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INVESTIGATING BREXIT IMPLICATIONS ON THE IRISH AGRI-FOOD EXPORTS: A SIMULATION-BASED SCENARIO MAPPING MODEL

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ABSTRACT

The Irish economy is highly dependent on the UK market with a total export value surpassing € 14 billion. Several reports have warned of severe bottlenecks at the Irish and British ports if new customs checks are reintroduced. A significant disruption is also expected to the traffic flow between Ireland and Britain because of the lack of proper checking infrastructure at some ports. This situation will cause devastating impact on the competitive advantage of various Irish exports to the UK market, particularly limited-shelf-life products. Hence, a simulation model has been developed to investigate three Brexit scenarios: 1) applying non-tariff barriers at ports, 2) replacing the UK Landbridge with direct routes to continental Europe, and 3) lack of checking infrastructure at the UK ports. The scenarios' implications on the transportation time and shelf life of Irish Cheese exports to the UK are investigated, leading to one recommendable scenario.

1 INTRODUCTION

As consumers, we often assume that the right products will be available to buy in retail outlets and online platforms 365 days a year. Consumer perception is that of a simple service delivery, but the reality is a complex, uncertain, and time-sensitive supply chain network. This network pervades every dimension of our lives. It is so intrinsic to our everyday activities that any potential risk of supply disruption or failure can have costly consequences for businesses and consumers alike (Crowe et al. 2015). This risk was amplified in 2016 by the UK's decision to exit from the EU, where Ireland is facing unprecedented challenges from political, social, and wider economic perspectives. Coupled with its geographical location as an island nation on the periphery of mainland Europe, Ireland is very vulnerable to supply chain disruptions, especially via maritime transport.

Irish maritime transport is a strategic route-to-market infrastructure, connecting the country to the majority of its international markets. According to the Irish Maritime Development Office (IMDO), more than 90 % of Ireland's international trade volume moves through its ports (IMDO 2019). Apart from their close trade relationship, where the UK is Ireland's third-largest trade partner (Ward 2020), Ireland has historically relied on the UK road and ports network, known as the UK Landbridge (Vega and Evers 2016) as the primary route-to-market to mainland Europe. The UK Landbridge is favored by traders in high-value or time-sensitive goods, because it offers a border-free land bridge with high-frequency short sea crossings, and significantly faster transit times than alternative routes. Ireland is also part of the European TEN-T network North Sea–Mediterranean core network corridor, where the UK infrastructure is an integral part (Breen et al. 2018). The uncertainty of border-free crossings has now put the attractiveness of this route

under huge scrutiny. In fact, the Irish government's core mission to mitigate the risk of trade disruption caused by Brexit is to maintain a close trade between the UK and the EU including Ireland whilst minimizing the regulatory burden for all goods transiting the UK Landbridge (Irish Government 2017).

The remainder of this paper explores how innovations through simulation can be used to understand and mitigate post-Brexit Irish supply chain disruptions. Section 2 reviews the literature focusing on the implications of Brexit and methods used to study supply chain disruptions, whilst Section 3 highlights the underlying problem that needs to be resolved. Sections 4 and 5 explain the model development and result analysis, and finally Section 6 concludes the article.

2 LITERATURE REVIEW

Recently, researchers have shown an increased interest in Brexit and the different aspects of its implications. Several studies have highlighted the negative impact of Brexit on the EU-UK trade, particularly the trade relationship between Ireland and the UK (Cheptea and Huchet 2019). For instance, Lawless et al. (2019) addressed the effect of Brexit on the south-north trade in Ireland. Morchid and O'Mahony (2019) assessed the impact of Brexit on the transport sector in Ireland assuming a hard border between Ireland and Northern Ireland. On the other hand, Brexit would have an impact on the trade flow between Ireland and Great Britain and on Ireland's trade relationship with other EU member states through the use of the UK Landbridge. Hence, Vega et al. (2018) suggested that the maritime freight transport demand for export trade shipments from Ireland to continental Europe would likely increase as an alternative route to the UK Landbridge. Moreover, Lawless and Morgenroth (2019) estimated the impact of a hard Brexit on both product and sector levels across the EU and identified Ireland as the most-exposed member state to Brexit risk by losing 4 % of its total exports.

Evidence suggests that Irish agri-food exports are among the sectors that are most affected by Brexit. According to Lawless and Morgenroth (2019), agri-food trade is vulnerable to a World Trade Organization (WTO) arrangement between the UK and the EU, including Ireland. Limited shelf life and food quality measures are the main reasons for such vulnerability. Different studies have examined the consequences of Brexit on the Irish agri-food sector. Matthews (2017) suggest that Brexit would have profound implications for Ireland's agri-food sector and would be unambiguously negative for Irish producers and exporters. Donnellan and Hanrahan (2016) identified the Irish dairy and beef sectors as the sectors most certain to be affected by Brexit. However, the literature lacks quantitative studies that identify Brexit implications on Irish agri-food exports.

