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ECONOMETRIC TRENDS AND FORECASTING OF DAIRY TRADE DYNAMICS IN PAKISTAN: EVIDENCE FROM BUTTER, GHEE, AND RAW MILK (1961–2024)

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ABSTRACT

The dairy industry in Pakistan is an important player in agriculture and the country's economy. Still, there has been little effort to study the dynamics of international trade in Pakistan's dairy industry. This study examines the export and import dynamics of three important dairy products: butter, ghee, and raw milk in Pakistan, based on yearly statistics from 1961 to 2024. The secondary data used in this study were taken from FAO, PBS, SBP, and the Economic Survey of Pakistan. To carry out the time-series analysis, the Augmented Dickey-Fuller (ADF) unit root test was performed, while the Autoregressive Integrated Moving Average (ARIMA) model was employed to make predictions regarding future trading patterns. The ADF tests indicate that the time series became stationary after the appropriate differencing procedure and can therefore be used for ARIMA estimates. The analysis shows that Pakistan's dairy trade patterns have fluctuated over the past six decades. The forecasted figures show an improved trend for dairy trade in general, with butter and ghee expected to perform better compared to raw milk exports in the future. The results show that Pakistan holds much promise in terms of becoming a bigger player in the international dairy market. It can achieve this by developing its dairy industry through improving its cold chain facilities, encouraging innovations, and adopting a sound trading policy.

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INTRODUCTION

The dairy industry forms a crucial part of the agricultural economy, as it plays a huge role in contributing towards food security, nutrition, job creation in rural areas, and economic development in general (FAO, 2009; World Bank, 2024). The dairy industry provides nutrients that humans need for survival and acts as an important source of income for millions of farm families (FAO, 2009; International Dairy Federation, 2023). The rising population, urbanization, income, and changes in people's diets in recent decades have led to an increase in the world's demand for milk and dairy products (OECD and FAO, 2025). As a result, there has been significant growth in international dairy trade, providing new prospects for developed and developing countries in international markets (FAO, 2023; OECD and FAO, 2025). However, the dairy business has been very dynamic in nature. It has been influenced by many other economic and institutional variables such as production capability, innovation, currency fluctuation, market integration, global commodity prices, sanitary and phytosanitary regulations, and bilateral trade agreements (OECD and FAO, 2025; WTO, 1995). Such variables have made the study of the dairy business very significant for policymakers, producers, exporters, and investors (FAO, 2023; OECD and FAO, 2025).

Pakistan ranks among those nations that have the largest livestock population in the world. Livestock plays an important role in the nation's agricultural economy. The dairy industry makes significant contributions to agricultural value added and acts as a vital source of employment and earnings for many small farmers living in rural areas (Cain et al., 2007; Lucini et al., 2016). Pakistan is among the top milk-producing nations, with milk production of over 72 million tons annually.

The dairy sector is the largest part of the livestock sector in the country and makes a huge contribution to agricultural development, employment generation, livelihoods, and food security (GOP, 2025). Most dairy farms in Pakistan are small-scale, serving as the primary income source for millions of rural households (Cain et al., 2007; Godfrey et al., 2019). Even though the country has a large capacity to produce milk, Pakistan's involvement in the global dairy business is rather insignificant due to several issues such as lack of value addition, inadequate processing, lack of cold chain, quality assurance issues, and a fragmented marketing system (Godfrey et al., 2019; Arshad and Moazzam, 2023). This indicates that limitations in the country hinder it from using full export capacity, requiring evidence-based policies and strategic decisions for the country's dairy industry (Godfrey et al., 2019; Arshad and Moazzam, 2023).

Milk production in Pakistan is increasing due to livestock production and rising demand for milk. Even then, the country has made no effort to take advantage of its strengths in the international dairy sector. Very few dairy products are exported from Pakistan compared to other leading dairy exporters. Some factors influencing the importation of selected dairy products include shortages in domestic dairy production, consumer demand, and global market trends. The challenges faced by Pakistan's dairy industry include inadequate cold storage facilities, inefficient marketing, a lack of a processing industry, poor quality assurance, and weak value chain management

(Godfrey et al., 2019; Ziad et al., 2019). Additionally, enhanced efficiency in the monitoring and surveillance of livestock production has been considered an essential aspect for improving productivity, quality, and export potential (Shahzad, 2022). To address these issues, there is a need for a clear understanding of past trade performance and future trade opportunities.

