Price outlook for greenshell mussels – NZTE report

12 December 2024

m.e consulting

Document reference:	NZTE001.24
Date of this version:	12/12/2024
Authors:	Lawrence McIlrath (021 042 1957)
	Tom Harris

www.me.co.nz

Contents

Figures and Tables

Appendices

1 Introduction

Greenshell mussels are an iconic species both culturally and economically for New Zealand. Indigenous to the country, their vibrant green and brown shell distinguishes them from global alternatives and makes them stand out in global seafood markets. They play a significant role in New Zealand's aquaculture and mussel product exports are valued at around NZ$300m each year. The industry supports jobs across the country from rural coastal centres where mussels are farmed to the locations where they are processed and consumed.

Most of the produce farmed in New Zealand is exported to markets in Australasia, North America, and Asia. The global appeal of these mussels is not only due to their unique colour and taste but also their nutritional profile. Greenshell mussels are marketed as both a gourmet food item and as a health-promoting superfood. This has elevated their status in international markets, making them a premium product within the seafood category.

Market dynamics for greenshell mussels are influenced by several factors, including:

- consumer preferences,
- global supply patterns,
- sustainability credentials and
- New Zealand’s trade relationships.

As environmental awareness and the preference for sustainable seafood grow, greenshell mussels stand out as an environmentally responsible choice for consumers. Their carbon footprint per gram of protein is less than that of eggs, dairy and farmed fish[1], an aspect which further aligns the product with current consumer trends towards ethical and sustainable consumption.

Despite this positive shift, most international economic conditions are outside the sector’s direct control. These conditions have a large bearing on profitability and export volumes. The evolution of demand in Asia from rising incomes and attitudes to food sources, for example, could boost the prospects of New Zealand exports or possibly lead to the establishment of more farms in Asia itself.

The continuing success of the greenshell mussel industry requires careful management of both biological and economic factors to sustain its growth and mitigate potential risks. Understanding these complex interdependencies is crucial for stakeholders involved in the mussel industry, from farmers to policymakers. The rest of this report analyses the impact of growing production volumes in New Zealand and the possible implications for export prices by analysing the market and global conditions for mussel trade.

1.1 Project aim and approach

This report has been prepared for New Zealand Trade and Enterprise (NZTE) by Market Economics Limited (M.E). Its aim is to provide an assessment of how mussel prices have changed over time and how they might be affected by future supply levels in New Zealand.

[1] Life Cycle Assessment of New Zealand Mussels and Oysters – Page 8, 2021

M.E has been supplied with indicative data on production forecasts by MPI via NZTE (19/11/2024). We use this data to try and understand the consequences for export prices in New Zealand. This involves projecting the potential price path of greenshell mussels out to 2040. Various methods are used to illustrate the potential spread of prices over time. This spread portrays the significant degree of uncertainty.

1.2 Caveats and limitations

Specific caveats and limitations are discussed throughout the body of the report in the sections where they are relevant. Summarised below are some of the key high-level limitations of this work.

- Despite greenshell mussels being a unique and differentiated species, setting the product apart from global alternatives, the mussel market is international and highly dependent on the demand and supply circumstances in each importing and exporting country. In theory, other countries could flood the market with product. Equally, consumer preferences could change in response to rising/declining incomes or social factors, leading to consequential demand swings. Within this ecosystem, the power of New Zealand aquaculture to affect global prices through increasing production volumes is limited. Importantly, this analysis does not capture or measure the impact of new marketing, branding or other supply-side efforts to shift preferences, either from New Zealand or international competitors (as this is beyond the scope).
- A fourteen-year time horizon provides ample time for the global market to change. By 2040 the world's population is projected to exceed 9.0 billion, up from 8.1 billion today.[2] Much of that growth will be concentrated in Africa. By contrast in Europe, which is currently the largest importer of mussels, population is expected to contract. Climate change could affect mussel production in some producing countries through higher water temperatures, sea level rises, extreme weather events, ocean acidification, changing rainfall patterns or diseases.[3] These risk factors could affect where farms can be located and their productivity. This assessment does not attempt to model the impact of changing global conditions.
- The forecast methods we apply incorporate the available data but are based on observable historic patterns and correlations. Their accuracy in predicting how indicators will behave in an inherently uncertain future world is limited by how much the future reflects the past. They provide a starting point to frame a discussion of possible outcomes but cannot be expected to foretell the eventual path of prices. The ranges presented demonstrate the scale of this uncertainty.
- We focus on export prices and use these to determine our estimates of farmgate prices on the basis that the series are historically correlated. If, for example, processing costs increase faster than export prices, farmgate prices might stay lower. The cost of labour and other inputs have been raising the cost of processing recently but these impacts are not modelled.

[2] UN population projections, accessed 25/11/2024.
[3] Climate change effects on aquaculture production: sustainability implications, mitigation and adaptations, Maulu et al., 2021

1.3 Report structure

The report structure is conventional and is outlined below.

- Section 2 starts with a general overview of mussels, setting out the national and global contexts of mussel supply and demand. The section then presents base information about production, trade and markets. The section also summarises historic price patterns.
- Section 3 presents the analytical findings from the different forecasts.
- Section 4 concludes the report and summarises its findings.

2 Baseline information

This section starts by providing an overview of New Zealand's mussel production in a global context. Next, we present historic trends about the New Zealand industry and its performance. The historical patterns form the basis for understanding the current situation and how the sector has evolved over time. These historic trends provide insight into the volatility and cyclical nature of the sector. We identify key patterns and features of the industry which help to explain how the supply and demand sides of this market interact. Looking through an international lens, we also assess New Zealand's position relative to the major importing and exporting countries, as well as opportunity areas and sources of potential growth. The section concludes with an overview of the trends in mussels.

The section draws heavily on information made available by Aquaculture New Zealand (AQNZ), covering:

- Product types (formats),
- Volumes and prices,
- Destination countries.

2.1 Overall context

Economic, political and social globalisation processes over recent years have led to changes in food production and consumption patterns.[4] Technological advancements continue to drive efficiency and productivity gains throughout the supply chain. Recent developments in areas such as crop genetics, harvesting robotics, Automated Storage and Retrieval Systems (ASRS), cold storage warehousing and many others have transformed food production.[5]

Meanwhile, the global trade system is becoming increasingly regional. Since reaching a low of 47% in 2012, the share of trade occurring within the same region has climbed to 50%.[6] Regional production networks are one way to reduce exposure to the myriad global risks that can disrupt trade and supply patterns. Geopolitical tensions and conflicts, climate change and Covid-19 have each highlighted fragilities within supply chains, prompting some countries to proactively reshore or nearshore – processes which seek to relocate parts of the supply chain or production back onshore, or to neighbouring countries.[7] Relatedly, food insecurity has been climbing since 2018.[8]

The market for New Zealand's greenshell mussels is set against this backdrop, though its characteristics as a premium product shield it from factors such as food insecurity choices. Nearly all mussels are exported to countries that are more economically developed. Market research by MPI in 2017 looked at consumers in two of New Zealand's largest export markets, France and the USA.[9] Most respondents had never heard of

[4] Evolution of global food trade network and its effects on population nutritional status, Silvestrini, Smith and Sarti, 2023
[5] A review of robotics and autonomous systems in the food industry: From the supply chains perspective, Duong et al., 2020
[6] Risk, resilience and rebalancing in global value chains, McKinsey Global Institute, 2020
[7] Disruption in Resource-Instensive Supply Chains: Reshoring and Nearshoring as Strategies to Enable Them to Become More Resilient and Sustainable, Fernandez-Miguel et al., 2022.
[8] 2023 Global food policy report: rethinking food crisis response, International Food Policy Research Institute, 2023
[9] Understanding Mussel Consumption, MPI (2017)

greenshell (green-lipped) mussels (France = 86%, USA = 62%). Of those who had, a reasonable share (36% in France and 39% in the USA) correctly identified that they came from New Zealand. This suggests a decent association between the product and where it originates, which could be linked to its status as a premium product.

All prospective markets have an elasticity of substitution between domestically produced goods and imported goods.[10] How consumers value greenshell mussels relative to international and domestic alternatives will therefore determine demand levels and consumption. Given the heterogeneity between mussel breeds, the market for mussels has the potential for substantial preference differentials. Greenshell mussels are distinctive for several reasons:

- They are endemic to New Zealand, anchoring their reputation to the positive global image of New Zealand aquaculture and giving New Zealand a degree of control over brand cultivation.
- Their green shells contrast with those of other mussel species, though there are species of green mussels, in areas of south and south-east Asia.
- Greenshell mussels grow larger than black mussels. They have unique tastes and textures, too.

In addition to other mussel breeds, greenshells and their derivative products compete with an array of fish products from salmon to oysters. Demand for mussels is jointly determined by the product's price and features, as well as the characteristics of consumers and their preferences over mussels and all available alternatives.

Globally, food consumption and diets are constantly evolving due to factors such as urbanisation, income changes, social and health factors, and food availability, each of which can be highly localised.[11] There is a growing demand for environmentally friendly and ethically produced food.[12] Because mussels have one of the lowest carbon footprints of all animal proteins[13], this enhances their appeal to increasingly conscious consumers. In Asia – where both populations and affluence are growing rapidly and food spending is forecast to grow at pace over the coming decades – consumers are increasingly willing to pay a higher price for foods perceived to be good for their health.[14] More than 40% of Asian customers are concerned about where their food is sourced from.[15] Coupled with this, meat and fish become a more important source of calories in the human diet as income grows.[16] Per capita rice consumption has in fact fallen in Japan, Taiwan and South Korea as incomes have risen.[17] All of these factors point towards a growing market opportunity in locations such as Asia, a market to which New Zealand already has access, and which it is well placed to service in the future.

---

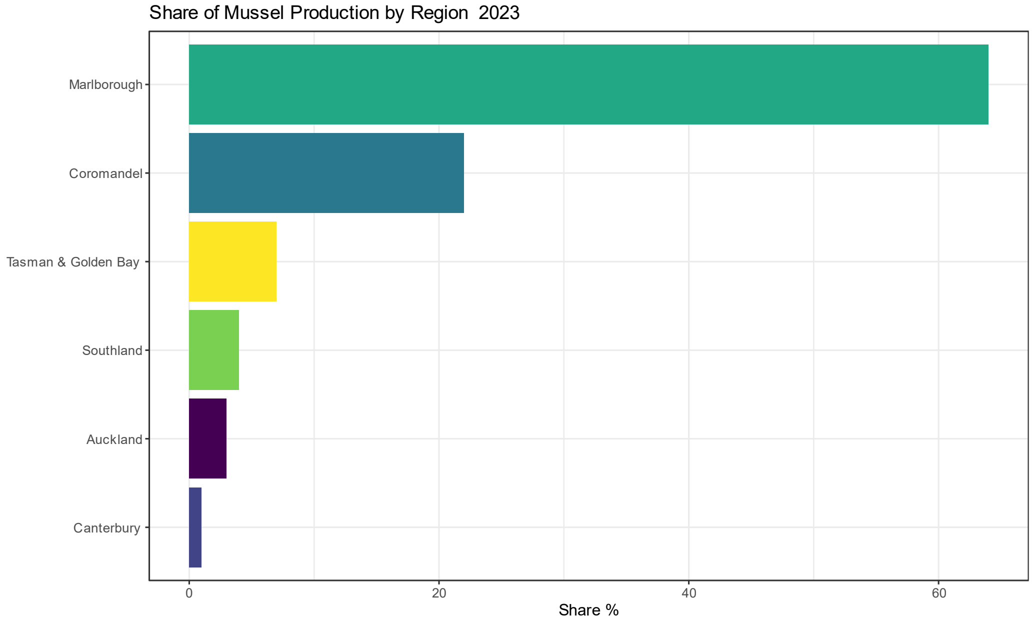
[10] A theory of demand for products distinguished by place of production, Armington, 1969
[11] Global food policy report 2017, International Food Policy Research Institute, 2017
[12] Organic agriculture in the twenty-first century, Reganold and Wachter, 2016
[13] Life cycle assessment of New Zealand mussels and oysters, thinkstep ANZ, 2021
[14] https://www.pwc.co.nz/industry-expertise/food-production/afc-report-202109.pdf
[15] ibid
[16] Global food consumption and impacts on trade patterns, Gehlhar and Coyle, 2001
[17] Ibid

2.2 Production data

Greenshell mussel farming takes place in six regions across New Zealand. Marlborough produces most (64%) of the product, with the Coromandel/Bay of Plenty (22%) being the other major producer.[18] Minor shares are delivered from Tasman/Golden Bay, Southland, Auckland and Canterbury. Figure 1 shows the regional distribution of mussel production.[19]

Product processing and the supply chain (forward linkages) create additional economic value and jobs throughout the country, though these tend to be concentrated near to farms to minimise transport costs.

