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Determinants of Milk Import Substitution in Eswatini

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ABSTRACT

Eswatini continues to face persistent dairy import dependency despite high per capita consumption and successive government policy commitments to achieve self-sufficiency. This study investigated the determinants of milk import substitution in Eswatini from 1981 to 2023 using annual time series data sourced from the Eswatini Dairy Board (EDB), the World Bank, and the International Monetary Fund (IMF). The milk import substitution ratio (IR) was constructed using the absolute measure of import substitution, calculated as the difference between import availability ratios over time: $R = (M_0/S_0) - (M_1/S_1)$, where M represents imports and S represents total supply (domestic production plus imports). A positive IR indicates that domestic production is displacing imports (import substitution is occurring), while a negative IR indicates that imports are growing faster than domestic production's ability to displace them (import dependency is increasing). A higher IR value indicates greater import substitution, with positive values signifying successful substitution. The analysis employed the Augmented Dickey-Fuller (ADF) unit root test and the Autoregressive Distributed Lag (ARDL) Bounds Testing approach with an Error Correction Model (ECM). ADF tests confirmed mixed integration orders (I(0) and I(1)), validating the ARDL framework. The Bounds test established a robust long-run relationship at the 5% significance level (F-statistic = 61.31627; 5% upper bound = 4.923). The estimated Error Correction Term (ECT = -1.1238) confirmed oscillatory but stable convergence to long-run equilibrium. In the long run, a 1% increase in domestic milk production (INDM) improved the import substitution ratio by 0.00196 points, while a 1% increase in milk imports (INMI) reduced the substitution ratio by 0.00198 points. The structural break in 1995 showed a negative coefficient (-0.0748), suggesting a possible decline in the substitution ratio, though this was not statistically significant (p = 0.2713). Similarly, the negative time trend (-0.0006 points per year) was not statistically significant (p = 0.7398). Real GDP, population growth rate, and the real effective exchange rate were not statistically significant long-run determinants at the 5% level. In the short run, changes in population growth had significant effects: current changes negatively influenced the ratio, while lagged changes positively influenced it. The overall Import Substitution Ratio averaged approximately -0.75, confirming persistent structural dependency. This is the first study to construct and analyze the milk import substitution ratio in Eswatini over the 1981-2023 period, providing a unique contribution to understanding dairy policy effectiveness and import substitution dynamics. Recommendations include strengthening domestic production capacity through targeted subsidies and veterinary extension services, implementing strategic import management mechanisms including variable tariffs and domestic supply buffers, and investing in dairy value chain infrastructure to reduce post-harvest losses.

KEYWORDS: *Milk Imports, Augmented Dickey-Fuller, Long and Short-run Dynamics, Bounds Cointegration, Error Correction Term, Autoregressive Distributed Lag Model, Dynamic Ordinary Least Squares.*

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1. Introduction

Eswatini is a small, landlocked country in Southern Africa, bordered by South Africa to the west and north, and Mozambique to the east (Dlamini-Mazibuko, 2020; FAO, 2022). Approximately 70% of

Emaswati rely on agriculture for food and income (Mabaso & Tfwala, 2022; IFAD, 2022). While agriculture contributed 8.93% to Eswatini's Gross Domestic Product (GDP) in 2021, this is relatively low compared to 31.94% from the industrial sector and 51.54% from the services sector (O'Neill, 2022). However, despite its small share of the country's GDP, agriculture remains pivotal for poverty alleviation and food security among smallholder farmers (Dlamini-Mazibuko, 2020).

The dairy industry is a key subsector of agriculture, as it generates income and employment for small and medium-sized farmers in Eswatini. The Eswatini Dairy Board (EDB) regulates the industry as a statutory government agent and public enterprise wholly owned by the Eswatini Government. The Board supports government efforts by providing a supportive socioeconomic environment to develop a sustainable dairy industry. This development aims to reduce reliance on imported milk and dairy products, thereby enhancing food security, minimizing poverty, promoting investment, creating jobs, and encouraging exports. The goal is to achieve self-sufficiency in milk supply and dairy products, and eventually export surpluses (EDB, 2020a).

Emaswati have traditionally consumed substantial quantities of milk and milk products such as Ultra High Temperature (UHT) milk, yoghurt, cheese, Emasi (sour milk), fresh milk, and dairy juices. With an average annual dairy consumption of 90 liters per capita, Eswatini ranks among the African countries with high per capita milk consumption. This high demand represents a promising investment opportunity for local milk producers. However, despite this high consumption, the country remains a net importer of dairy products (EDB, 2020a).

The government has introduced policies and strategic plans intended to reduce dairy imports and promote self-sufficiency, including the National Development Plan (2018/19-2022/23), Agriculture Strategic Plan (2018-2023), and Eswatini Strategic Road Map (2019-2022). These initiatives focus on increasing agricultural production, improving marketing, and adding value in the agricultural sector to achieve food and nutrition security through import substitution (EDB, 2020b; Singh et al., 2020). Nonetheless, domestic production has consistently failed to meet demand, forcing reliance on imports (IFAD, 2022). The ability of domestic production to displace imports, measured as the import substitution ratio, remains a critical indicator of policy effectiveness and sector transformation.

1.2 Problem Statement

Dairy production is an important agricultural activity contributing to Eswatini's economy and food security. Despite a high per capita dairy consumption rate (approximately 90 litres per annum), Eswatini still remains self-insufficient in dairy production. The country imports over 80% of its consumed dairy products, mainly from South Africa. For example, in 2020, domestic production was 20.68 million litres (liquid milk equivalent), valued at E175.78 million, while national demand reached 88.44 million litres (EDB, 2020a). The shortfall was met by importing 66.76 million litres of dairy products worth E499.10 million (EDB, 2020a; FAO, 2022).

The persistent gap between domestic milk production and consumption highlights the need for research focused on understanding the determinants of milk import substitution in Eswatini. The milk import substitution ratio, calculated as the difference between import availability ratios over time, captures the extent to which domestic production displaces imports. A positive ratio indicates that domestic production is displacing imports (import substitution is occurring), while a negative ratio indicates that imports are growing faster than domestic production's ability to displace them, signaling policy ineffectiveness and structural dependency. This ratio serves as a direct measure of the success or failure of import substitution policies and provides insights into the structural transformation of the dairy sector.

While previous studies have examined the determinants of milk import volumes, there remains a gap in understanding the factors that enable domestic production to effectively displace imports. The import substitution ratio offers a more comprehensive assessment of dairy sector performance because it accounts for both domestic production growth and changes in import demand. A negative import substitution ratio indicates that imports are growing faster than domestic production's ability to displace them, signaling policy ineffectiveness and structural dependency.