Of all dairy products traded in international markets, butter, ghee, and raw milk have special significance because of their economic value, nutritive value, and consumption patterns (Bauman and Griinari, 2003). Butter and ghee are considered processed dairy products whose demand is growing not only in the domestic but also international markets. Whereas raw milk is the major input for dairy processing firms (McCarthy et al., 2017; Jansik and Kuosmanen, 2014). Trade performance of these products reflects many factors, such as production dynamics, changes in consumer demand, technological innovation, processing efficiency, and international market conditions (Baldwin and Lopez-Gonzalez, 2015; McCarthy et al., 2017). In addition, changes in the exchange rate, inflation rate, transport cost, climatic factors, and trade policy may play a critical role in the performance of exports and imports (Anderson and Nelgen, 2012; Disdier and Marette, 2010). Climate change issues, which include increasing temperatures and changing rainfall patterns, have become an important issue impacting the efficiency of milk and livestock in Pakistan (Abbas et al., 2024). It is therefore important to understand the behavior of such commodities over time to develop policies for agriculture, industry, and trade.

The agricultural commodity market is always associated with unpredictability and volatility. Changes in the production environment, climatic phenomena, logistics problems, geopolitical events, and fluctuations in international market prices affect traders' behavior and market performance. As a result, governments tend to use quantitative forecasting methods to predict market conditions and adopt evidence-based policies. Accurate predictions allow the government to develop the right trade policy, increase market efficiency, etc. Private investors, dairy processors, and exporters rely on forecasting models to plan production, manage stocks, make investments, and formulate risk management strategies. Consequently, accurate forecasting has become a critical part of agricultural economics and international trade studies (Box et al., 2016; Chatfield, 2000).

The time-series econometric approach serves as a suitable tool in analyzing past trade patterns and making forecasts. While descriptive analysis only explains observable patterns of economic variables, econometric models consider the statistical properties of economic variables and allow researchers to detect long-run tendencies, cycles, and future direction. To forecast, it is necessary first to examine the statistical features of the data. Economic time series are usually characterized by non-stationary behavior due to the presence of a trend and structural breaks. Model estimation based on non-stationary data may yield results that are incorrect from both practical and statistical perspectives. This is why testing for stationarity is an essential step to undertake before conducting time series analysis. With the order of integration determined, it will become possible to develop models for making accurate forecasts regarding future trade performance (Hyndman and Athanasopoulos, 2014).

Forecasting models include ARIMA, which has long been used for analyzing agricultural and economic time series. The method has proved its forecasting capabilities in a variety of applications involving prices, agricultural output, exports, imports, inflation, exchange rates, and food. The model's versatility in handling autoregressive processes, trends, and disturbances makes it useful for modeling historical trade data that depend on time. Additionally, the ARIMA approach enables forecasters to develop short- and medium-term forecasts using historical data, since the approach does not require any external explanatory variables. This makes ARIMA very useful in instances where the explanatory variables are absent or hard to collect for long time periods (Box et al., 2015).

While many past studies have examined various factors relating to Pakistan's livestock industry such as milk production, dairy farming systems, value chain, productivity, and marketing problems (Cain et al., 2007; Godfrey et al., 2019; Ziad et al., 2019), little work has been done on understanding the temporal dynamics of the dairy trade utilizing the latest time series econometric approaches. Previous studies have largely focused on performance, consumption, or efficiency issues, while the analysis of the exporting and importing trends of specific dairy products has received little focus. In addition, very few studies have analyzed butter, ghee, and raw milk over a historical period of more than 60 years, along with forecasting methods that can provide evidence for future trade planning. Lack of such empirical evidence makes it difficult for policymakers to devise a strategy for exporting these commodities internationally.

To fill this gap, the current study analyzes the historical pattern of exports and imports of three prominent dairy products: butter, ghee, and raw milk in Pakistan from 1961 to 2024. In particular, the current study analyzes the historical trends in the trading of these dairy products, analyzes the stationarity nature of these trade series by employing the Augmented Dickey-Fuller (ADF) unit root test (Dickey and Fuller, 1979), and uses the ARIMA model to forecast future dairy product trade trends for the years 2025 to 2034. By analyzing over six decades of historical observations, this study gives an extensive analysis of the history of dairy trade in Pakistan. By offering empirical data on Pakistan's dairy industry, this study is anticipated to advance the field of agricultural trade forecasting significantly. These findings may be very helpful to policymakers as they develop strategies to boost the industry's export performance, boost market efficiency, and encourage investments in the nation's dairy-related infrastructure. Additionally, researchers, exporters, and others engaged in the expansion and advancement of the sector in Pakistan may find the study useful.