Figure 1 - Share of Mussel Production by Region



Most of the mussels farmed in New Zealand are exported. The value of New Zealand's mussel exports has been rising for the past two decades. In real terms (after adjusting for inflation) the value of mussel production has grown substantially since the early 2000s. Figure 2 displays data from the AQNZ database across all mussel products converted into 2023 prices. Current export values are $389m, up from approximately $120m in 2006. The long-term trend is upward – the compound growth rate of the series is 7.2% per annum. As shown in Figure 3, which plots export volumes, some of this growth has been due to increased volumes. The mix of products and their respective unit prices has been important, too. The relationship between these variables is analysed in subsequent sections of the report.

[18] AQNZ Sector overview, 2023
[19] These regions are based on the AQNZ definitions, and do not align with the 'regional council' boundaries.

Figure 2 - Real Value of Mussel Exports ($)

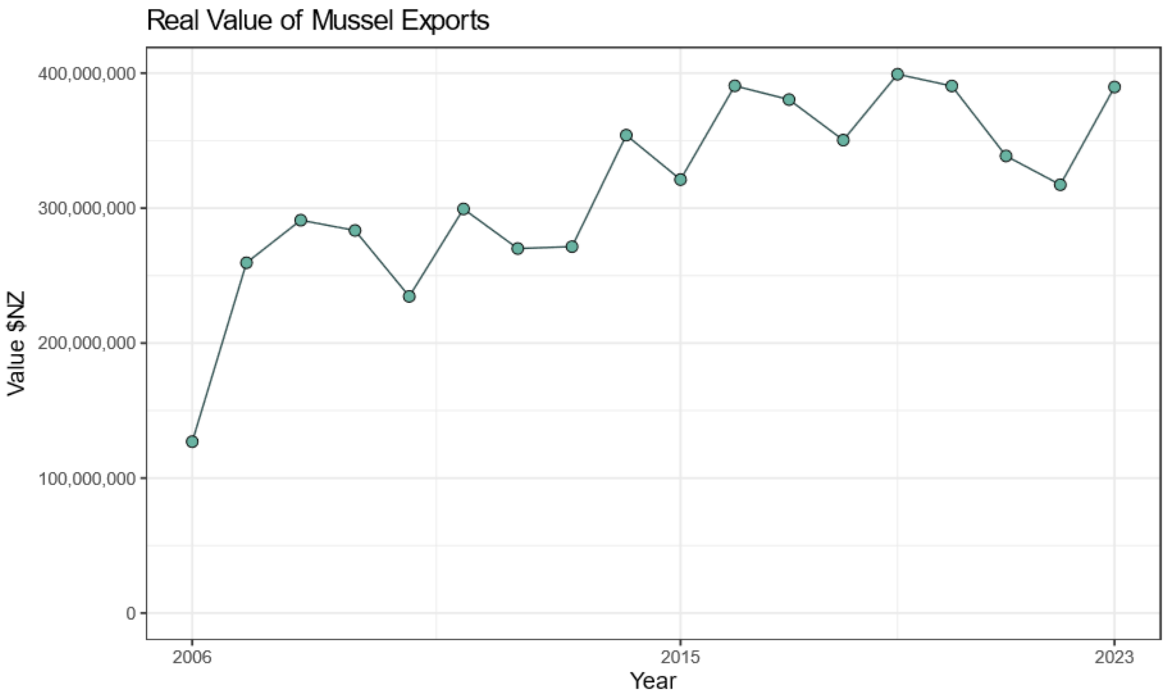
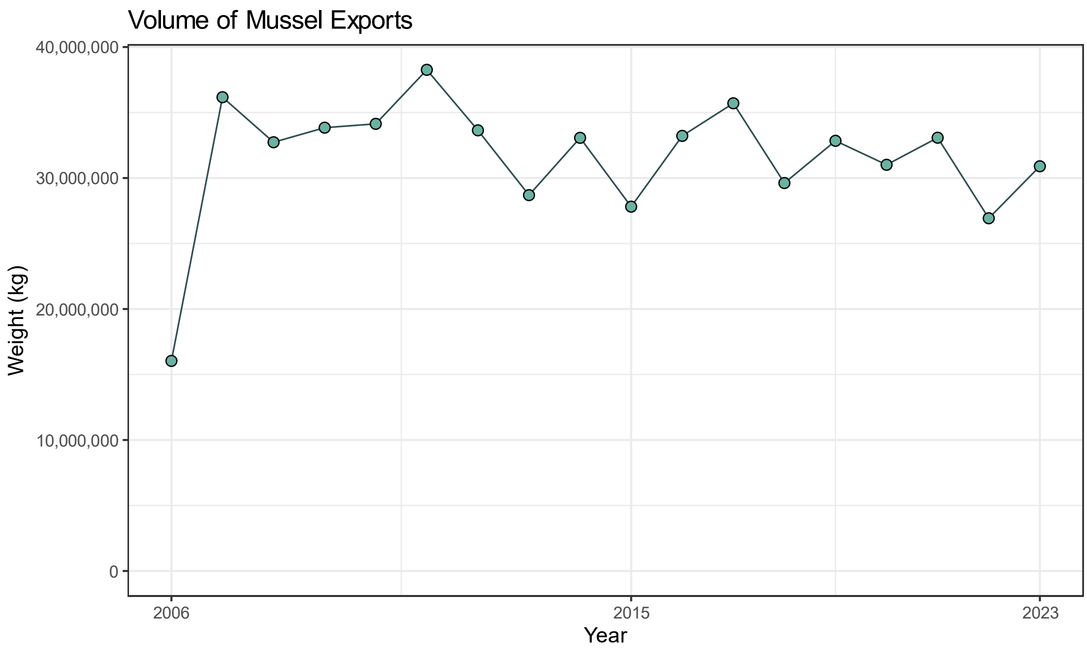


Figure 3 - Volume of Mussel Exports (kg)



Greenshell mussels can be used in an array of products. AQNZ records 17 unique product categories in their exports data, which includes categories of frozen, crumbed, fresh, live, oil and smoked products. In recent years around 95% of value has come from just five products:

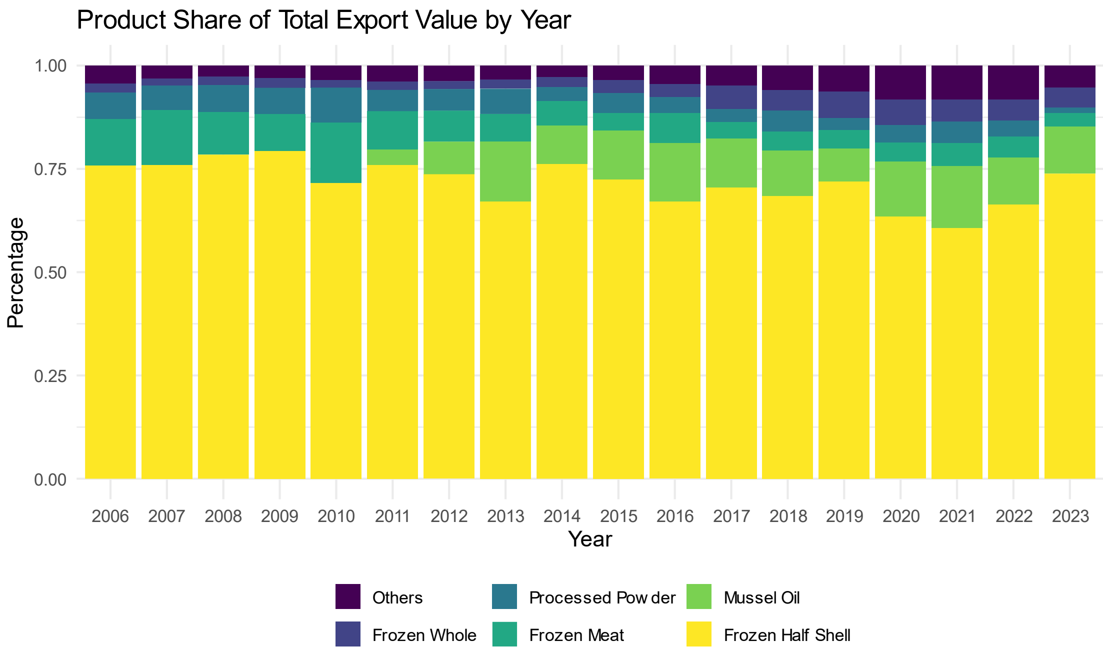
- Frozen Half Shell,
- Mussel Oil,
- Frozen Meat,

- Processed Powder, and
- Frozen Whole.

Some of the ensuing analysis isolates these products because of their dominance within New Zealand's industries. Homing in on the individual products enables a more robust assessment of price drivers and market trends. However, the relative dollar value of some emerging and niche product lines are significant when considered on a per unit basis.

Figure 4 displays the products and their relative share of export value. Frozen half shell mussels have comprised around 75% of total value over the period, making this format the largest single export item. Mussel oil, which is sold at a much higher price per kilogram, has been making up an increasing share of this value since 2011, the first year of its inclusion in the export data as a distinct item. Over that time its share of total annual value has grown from 4% to 12%. Products excluded from the five main items are grouped together and summarised as "Others".

Figure 4 - Product Share of Total Export Value by Year



2.3 Global Trade

The UN Comtrade Database contains data on global imports and exports by volume and value. The following analysis includes the four Harmonised System (HS) codes for mussels: 30731, 160553, 30739 and 30732.[20] This

[20] Because of ongoing changes to the classification system, the product definitions included in these labels relate to:

- Molluscs; mussels (mytilus spp., perna spp.), live, fresh or chilled (whether in shell or not).
- Mollusc preparations; mussels, prepared or preserved
- Molluscs; mussels (mytilus spp., perna spp.), frozen, dried, salted or in brine (whether in shell or not)
- Molluscs; mussels (Mytilus spp., Perna spp.), whether in shell or not, frozen, dried, salted, in brine, or smoked, cooked or not before or during the smoking process
- Molluscs; mussels (Mytilus spp., Perna spp.), whether in shell or not, live, fresh or chilled
- Molluscs; mussels (Mytilus spp., Perna spp.), whether in shell or not, frozen

is a broader aggregation than the detail that is available through the AQNZ database, preventing a direct comparison at a product level. However, this data is useful in formulating insights into how the New Zealand supply picture fits within:

- global markets (import and export), and
- observed trends associated with destination markets.