Understanding the determinants of the import substitution ratio is crucial for policymakers because it identifies whether observed increases in domestic production are actually reducing import reliance or merely coinciding with even faster import growth. This study aimed to identify the key factors

influencing the milk import substitution ratio, providing empirical evidence to inform policies aimed at reducing import dependency and achieving self-sufficiency.

1.3 Objective of the Study

The specific objective of this study is to identify the determinants of milk import substitution in Eswatini.

1.4 Research Hypothesis

H_0: Domestic milk production, milk imports, real gross domestic product, population growth rate, and real effective exchange rate have no significant impact on milk import substitution in Eswatini.

H_1: At least one of the factors (domestic milk production, milk imports, real gross domestic product, population growth rate, and real effective exchange rate) has a significant impact on milk import substitution in Eswatini.

1.5 Significance of the Study

This study aimed to identify key determinants affecting milk import substitution, providing insight for the review and formulation of policies to reduce import reliance. The findings will guide policymakers, the Eswatini Dairy Board, and stakeholders in enhancing domestic milk production, supporting export growth, and improving food security. A better understanding of import substitution determinants may also inform agricultural pricing policies and help allocate government resources efficiently. This will reduce the government import bill, thus promoting investment in other public sectors for economic growth and development. Furthermore, this study will fill information gaps on milk import substitution dynamics and serve as a benchmark for future agricultural import substitution research in Eswatini.

2. Literature Review

While earlier studies have examined determinants of import volumes in Eswatini, the current study focuses specifically on import substitution capacity, a distinct but complementary research question. Import substitution, measured as the ratio of domestic production displacement of imports, captures the effectiveness of policy interventions aimed at achieving self-sufficiency. This study contributes to the literature by shifting the analytical focus from import demand to import substitution dynamics, providing empirical evidence on the factors that enable domestic production to replace imported dairy products.

2.1 Theoretical Framework

This study adopts a multi-layered theoretical framework to identify the determinants of milk import substitution in Eswatini. The framework integrates the Heckscher-Ohlin Model to explain structural import dependency, Import Substitution Industrialization Theory to frame the policy context, the Theory of Imperfect Substitution to capture product differentiation, and supporting theories to justify each variable included in the empirical model.

2.1.1 Heckscher-Ohlin Model

Originally developed by Heckscher (1919) and Ohlin (1933), later augmented by Samuelson (1949 and 1953), the Heckscher-Ohlin model explains international trade based on countries' relative factor endowments—land, labour, and capital (Kopp, 2022). According to this equilibrium trade theory, country exports goods that intensively use relatively abundant factors and imports goods that use scarcer factors. The assumptions include differing factor availability across countries, similar production technologies, and similar consumer preferences globally.

In the context of Eswatini, the H-O model provides a foundational explanation for the country's persistent dairy import dependency. Efficient large-scale dairy production requires significant capital (for infrastructure, milking machines, cooling tanks, and processing facilities) and suitable land for grazing and fodder production. These factors are relatively scarce in Eswatini compared to South Africa, which possesses a more capital-intensive, technologically advanced, and scale-efficient dairy industry. Consequently, the H-O model predicts that Eswatini will import dairy products, particularly processed and value-added products, because these goods require capital and technology that are relatively scarce domestically. This structural scarcity directly translates into a low import substitution ratio, as domestic production cannot easily replace imported products.

2.1.2 Import Substitution Industrialization Theory

Import Substitution Industrialization (ISI) theory advocates protecting and developing domestic industries in developing countries through protective tariffs, quotas, and exchange rate management to reduce import reliance (Segal, 2019). Achieving dairy self-sufficiency aligns with ISI principles by fostering domestic milk production to replace imports. However, practical implementation requires addressing import risks, pricing policies, and investment in technology and human capital (Vorotnikov et al., 2018; Nassyrova et al., 2019).

In the context of milk import substitution, ISI theory predicts that policies aimed at expanding domestic production capacity, improving productivity, and enhancing competitiveness should lead to a reduction in the import-to-consumption ratio—i.e., an improvement in the import substitution ratio. The effectiveness of such policies depends on the responsiveness of domestic supply to price and policy incentives, as well as the substitutability between domestic and imported dairy products. The import substitution ratio directly measures the success or failure of these policies by tracking the extent to which domestic production displaces imports over time.

2.1.3 Theory of Imperfect Substitution

The theory of imperfect substitution posits that domestic and imported dairy products are imperfect substitutes, which significantly influences consumer preferences and demand elasticity (Armington, 1969). The imperfect substitutability implies that completely replacing imports with domestic products poses challenges for import substitution policies. In Eswatini, this is evident in products like UHT milk, cheese, and yoghurt where imports often dominate due to perceived quality or taste preferences, despite local availability of fresh milk or emasi (sour milk).

Consequently, policy interventions should aim to accommodate diverse consumer preferences while simultaneously promoting local production. Such an approach would gradually reduce import dependency without disrupting market stability (Priest & Campos, 2002; Besanko et al., 2013). In this study, the theory justifies modeling domestic milk production and milk imports as distinct variables in the import substitution equation, with the real effective exchange rate capturing the relative price incentives for substitution.

2.1.4 Neoclassical Growth Theory

The neoclassical growth theory (Solow-Swan model) posits that economic growth results from labour, capital, and technological progress (Bandton, 2020). Technological advances enhance productivity and output, critical for the development of sectors like dairy farming. This theory suggests that Eswatini's dairy sector growth depends on technological adoption, capital accumulation, and labour efficiency. The theory justifies the inclusion of real GDP as a determinant of import substitution, as economic growth may facilitate investment in domestic dairy capacity, thereby improving the ability of domestic production to displace imports.

2.1.5 Consumer Demand Theory

Demand theory explores how consumer preferences and incomes affect market demand for goods and services (Hayes, 2020). Income elasticity of demand is crucial in dairy import substitution, as rising incomes may increase consumption either of domestic or imported dairy products, depending on substitutability and prices. Population growth acts as a direct shifter of the aggregate demand curve, explaining the inclusion of population growth as a determinant of import substitution. The impact of population growth on import substitution depends on whether domestic supply growth can keep pace with demand increases.

2.2 Empirical Review

2.2.1 Domestic Milk Production and Import Substitution

Empirical studies consistently demonstrate that domestic milk production is a key determinant of import substitution. The International Dairy Federation (IDF) reported a strong inverse correlation of -0.78 between self-sufficiency and import levels (IDF, 2018). The Food and Agricultural Organization (FAO) documented a similar correlation of -0.69 (FAO, 2018). The United States Department of Agriculture (USDA) established that a 1% increase in domestic production reduces imports by 0.74% (USDA, 2019). The European Commission observed a 0.53% import decrease for every 1% production gain (European Commission, 2020). These findings collectively support the view that expanding domestic production directly improves import substitution by displacing imported products. However, in developing economies or rapidly expanding sectors, increased domestic production can stimulate demand for complementary imported inputs (e.g., specialized milk powders for processing, advanced dairy equipment) or cater to a diversified consumer base that simultaneously demands a wider range of imported finished products (Amiti & Konings, 2007). This aligns with more recent World Bank-supported evidence, which demonstrates that as domestic dairy systems intensify, domestic production and trade frequently grow together because imports often complement, rather than substitute, local production (Beliyou & Musco, 2025). In the context of import substitution, this suggests that the relationship between domestic production and import substitution may be more complex in developing economies.