METHODLOGY

Research Design and Data

The proposed study design measures the historical performance of Pakistan's dairy business and forecasts future trends using a quantitative research approach with secondary time-series data. The Food and Agriculture Organization (FAO) of the United Nations provided annual data collected between 1961 and 2024 (64 observations) as secondary data for the study. The independent variables studied are annual exports and imports (US$) of the following important dairy items: butter, ghee (butter oil), and raw milk. Data compilation, statistical analysis, model estimation, and forecasting were carried out using EViews 14 software.

Augmented Dickey–Fuller (ADF) Unit Root Test

Since most economic time-series data exhibit trends and non-stationary behaviour, testing for stationarity is an essential prerequisite before estimating forecasting models. Non-stationary variables may produce spurious statistical relationships and unreliable forecasts. Therefore, the stationarity properties of all variables were examined using the Augmented Dickey–Fuller (ADF) unit root test.

The ADF regression equation is expressed as:

$$[\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta Y_{t-i} + \varepsilon_t] \quad (1)$$

where:

(Y_t) denotes the variable under investigation;

(\Delta) represents the first-difference operator;

(\alpha) is the intercept;

(\beta) denotes the deterministic time trend;

(\gamma) is the coefficient of the lagged level of the variable;

(k) represents the optimal lag length; and

(\varepsilon_t) is the white-noise error term.

The null hypothesis (H_0) states that the series contains a unit root and is therefore non-stationary, whereas the alternative hypothesis (H_1) indicates that the series is stationary. The calculated ADF statistics were compared with the MacKinnon (1996) critical values at the 1%, 5%, and 10% significance levels. Variables found to be non-stationary at level were differenced until stationarity was achieved.

ARIMA Forecasting Model

Following the stationarity analysis, the Autoregressive Integrated Moving Average (ARIMA) model developed by Box and Jenkins (1976) was employed to forecast Pakistan's dairy trade for the period 2025–2034. ARIMA is widely used in economic and agricultural forecasting because it effectively captures temporal dependence using only historical observations.

The general ARIMA ((p,d,q)) model consists of three components:

AR (p): the autoregressive component, representing the relationship between the current value and its lagged values;

I (d): the integrated component, representing the number of differences required to achieve stationarity; and

MA (q): the moving average component, representing the relationship between the current value and previous random shocks.

The general ARIMA model can be written as:

$$Yt=c+\phi 1Yt-1+\phi 2Yt-2+\cdots+\phi pYt-p+\varepsilon t+\theta 1\varepsilon t-1+\theta 2\varepsilon t-2+\cdots+\theta q \varepsilon t-q \quad (2)$$

Where:

Y_t = observed value of the time series at time ttt;

c= constant term;

$\phi_1,\phi_2,\ldots,\phi_p$ = autoregressive (AR) coefficients;

$\theta_1,\theta_2,\ldots,\theta_q$ = moving average (MA) coefficients;

p = order of the autoregressive process;

d = order of differencing required to achieve stationarity;

q = order of the moving average process; and

ε_t = white-noise error term.

In this study, the order of differencing (d) was determined based on the results of the Augmented Dickey–Fuller (ADF) unit root test, while the optimal values of the autoregressive (p) and moving average (q) components were selected by comparing alternative model specifications using the Akaike Information Criterion (AIC). An ARIMA model was estimated separately for both the export and import of butter, ghee, and raw milk series. The best-fitted model was selected based on the lowest AIC score with adequate residual diagnostics for forecasting the future trend in dairy exports and imports during 2025–2034.

3.4 Model Diagnostic Checking and Forecasting

A few tests were conducted after choosing the appropriate ARIMA model to assess its adequacy. The tests conducted involved the Ljung-Box Q test and the residual correlograms (ACF and PACF), which were meant to test the autocorrelation of the residuals. Residuals in a correctly specified ARIMA model must exhibit the qualities of white noise, meaning there is no more systematic information left in the residuals.