The potential re-introduction of customs and sanitary and phytosanitary standards (SPS) checks as a consequence of Brexit will severely disrupt the Irish and British ports' operations leading to border-crossing bottlenecks. In the border-crossing context, Sardar and Lee (2015) suggested an approach to quantify complexity and its impact on supply chain disruption. However, the authors highlighted that the majority of the research on border-crossing bottlenecks is either descriptive or lacks a supply chain focus. In addition, port operation disruptions will cause transportation delays, uncertain transit times, and more-complex supply chains. Hence, Irish agri-food exports will be significantly exposed to disruption and risk, in particular, with respect to perishable food supply chains. Given its operational complexities (Nyamah et al. 2017) and being subject to SPS checks, the agri-food sector is highly vulnerable to Brexit disruptions and risks. A considerable amount of literature has been published on disruption and risk management in the agri-food industry and agri-food supply chains. Bachev (2013) analyzed risk management in the agri-food sector by identifying the different types of risks and the modes of their management. Srivastava et al. (2015) carried out a structural analysis of potential supply chain risks and performance measures in fresh food retail. Zhao et al. (2017) conducted a systematic review on risk sources and resilience factors in agri-food supply chains. Septiani and Astuti (2017) reviewed the supply chain risk management literature for agri-food industries to identify research advancements. Moreover, Yu and Huatuco (2016) and Prakash et al. (2017) addressed risk management for dairy supply chains in China and India, respectively.

Many authors utilized simulation to effectively model and quantify the impact of disruption and risk. In the context of the agri-food industry, Jacxsens et al. (2010) assessed the impact of climate change and risks associated with the fresh produce supply chain using simulation. Moreover, Leblanc et al. (2015) presented a national produce supply chain database for food safety risk analysis that was used in the development of an integrated simulation tool. On the other hand, Crainic et al. (2018) highlighted the use and importance of simulation within the field of operations research to manage the complexity of intermodal transport systems and support decision-making processes. For example, simulation has been used by Vilko and Hallikas (2012) to evaluate the overall risk impact of delay of multimodal maritime supply chains. Siswanto et al. (2018) examined supply disruptions and congestion problems for sea-transport-based fertilizer products using simulation. In relation to Brexit, Vega et al. (2018) used simulation to analyze the potential impact of Brexit on maritime freight transport demand from Ireland to continental Europe. O'Connor et al. (2019) utilized simulation to examine demand and substitutability across terminals in the Irish ports network. Mahfouz et al. (2019) developed a simulation model to examine different transportation decisions of agri-fresh produce supply chains between Ireland and Northern Ireland after Brexit. However, simulation has been rarely used to model the potential effects of different policy scenarios stemming from a possible no-deal Brexit and to quantify their implications on the Irish agri-food exports.

3 PROBLEM CONTEXT

As noted in Section 1, Brexit has presented a significant and immediate threat to the Irish economy. The Irish government has identified the impact on trade as a priority in policy development and risk mitigation. After the UK government's formal request to leave the European Union on 29th March 2017, the official withdrawal process set out in Article 50 commenced. In July 2019, the Irish government published a detailed paper on its approach to this complex process, based on the negotiation guidelines developed by the European Council of the EU. This working paper focuses on government policy, including the Article 50 process from an Irish perspective; the financial commitments of withdrawal; future relationships between the UK and the EU; and finally the impact on the Irish economy and society (Irish Government 2019). The extended timelines of Article 50 agreements anticipate a trade deal to be in place by the end of 2020, although most observers consider this to be an extremely challenging timeline (Bord Bia 2019). It is widely accepted that the three most-likely outcomes are:

1. Agreement with very strong alignment to the EU rules: the UK leaves the EU with a free trade agreement that is strongly aligned with the EU rules on 1st January 2021.
2. Agreement with very weak alignment to the EU rules (Canada Style FTA): the UK leaves the EU with a free trade agreement that is weakly aligned with the EU rules on 1st January 2021.
3. Hard Brexit: the UK leaves the EU without a free trade agreement in place on 1st January 2021 causing a hard border in the Irish Sea and introducing new custom and SPS checks in the Irish ports.