2.2.2 Milk Imports and Import Substitution

Milk imports represent the volume of milk and milk products brought into a country from other countries. These imports include butter, cheese, skim milk powder, and whole milk powder. Only about 7% of world milk production is traded internationally due to milk's perishability and high water content (over 85%). Fermented milk products see limited trade between neighboring dairy producers. Liquid milk trade relies on Ultra-High Temperature (UHT) processing, which enables long-distance shipping (OECD, 2022).

The relationship between milk imports and import substitution is inherently inverse: higher import volumes directly reduce the substitution ratio because imported milk displaces domestic production in meeting consumer demand. Studies by Kibirige et al. (2022) in Eswatini on maize import substitution found that import levels are a direct drag on substitution ratios. The theory of imperfect substitution (Armington, 1969) supports this relationship by arguing that imported products often dominate specialized categories due to consumer preferences and processing deficits. Therefore, reducing import volumes is a direct pathway to improving the import substitution ratio.

2.2.3 Population Growth and Import Substitution

Population, defined as individuals sharing resources within a defined area (Tarsi & Tuf, 2012), exhibits annual growth measurable as a percentage increase in residents (Gajar, 2017). From a demand perspective, population growth generally leads to increased consumption of food and other goods, often translating to higher import demand if domestic supply cannot keep pace (Godfray et al., 2010). This implies a negative relationship between population growth and import substitution, as faster population growth increases demand pressure on domestic supply, potentially reducing the ability of domestic production to displace imports.

However, some empirical studies also explore how population growth can indirectly influence import dependency by stimulating expanded domestic production capabilities (Alexandratos & Bruinsma, 2012). Guzman (2011) established that population growth stimulates agricultural production globally. Chowdhury and Hossain (2018) reported that Bangladesh's 30% agricultural GDP expansion (2008 to 2017) was driven by labour force growth stemming from population increase. Tessema's (2022) analysis of 43 sub-Saharan African nations revealed positive GDP per capita growth tied to population increases, further supporting the link between population growth, expanded output, and economic resilience.

2.2.4 Real GDP and Import Substitution

Real GDP measures inflation-adjusted economic output (Dynan & Sheiner, 2018), calculated using the formula: Real GDP = Nominal GDP / R, where R represents the GDP deflator (Ganti, 2023). Trade balance critically influences this metric. Kramer (2022) reported that trade surpluses (exports > imports) consistently increase GDP. Econometric analysis in Bangladesh showed that a $1 increase in exports raised GDP by $1.079, while a $1 increase in imports reduced it by 0.275 (Mukit, 2020). Southern African nations subsequently exhibited significant import reduction following GDP growth (Tivatyi et al., 2022).

The relationship between real GDP and import substitution is ambiguous. Rising income may increase consumption of both domestic and imported dairy products. However, economic growth may also facilitate investment in domestic dairy capacity, leading to improved import substitution. The net effect depends on the relative income elasticities of demand for domestic versus imported dairy products. In the context of import substitution, the key question is whether economic growth disproportionately benefits domestic production capacity relative to import demand.

2.2.5 Real Effective Exchange Rate and Import Substitution

The Real Effective Exchange Rate (REER) quantifies a currency's inflation-adjusted value against a weighted basket of major trading partners' currencies, serving as an indicator of international competitiveness (World Bank, 2023; OECD, 2013). Crucially, REER exhibits a negative relationship with net exports: an appreciation (high REER) raises the relative price of domestic goods, increasing import demand while reducing exports; conversely, depreciation (low REER) enhances export competitiveness and suppresses imports.

Empirical studies consistently validate REER's influence on trade dynamics. Heyes (2021) established a positive correlation between REER appreciation and import growth, demonstrating that stronger exchange rates reduce import costs and incentivize foreign purchases. Lossifov and Fei (2019) analyzed Turkey (1998-2017) using ARDL/NARDL models, revealing that REER appreciation elevated imports by 5.4% due to enhanced purchasing power for foreign goods, while depreciation periods simultaneously boosted exports and suppressed imports. Razak and Masih (2022) in

Malaysia confirmed that REER appreciation devalued the ringgit, depressing export prices internationally while lowering import costs domestically.

In the context of import substitution, a real appreciation of the domestic currency makes imports cheaper relative to domestic products, potentially reducing the incentive for consumers and processors to switch to domestic sources. Conversely, a depreciation makes imports more expensive, improving the competitiveness of domestic production and potentially improving the import substitution ratio.

2.2.6 Structural Breaks and Import Substitution

Structural breaks in time series data can significantly influence import substitution dynamics. Demographic shifts, policy changes, and economic shocks can fundamentally alter the relationship between import substitution and its determinants. Studies by Kibirige et al. (2022) in Eswatini found that the 1995 structural break significantly affected maize import substitution ratios. Similarly, the post-2015 period in Eswatini's dairy sector witnessed accelerated domestic milk production driven by investments in modern farming techniques and policy initiatives, leading to improved import substitution ratios.

2.3 Measures of Import Substitution

According to Desai (1969), there are basically two alternative types for measuring import substitution. The first alternative involves some notion of optimality and the other one is purely descriptive, noting changes in the actual pattern of imports and domestic production, regardless of any reference to whether the actual situation is optimal or not. The measures are based on the actual pattern of imports and production and can either be used at micro or macro level.

2.3.1 Absolute Measure of Import Substitution

Saleem (1992) acknowledged that the Absolute measure computes the difference between the ratios of import availability during different periods of time. A positive change indicates that import substitution is taking place. If M_1 and M_0 are the imports during the current and base year, Z_1 and Z_0 are total availability, the import substitution ratio is calculated based on the formula:

$S_1 = M_1 + D_1$ (total milk available during current year)
$S_0 = M_0 + D_0$ (total milk available during base year)
$R = (M_0/S_0) - (M_1/S_1)$ (Milk import Sustituttion Ratio)

If the Import Substitution Ratio (R) is greater than zero, then import substitution is occurring. This measure directly captures the extent to which domestic production displaces imports, making it the appropriate dependent variable for a study on the determinants of import substitution. A positive IR indicates that domestic production is displacing imports, while a negative IR indicates that imports are growing faster than domestic production's ability to displace them. Higher IR values represent greater import substitution.