Having carried out the tests on the model and found that the chosen models were adequate, the models were used to make annual predictions of the dairy exports and butter, ghee, and raw milk imports for Pakistan for the period 2025 to 2034. The findings of the forecast will enable us to know the future trend of the Pakistani dairy trade.

RESULT AND DISCUSSION

This part provides the empirical results of the study and explains the results in the context of the research objectives. The first step in the analysis involves studying the historical trends and variations in the export/import of important dairy products such as butter, ghee, and raw milk during the period from 1961 to 2024. The stationarity of the time series data is examined through the Augmented Dickey-Fuller (ADF) unit root test to find the order of integration of each series. After that, the ARIMA model is estimated to forecast the dairy trade from 2025 to 2034. These results will help in comprehending the past trends and future path of the dairy trade in Pakistan. Decision makers and researchers can use the results to make better decisions regarding Pakistan's dairy trade.

Historical Trade Trends

This section is all about the analysis of the trends that exist in Pakistan’s dairy business. This has been done by analyzing trends in the import/export of butter, ghee, and raw milk from 1961 to 2024. The analysis provides an overview of the trends in Pakistan’s dairy business. The trend can be seen visually through Figures 1- 3.

Butter Import and Export Trends

The trend in Pakistan’s butter imports and exports from 1961 to 2024 is displayed in Figure 1 below. Figure 1 shows that there were significant changes in imports and exports over the years, even though the imports were always higher than the exports during almost all periods. Imports were fairly stable during the initial decades with slight variations each year until the late 1990s. There was a sharp rise in imports after the early 2000s due to increased import demand. Imports were at their highest point during the late 2010s before showing slight variation later on. Although there have been fluctuations in the trend, imports were still on a consistent upward trend, which means that imported butter is becoming increasingly important in Pakistan's dairy trade. Exports of butter were insignificant for several decades, and there was only some action in the first few years of this study period. Export performance started improving gradually after 2005, and there has been a noticeable rise in the last decade. Maximum exports were seen in 2024.

Comparing the two trade series shows a consistent butter trade deficit throughout the research period. The widening gap between imports and exports in years when demand for imports increases clearly shows Pakistan's dependence on butter imports. Still, the growing trend in export performance in recent years indicates a shift in the country's involvement in the international butter business. Overall, Figure 1 shows that Pakistan's butter trade has shifted from a stable, low-volume trade to a dynamic one with growing imports and improving exports.

Ghee Import and Export Trends

Figure 2 illustrates the historical pattern of Pakistan's ghee imports and exports from 1961 to 2024. Among all the dairy products included in this study, ghee recorded the strongest export growth over the study period, whereas imports remained

comparatively low throughout most years. In the early decades, Pakistan's ghee exports were very low. Improvement started after 2001, when Pakistan's export earnings increased. These export earnings increased from around USD 89 thousand in 2001 to around USD 2.3 million in 2011. The upward trend continued in the coming years, and export earnings reached around USD 7.1 million in 2016. Finally, in 2024, Pakistan earned around USD 8.11 million through ghee exports. This upward trend in export profits indicates that Pakistan has improved its standing in the global ghee market.

Ghee imports, on the other hand, showed only slight fluctuations and were quite modest throughout the study period. There was no discernible growth in imports over the period under study, which suggests that local production continued to satisfy most local demand, in contrast to the trajectory of exports.

The different trends of imports and exports show a positive trend in the case of ghee relative to the other dairy products that were considered. While imports showed stability, exports showed steady growth, and as a result, Pakistan's export performance improved over the years. In general, Figure 2 shows that ghee has become increasingly important as one of Pakistan's value-added dairy export products. The fact that this pattern was observed over time gives us a very strong indication of export growth, which will be very useful for our further forecasting study.

Table 1 gives a comparative account of the characteristics of the ghee export industry of both countries in 2024. The level of industry development, the amount of export income, the diversity of products exported, the level of processing capacity, and the competitive advantage are quite different between Pakistan and India's ghee export industries. Pakistan is at the stage of developing its ghee export industry, while India has already established itself in the international market. In the year 2024, Pakistan exported ghee worth around USD 8.11 million, whereas India exported ghee worth more than USD 160 million.