There is a high variation of requirements (resources, infrastructures, port capacities, etc.) needed to plan for a strongly aligned agreement and a hard Brexit, or cliff-edge outcome. It is this level of uncertainty that is having a devastating effect on the ability of the agri-food sector policy and decision makers to invest in long-term plans. Firstly, upon leaving the EU, the UK will accede to the Common Transit Convention (CTC). Depending on which outcome has been successfully negotiated, the application of certain EU rules and procedures with regard to SPS controls on animals and products of animal origin remains uncertain. Therefore, throughput rates at ports and overall transit times from the point of origin to the final destination could be significantly higher, but to date this impact remains unknown (Irish Government 2019). Secondly, any potential increase in transit times will severely impact the shelf life of short-life-cycle food produce, such as semi-hard and soft cheeses. According to the food safety authority of Ireland (FSAI), the shelf life of some soft cheeses can be less than one week, with a high risk of supporting the growth of harmful

L monocytogene's if shelf life decreases or storage conditions deteriorate (FSAI 2019). Thus, even a 24-hour delay at a port can decrease the shelf life by 20 % and increase the risk of harmful pathogenic growth. Therefore, it is of critical importance that supply chain decision makers within the cheese sector understand the potential costly risks involved in both transit times and shelf life that each post-Brexit scenario will bring.

4 METHODOLOGY

The simulation model focuses on Roll-on/Roll-off (Ro/Ro) maritime transport connectivity between Ireland, the UK, and other EU member states. In total, 16 maritime routes are identified, including Ireland-UK (east-west corridor), UK-EU (channel tunnel), Ireland-EU (using the UK as a land bridge), and Ireland-EU (direct routes). The dynamics of the freight flow between different maritime corridors were set based on the four main entities: products, trucks, ports, and vessels. The simulation starts by generating the number of inbound and outbound trucks needed to transfer the products between various ports of Ireland, the UK, and the EU. On their arrivals to the origin ports, the trucks roll-on to the vessels. Then, based on the vessels' frequencies or capacities, they sail to their destinations according to the identified maritime routes. Upon arrival to their destined port, trucks roll-off from the vessels and depart to their destinations.

Moreover, two types of truck transportation are considered in the model: 1) accompanied trucks (i.e., trucks that roll-on/off the ship with the driver), and 2) unaccompanied trucks (without driver). This model captures the current situation where no checks are required for both inbound and outbound vehicles. However, the UK has exited the European Union and a single market, which makes tariff and non-tariff barriers inevitable. Hence, along with the overall flow of trucks and products, custom and SPS checks are also included. The process mappings of various checks are depicted in Figure 1.

An agent-based model and discrete event model along with geographic information system (GIS) features included in the simulation software AnyLogic 8.4 were applied. Specifically, agent-based modelling is used for communication between the four main entities (products, trucks, vessels, and ports). On the other hand, discrete event modelling is applied for sequencing the procedures inside the different agents. In total, 15 agents were used to mimic the flow of import and export products along with one main agent, which was used to depict the interaction between different agents. The various agents include suppliers (starting location of trucks), distributors (end location of trucks), and ports in Ireland and GB.

5 IRISH CHEESE EXPORTING: A USE CASE

In 2018, the Irish agri-foods sector contributed nearly €15 billion to the economy and is Ireland's most important indigenous industry, employing 8 % of the total workforce (DAFM 2019). The sector exports to over 180 countries, and the UK remains its largest trading partner with 41 % of all exports. Dairy produce is the largest product category exported with 34 % of total global trade, with cheese produce accounting for over €800 million exports per year alone (DAFM 2019). Cheese products are extremely vulnerable to Brexit due to the importance of trade with the UK. Cheddar cheese in particular is most at risk, with over 50 % of all exports going to the UK market (Euromonitor 2019). Cheese is also Ireland's largest dairy export by volume, meaning it will be most impacted by delays at ports caused by the potential reintroduction of customs or border controls due to Brexit.

5.1 Use Case Setting

The simulation model has been designed in a way that it can be easily adapted to different types of sectors and their subcategories. In this case study, a focus was put on one of the subcategories of the agri-food sector in Ireland, i.e., the cheese industry. The aim of the simulation model is to analyze and quantify the expected disruptions and delays at Irish ports after Brexit and their impact on the cheese produce flow between Ireland and the UK. The model will investigate three post-Brexit scenarios: 1) applying non-tariff barriers at Ireland's and the UK's ports; 2) replacing the UK Landbridge with direct maritime routes to