Kibirige et al. (2022) conducted a study aimed at estimating maize import substitution ratios and determinants of the maize import substitution in Eswatini using time series data from 1981 to 2019. The regression results from ARDL and ECM models showed an average import substitution ratio of -0.1728, which is less than zero, indicating that there is no import substitution for maize, thus Eswatini is still dependent on maize imports. The highest maize import substitution ratio occurred in 2019 with a -0.001 score, and the poorest occurred in 1995 with a score of -0.462.

3. Methodology

This study adopted a quantitative, longitudinal research design utilizing annual time series data from 1981 to 2023. A longitudinal design is appropriate for this study because it allows for the analysis of economic relationships over time, capturing both short-term fluctuations and long-term dynamics in import substitution (Jose, 2022). The study period (1981-2023) was chosen to capture the full spectrum of Eswatini's dairy trade patterns, including periods of policy shifts, structural adjustments, and varying macroeconomic conditions.

The study employed a causal-explanatory research design, as the objective was to identify and estimate the causal relationships between milk import substitution (the dependent variable) and a set of independent variables, including domestic milk production, milk imports, real GDP, exchange rates, and population growth.

3.2 Data Collection

The study exclusively utilized time series secondary data obtained from the Eswatini Dairy Board (EDB), World Bank, Food and Agriculture Organization (FAO), and International Monetary Fund

(IMF), dating from 1981 to 2023. The time series data collected included the milk import substitution ratio (IR), domestic milk production quantities (INDM), milk imports (INMI), real GDP (INRGDP), population growth rate (POPGR), and real effective exchange rate (INREER) as indicated in Table 1 below.

Table 1: Data Sources

Variable	Data Source
Milk Import Substitution Ratio (IR)	Calculated from EDB data
Domestic Milk Production (INDM)	Eswatini Dairy Board (EDB)
Milk Imports (INMI)	Eswatini Dairy Board (EDB)
Population Growth Rate (POPGR)	World Bank
Real Gross Domestic Product (INRGDP)	International Monetary Fund (IMF)
Real Effective Exchange Rate (INREER)	World Bank

Source: Prepared by author

3.3 Specification of Variables

The dependent variable used in the study was the milk import substitution ratio (IR), calculated using the absolute measure of import substitution. A positive IR indicates import substitution is occurring (domestic production displacing imports), while a negative IR indicates increasing import dependency. Higher IR values represent greater substitution, with values closer to zero indicating reduced import reliance.

The independent variables included the logarithms of domestic milk production (INDM), milk imports (INMI), real gross domestic product (INRGDP), and real effective exchange rate (INREER), while population growth rate (POPGR) was kept in its original linear form due to its negative values. A structural break dummy (D95) was included to capture the post-1995 demographic shift, and a time trend was included to capture unobserved factors or gradual shifts over the study period (See Table 2 below).

Table 2: Expected Relationship between Dependent Variable and Independent Variables

Variable	Description	Expected Sign and Rationale
IR	Milk Import Substitution Ratio	N/A: Dependent variable
INDM	Log of Domestic Milk Production	Positive (+): Increased domestic production should improve import substitution by displacing imports
INMI	Log of Milk Imports	Negative (-): Higher imports directly reduce the substitution ratio
INRGDP	Log of Real GDP	Ambiguous (+/-): Economic growth may increase consumption of both domestic and imported products
POPGR	Population Growth Rate (linear)	Ambiguous (+/-): Population growth increases demand, potentially reducing substitution if supply doesn't keep pace
INREER	Log of Real Effective Exchange Rate	Ambiguous (+/-): Appreciation makes imports cheaper, potentially reducing substitution incentive
D95	Structural Break Dummy (0:1981-1994, 1:1995-2023)	Ambiguous: Captures the permanent shift in demographic and economic structure

TREND	Linear Time Trend	Positive (+): Captures gradual autonomous improvement over time

Source: Prepared by author

3.4 Model Specification

Based on the theoretical framework, the general econometric model specified to investigate the long-run relationship of milk import substitution in Eswatini is:

Equation 1: Long-Run Equation

$$IR_t = \beta_0 + \beta_1 INDM_t + \beta_2 INMI_t + \beta_3 INRGDP_t + \beta_4 POPGR_t + \beta_5 INREER_t + \beta_6 D95_t + \delta \cdot TREND_t + \varepsilon_t$$

Where: t represents the time period

:ε_t is the error term

:β_1 to β_6 are the long-run coefficients

:D95 is a structural break dummy (0 for 1981-1994, 1 for 1995-2023)

:TREND is a linear time trend (1, 2, 3, ..., 43)

3.5.1 Unit Root Test

The Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979) with a trend and intercept was used to check for the stationarity of each variable. The test was crucial because non-stationary data could lead to spurious regression results (Granger & Newbold, 1974). The optimal number of lags for each variable was determined using the Akaike Information Criterion (AIC), ensuring the residuals were white noise.

Null Hypothesis (H_0): Data is not stationary (there is a unit root)

Alternative Hypothesis (H_1): Data is stationary (there is no unit root)

Decision Rule: Reject H_0 if the ADF test statistic is more negative than the MacKinnon critical value at a chosen significance level.

3.5.2 Cointegration Test: ARDL Bounds Approach

Following the unit root tests, cointegration was tested using the Autoregressive Distributed Lag (ARDL) Bounds Testing approach developed by Pesaran, Shin, and Smith (2001). This method is particularly well-suited for models where variables are integrated of different orders (a mix of I(0) and I(1)).

The ARDL Bounds Test involves estimating an unrestricted error correction model (UECM), and an F-test is conducted on the joint significance of the lagged level variables. For this study, the UECM specification for the selected ARDL(1,0,0,0,2,0) model can be expressed as:

Equation 2: Unrestricted Error Correction Model (UECM)

$$\Delta IR_t = \alpha_0 + \varphi_1 IR_{t-1} + \varphi_2 INDM_{t-1} + \varphi_3 INMI_{t-1} + \varphi_4 INRGDP_{t-1} + \varphi_5 POP_{t-1} + \varphi_6 INREER_{t-1} + \sum_{i=1}^{p1} \Delta IR_{t-i} + \sum_{j=0}^{qj} \Delta INDM_{t-} + \sum_{k=0}^{rk} \Delta INMI_{t-} + \sum_{l=0}^{s1} \Delta INRGDP_{t-} + \sum_{m=0}^{tm} \Delta POPGR_{t-} + \sum_{n=0}^{un} \Delta INREER_{t-} + \beta_6 D95_t + \delta \cdot TREND_t + \varepsilon_t$$

Where:

:Δ is the first difference operator

: α_0 is the constant term

: φ_1 to φ_6 are the long-run coefficients on the lagged level variables

: β_i, γ, δ, θ, φ, ψ are short-run coefficients for the lagged differences of the variables

: D95 is the structural break dummy

: TREND is the linear time trend

: ε_t is the error term

Hypothesis:

- H_0: No cointegration ($\varphi_1 = \varphi_2 = \varphi_3 = \varphi_4 = \varphi_5 = \varphi_6 = 0$)
- H_1: Cointegration exists (at least one φ coefficient is not zero)

Decision Rule: If the calculated F-statistic exceeds the upper bound critical value, reject H_0 (cointegration exists). If it falls below the lower bound, fail to reject H_0 (no cointegration). If between bounds, the result is inconclusive.