The second difference is the variety of goods supplied by both countries. While India exports buffalo ghee, cow ghee, organic ghee, flavored ghee, and other forms of ghee, Pakistan mostly sells desi ghee. India can target different audiences and respond more quickly to changes in the market thanks to this product diversity. Additionally, there are differences in the methods used to collect milk and produce dairy products. Even though Pakistani milk processing has improved, further chain integration is still required. India, on the other hand, has an efficient system for collecting and processing milk, which leads to better product quality, efficient manufacturing, and consistent export supply. When it comes to export markets, it is clear that the nation wishes to sell its ghee to halal and ethnic customers in the USA, the UK, and the GCC. But ghee is also exported from India to other countries.

The analysis shows that both countries have a competitive advantage. While India has an edge over Pakistan in large-scale manufacturing, product diversity, processing technology, and an international distribution network, Pakistan's competitive advantages include low production costs and strong demand for halal food items. In conclusion, the results point to Pakistan's potential for ghee exports. Modernizing processing facilities, broadening the range of export goods, improving supply chain effectiveness, and expanding market access could increase the country's competitiveness and contribute to the long-term expansion of the ghee trade internationally.

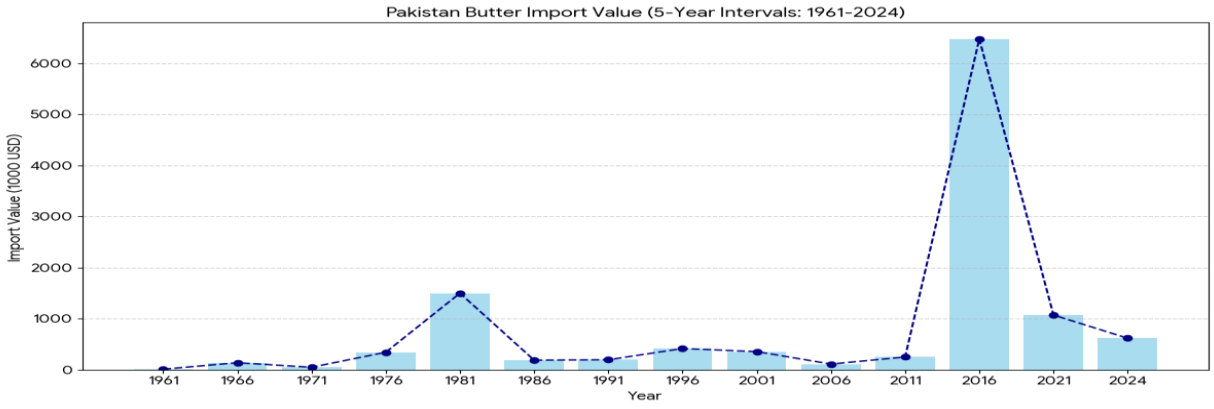

Figure 1. Historical Trends in Butter Imports and Exports in Pakistan, 1961–2024.

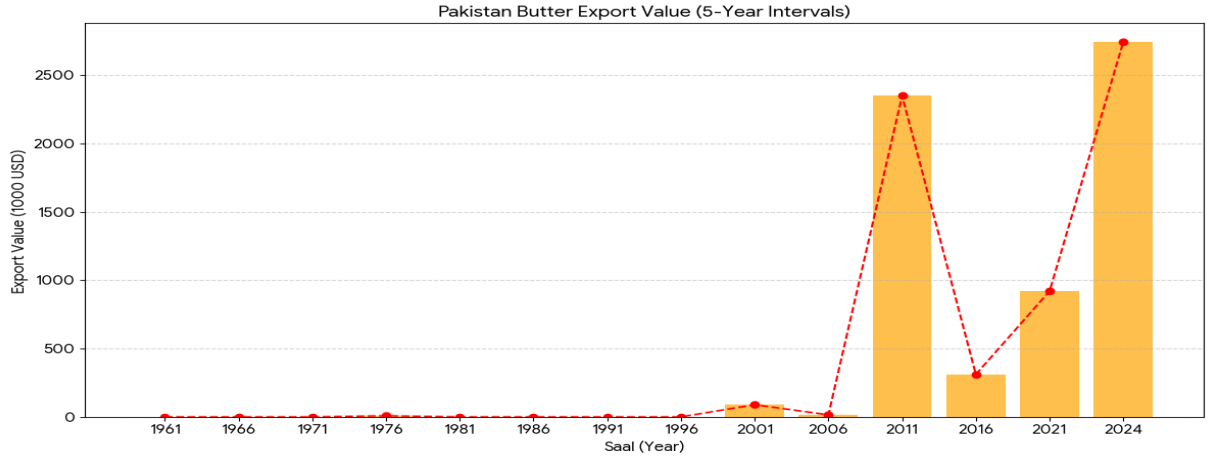

Figure 2. Historical Trends in Ghee Imports and Exports in Pakistan, 1961–2024.