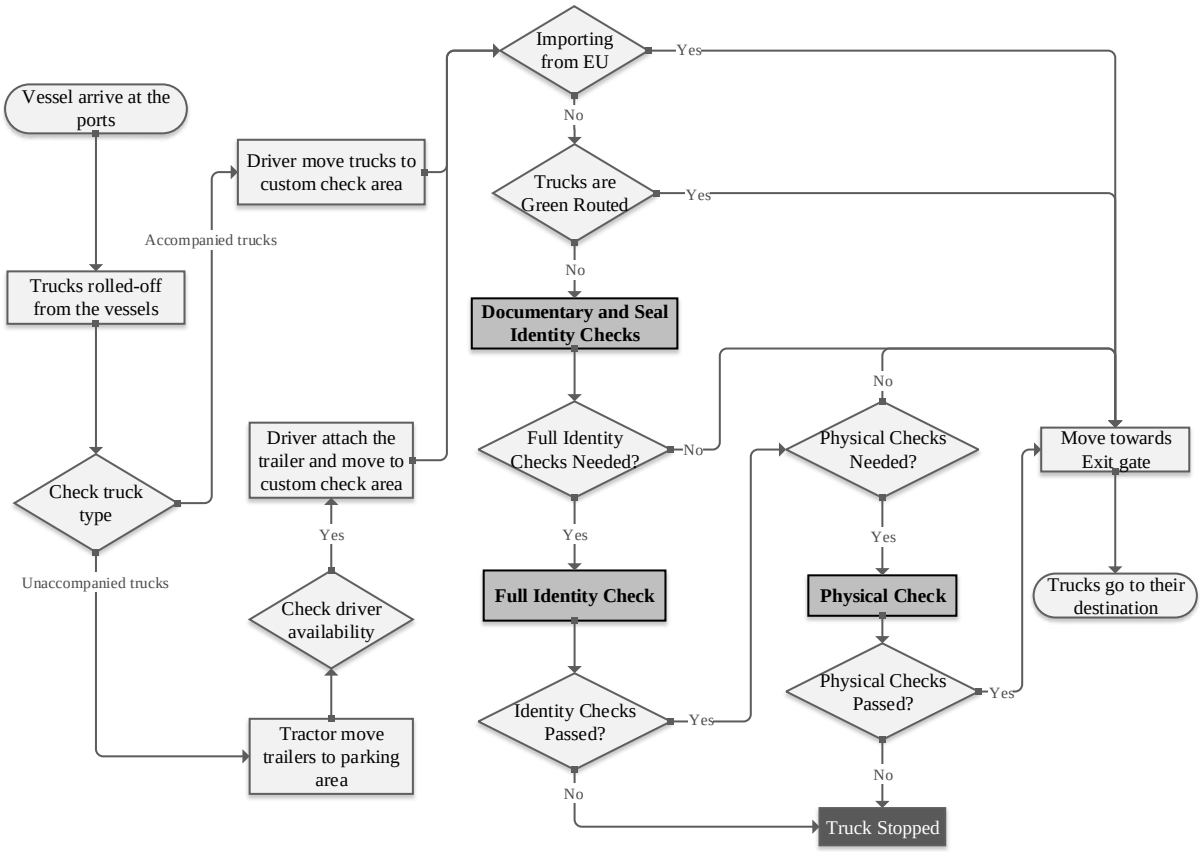

Figure 1: Conceptual model of incoming and outgoing truck checks.

mainland Europe; and 3) lack of checking infrastructure at the UK ports and their implications on the transportation time and shelf life of the Irish cheese exported to the UK market.

5.2 Data Sources and Calibration

The data are divided into subtypes, which were collected from several data sources. Firstly, with regard to the trade flow between Ireland, the UK, and the EU, product volumes across different ports were collected from publications of the Central Statistics Office, Ireland (CSO), the Office of National Statistics (UK), Eurostat, and the Irish Maritime Development Office (IMDO). The average unit weight (AUW) metric is used to convert the Ro/Ro trade volumes into the number of trucks (Breen et al. 2018).

Secondly, the custom and SPS checks procedures were gathered from reports of the Irish Tax and Custom (Revenue) and from the Department of Agricultural, Food and the Marine (DAFM). In addition, site visits to Irish ports (Rosslare Europort and Dublin) were undertaken to achieve a clearer picture of operations, transportation activities, and changes in administrative procedures. However, the check timings and their frequencies are estimated based on expert information and assumptions.

Finally, information about the vessels that serve the routes of the studied maritime corridor was collected. Six shipping companies operate in the various corridors and provide Ro/Ro transportation services including Irish Ferries, Stena Line, SeaTruck, P&O Ferries, CLDN, and Britany Ferries. The companies' websites were used to collect data regarding vessel routes, departure frequency, and maximum load capacity in terms of freight units. Also, several meetings were conducted with different industrial stakeholders and haulers to gain a better understanding of the shipping processes.

5.3 Model Validation

To reduce the model development cycle time and to increase the confidence in the results, verification and validation were executed throughout the development phases of the simulation model. After each development phase, the model was verified and validated in conjunction with the completed phases. For the verification process, the model logic was verified to ensure that trucks and vessels follow the correct routes as expected. This was achieved by tracing and debugging functions besides the visual tracking of trucks and vessels. It was also supported through checking intermediate output values such as queue lengths and waiting times between processes. The conceptual model was documented and validated by circulating the document among the project stakeholders.