3.5.3 Lag Length Selection

Selecting appropriate lag lengths is crucial in time series modeling to ensure the model accurately captures underlying dynamics and avoids issues such as serial correlation (Lütkepohl, 2005). Given the mixed integration orders (I(0) and I(1)) identified by the ADF test, an Autoregressive Distributed Lag (ARDL) Bounds Test approach (Pesaran, Shin, & Smith, 2001) was justified, making optimal lag selection paramount.

For the ARDL model used to identify the long-run determinants of milk import substitution, optimal lag orders were determined automatically using EViews 14 software, based on minimizing the Akaike Information Criterion (AIC) (Akaike, 1974). The maximum lags for the dependent and regressor variables were set to 2 to avoid overfitting and ensure model stability. The automatic selection process evaluated 486 possible model combinations and identified ARDL (1,0,0,0,2,0) as the optimal model structure specification (See Table 3 below).

Table 3: Optimal ARDL lag structure

Variable	**Lag Order**
IR (Dependent Variable)	1
INMI	0
INDM	0
INRGDP	0
POPGR	2
INREER	0

Source: Output generated by the author using EViews (version 14)

The selected model was then estimated, and its long-run coefficients were derived using the ARDL Bounds Testing approach. The model included a constant term, a linear time trend, and a structural break dummy (D95) as deterministic regressors. Following estimation, diagnostic tests including serial correlation (Breusch-Godfrey LM test), heteroskedasticity (Breusch-Pagan-Godfrey test), normality (Jarque-Bera test), and stability (CUSUM and CUSUMSQ tests) were conducted to ensure the reliability and validity of the estimated coefficients.

3.5.4 Long Run and Short-Run Estimation

Following the confirmation of a long-run cointegrating relationship among the variables via the ARDL Bounds Test, the next step involved estimating the long-run coefficients and the short-run dynamics.

3.5.4.1 Long Run Estimation

Once cointegration is established, the long-run coefficients are derived from the ARDL model. The long-run relationship represents the equilibrium path to which the variables converge over time. For the selected ARDL(1,0,0,0,2,0) model, the long-run coefficients are obtained by normalizing the coefficients of the lagged level variables.

The long-run equation is specified as:

Equation 3: Long Run Cointegrating Equation

$$IR_t = \beta_0 + \beta_1 \cdot INDM_t + \beta_2 \cdot INMI_t + \beta_3 \cdot INRGDP_t + \beta_4 \cdot POPGR(-1)_t + \beta_5 \cdot INREER_t + \beta_6 \cdot D95_t + \delta \cdot TREND_t + \varepsilon_t$$

Where:

: IR_t is the milk import substitution ratio at time t
: $INDM_t$ is the log of domestic milk production
: $INMI_t$ is the log of milk imports
: $INRGDP_t$ is the log of real GDP
: $POPGR(-1)_t$ is the lagged population growth rate
: $INREER_t$ is the log of the real effective exchange rate
: D95 is the structural break dummy (0 for 1981-1994, 1 for 1995-2023)

: TREND is a linear time trend
: β_0 is the constant term
: β_1 to β_6 are the long-run coefficients
: δ is the coefficient on the time trend
: ε_t is the error term

3.5.4.2 Short Run Dynamics and Error Correction Model (ECM)

Since the ARDL bounds test confirmed cointegration, the Error Correction Model (ECM) was applied to estimate the short-run dynamics. The ECM, rooted in the work of Engle and Granger (1987), measured how quickly milk import substitution adjusted to equilibrium after shocks.

The Error Correction Term (ECT_{t-1}) was derived from the residuals of the long-run equilibrium relationship estimated by the ARDL model. It represents the deviation of the import substitution ratio (IR_{t-1}) from its steady-state value, which was determined by domestic milk production ($INDM_{t-1}$), milk imports ($INMI_{t-1}$), real GDP ($INRGDP_{t-1}$), population growth rate ($POPGR_{t-1}$), and the real effective exchange rate ($INREER_{t-1}$).

The general form of the ECM for this study is expressed as:

Equation 4: Error Correction Model (ECM)

$$\Delta IR_t = \alpha_0 + \sum_{i=1}^{p1}\Delta IR_{t-i} + \sum_{j=0}^{q}\Delta INDM_{t-} + \sum_{k=0}^{r}\Delta INMI_{t-} + \sum_{l=0}^{s1}\Delta INRGDP_{t-} + \sum_{m=0}^{t}\Delta POPGR_{t-} + \sum_{n=0}^{u}\Delta INREER_{t-} + \lambda \cdot ECT_{t-1} + \beta_6 D95_t + \delta \cdot TREND_t + \varepsilon_t$$

Where:
: Δ is the first difference operator
: α_0 is the constant term
: β_i, γ, δ, θ, φ, ψ are short-run coefficients for the lagged differences of the variables
: λ is the speed of adjustment coefficient (must be negative and statistically significant)
: ECT_{t-1} is the error correction term (lagged residual from the long-run equation)
: D95 is the structural break dummy
: TREND is the linear time trend
: ε_t is the error term

Hypothesis on Adjustment Speed:

H_0: $\lambda = 0$ (No error correction mechanism, meaning no long-run adjustment towards equilibrium)
H_1: $\lambda < 0$ (Significant error correction mechanism, indicating convergence to long-run equilibrium)

Decision Rule: Reject H_0 if λ is negative and statistically significant (e.g., $p < 0.05$). A negative and significant coefficient λ confirms that any short-run deviations from the long-run equilibrium are corrected over time.

3.6 Diagnostic Tests

Following the estimation of the ARDL and ECM models, a series of diagnostic and stability tests were performed to ensure the model's reliability, consistency, and compliance with the fundamental classical linear regression (CLR) assumptions.

3.6.1 Serial Correlation Test

The Breusch-Godfrey LM Test was used to check whether the error terms of the model were correlated over time (autocorrelation). The null hypothesis (H_0) is that there is no serial correlation. Failure to reject H_0 implies that the estimated model provides an unbiased and efficient estimate of the relationships.

3.6.2 Heteroskedasticity Test (Breusch-Pagan-Godfrey Test)

Heteroskedasticity refers to the situation where the variance of the error term is not constant across all levels of the independent variables. This leads to inefficient estimates. The test's null hypothesis (H_0) is that the variance of the errors is homoskedastic (constant). Passing this test ensures the standard errors and t-statistics are reliable.