Table 1. Comparative characteristics of the Ghee export industry in Pakistan and India (2024).

Characteristic	Pakistan	India
Industry development	Emerging export sector	Well-established global export industry
Ghee export value (2024)	USD 8.11 million	Over USD 160 million
Product portfolio	Primarily traditional (Desi) ghee	Diversified products including buffalo, cow, organic, and flavored ghee
Milk collection and processing	Developing processing infrastructure	Extensive integrated milk collection and processing network
Major export markets	Ethnic and halal markets (GCC, UK, USA)	Global wholesale and retail markets
Competitive strengths	Lower production costs and halal-certified products	Large-scale production, diversified products, and established international distribution networks

Raw Milk Import and Export Trends

Figure 3 presents historical data on the trends in raw milk imports and exports in Pakistan for the period 1961-2024. One can see specific tendencies in Pakistan's raw milk trade, showing slow changes in the development of import/export activity over more than sixty years. Raw milk imports in Pakistan were relatively low and constant from 1961 to the late 1990s, with no significant changes in year-to-year dynamics. However, imports increased in the early 2000s; after that, a stronger upward trend continued from 2005. The highest value of imports occurred in 2016, after which imports decreased until 2024.

On the other hand, raw milk exports were quite insignificant for most of the period under consideration owing to Pakistan's poor involvement in global raw milk trade. Export performance improved after 2011, and export values increased continuously in subsequent years until the end of the time series analysis. The maximum export value was observed in 2024, though the export values were still well below the import values. The comparison of the import series and the export series shows that import values have always exceeded the export values. The gap between the two series has widened during periods of high import growth and has narrowed in recent years. Overall, Figure 3 shows the gradual evolution of Pakistan's trade in fresh milk. On the one hand, imports increased rapidly and later stabilized; on the other hand, exports grew steadily in the second half of the observation period.

Stationarity Analysis: Augmented Dickey–Fuller (ADF) Unit Root Test

Before estimating ARIMA models, the stationary features of the dairy trade series were tested by applying the Augmented Dickey-Fuller (ADF) unit root test. The importance of testing stationarity lies in the fact that a stationary process is one of the basic preconditions for modeling a time series using the ARIMA model, because otherwise the time series might provide incorrect parameter estimates and forecasts. Thus, the Augmented Dickey-Fuller test was used to establish the order of integration and degree of differencing for each variable.

Based on the results of the Augmented Dickey–Fuller test shown in Table 2, the six series related to dairy trade are found to be integrated at various levels. Of these, the three series Raw Milk Import, Ghee Export, and Butter Import are stationary at their levels, which means they are integrated of order zero [I(0)]. However, for instance, Raw Milk Export and Butter Export are non-stationary at the level but become stationary after the first differentiation, indicating that they are of I(1). The implication is that the data will need to be differentiated to be stationary. It can be observed that among all the variables examined, Ghee Import is the variable that exhibits maximum persistence. It is observed that even after the first differentiation, it is not stationary, but only after the second differentiation, indicating that it is of I(2).