Imports and exports are reported by both origin and destination markets. Efforts to measure international flows inevitably lead to discrepancies in recorded import or export numbers for several reasons, including:

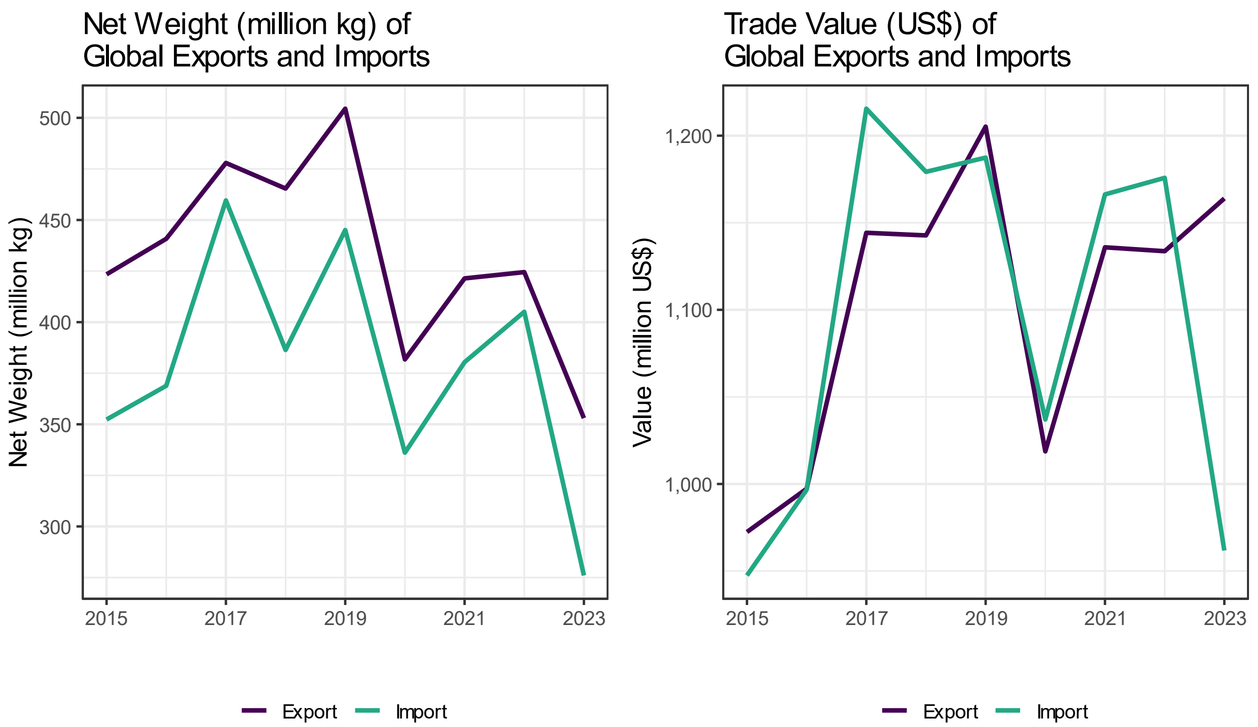
- **Valuation metrics.** Exports are usually recorded at FOB (Free On Board) value, which includes the cost of the goods and the charges for getting them onto the transport vessel. Imports, conversely, are usually recorded at CIF (Cost, Insurance and Freight) value, which includes the cost of goods plus insurance and freight charges to the destination port.
- **Exchange rate fluctuations.** Trade data are usually recorded in the origin currency and then converted to USD so fluctuations in exchange rates can cause mismatches.
- **Measurement timing differences.** Exports are compiled when goods leave a country, imports upon arrival. Delays in shipping can lead to goods being recorded in different time periods. This is less of an issue for bulk goods and in this analysis data time periods are aggregated to annual totals.

This analysis begins by presenting both the import and export figures to highlight the reporting differences with the Dollar value recorded in nominal US Dollar terms (see Figure 5).

Globally, the value of mussel exports (imports) is around US$1bn. This comes from products whose net weight is around 350 - 400 million kilograms per year. The net weight of trade-flows shows the impacts of Covid on production, transport and the associated disruptions. However, when considering the trade value (not weight), then the effects are less pronounced, suggesting that there is more stability from a value perspective.

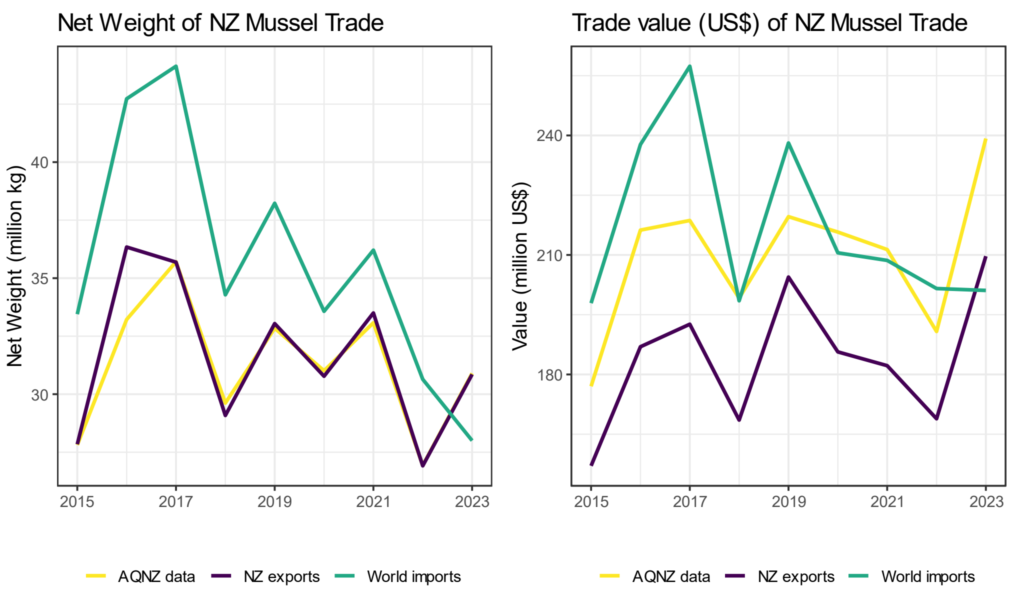
- Molluscs; mussels (Mytilus spp., Perna spp.), whether in shell or not, dried, salted, in brine, or smoked, cooked or not before or during the smoking process

Figure 5 - Global Imports and Exports of Mussels



New Zealand's mussel exports are important in the global marketplace. Figure 6 plots the New Zealand data from the different data sources (UN Comtrade's imports and exports, and the AQNZ exports). The AQNZ data has been converted to US$ to enable comparison[21].

Figure 6 - New Zealand Trade Values

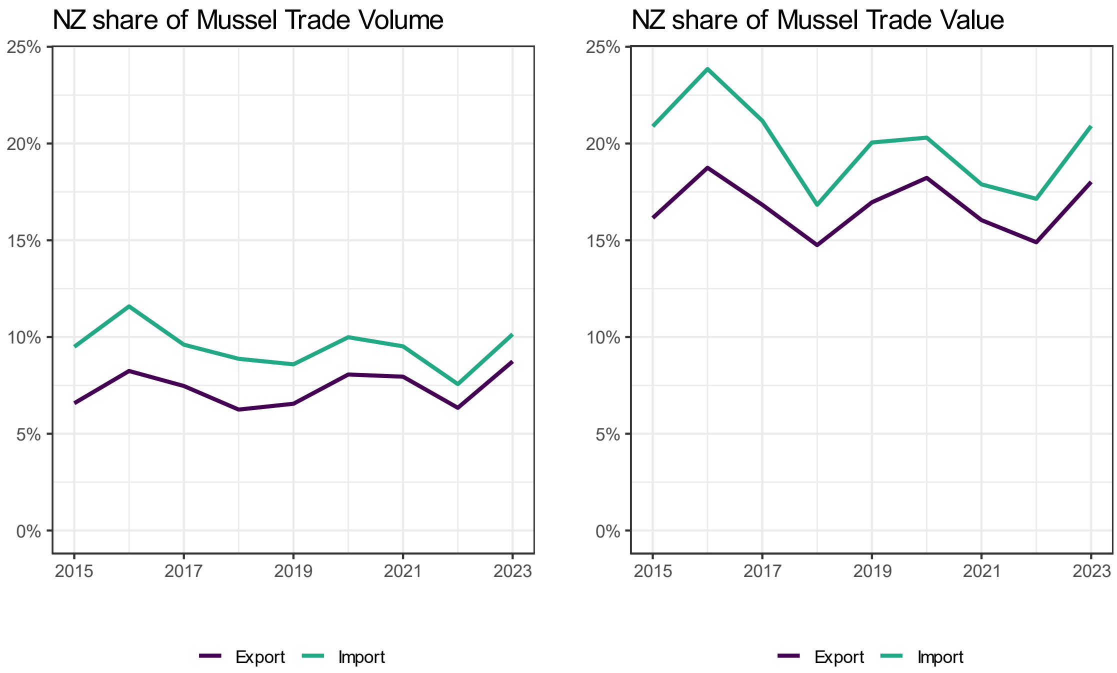


[21] This conversion will add some variation because the exchange rate fluctuates during the year.

The net weights reported by the different sources are similar for exports, with only minor variances. For trade value (US$), however, the series are more divergent. This is unsurprising given exchange rate fluctuations and the imprecise recording of these flows. The two data sources serve to validate each other, enabling their use with relative confidence, especially the export weight values.

Figure 7 reports New Zealand's relative share of international trade, using two metrics – share of trade volume (weight) and share of mussel value (US$).

Figure 7 - New Zealand Share of Global Trade



New Zealand accounts for a large share of the international mussel trade's value, but a lower share of total volume. This suggests that greenshell mussels have a unit price premium over global alternatives. Between 2015 and 2023 its products have amounted to around 8% of global trade volumes but close to 20% of global value. This is driven by factors such as:

- **Premium quality and branding.** Greenshells are treated as a premium product in international markets, leading to a higher value per kilogram.
- **Higher processing and added value.** The value-added processing of mussels (e.g., ready-to-eat products, powders and oils) can contribute to higher export value relative to in-bulk or unprocessed mussels.
- **Trade agreements and market access.** Demand price elasticity and consumers' willingness to pay a product premium will differ between markets. If New Zealand's export markets are more willing to pay premiums, it can lead to higher values. This willingness to pay can also be influenced by ability to pay (i.e., higher income countries).

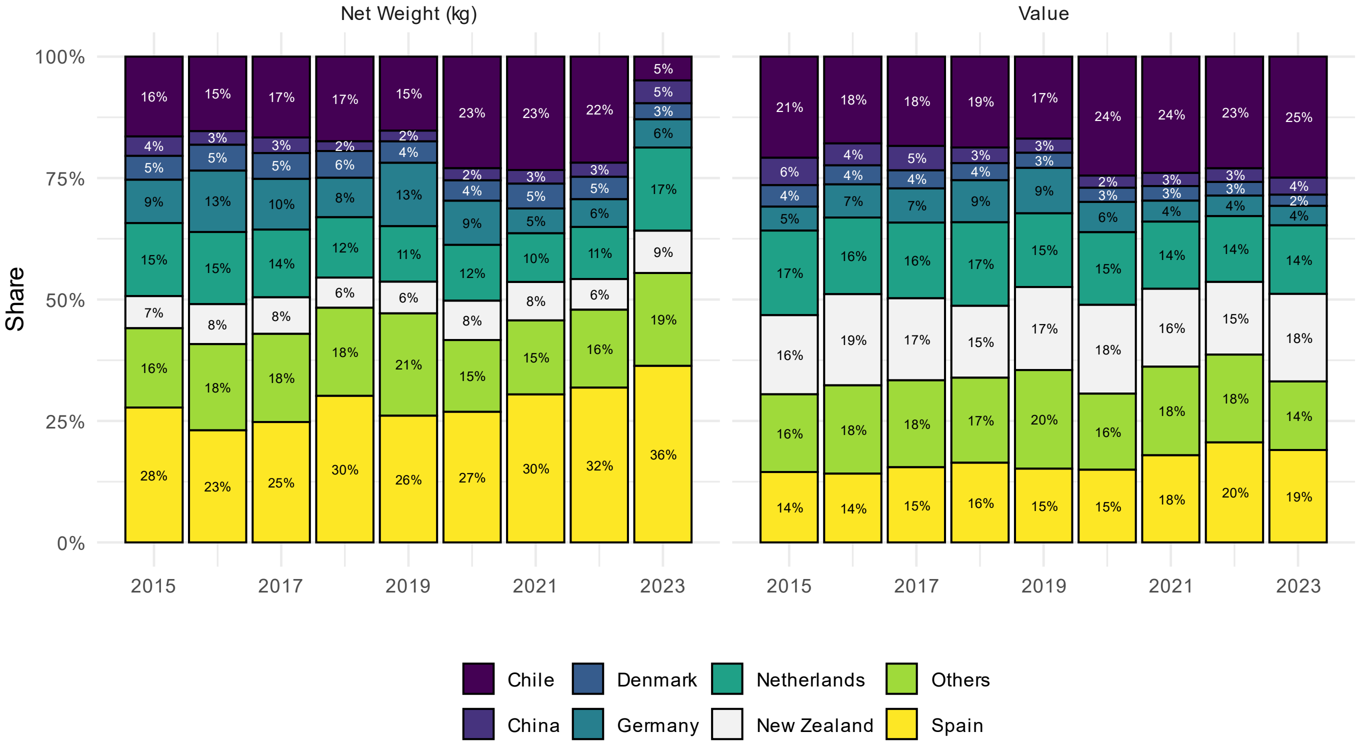
The major mussel exporters are distributed throughout the world. The largest producers by volume are:

1. Spain

2. Chile
3. The Netherlands.

Chile is the largest exporter by value, but it is closely followed by Spain, New Zealand and the Netherlands. The plots below (Figure 8) show the relative size of global producers. If a country produces less than 5% of global exports, it is reported as part of the “Others” category. Countries within this aggregation include Mexico, the UK and Canada. In total these smaller producers comprise about one quarter of total volume and value, making them as influential as the largest producers when taken together, but individually their impact on global quantities is minimal.

