
(x_{1it}) (x_{2it})	0.18***	0.34***	0.18***	-0.01	0.42***
(x_{1it}) (x_{3it})	0.10***	-0.17**	-0.02	0.09	-0.07
(x_{1it}) (x_{4it})	-0.03	-0.15**	-0.03	0.02	-0.09
(x_{2it}) (x_{3it})	-0.06*	0.08	-0.06	-0.09	-0.02
(x_{2it}) (x_{4it})	0.04	0.08	0.03	-0.01	0.17**
(x_{3it}) (x_{4it})	-0.03	0.01	-0.05	-0.05	-0.13**
(x_{1it}) (t)	0.01***	-0.0004	0.002	-0.003	-0.001
(x_{2it}) (t)	0.02***	-0.0001	-0.003	0.001	-0.00003
(x_{3it}) (t)	0.03***	0.003	0.003	-0.002	-0.01
(x_{4it}) (t)	-0.0004	-0.002	-0.001	-0.0004	0.002
Constant	0.09	0.22***	0.16***	-0.001	0.04
Mean TE	0.92	0.87	0.90	0.93	0.92
Log Likelihood	1,292	262	260	225	197

Note: ***P<0.01; **P<0.05; *P<0.10

Table D2. TL Marginal effects of farm-specific variables on technical inefficiency

Elasticity: TE	IRL	East	South	South West	Rest
Herd size (z_{1it}^k)	-0.10***	-0.16***	-0.15***	-0.10***	-0.11***
Age (z_{2it}^k)	0.0001	0.001	0.0003	-0.0002	0.001
Quota (D_{1it}^k)	-0.02***	-0.03	-0.02	-0.04***	-0.02
Soil type (D_{2it}^k)	-0.03***	-0.06***	-0.01	-0.03*	-0.02
Discussion Member (D_{3it}^k)	-0.04***	-0.04**	-0.04***	-0.20	-0.02
Fulltime (D_{4it}^k)	0.01	0.03	0.003	0.03	0.04
Advisory service (D_{5it}^k)	-0.01	0.01	-0.01	-0.02	-0.01
Household members (z_{3it}^k)	0.002	0.002	-0.001	0.0002	-0.004

Note: ***P<0.01; **P<0.05; *P<0.10

Table D3. Average technical efficiency and meta-technology estimates for Irish dairy farms

Regions	East	South	South West	Rest	F test
<i>TEs to the regional frontier (TE_{it}^k)</i>					
Mean	0.87	0.90	0.93	0.92	50.9***
<i>SD</i>	<i>0.10</i>	<i>0.08</i>	<i>0.08</i>	<i>0.07</i>	
<i>Min</i>	<i>0.52</i>	<i>0.52</i>	<i>0.56</i>	<i>0.62</i>	
<i>Max</i>	<i>0.98</i>	<i>0.99</i>	<i>1</i>	<i>0.99</i>	
<i>Meta-technology ratio (MTR_{it}^k)</i>					
Mean	0.93	0.93	0.91	0.89	48.7***
<i>SD</i>	<i>0.06</i>	<i>0.05</i>	<i>0.07</i>	<i>0.09</i>	
<i>Min</i>	<i>0.63</i>	<i>0.62</i>	<i>0.60</i>	<i>0.56</i>	
<i>Max</i>	<i>0.99</i>	<i>0.99</i>	<i>0.98</i>	<i>0.99</i>	
<i>TEs to the meta-frontier (MTE_{it})</i>					
Mean	0.82	0.84	0.85	0.82	7.5***
<i>SD</i>	<i>0.13</i>	<i>0.11</i>	<i>0.12</i>	<i>0.13</i>	
<i>Min</i>	<i>0.34</i>	<i>0.34</i>	<i>0.34</i>	<i>0.36</i>	
<i>Max</i>	<i>0.97</i>	<i>0.98</i>	<i>0.98</i>	<i>0.98</i>	

Note: ***P<0.01; **P<0.05; *P<0.10

Table D4. Differences between the CD and TL findings

CD vs TL	Difference	T-test	Correlation
mtr_cd vs mtr_tl	-0.019	-8.6***	0.95
te_cd vs te_tl	-0.003	-1.1	0.98
mte_cd vs mte_tl	-0.018	-4.8***	0.98

Note: ***P<0.01; **P<0.05; *P<0.10

9.2.4. Appendix E

Figure E1. Map of Ireland



Source: www.clipartmaps.com/product/ireland-powerpoint-map-counties-capital/

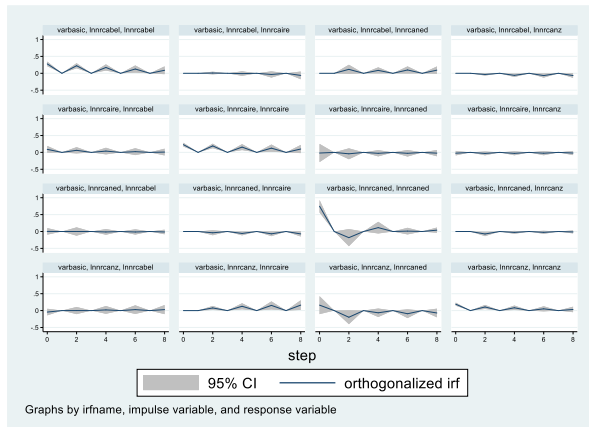
Figure E2. Map of Irish dairy primary and secondary processors



Source: <https://www.dairyindustryireland.com/dairy-industry>

9.3. Appendix F (Chapter 6)

Figure F1. Competitiveness impulse-response factors



Source: Authors' calculations