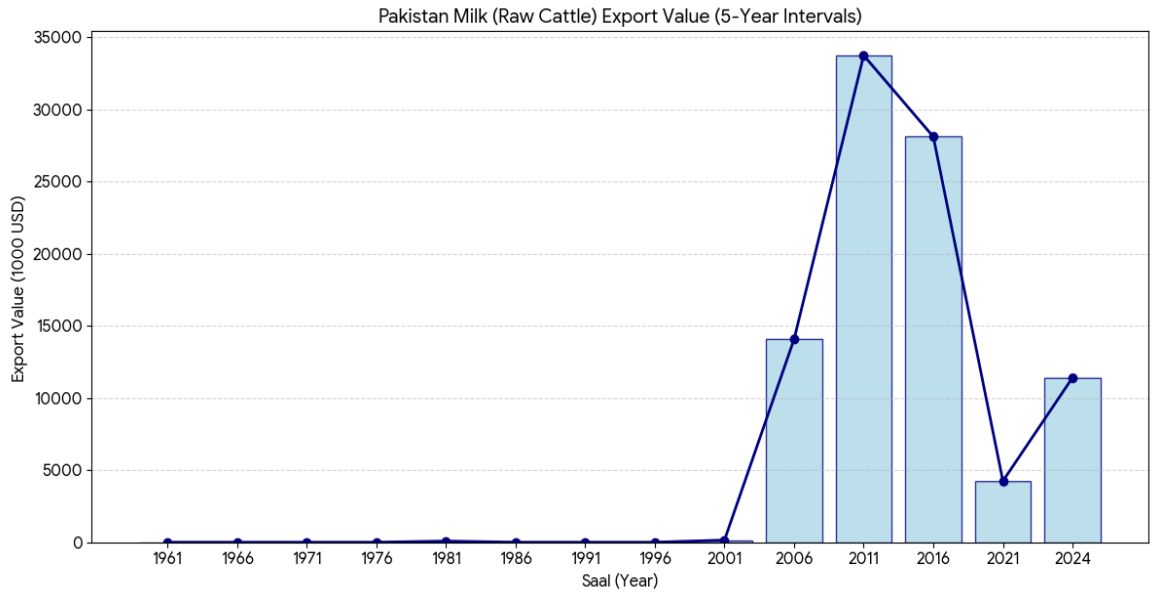

Figure 3. Trends in the Imports and Exports of Raw Milk in Pakistan from 1961-2024.

In general, the empirical results indicate that the series of dairy trade variables of Pakistan have mixed orders of integration which vary between I(0) and I(2). Mixed order of integration implies that individual stochastic processes need to be applied to each ARIMA series, since there is no general process that can be used to model all series. As such, the value of d was specified for each ARIMA based on the stationarity test results as provided in Table 2.

The estimated ARIMA models have clearly brought out the difference in dynamics of the Pakistan dairy trade variables (Table 3). The criterion used in model selection involved the use of the Augmented Dickey-Fuller (ADF) unit root test to establish the stationarity properties and hence the most suitable representation of the series by the data generating process. An ARIMA(1,1,1) model proved to be a good fit for butter exports, where both the autoregressive and moving average coefficients were significant. A negative autoregressive coefficient means that short-term disturbances from previous periods tend to decay in the long run, while a positive moving average coefficient implies that random shocks persist in the export series for future periods. All the estimated parameters suggest that butter exports are both mean-reverting and persistent in nature.

Butter imports, on the other hand, have been modeled using ARIMA(1,1,1). The positive autoregressive coefficient means that current import values are positively related to the previous period. Although the moving average coefficient has a fairly high value, its interpretation must be made in the context of the entire model and not independently. The raw milk imports and exports have been modeled using ARIMA(1,0,0). In both cases, positive autoregressive parameters mean the presence of persistence in time, meaning that current trade values depend on past observations. With respect to their autoregressive coefficients, raw milk exports demonstrate a higher level of persistence than imports, as the autoregressive coefficient of exports is larger than that of imports.

Ghee imports and exports had the best fit to the ARIMA(3,0,0) model, which means that these series' values are affected by several past periods' information. Positive autoregressive parameters demonstrate a relatively high level of persistence in imports and exports. Out of the whole set of models estimated, ghee imports and exports yielded the highest values of the adjusted R^2, demonstrating the best statistical fit to the data compared to other dairy trade variables. The diagnostic statistics also further confirm the appropriateness of the estimated models. Durbin-Watson statistics lie between 1.787 and 2.145, indicating that there is no significant first-order serial correlation in the model residuals. From the above diagnostic analysis, it can be said that the selected ARIMA models appropriately account for the behavior of the dairy trade series in history.

Forecast Results (2025–2034)

Using the estimated ARIMA models, forecasts have been made to assess the probable path that Pakistan's dairy trade will take between 2025 and 2034. These forecasts are based on the assumption that the trends observed during model estimation will continue in the forecast period. This provides information about how some of the important dairy imports and exports of Pakistan might behave in the future. From the forecast results obtained, it is clear that there are promising signs regarding Pakistan's future dairy exports. Butter exports are forecast to grow gradually during the forecast period due to stable export performance. Butter imports are also forecast to grow gradually but at a slow pace.