Figure 8 - Largest Exporting Countries



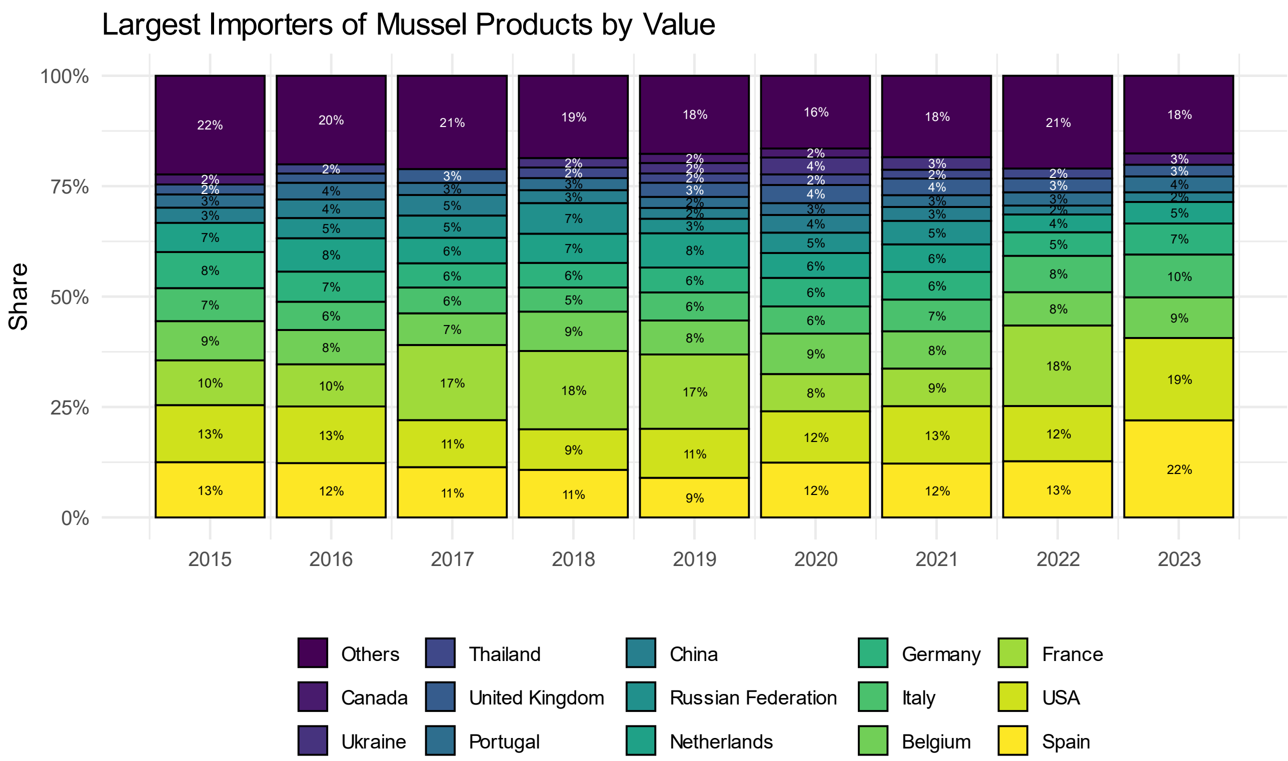
The 2023 the unit price of mussels varies greatly between countries from US$1.72 / kg for products from Spain to US$6.79 in New Zealand. Importantly, this does not delineate between mussel products so also captures differences in product types. New Zealand is the largest exporter of frozen mussel products. The vast majority of New Zealand’s exports by weight are frozen. The average unit price for frozen products from the largest exporters are shown in Table 1. Again, the format of these frozen products could play a role, especially whether the shell has been fully or partially removed.

Table 1 - Unit Prices (Frozen Mussels), 2023

Year	Country	Net Weight Exports (million kg)	Value ($USD)	Unit Price
2023	New Zealand	28.0	$196.97	$7.03
2023	Portugal	2.8	$15.18	$5.34
2023	Denmark	1.1	$5.41	$4.81
2023	Spain	4.6	$19.14	$4.19
2023	Germany	2.2	$5.58	$2.51
2023	China	9.0	$22.29	$2.47

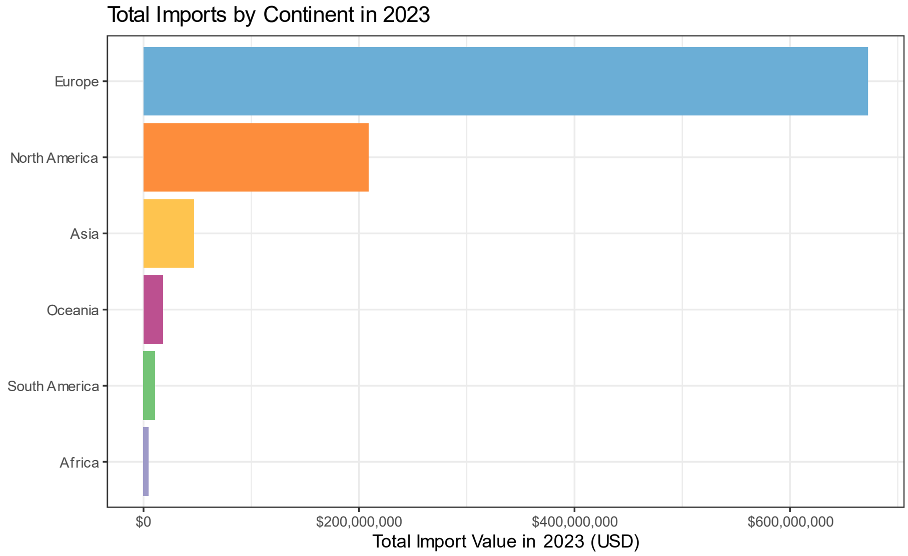
Figure 9 shows the relative size of the destination countries (by value of imports). Western Europe has the highest concentration of countries importing large quantities of Mussels, ranked by product value. Other large importers are the USA, Russia and China. Again, for visual simplicity countries who did not import at least 2% of global value in any year across the period are grouped together as "Others".

Figure 9 - Largest Importing Countries



In addition to having many of the largest individual exporters, Europe accounts for the bulk of total global imports. Mussels are a popular feature in European cuisine, whereas they feature less in dishes from North America and Asia. Totalling $672 million in 2023, the continent's imports dwarf those of North America ($208m) and Asia ($47m) – refer to Figure 10 and Figure 11. A key aspect of this data is that it only captures cross border flows, rather than quantifying domestic consumption. Factors such as their relatively small size, the trade barrier-eliminating effect of the European Customs Union and the development levels across the continent support this dominance.

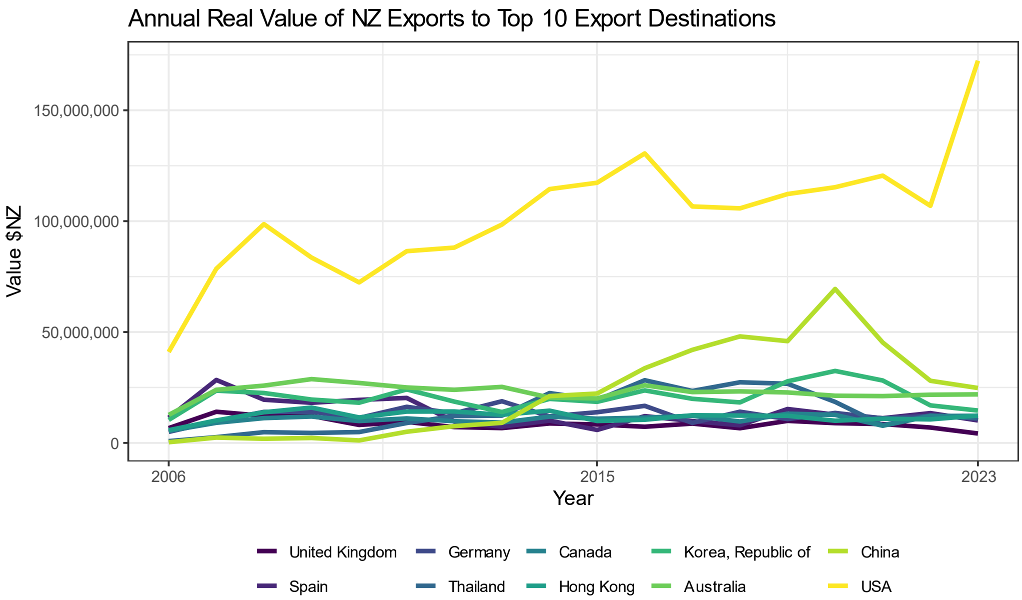
Figure 10 - Total Imports by Continent



Appendix 1: Import Values and Historic Change by Country contains two plots showing each country's 2023 import value and the change since 2015. Most of the biggest countries by volume are in Europe. So too are most of those which have had large increases in imports over the period. Australia's imports were up by $3.5m, though there was minimal growth among any big Asian importers including China, where imports fell over the period – the effects of Covid, and the ongoing economic pressures in the Chinese market are evident.

New Zealand exports mussels to a range of locations around the world. There is some concentration among core markets, most notably the USA, which consumed around half of all New Zealand exports, but many countries constitute significant destinations. Exports to 29 different countries exceeded NZ$1m in 2023. In the decade from 2013 to 2023, 20 countries received exports of at least NZ$1m (2023 prices) in each year. Only 35 unique countries had more than NZ$1m in any given year, suggesting there is not a large amount of change in notable export destinations year-on-year. Figure 1Figure 11 shows the relative value of New Zealand's top 10 export destinations and how this has changed over the past 17 years. The most notable trend is the growth from the USA, both in relative and absolute terms.