The face validation of the model and the process flow was conducted in a focused workshop on the management level and semi-structured expert interviews with the haulers and stakeholders on the operating level. The attendees of the seminar included transportation policy-makers from different state agencies, such as the Department of Transport, Tourism & Sports (DTTAS), the Freight Trade Association (FTA), Revenue, Irish Rail, and the Department of Agricultural, Food and the Marine (DAFM). The policy-makers' information regarding the overall flow was valuable to validate whether the implementation of the computer-based model was reasonable. In the focus workshop, the the accuracy of the collected data was validated, including the average truck capacity of the Ro/Ro transportation mode, the conversion of the tonnage volumes into freight units using the AUW metric, the vessel capacities, and the vessels' operating schedules. The interviews with the stakeholders of the dairy sector and transportation companies on the operating level were used to fix parameter values and to collect information related to the industry. Moreover, a structured walk-through of the computer-based model was performed to ensure model credibility.

The second approach was 'Comparison Testing' accomplished by comparing the output of the simulation model with the real output of the system under identical input conditions. To validate the simulation model results, eight KPIs were used as described in Table 1.

Table 1: Description of KPIs.

KPI	KPI Description
TT-O-IE-GB	Transportation Time for outbound trucks carry from IE to the GB
TT-I-IE-GB	Transportation Time for inbound trucks carry cheese from the GB to IE
TT-O-IE-EU	Transportation Time for outbound trucks carry cheese from IE to the EU
TT-I-IE-EU	Transportation Time for inbound trucks carry cheese from the EU to IE
RSLT-O-GB	Remaining shelf life for the outbound cheese exported to the GB
RSLT-I-GB	Remaining shelf life for the inbound cheese imported from the GB
RSLT-O-EU	Remaining shelf life for the outbound cheese exported to the EU through the UK Landbridge
RSLT-I-EU	Remaining shelf life for the inbound cheese imported from the EU through the UK Landbridge

5.4 Scenario Analysis

Three scenarios were selected for the cheddar cheese case study. The first scenario applies non-tariff barriers, including product standards, safety regulations, and SPS checks on agri-food products. This will be used for the trade between Ireland and the UK. Scenario 2 explores the feasibility of a direct route of truck traffic to other EU member states. Finally, some UK ports are not ready and do not have the proper checks infrastructure, which will be examined in the third scenario.

5.4.1 Scenario 1: Non-tariff Barriers

This scenario applies non-tariff barriers on the trade between Ireland, GB, and the EU, including identity checks, SPS inspections, security and immigration checks, and documentary checks. In the case of applying non-tariff barriers, checks would take place on the inbound and outbound trucks between the EU-27 (including Ireland) and the UK. It is expected that more checks would be applied on the incoming

vehicles to EU-27 and the UK, including full-identity checks and SPS checks. Different types of checks are used in this scenario (moderate documentary and SPS checks, strict documentary and SPS checks, moderate security checks, strict security checks).

To mimic this scenario, changes are applied to the percentage of trucks directed to the Green, Orange, and Red routes and the timing of the checks (Table 2). A higher proportion of agri-food trucks will be directed to physical checks at Irish and EU ports. Also, transit check timings are assumed at the UK ports to be applied on the transit trucks using the UK Landbridge. It is expected that checks will take place at all the ports that link Ireland, the UK and EU-26 ports.

Table 2: Mapping of the first scenario.

Scenario Mapping	Description
AS-IS	• No checks applied on the inbound/outbound trucks (including trucks carrying cheese) at IE, GB or the EU Ports
Moderate documentary and SPS checks at IE, GB, and the EU-26 ports	• Majority of the inbound/outbound trucks directed to green route (80 %) • Few incoming trucks are directed to SPS checks (30 %) • 50 % of the trucks carrying cheese are directed to SPS checks (according to the EU rules)
Strict documentary and SPS checks at IE, GB, and the EU-26 ports	• A lower percentage of the inbound/outbound trucks directed to green routes (60 %) • More inbound trucks (including trucks carrying cheese) are directed to SPS checks (70 %)
Moderate security, immigration and documents compliance checks (SIC checks)	• Few proportions of the inbound trucks (including trucks carrying cheese) are directed to SIC checks (30 %)
Strict SIC checks	• 50 % of the inbound trucks (including trucks carrying cheese) are directed to SIC checks

Table 3 exhibits the simulation results of the first scenario for the four types of checks against the AS-IS situation. The AS-IS model represents the values of the KPIs in case there are no checks applied on the inbound and outbound trucks at IE, GB, and the EU borders. Moderate documentary and SPS checks at IE, GB, and the EU have an insignificant impact on all the KPIs as 80 % and 70 % of the inbound and outbound trucks avoid documentary and SPS checks, respectively. The effect of the strict strategy is substantially increasing the inbound and outbound trucks' transportation time (TT-O-IE-GB and TT-I-IE-GB). Hence, it has a significant reduction in the remaining shelf lifetime of the cheese imported or exported from or to IE, GB, and the EU.

Table 3: Results of Scenario 1.