3.6.3 Normality Test (Jarque-Bera Test)

The Normality Test (Jarque-Bera Test) assessed whether the residuals of the model are normally distributed, which was an assumption required for hypothesis testing and interval estimation, especially in smaller samples. The null hypothesis (H_0) was that the residuals are normally distributed.

3.6.4 Model Stability Test (CUSUM and CUSUMSQ Tests)

The CUSUM and CUSUMSQ tests were applied to assess the structural stability of the estimated long-run and short-run coefficients. If the cumulative sum remained within the 5% critical boundaries,

the model parameters are stable over the entire estimation period, indicating no significant structural breaks.

4. Results and Discussion

4.1 Unit Root Test Results

The Augmented Dickey-Fuller (ADF) unit root test was conducted to ascertain the stationarity properties of the time series variables. The test was performed at both levels and first differences, with the optimal lag lengths determined by the AIC and assessed at a 5% significance level. Table 4 below presents the unit root test results.

Table 4: Unit Root Test Results

Variable	At Level			At First Difference			Order of Integration
	ADF Statistic	5% Critical Value	P-value	ADF Statistic	5% Critical Value	P-value	
IR	-1.824869	-3.520787	0.6748	-3.975614	-3.540328	0.0187	I(1)
INDM	-4.275737	-3.540328	0.0090	N/A	N/A	N/A	I(0)
INMI	-1.824869	-3.520787	0.6748	-10.97829	-3.520787	0.0000	I(1)
INRGDP	-6.113108	-3.518090	0.0000	N/A	N/A	N/A	I(0)
POPGR	-2.125872	-3.523623	0.5166	-6.411722	-3.523623	0.0000	I(1)
INREER	-2.637018	-3.520787	0.2669	-5.048511	-3.523623	0.0010	I(1)

Source: Output generated by the author using EViews (version 14)

The results indicate a mixed order of integration among the variables. IR, INMI, POPGR, and INREER were found to be stationary at first difference, I(1), while INDM and INRGDP were stationary at levels, I(0). This mixed order of integration, with no variable integrated of order two or higher, confirms the appropriateness of employing the Autoregressive Distributed Lag (ARDL) Bounds Test approach for cointegration analysis.

4.2 ARDL Bounds Test for Cointegration Results

Following the lag length selection, the ARDL model was utilized to test for the presence of a long-run cointegrating relationship among the variables. The model was estimated with the selected ARDL(1,0,0,0,2,0) specification and included the structural break dummy (D95) and a time trend. The results of the ARDL Bounds Test are presented in Table 5 below.

Table 5: ARDL Bounds Test Results

Test Statistic	Value	Significance	I(0) Bound	I(1) Bound
F-statistic	61.31627	10%	3.032	4.213
		5%	3.577	4.923
		1%	4.885	6.550
t-statistic	-15.5758	10%	-3.13	-4.04
		5%	-3.41	-4.36
		1%	-3.96	-4.96

Source: Output generated by the author using EViews (version 14)

4.2.1 F-Bounds Test for Cointegration

The calculated F-statistic from the ARDL Bounds Test for the selected ARDL(1,0,0,0,2,0) model was 61.31627. This value was compared against the critical values for the Bounds Test. For an actual sample size of 42, the closest finite sample critical values were for n=40. At the 5% significance level, the lower bound (I(0)) critical value was 3.577, and the upper bound (I(1)) critical value was 4.923. Since the computed F-statistic of 61.31627 was far greater than the upper bound critical value of 4.923 at the 5% significance level, the null hypothesis of no long-run relationship was rejected. This provided strong and conclusive evidence that a long-run cointegrating relationship existed among

the milk import substitution ratio (IR), domestic milk production (INDM), milk imports (INMI), real GDP (INRGDP), population growth rate (POPGR), and real effective exchange rate (INREER).

4.2.2 t-Bounds Test for Cointegration

As a complementary test, the t-statistic for the lagged dependent variable was examined. The calculated t-statistic was -15.5758. At the 5% significance level, the upper bound (I(1)) critical value was -4.36. Since the calculated t-statistic of -15.5758 was more negative than the upper bound critical value, it further reinforced the rejection of the null hypothesis of no levels relationship.

4.3 Long-Run Estimation Results

The estimated long-run coefficients from the ARDL(1,0,0,0,2,0) model are presented in Table 6 below. These coefficients represent the long-run equilibrium relationships between the milk import substitution ratio (IR) and the explanatory variables.

Table 6: Long-Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
INMI	-0.1975	0.0412	-4.7976	0.0000
INDM	0.1955	0.0202	9.6724	0.0000
INRGDP	-0.0037	0.0038	-0.9647	0.3422
POPGR(-1)	-0.0231	0.0183	-1.2598	0.2171
INREER	0.0724	0.0969	0.7478	0.4602
D95	-0.0748	0.0668	-1.1201	0.2713
TREND	-0.0006	0.0017	-0.3352	0.7398

*Note: * indicates statistical significance at the 5% level. HAC standard errors (Newey-West) were used to correct for heteroskedasticity and serial correlation.*
Source: Author's calculation using EViews 14

The estimated long-run cointegrating equation can be expressed as:

$$IR_t = -0.1975 \cdot INMI_t + 0.1955 \cdot INDM_t - 0.0037 \cdot INRGDP_t - 0.0231 \cdot POPGR(-1)_t + 0.0724 \cdot INREER_t - 0.0748 \cdot D95_t - 0.0006 \cdot TREND_t - 0.6487$$

Note: The constant term (-0.6487) is derived by dividing the short-run constant (-0.7289) by the negative of the ECT (-1.1238).

4.3.1 Effect of Domestic Milk Production (INDM) on Milk Import Substitution

The coefficient for *INDM* is +0.1955 and is highly statistically significant (p-value = 0.0000). Since the p-value is less than 0.05, the null hypothesis that *INDM* has no significant long-run effect was rejected. This suggests that, in the long run, a 1% increase in domestic milk production is associated with approximately a 0.00196-point improvement in the milk import substitution ratio (e.g., moving from -0.82 to -0.8180).

This positive relationship is consistent with the fundamental premise of the Import Substitution Industrialization (ISI) Theory, which anticipates that increased domestic production should actively displace and reduce import volumes (Armington, 1969; Besanko et al., 2013). The finding aligns with generalized empirical evidence cited in the international literature, where studies by the International Dairy Federation (IDF, 2018), FAO (2018), and the USDA (2019) typically reported strong inverse correlations between self-sufficiency and imports.

The result is also consistent with neoclassical growth theory, which posits that increased domestic production capacity, driven by technological adoption and capital accumulation, enhances the ability of the domestic sector to meet demand. In the Eswatini context, the finding reflects the success of policy initiatives such as the National Agricultural Investment Plan (NAIP) and the Agriculture Strategic Plan (2018-2023) in expanding domestic milk production capacity through improved cattle breeds (Friesian and Jersey crossbreeds), artificial insemination, and specialized feed formulation. These investments directly contribute to import substitution by increasing the availability of domestically produced milk relative to imported products.