Figure 11 - New Zealand Export Value to top Export Destinations

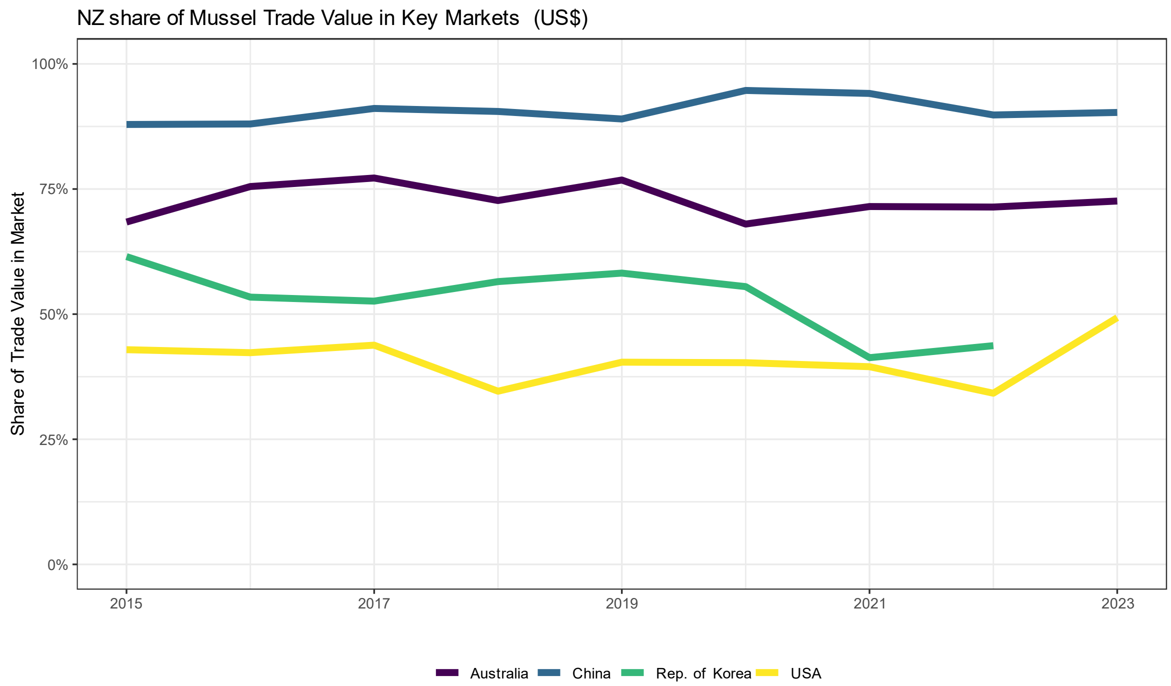


2.4 Key Markets

New Zealand has a selection of key markets into which it sells. Of these markets, products from New Zealand comprise a large share of total import value. Figure 12 illustrates the market share of New Zealand mussels in selected destination markets. For example, New Zealand provides between 85% and 95% of the mussels which China imports. Due to proximity, it is less advantageous for producers in West Europe to export to China. Chile, another major producer, is approximately twice as far from China as New Zealand[22]. The transport costs associated with accessing these markets are a key driver of New Zealand's market successes. Australia imports around 70% of its mussel products from New Zealand. The USA, which is the second largest global importer, has typically imported around 40% of its mussel products (by value) from New Zealand.

This could leave limited growth potential in markets where New Zealand is already a major producer. In such markets there is, by implication, less opportunity to displace alternative supply to capture greater market share. To grow, export value would instead require additional demand to be generated from shifting consumer preferences.

Figure 12 - New Zealand Market Share in Key Destination Countries



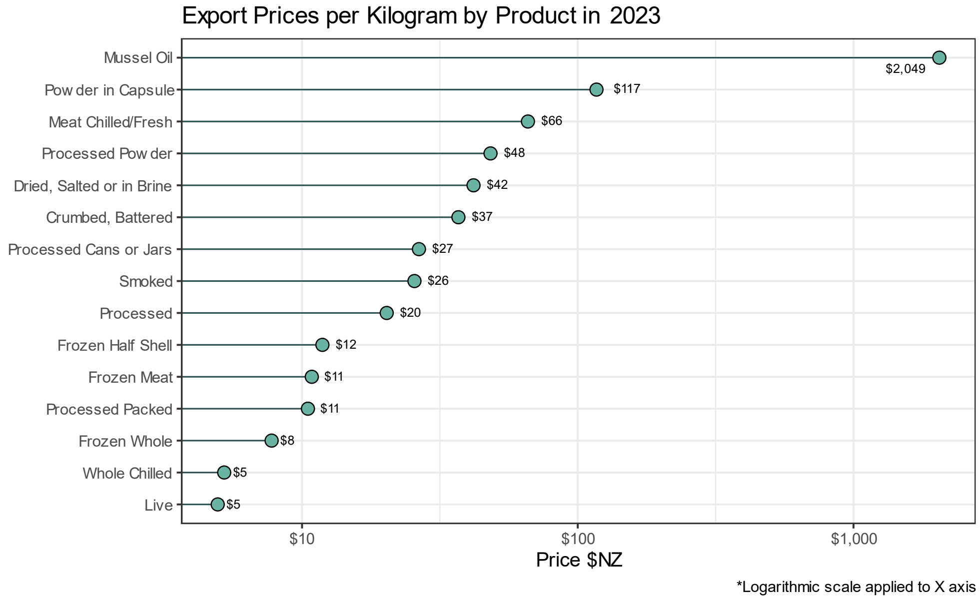
2.5 Mussel prices

The average export prices of different mussel products vary considerably, with a significant spread as illustrated in Figure 13. Mussel oil costs NZ$2,049 per kg, whereas live mussels cost just NZ$5 per kg, on

[22] The approximate distance between Beijing and the respective capital cities of Chile and New Zealand is 19,000km vs 11,000km.

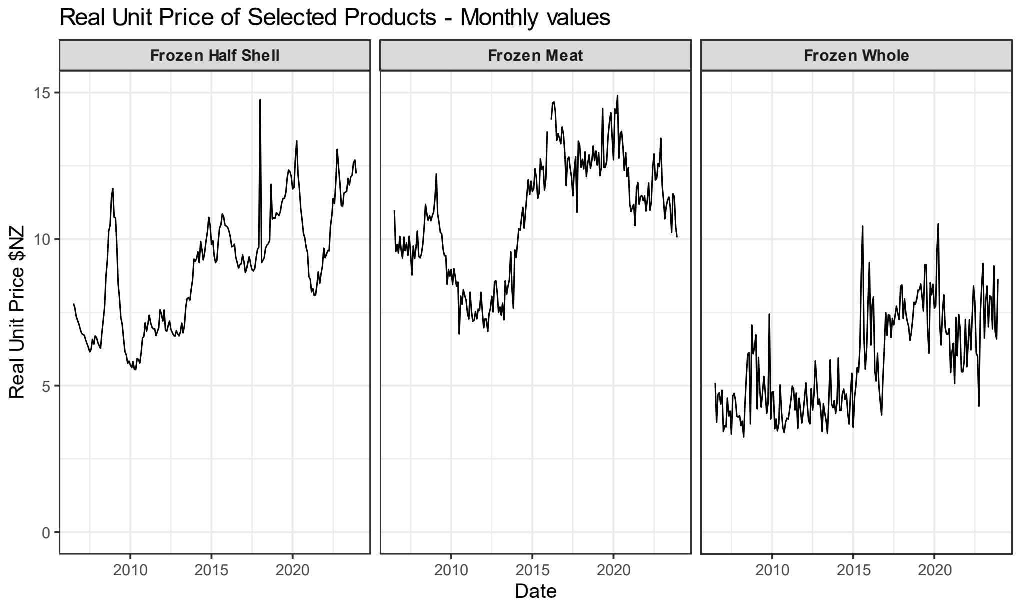
average. These prices reflect the underlying features of the products, including the additional value that is added through processing and the degree to which mussels are 'used'. For example, a high-level analysis suggests that over 114 kg of greenshell mussels are used to yield 1 kg of oil.[23]

Figure 13 - Mussel Product Export Prices (log scale)



Historically, unit prices have been volatile but have been trending upwards. Large orders can have a substantial bearing on the average value of product exported in each month. Equally, a variety of factors including destination country, shipping rates and seasonality can affect the export price. Figure 14 shows the average real unit price (2023 base year, NZ$) of three of the main mussel products in each month from January 2006 to December 2023.

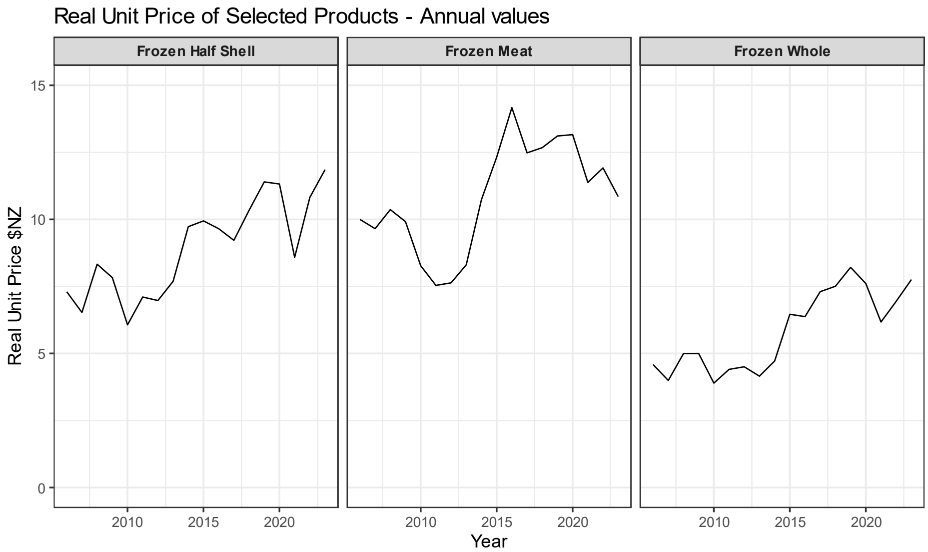
Figure 14 - Monthly Product Price Fluctuations



[23] Life cycle assessment of New Zealand mussels and oysters, Thinkstep ANZ, 2021

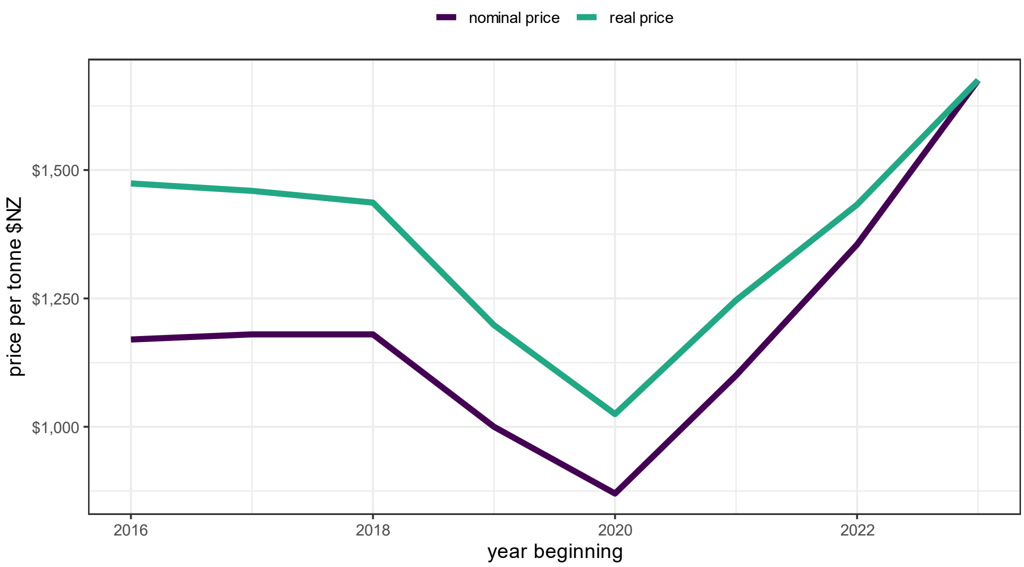
Grouping exports by year eliminates some of noise in these graphs (Figure 15). Prices have risen since 2006 for each of the products. There was a slight dip in 2010 before prices rebounded; they have since gone on to exceed 2006 levels by 9%, 62% and 69% for frozen meat, frozen half shell and frozen whole mussels respectively. The impacts of Covid and the associated disruptions are visible in the price movements.