Strategies	**Transportation Time**				**Remaining shelf life**			
	TT-O-IE-GB	**TT-I-IE-GB**	**TT-O-IE-EU**	**TT-I-IE-EU**	**RSLT-O-GB**	**RSLT-I-GB**	**RSLT-O-EU**	**RSLT-I-EU**
AS-IS Value	14	17	26	26	98 %	98 %	96 %	96 %
Moderate Doc & SPS Checks	20	21	28	27	97 %	97 %	96 %	96 %
Strict Doc & SPS Checks	134	160	95	196	81 %	78 %	87 %	73 %
Moderate Security Checks	126	161	90	199	82 %	78 %	87 %	72 %
Strict Security Checks	133	185	96	201	82 %	74 %	87 %	72 %

The transportation time for inbound and outbound trucks between IE and GB has increased by at least nine times compared to the AS-IS setting (TT-O-IE-GB and TT-I-IE-GB). The inbound trucks from the EU to IE witnessed more than three times increase in the transportation time compared to the current setting (TT-O-IE-EU). The strict strategy has a tremendous negative impact on the remaining shelf life of the

cheese. Table 3 shows that the minimum drop was 9 % in the RSLT-O-EU while the maximum reduction was 24 % in RSLT-I-EU. Similarly, the impact of moderate security and the strict SIC check was too severe in the delay and shrinking the remaining shelf life.

Traffic through the channel tunnel would experience significant bottlenecks under all strategies except for moderate documentary and SPS checks. The capacity of customs officers has a critical effect in smoothing the flow and reducing the delays. Any reduction of the cheese products' shelf life because of non-tariff barriers presents a real risk for the value of Irish cheese. In the case of applying strict non-tariff barriers, the cheese sector will lose significant competitive advantages against competitors like New Zealand. Therefore, avoiding the non-tariff barriers on the trucks flowing to the UK market should be a priority for Irish cheese exporters.

5.4.2 Scenario 2: Uncertainty of Landbridge

There is a lack of clarity regarding the UK's strategies for dealing with Irish drivers and operators after Brexit in terms of (1) mutual recognition of the AEO status, (2) access to the UK road transport market, (3) recognition of drivers' and operators' licenses, and (4) fair treatment for Irish transport companies.

The direct route to continental Europe can be used as an alternative to the Landbridge, providing the required certainty for the businesses. To test this scenario, all volumes of cheese products imported or exported from and to the continent through the Landbridge will be redirected to the direct routes to Cherbourg, Rotterdam, and Zeebrugge (Table 4). Using the direct route will be subject to the existing vessel frequencies and capacities. The results of this scenario are exhibited in Figure 2.

Table 4: Mapping of the second scenario.

Scenario Mapping	Description
Utilizing direct route as an alternative to the UK Landbridge	• Volumes of cheese products imported and exported from and to the continent through the Landbridge will be redirected to the direct routes to Cherbourg, Rotterdam, and Zeebrugge • Using the direct route will be subject to the current vessel frequencies and capacities

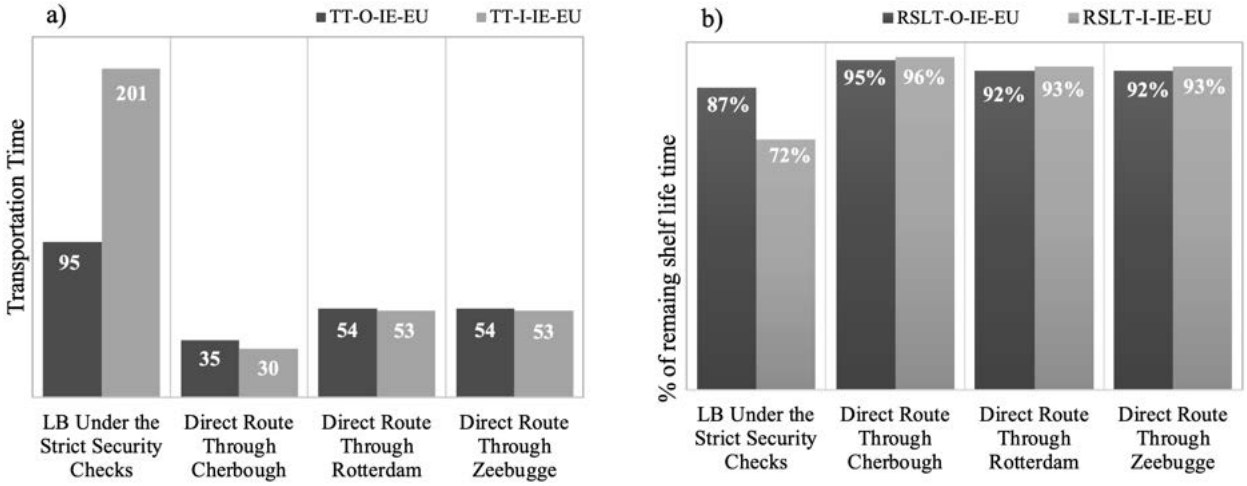

Figure 2: Results of Scenario 2 – uncertainty of UK Landbridge; (a) transportation time for inbound and outbound trucks, (b) remaining shelf life time of cheese.