Similarly, it is projected that there will be a continued upward trend in the volume of raw milk exports in the coming years, indicating the possibility of further expansion in international markets. However, the volume of raw milk imports is expected to remain stable, with only slight variations, implying balanced domestic availability of the product. Compared with other dairy products studied, the highest growth in exports of the commodity is expected for ghee. The increasing trend implies a rising international demand for the product and its export potential. On the contrary, ghee imports are likely to remain low and stable, as domestic production capacity is expected to meet domestic demand in the future.

On the whole, the forecast results indicate that Pakistan’s dairy industry is likely to witness a continuous improvement in its export performance during the forecast period of 2025-2034. On the other hand, imports would continue at a steady pace. Value-added products like ghee are expected to account for the majority of the rise in exports, demonstrating the industry's capacity to generate foreign cash and support economic growth. For legislators and other dairy sector stakeholders, the study's findings are highly consequential.

Table 2. Results of the Augmented Dickey-Fuller (ADF) unit root test for dairy trade variables.

Variable	At Level	First Difference	Second Difference	Order of Integration
Raw Milk Import	Stationary	–	–	I(0)
Raw Milk Export	Non-stationary	Stationary	–	I(1)
Ghee Import	Non-stationary	Non-stationary	Stationary	I(2)
Ghee Export	Stationary	–	–	I(0)
Butter Import	Stationary	–	–	I(0)
Butter Export	Non-stationary	Stationary	–	I(1)

Note: Stationarity of the series is confirmed using the Augmented Dickey–Fuller (ADF) test for unit roots. The notation I(0), I(1), and I(2) indicates that the series is stationary at levels, first difference, and second difference, respectively.

Table 3. Estimated ARIMA models and their diagnostics for Pakistan's dairy trade variables.

Variable	Selected Model	AR Coefficient	MA Coefficient	Adjusted R^2	Durbin–Watson Statistic	Prob (F-statistic)
Butter Export	ARIMA (1,1,1)	-0.439*	0.907*	0.170	2.145	0.003
Butter Import	ARIMA (1,1,1)	0.680*	-1.000	0.114	1.960	0.019
Raw Milk Import	ARIMA (1,0,0)	0.255*	–	0.035	2.012	0.126
Raw Milk Export	ARIMA (1,0,0)	0.707*	–	0.462	1.958	0.000
Ghee Export	ARIMA (3,0,0)	1.326*	–	0.544	1.996	0.000
Ghee Import	ARIMA (3,0,0)	0.887*	–	0.548	1.787	0.000

Note: * indicates significance at 5 percent level of significance. AR=Autoregressive Coefficient; MA=Moving Average Coefficient; Adjusted R^2=Adjusted coefficient of determination; DW=Durbin Watson Statistic.

CONCLUSIONS

Using ADF and ARIMA models, this study looked at Pakistan's dairy export trends for butter, ghee, and raw milk from 1961 to 2024. Despite being one of the world's top milk producers, Pakistan has not fully capitalized on its export potential because of challenges with quality compliance, low value addition, inadequate cold chains, and insufficient processing capacity. Stationarity tests supported the use of distinct ARIMA models for forecasting, revealing different integration orders among commodities. Forecasts indicate a favorable export outlook for the next ten years, with ghee showing the biggest increase and butter and raw milk rising gradually. It is anticipated that imports will stay steady, indicating that local demand can be satisfied by domestic supply while exports increase. Pakistan does fairly well in several items when compared to its neighbors, but it trails behind India in global value chain integration, processing, and diversification. Targeted improvements in processing, quality control, infrastructure, and market access are crucial to realizing this potential; these initiatives would increase the dairy industry's competitiveness, earnings, and employment.

Several crucial steps are required to develop Pakistan's dairy industry and increase exports. Modern collection systems, cold chains, and processing facilities should be upgraded first to reduce losses and meet export regulations. Increasing food safety through ISO and HACCP certifications would help increase confidence outside. Farmers and processors would be able to invest in improved breeds, technology, and packaging if credit were easier to obtain. To improve logistics and quality control, the government should focus on promoting value-added products through market diversification, export facilitation, and digital tools like AI and IoT. To promote innovation in production, disease management, processing, and shelf-life extension, stronger cooperation between academic institutions, research organizations, and business is equally essential. When combined, these actions can increase output, add value, and strengthen Pakistan's position as a leader in the international dairy market.

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