Figure 15 - Annual Product Price Fluctuations



Neither AQNZ nor Stats NZ publish data on farmgate prices. Instead, we use insights from major suppliers to triangulate historic farmgate prices and use these as a proxy for the market rates on the assumption of competitive pricing strategies. The farming seasons run from October to July, so the prices presented are for the average in the year of the season start. Farmgate prices have been increasing over the past 8 years, though there was a dip in 2019/20 and 2020/21. Figure 16 plots the real and nominal farm gate prices. The real farmgate prices at the start of the 2023/24 season were around $1,675/tonne ($1.65/kg), after increasing from lows during Covid of around $1,024/tonne ($1.02/kg).

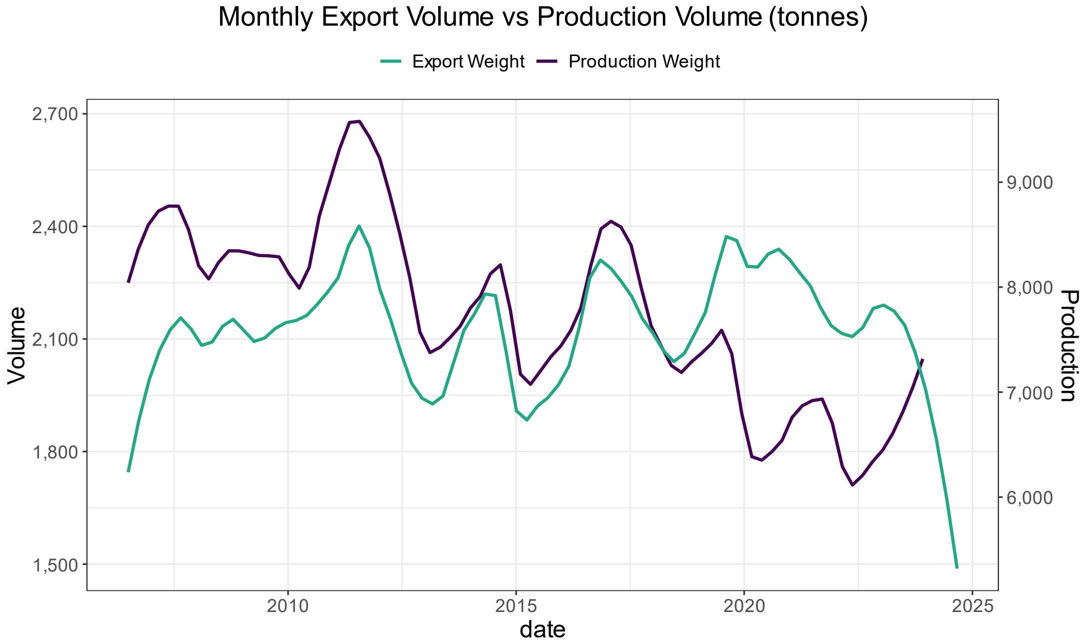
Figure 16 - Nominal and real farmgate prices



In addition to the relationship between farmgate prices and export prices, we are also interested in how production quantities equate to product and export tonnages.

Monthly mussel production volumes were analysed in addition to the export data. Dating back to 2006, the monthly production volumes are 60% correlated with export volumes. Part of the diversion is possibly due to lags between the recording of the data series. Another large part is the eventual product formats and how this has evolved over the period. For the ensuing analysis we have tested tested the outputs when using total production volumes as forecast regressors in both ARIMA and the VAR approaches. In both cases, the historic export volumes of half shells are significantly better predictors - due to higher correlation with prices – so we use this series in the our models. Figure 17 shows the two data series with the Y axis scales adjusted for comparison.

Figure 17 – Comparison of Export volumes with production volumes



2.6 Concluding remarks

Despite the challenges posed by Covid-19 and broader economic uncertainties, the upward trajectory of export volumes and value point to a resilience of New Zealand's mussel exports, supported by strong and growing demand in developed countries. Consumer preferences – such as those exemplified by the 2017 MPI market research of consumers in France and the USA[24] – highlight both opportunities and barriers for market penetration. The greenshell mussel industry's future prospects will depend on its ability to maintain

[24] Understanding Mussel Consumption – MPI (2017)

premium market positioning, adapt to changing consumer preferences and navigate the complex global trade environment.

3 Analysis

Aquaculture is identified as a growth sector with potential to increase total export volumes and values. This section presents the analysis and forecasts of unit prices for mussels, assessing the potential price effects of adding production capacity in line with possible development profiles. These projections must be considered in the context of uncertainty and the many unknowns associated with the growth plans. These include the supply commencement timelines, reliance on market conditions in destination markets and the anticipated effects of climate change. Moreover, New Zealand is one producer within a global trade network. The unit prices of mussel products are simultaneously determined by market dynamics in each exporting country and each importing country. Predicting a future path requires assumptions about each agent within this system, as well as the system itself. The estimates presented here exhibit large ranges as a result. They should be treated with caution and used as a guide, rather than being expected to foretell the 'exact future position'.

3.1 Approach

Future prices can be estimated using an array of different approaches. At one end of the spectrum are general equilibrium trade models[25] such as the Global Trade Analysis Project (GTAP),[26] which offer users the ability to model possible responses to changes in producer, consumer, or Government behaviour. The outputs from these models tend to be difficult to interpret or to elicit the specific drivers of results.

Opting instead for more intuitive and transparent methods enables the incorporation and explanation of the contextual factors which inform the forecasts. Our approach uses two distinct methods:

- Autoregressive Integrated Moving Average (ARIMA) models, and
- Vector Autoregressive (VAR) models.

These two approaches are used to project the price path of mussels under different production scenarios. These methods and their application are noted for the relative robustness and comparative simplicity, which facilitates the effective use of available data. Confidence in the methods appears to be increasing, too, owing to the ubiquity of software capable of configuring appropriate and effective models. However, the rise of ever more sophisticated and complex methods continues to challenge the orthodoxy. Appendix 2 provides a brief overview of how these approaches have been used in other studies.

There are numerous possible approaches, with the correct method depending on the question and available data. We incorporate insights from the existing literature into our model parameters but acknowledge this debate. The dual framework highlights the relative merits of each method and aims to instil confidence in the overall trends through cross validation.

Our focal variable is the real unit price of New Zealand mussel exports. However, forecasting the average unit price of all mussel products would require assumptions that undermine the methods being applied. The

[25] M.E has other CGE models that could also be used to assess price changes, but the scale and complexity of such an approach (and the costs) negates this option.
[26] The Global Trade Analysis Project

proportion of each individual product within that mix would need to be held constant through time or be forecast itself. The following points should be noted as they relate to assumptions about the model configurations and inputs.

- **The introduction of mussel oil in 2011 as a category and its growth since**. Statistical forecasts of the share of mussel oil in the total product mix allocate an extremely high share to oil by 2040. Given its high price per kg and possible departure from price correlation with other core mussel products because of the high processing value, this becomes troublesome. We therefore do not model a continual growth path.
- **Frozen half shells have consistently comprised 75% of total export value, so using their price path as a proxy for sector-wide prices is deemed appropriate.** We can use the maximum amount of relevant data to inform the analysis of this over time and use the outputs to then inform estimates of farmgate price. There is too little data to focus solely on farmgate prices.
- **The incorporation of the new capacity assumes that the location in which the mussels are farmed does not impact the price of those mussels.** Without suitable data, it is not possible to assess whether processing or transport costs would be higher for mussels coming different regions. Production in Marlborough already has an established processing industry located proximate to the farms.

The two approaches – VAR and ARIMA – are reported separately. In each section, the historic real price of half shell mussels is plotted from 2006 – 2023 at monthly intervals. The future/forecast real price (2023 base year) of half shell mussels is then projected. Confidence intervals are included to indicate the uncertainty of future values. *The dark orange ribbon represents the 80% confidence interval and the light orange ribbon the 95% interval.* Points within these areas or the boundaries themselves should not be interpreted as having equal likelihood as the central forecast. Rather, these bands represent the area within which the projected value will fall at least 80% (95%) of the time.

3.2 ARIMA approach

The first approach uses Autoregressive Integrated Moving Average (ARIMA) forecasts.[27] The ARIMA model incorporates *p* lagged observations of the monthly half shell time series back to 2006, a parameter which is optimised using an algorithm-based automated selection. The model then performs mathematical transformations to make key properties of the series stationary (consistent) throughout time. The final component determines how many lagged forecast errors to include in the prediction equation, which are effectively regressions of the current value of the series against previous errors in forecasting, enabling the model to incorporate the shock of random fluctuations in the data. Suitable external regressors are tested based on the existence of historic correlation between our target variable, the real unit price of half shells, and a possible set of related indicators.

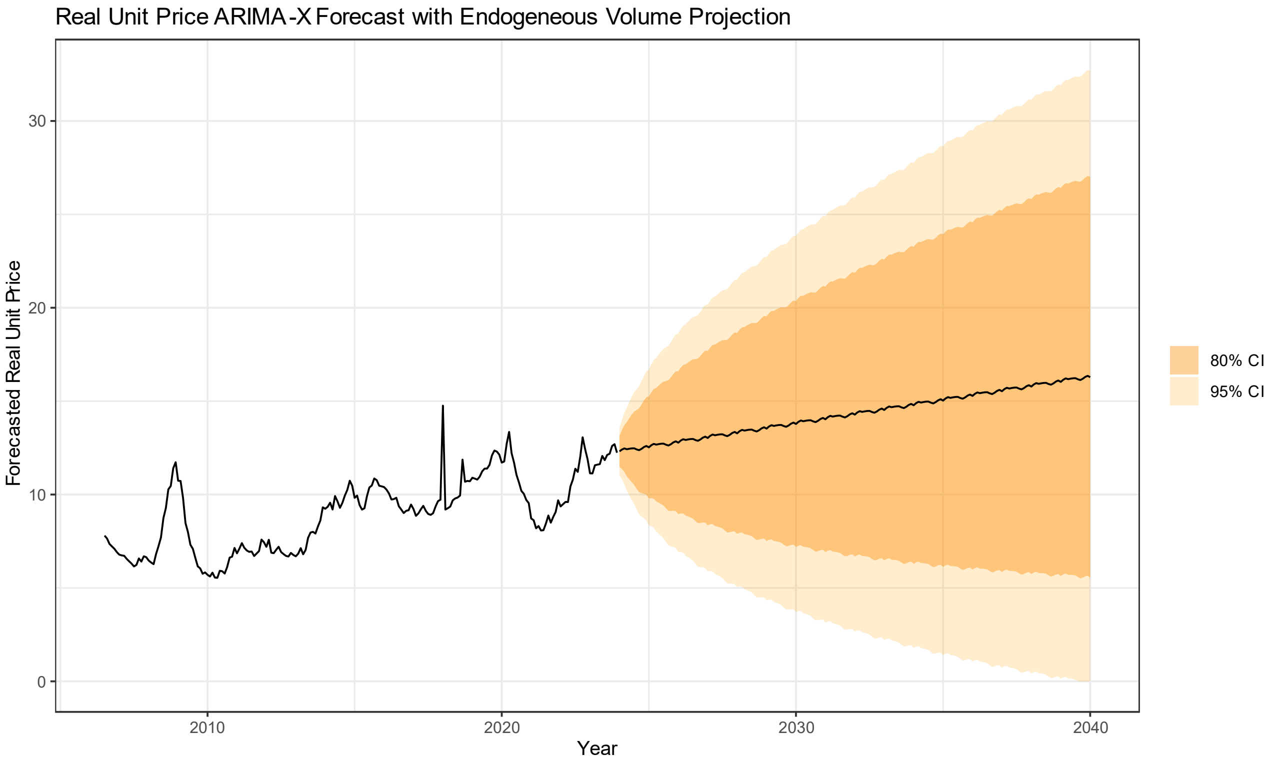
We configure the model using the real unit price of a kilogram of half shell mussels and include exported monthly volume as an external regressor. (The series is labelled ARIMA-X to indicate the inclusion of a

[27] Where external regressors are included, as we do below, these models are referred to in the literature as ARIMA-X models.

regressor.) Other regressors, such as the historic series of global trade volumes across all mussel products, were tested, but they do not add predictive power to the forecast so are excluded.