The second scenario (Figure 2a) shows that, under strict security checks, the transportation time is expected to continue to grow if the Landbridge is the main route for inbound and outbound cheese products between Ireland and the EU. This scenario has a dramatic impact on the shelf life of the cheese products; with a reduction of 13 % in RLST-O-IE-EU and 28 % in RLST-I-IE-EU (Figure 2b). Prolonged delays of

the inbound trucks to Dublin from the EU-26 using the Landbridge are affected by the expected delays at the channel tunnel, west GB ports, and Dublin port.

In contrast, all other direct maritime routes demonstrated a consistent and reasonable transportation time as well as an acceptable remaining shelf life. Even under strict checking rules, the Landbridge remains an acceptable route for the cheese produce exporters. However, the uncertainty of the Landbridge makes the use of direct routes through Cherbourg, Rotterdam, or Zeebrugge an attractive alternative.

5.4.3 Scenario 3: Lack of Checking Infrastructure at West GB Ports

In case of the cliff-edge situation, there are concerns about the readiness of many west UK GB ports, linked with east Irish ports in Dublin and Rosslare, for applying new border checks. All the UK's west GB ports, except Liverpool, converted their check infrastructure facilities to restaurants and other facilities. The implications of this action will be modelled, where Heysham, Holyhead, Fishguard, and Pembroke ports will not receive any inbound trucks from the Irish side. Table 5 presents the scenario mapping for the lack of checking infrastructure at the west GB ports. Results of this scenario are contrasted with the moderate documentary and SPS checks strategy from Scenario 1 (Figure 3).

Table 5: Mapping of the third scenario.

Scenario Mapping	Description
Lack of Checking Infrastructure at west GB ports	• All outbound trucks moving to GB or EU-26 through the Landbridge from IE will use the Dublin-Liverpool route only • The scenario will be tested using the current capacities and frequencies of the ferries between Dublin and Liverpool • Other routes – channel tunnels and direct routes – are operating normally • The scenario outcomes are compared with the results of the moderate non-tariff barriers in Scenario 1

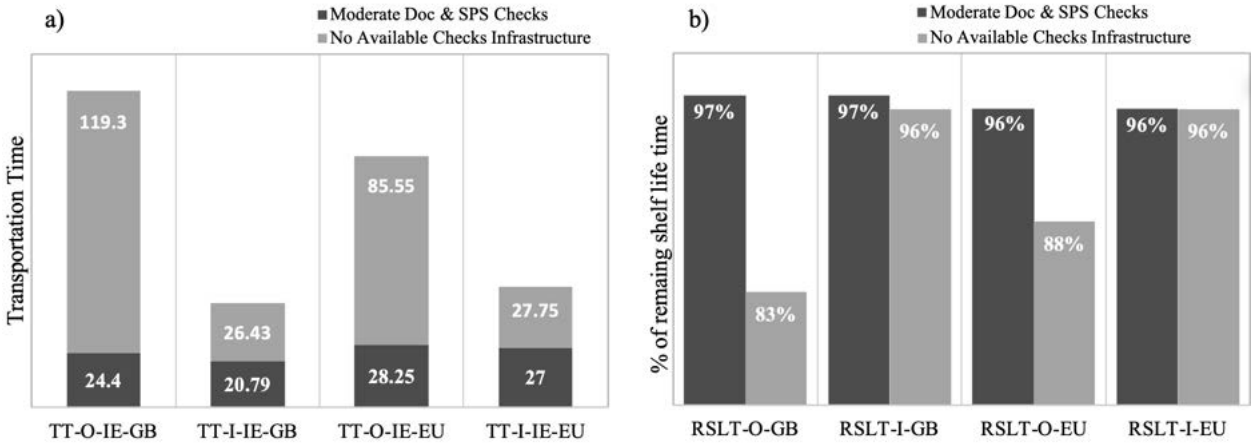

Figure 3: Results of Scenario 3 – lack of checking infrastructure at west GB ports; (a) transportation time of trucks between IE, GB, and EU, (b) remaining shelf life time of cheese between IE, GB, and EU.

In comparison to the moderate checks, Figure 3a shows that there is obviously a sharp increase in the shipping time for the outbound flow from Ireland to the GB and the EU under Scenario 3.

Likewise, Scenario 3 has a significant consequence on the remaining shelf life of the outbound cheese between Ireland and GB with 14 % and 8 % drop in RSTL-O-GB and RSTL-O-EU, respectively (Figure 3b). In contrast, the lack of checking infrastructure at the west GB ports has insignificant implications on the transportation time of the inbound flow between Ireland and the EU (Figure 3a). Consequently, this

seemed not to have any impact on the remaining shelf life time of the inbound cheese (Figure 3b), because all inbound trade between Ireland and the EU use alternative routes in this case.