4.3.2 Effect of Milk Imports (*INMI*) on Milk Import Substitution

The coefficient for *INMI* is -0.1975 and is highly statistically significant (p-value = 0.0000). This indicates that, in the long run, a 1% increase in milk imports is associated with approximately a 0.00198-point decrease in the milk import substitution ratio (e.g., moving from -0.82 to -0.8220).
This negative relationship is consistent with economic theory and the empirical literature. Higher imports directly reduce the substitution ratio because imported milk displaces domestic production in meeting consumer demand. This finding is robustly aligned with the theory of imperfect substitution (Armington, 1969), which posits that imports often dominate specialized or higher-value categories driven by established consumer preference and processing deficits.
The result is also consistent with the Heckscher-Ohlin model, which predicts that countries with relatively scarce capital and technology will import products that require these factors intensively. In Eswatini's dairy sector, imports of processed and value-added products reflect the structural limitations of domestic processing capacity, directly contributing to the persistently negative import substitution ratio.

4.4 Short Run Dynamics and Error Correction Model (ECM) Results

Following the confirmation of a cointegrating relationship through the Bounds Test, the short-run dynamics of milk import substitution were examined using the Error Correction Model (ECM) derived from the ARDL(1,0,0,0,2,0) framework. The ECM allows for the analysis of short-term adjustments of variables towards their long-run equilibrium. The results of the ECM are presented in Table 7 below.

Table 7: Error Correction Model (ECM) Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Cointegrating Equation				
COINTEQ (ECT)	-1.1238	0.0707	-15.8922	0.0000
Short Run Regressors				
D(POPGR)	-0.0213	0.0044	-4.8125	0.0000
D(POPGR(-1))	0.0270	0.0057	4.7220	0.0000
Deterministic				
C	-0.7289	0.0475	-15.3564	0.0000
@TREND	-0.0006	0.0003	-1.6236	0.1132
D95	-0.0748	0.0154	-4.8689	0.0000

Source: Output generated by the author using EViews (version 14)

4.4.1 Error Correction Term (ECT)

The coefficient of the error correction term (COINTEQ) is -1.1238 and is highly statistically significant (p-value = 0.0000). The negative sign and statistical significance confirm that a long-run equilibrium relationship exists, and any short-run deviations from this equilibrium are corrected over time, as theorized by Engle and Granger (1987).
The magnitude of -1.1238 indicates oscillatory convergence (since $-2 < -1.1238 < 0$). This means that if there is a shock to the import substitution ratio, the system corrects back to equilibrium with minor, dampened fluctuations. The speed of adjustment is relatively fast, indicating that the milk import substitution ratio responds quickly to deviations from its long-run equilibrium. Specifically, approximately 112% of the disequilibrium is corrected within the current period, with some over-correction followed by dampened oscillations.
This suggests that policies aimed at improving milk import substitution can have relatively rapid effects, as the system quickly returns to equilibrium after any disruption. The oscillatory nature implies that while the correction is swift, there may be some short-term volatility as the system stabilizes.

4.4.2 Short-Run Impact of Population Growth Rate

The short-run dynamics reveal significant effects of population growth rate changes on milk import substitution. The current change in population growth (D(POPGR)) has a significant negative effect on the import substitution ratio (-0.0213, $p < 0.01$), indicating that a 1 percentage-point increase in the current change of population growth decreases the import substitution ratio by 0.0213 points in the short run. This suggests that immediate increases in population growth exert downward pressure on import substitution, likely because they increase import demand faster than domestic supply can respond.

Conversely, the first lag of population growth (D(POPGR(-1))) has a significant positive effect on the import substitution ratio (0.0270, $p < 0.01$), indicating that a 1 percentage-point increase in the lagged change of population growth increases the import substitution ratio by 0.0270 points in the short run. This delayed positive effect may reflect the time required for domestic production to adjust to demographic changes. As population growth accelerates, it may initially increase import demand, but over time, it could stimulate domestic production investments that improve the substitution ratio. The alternating signs between D(POPGR) and D(POPGR(-1)) suggest that population dynamics exert a delayed and oscillating influence on import substitution. A contemporaneous increase in population growth reduces the substitution ratio, possibly because it increases import demand immediately, while the lagged positive effect may reflect delayed adjustments in domestic production or consumer behavior.

4.5 Milk Import Substitution Ratio Trends

Figure 1 Below presents Eswatini's milk import substitution ratios from 1981 to 2023.

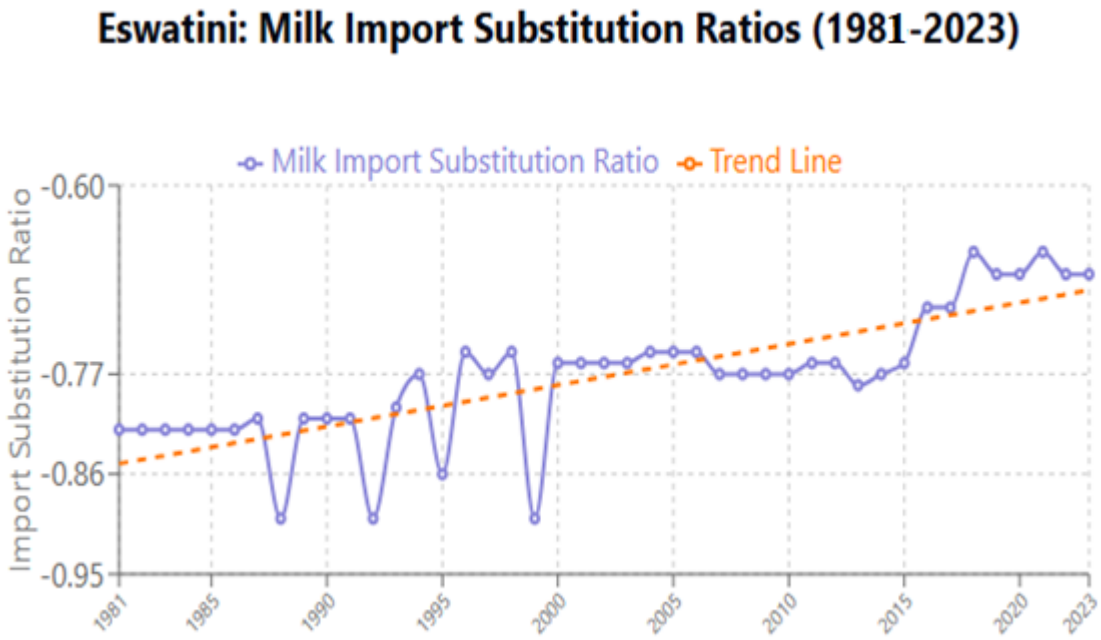


Figure 1: Milk import substitution ratio trends

Source: Author's personal calculation from Eswatini Dairy Board data, (1981 to 2023)

The milk import substitution ratio remained persistently negative throughout 1981-2023, with values ranging from -0.90 (highest dependency) in years like 1988, 1992, and 1999 to -0.66 (least dependency) in 2018 and 2021. The overall average IR was approximately -0.75, which indicates chronic structural dependency. An IR of -0.75 means that for every unit of total milk supply, imports accounted for 75% more than domestic production's share.