To understand the impact of future volumes on unit prices, a forecast of future volumes is required. The first model (Figure 18) incorporates a forecast of volume based on an ARIMA forecast of the volume time series. This is endogenous: we do not specify the future path of production volumes. This produces some slightly noisy seasonality and creates larger confidence intervals. Given the historic growth of production volumes, this method also projects a substantial long-term increase in total production, greater than that with our forecasted development.

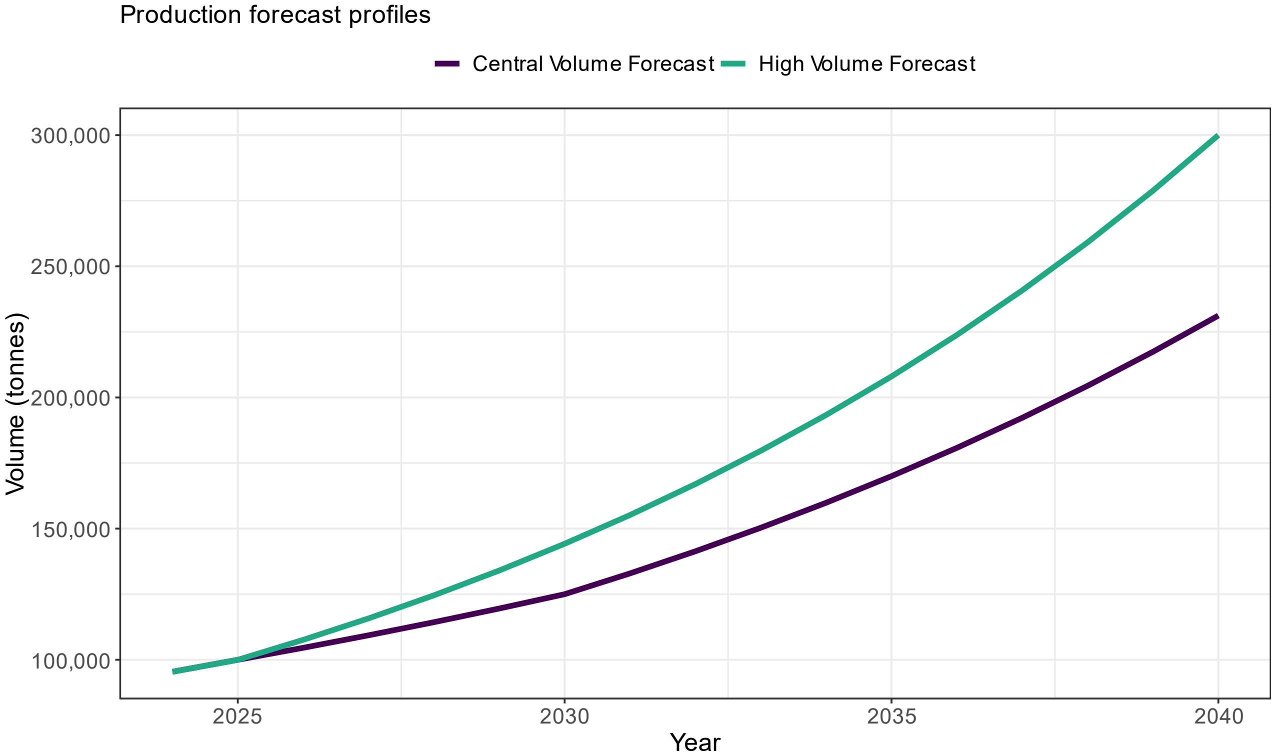
Figure 18 - ARIMA-X with Endogenous Volume Forecast



In the next models we specify the future half shell production volumes in New Zealand based on two scenarios:

- Central Volume Forecast (provided by MPI),
- High Forecast Volume (adapted from the central forecast).

Figure 19 - Production Forecast Profiles



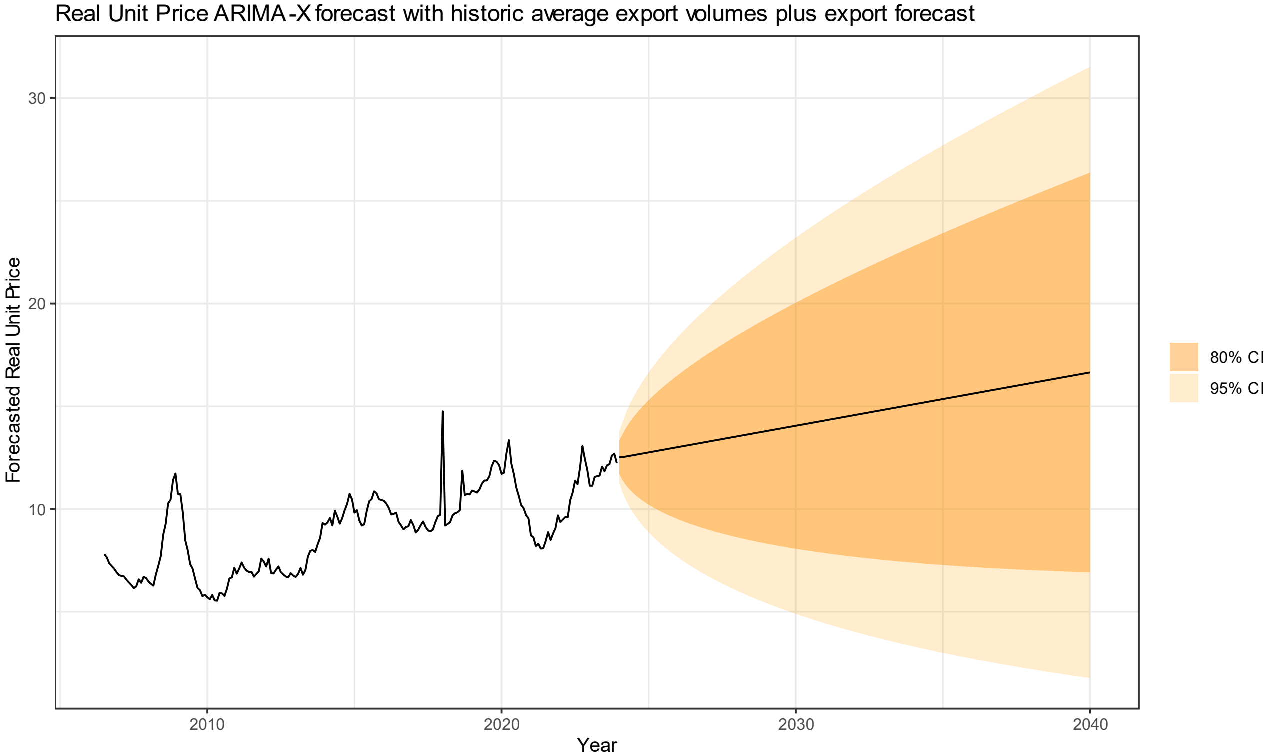
Three quarters (75%) of total production volume is assumed to go towards half shell production and all of this is exported. This assumption proposes that any increase in demand from within New Zealand is relatively insignificant or could be absorbed by increased production from existing farms without needing to change how much they too export. Finally, we reduce the weight by 34.5% to account for the removed shell weight.[28]

The two scenarios yield identical price forecasts to 2040. The point estimate of price in 2040 is $16.65. The variation is due to the path of the historic price series. This finding is borne out by regression analysis of real unit prices on the trade volume. A simple log-log regression of price on volume with a full set of controls suggests that as volume increases by 1% real unit prices fall by just 0.09%, with a very low share of variability explained by the regressor. Intuitively, this suggests that historic changes in volume have had little bearing on the unit price received. This does not guarantee that future volume changes would be as insignificant. The ARIMA forecast introduces "shocks" of future volume based on what has historically been observed, but given the step change in volume produced, the differences between historic and future volume limit its ability to fully incorporate.

The suggestion is that increases in production New Zealand would do very little to global prices under the central forecast.

[28] Life cycle assessment of New Zealand mussels and oysters, Thinkstep ANZ, 2021

Figure 20 – ARIMA-X forecast with volume incorporating medium volume forecast



In both models the confidence intervals are large and significant. The historic volatility of the series suggests that a path diverging from the central, fairly linear forecast is very possible. By incorporating the forecast errors in a recurrent process exacerbates the uncertainty of the estimates, the method causes the bands to grow over time. This speaks to the inherent entropy which we are unable to overcome through these forecasts.

The point forecast and bound values are shown in Table 2. In reality, the low estimates are too low for production to be profitable. The high values, meanwhile, would likely exceed nearly all consumers' willingness to pay. Therefore, the boundaries are seen as the extreme positions, and market forces would, by necessity, push the resulting prices closer to the central position.

Table 2 – ARIMA forecasts final series values

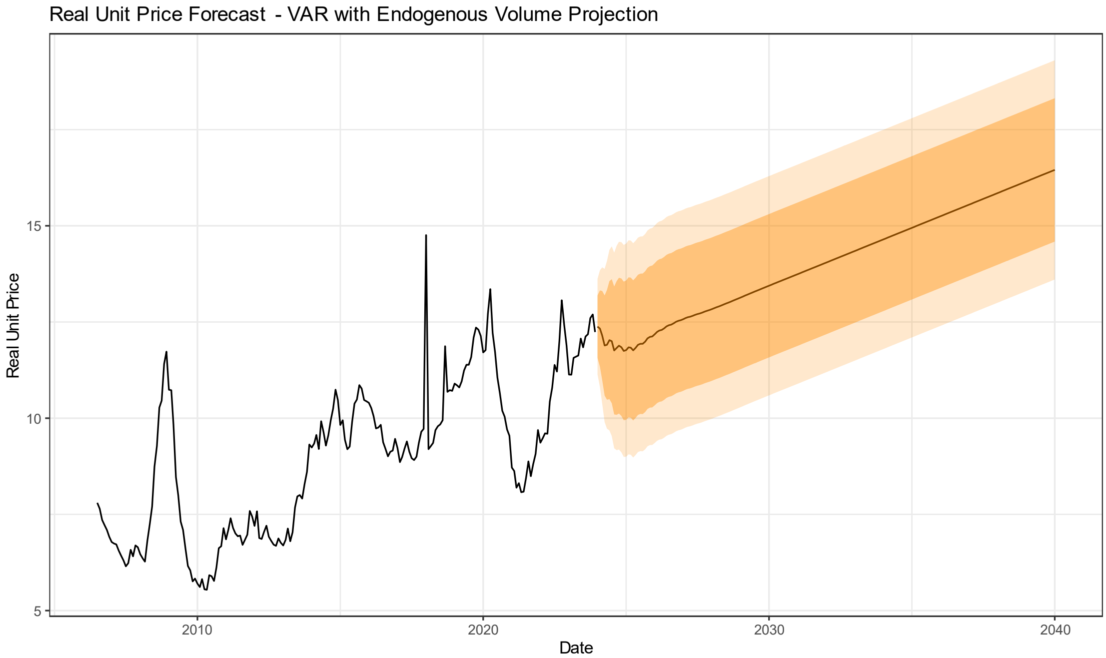
Date	Scenario	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
Jan 2040	Endogenous Volume	**$16.28**	$5.55	$27.01	$0	$32.69
Jan 2040	Central Volume Forecast	**$16.65**	$6.92	$26.38	$1.77	$31.53
Jan 2040	High Volume Forecast	**$16.65**	$6.92	$26.38	$1.77	$31.53

3.3 VAR approach

Vectorised Autoregression (VAR) forecast models include variables as part of a joint multivariate system, where each variable is modelled as a function of the past values of all variables in the system. Essentially, it assesses how each variable in the system influences itself and others through time. The projections are then based on these historical interdependencies. If a variable has historically not shown a strong predictive influence on the real unit price, or if both variables are driven strongly by their own past values rather than by each other, then changes in volume might not significantly impact the forecast. VAR captures the interactions and feedback between all variables, simultaneously. If the relationship between volume is weak or overshadowed by other dynamics, its influence will be minimal.