This scenario exposed a significant bottleneck at the outbound flow from Dublin to Liverpool. Mitigating the bottleneck requires optimizing the use of the current capacities and the scheduled frequencies of the Dublin-Liverpool ferries to cope with the notable growth in the inbound traffic.

6 DISCUSSION AND CONCLUSION

No other country in the EU is as reliant on the UK as Ireland. Both countries enjoy a tight trade partnership, frictionless supply chains, and easy access to the EU market through the UK Landbridge. The UK is seen as a significant market for different Irish exports including beef, food and drink, and iron and steel products. However, recent research showed that Irish exporters will lose a significant competitive advantage if WTO tariffs are applied to merchandise trade between Ireland and the UK Post-Brexit. Also, non-tariff barriers will add to the complexity and cost of Irish products exported to the retailers' shelves and processor facilities in the UK and the EU. The lack of the proper checking infrastructure at the entry points to Ireland, the UK, and the EU (i.e., ports) also contributes substantially to the ambiguity that surrounds the transportation procedures and the trucks' traffic performance between Ireland, the UK, and the EU through the UK Landbridge.

Cheese, as an important export sector in Ireland, is directly affected by the obligations of non-tariff barriers, because it is reliant on the UK market and the limited shelf life of the cheese products. From the businesses perspective, the study presents valuable indications for the decision-makers to assess the potential implications of a range of scenarios that may arise as a result of Brexit. The model outcomes suggest that the Irish and EU negotiators need to emphasize on easing the non-tariff barriers at the UK ports and providing fast lanes (i.e., Green Route lane) for the trucks that carry limited shelf life and perishable products. For the cheese sector, this is an important negotiating position since the value of the cheese products is tightly related to the shelf life time and the fast product delivery to the clients. In the same context, cheese exporters realized that more investments are required to afford more refrigerated trucks (i.e., reefer trucks) to maintain the products' shelf life against the expected delay at the UK borders.

In another context, cheese exporters were continuously questioning the benefits of using the UK Landbridge as the only maritime route to Europe after Brexit. The model outcomes have emphasized these concerns given the resulting long delay of the trucks at the ports' checkpoints under the tested scenarios, particularly strict documentary and immigration checks scenario. Additionally, the lack of mutual recognition of the Irish drivers' and operators' documents at the UK side and the regulatory divergence between the UK and the EU post-Brexit obliged cheese businesses and logistics operators to find alternative routes to avoid the UK Landbridge. Moving from using the UK Landbridge, the most efficient route from a financial and time-competitiveness point of view, to direct routes to continental Europe must be accompanied with feasible ferries' capacities and frequencies. Establishing robust direct continental routes is essential not only to replace the UK Landbridge, but also to support Irish cheese exporters to extend their markets beyond Europe. However, to achieve this objective, a close collaboration between the state agencies, shipping lines, and exporters is required. In addition, more investments are essential to replace the traditional Roll-on/Roll-off refrigerated trucks with refrigerated containers to maintain the shelf life of the products during the long transportation journeys to the new cheese markets in the Middle and Far East.

The model outcomes have also shown the importance of preparing a suitable checking infrastructure at the Irish and the UK ports before the end of the transition period. Failure of doing so will cause bottlenecks on both sides of the Irish Sea that will severely harm cheese supply chains. Cheese businesses are designed based on just-in-time dynamics and fast movement of the products across the current frictionless borders between Ireland and the UK. The level of uncertainty inherently associated with Brexit may raise unforeseen effects and changes beyond the considered variables in the study. Cheese exporters may respond to this uncertainty by reviewing their supply chain designs, opting for direct service to the continent or shifting the

trade to other markets. Further research is recommended to assess the potential changes and new scenarios, and to apply the utilized research methodology to support other economic sectors against the Brexit risk.

The unclear situation at the border control posts in Ireland and the UK after the transition period undermines the ability of the Irish businesses to take effective decisions and make long-term plans with regard to their supply chain designs, expansion trades to new markets and the shape of trade relations between Ireland and the UK. A simulation-based scenario mapping model could play a pivotal role to lift a segment of this uncertainty and provide decision-makers with a better visibility to their supply chains and the related trade flow. There is also a worry that if WTO rules come into effect following the transition period, tremendous additional cost would be added to the cheese exporters as the introduction of tariffs and quotas to Irish dairy products is estimated to increase by 35.5 %. If tariffs are to be applied to Irish cheddar exports, this would cost the producers around €161,899,848 million per annum, should 2016 export volumes be maintained. In this case, the competitive advantage for Irish cheese in the UK market will be significantly affected compared to the benefits of other cheese producers, e.g., New-Zealand.

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