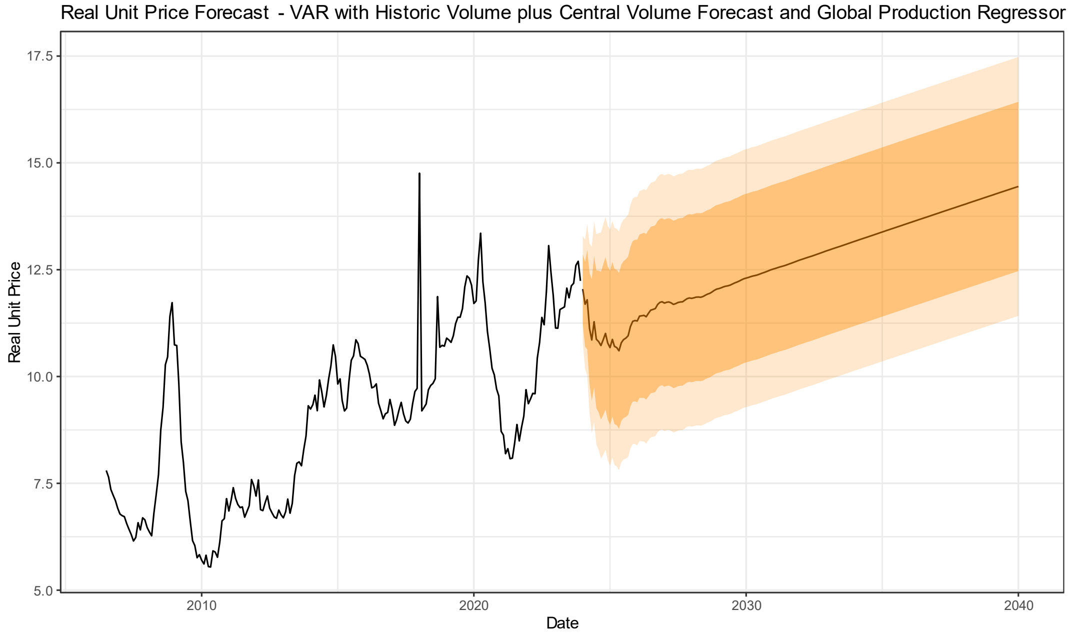
The first model includes an endogenous forecast of volume without incorporating international trade volumes (Figure 21). As above, the dark orange ribbon represents the 80% confidence interval and the light orange ribbon the 95% interval.

Figure 21 – VAR with Endogenous volume



Compared with the ARIMA forecasts, the confidence intervals for both forecasts are much smaller, suggesting that this method more comprehensively captures the interactions and dynamics between the variables. Including global production as part of the covariate system increases the uncertainty but also dampens the forecasted price increase. This is shown in Figure 22. Factoring in global trade volumes increases the uncertainty because of the numerous ways in which international volume, as forecast within the model, could impact the unit price of New Zealand mussels. In the other models, global production is taken as a given, in line with historic trends.

Figure 22 – VAR with Central Volume Forecast and Global Production



Manually incorporating volume forecasts does not affect the series forecast. The model produces the same results regardless of the volume input, suggesting that these series are not jointly determined. Thus, the impact of increasing production in New Zealand on the half shell export price would be negligible or akin to randomness.

Table 3 – VAR forecast final series values

Date	Scenario	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
Jan 2040	Endogenous Volume (EV)	**$16.45**	$14.59	$18.31	$13.60	$19.30
	EV + Global Production Regressor (GPR)	**$14.45**	$12.47	$16.43	$11.42	$17.48
	GPR + Central Volume Forecast	**$14.45**	$12.47	$16.43	$11.42	$17.48
	GPR + High Volume Forecast	**$14.45**	$12.47	$16.43	$11.42	$17.48

3.4 Summary

The models suggest that the real price in 2040 will be around $14.45 (VAR models 2, 3, 4) to $16.65 (ARIMA models 2, 3). There is still a very high degree of uncertainty, and this could vary due to an array of conditions as summarised above. The December 2023 unit price was $12.23, suggesting that growth over the period would be 18% - 36%, plus inflation. Annualised, that is equivalent to 1.0% - 1.9%. This is lower than the increase from 2006 – 2023 of 2.7% annually, which amounted to 62% total growth (over a 17-year period), though this growth has slowed recently, which contributes to the lower forecast path.

Assuming that farmgate prices are highly correlated with export prices, and that different mussel products are subject to similar price paths, would lead farm gate prices to rise by approximately this value over the period, too. If this assumption does not hold and, for example, processing costs rise due to labour or other input costs, the price received at the farmgate could be suppressed further than these forecasts would suggest. Table 4 applies the percentage increases to an estimate of average 2023/24 farmgate prices, giving an anticipate real farmgate price in 2039/2040 of $1,979 - $2,280 (per tonne). The nominal price would include the total inflation over the period.

Table 4 – Farmgate Real Price Estimate Summary

Indicator	2023/2024	2039/2040 Low	2039/2040 High
Average farmgate price (per tonne)	$1,675	$1,979	$2,280

In May 2024 the Treasury released its fiscal update, which contains medium-term forecasts of the Consumer Price Index (CPI), a measure of inflation[29]. This forecast suggests increases in the price level of 3.4% and 2.2% in 2024 and 2025 respectively, and 2% thereafter. Projecting this stable 2% increase forward, the inflation between the end of 2023 and 2040 is expected to be 39%. If export and farmgate prices rise in line with CPI, the total nominal price rise over the series would be 65% - 90%.

[29] Budget Economic and Fiscal Update 2024 – The Treasury, 30 May 2024

4 Conclusion

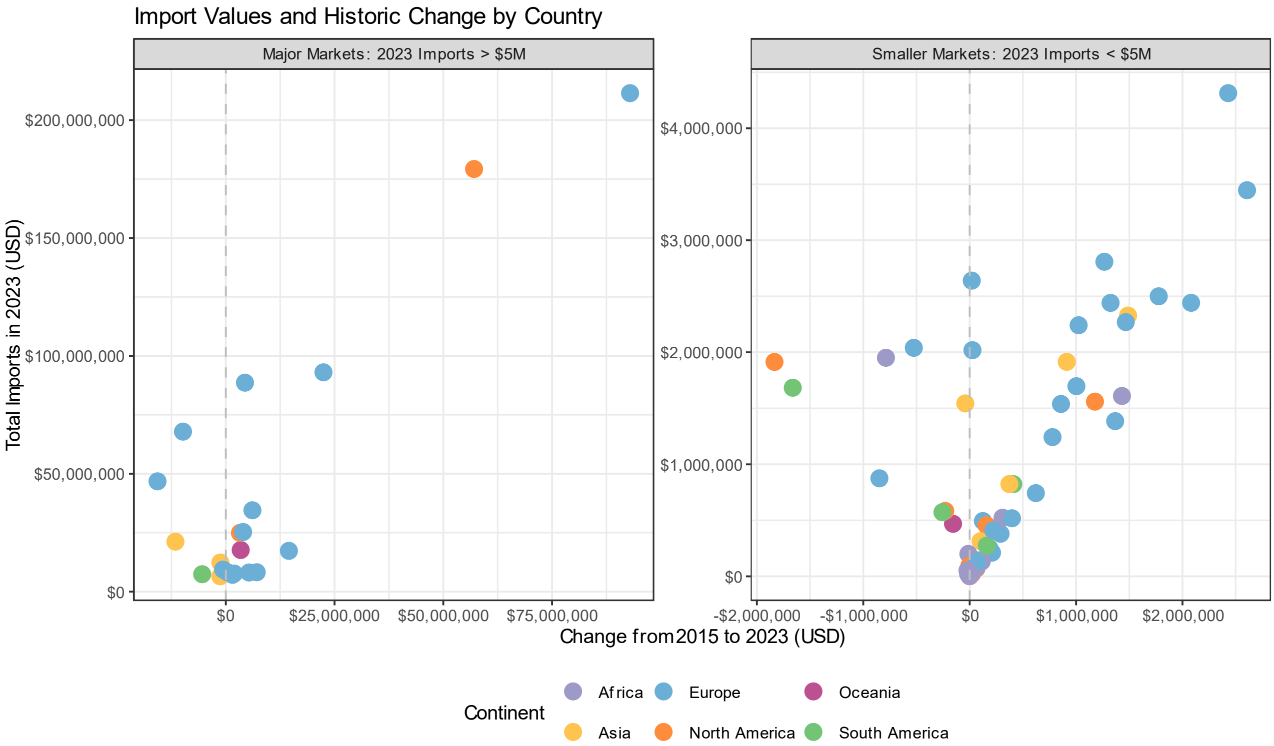
This work has sought to understand how changing production volumes in New Zealand might affect export and farmgate prices for greenshell mussels. Because of the numerous external factors influencing global mussel consumption and preferences for New Zealand's greenshell mussels, the forecasting methods must handle high degrees of uncertainty. How the demand and supply situations evolve worldwide, both for greenshell mussels and substitute goods, has the potential to influence prices to a greater degree than domestic production decisions. New Zealand is the largest exporter of frozen mussels globally. The continued substitutability of frozen products for fresh alternatives in global markets is necessary for local production increases to have a minimal impact on the global supply composition.

Applying both ARIMA and VAR models to the historic data series (2006 – 2023) and forecasting the real unit price forward to 2040 suggests that the additional production levels we model are unlikely to have a significant impact on the export price. As far as analysis of the available data can reveal, volume has not had a significant impact on the past values of price. This does not preclude it from playing a role in the future, however.

The different models diverge in their estimates for future values, suggesting that the real price of half shell exports will grow by 18% - 36% to between $14.45 and $16.65 (2023 base year) in 2040. We use this as a proxy for how farmgate prices will also change over the period based on the two prices maintaining their historic correlation. Applying these increases to the farmgate price leads to estimates of real prices between $1,979 and $2,280 (per tonne). Adjusting for the Treasury's inflation forecasts suggests that total nominal prices rise over the series would be 65% - 90%.

Appendices

Appendix 1: Import Values and Historic Change by Country



Appendix 2: Additional detail about the approach and how these have been applied

The examples below illustrate some successful applications of the approaches used in this assessment. There is an extensive literature challenging the accuracy of predictions based on past events, with alternative propositions including stochastic models where randomness is incorporated into predictions and simulations, reflecting the inherent unpredictability of the system being modelled.[30]

- Jadhav, Reddy and Gaddi recently used ARIMA techniques to forecast cereal crop prices in Karnataka, India, with a high degree of accuracy.[31]
- Other successful applications of ARIMA models to commodity and food prices include Nochai and Nochai,[32] Chu[33] and Ohyver and Pudjihastuti[34]. Kalliovirta et al.,[35] applied VAR models to understand drivers of farmgate milk prices in Finland, identifying links between domestic sectors but other international indicators.
- Other studies, for example Anggraeni et al.[36], have evaluated the relative performance of ARIMA models and VAR models for forecasting food prices.

An emerging and growing approach is to use machine (/statistical) learning methods to produce forecasts.

---

30 Forecasting commodity prices: empirical evidence using deep learning tools

31 Application of ARIMA model for forecasting agricultural prices, Jadhav, Reddy, Gaddi, 2017

32 ARIMA model for forecasting oil palm price, Nochai and Nochai, 2006

33 Short-run forecasting of commodity prices: an application of autoregressive moving average models, Chu, 1978

34 Arima model for forecasting the price of medium quality rice to anticipate price fluctuations, Ohyver and Pudjihastuti, 2018

35 Forecasting milk prices with VAR models – application to farm gate prices in Finland, Kalliovirta, Niskanen, Heikkila, 2019

36 The performance of ARIMAX model and VAR model in forecasting strategic commodity price in Indonesia, Anggreni, Andri, Sumaryanto and Mahananto, 2017.