A turning point emerged post-2015, as ratios improved steadily, reaching -0.66 by 2018 and 2021, which are the least negative values in the dataset. This shift coincided with accelerated domestic milk production, driven by investments in modern farming techniques, dairy infrastructure, and policy initiatives like the National Agricultural Investment Plan (NAIP). However, setbacks occurred in recent years, with the ratio rising to -0.68 in 2023, likely due to climate shocks or pandemic-related supply chain disruptions. The trend shows that while the ratio has improved (moved closer to zero) in recent years, particularly post-2015, it remains negative, signaling persistent import reliance. Values closer to zero indicate reduced import dependency.

4.6 Post Estimation Diagnostic Tests Results

To ensure the reliability and validity of the estimated ARDL(1,0,0,0,2,0) model, a series of post-estimation diagnostic tests were conducted on the residuals.
These comprehensive tests included assessments for serial correlation, heteroskedasticity, normality of residuals, and model stability. The key findings from these diagnostic checks are summarized in Table 8 below.

Table 8: Post Estimation Diagnostic Test Results

Diagnostic Test	Test Statistic	P-value	Result
Breusch-Godfrey LM Test	F-stat: 1.6258	0.2142	No serial correlation
Breusch-Pagan-Godfrey Test	F-stat: 1.1612	0.3525	No heteroskedasticity
Jarque-Bera Test	2.2642	0.3224	Normal residuals
CUSUM Test	Within bounds	N/A	Model stable
CUSUM of Squares Test	Within bounds	N/A	Model stable

Note: All tests were conducted at the 5% significance level. The null hypotheses of no serial correlation, homoskedasticity, and normal distribution are not rejected as the p-values are greater than 0.05

Source: Output generated by the author using EViews (version 14)

4.6.1 Serial Correlation Test

The Breusch-Godfrey Serial Correlation LM Test was applied to assess for serial correlation in the residuals of the ARDL model. The test was conducted with up to 2 lags. The test yielded an F-statistic of 1.6258 with a p-value of 0.2142. Since the p-value is greater than the conventional significance level of 0.05, the null hypothesis of no serial correlation was not rejected. This indicates that the residuals of the ARDL model are free from serial correlation, which is a desirable property for reliable inference.

4.6.2 Heteroskedasticity Test

The Breusch-Pagan-Godfrey test was conducted to examine for the presence of heteroskedasticity in the residuals of the ARDL model. The test yielded an F-statistic of 1.1612 with a p-value of 0.3525. Since the p-value is greater than 0.05, the null hypothesis of homoskedasticity was not rejected. This confirms the absence of heteroskedasticity in the residuals, indicating that the variance of the error terms is constant across observations and satisfying the homoskedasticity assumption required for valid inference.

4.6.3 Normality Test

The Jarque-Bera test was employed to assess the normality of the residuals. The test yielded a Jarque-Bera statistic of 2.2642 with a p-value of 0.3224. Since the p-value is greater than the conventional significance level of 0.05, the null hypothesis of normal distribution was not rejected. This confirms that the residuals are normally distributed, which is a desirable property for validating inference and satisfying the normality assumption required for hypothesis testing.

4.6.4 Stability Test

The CUSUM and CUSUMSQ tests were conducted to assess the stability of the ARDL model's parameters over the sample period. As shown in the CUSUM and CUSUMSQ plots, the plots for both test statistics remained well within the 5% critical bounds. This outcome confirms the stability of the model's parameters over the estimation period, suggesting the absence of significant structural breaks and reinforcing the reliability of the estimated coefficients.

5. Conclusion and Recommendations

5.1 Conclusion

This study examined the determinants of milk import substitution in Eswatini from 1981 to 2023, motivated by the nation's heavy reliance on dairy imports despite growing domestic consumption. The research tested the null hypothesis that domestic milk production (INDM), milk imports (INMI), real GDP (INRGDP), population growth (POPGR), and real effective exchange rate (INREER) do not significantly influence the milk import substitution ratio (IR), against the alternative hypothesis that at least one of these factors plays a critical role.

Utilizing time series data from the Eswatini Dairy Board, FAO, IMF, and World Bank, a robust ARDL(1,0,0,0,2,0) model was applied. Methodologically, the study incorporated unit root tests to ascertain stationarity, followed by bounds cointegration analysis to confirm long-run relationships, and error correction modeling to disentangle long-run and short-run dynamics.

The Bounds test established a strong long-run relationship at the 5% significance level (F-statistic = 61.31627; 5% upper bound = 4.923). The estimated Error Correction Term (ECT = -1.1238) confirmed oscillatory but stable convergence to equilibrium, with the system correcting approximately 112% of disequilibrium within one year, followed by dampened oscillations.

The long-run results identified two pivotal drivers of milk import substitution. A 1% increase in domestic milk production (INDM) was associated with a 0.00196-point improvement in the import substitution ratio, while a 1% increase in milk imports (INMI) reduced the substitution ratio by 0.00198 points. The structural break in 1995 showed a negative coefficient (-0.0748), suggesting a possible decline in the substitution ratio, but this was not statistically significant ($p = 0.2713$). Similarly, the negative time trend (-0.0006 points per year) was not statistically significant ($p = 0.7398$). Real GDP, population growth rate, and the real effective exchange rate were not statistically significant long-run determinants at the 5% level.

In the short run, changes in population growth had significant effects on the substitution ratio: current changes (D(POP)) negatively influenced the ratio (-0.0213, $p < 0.01$), while lagged changes (D(POP(-1))) positively influenced it (0.0270, $p < 0.01$). The structural break dummy (D95) was significant in the short-run equation (-0.0748, $p < 0.01$), confirming that the post-1995 demographic shift had a significant negative impact on the import substitution ratio.

Overall, the null hypothesis that domestic milk production and milk imports do not significantly influence the milk import substitution ratio was rejected. The persistent negative import substitution ratio throughout the study period (averaging approximately -0.75) underscores Eswatini's structural dependence on dairy imports, despite notable increases in domestic production. The diagnostic tests confirmed that the model satisfies the classical linear regression assumptions, with no evidence of serial correlation, heteroskedasticity, or non-normality of residuals, and stable parameters over the estimation period.

5.2 Recommendations

Based on the empirical findings and the confirmed dynamic relationships, the following targeted interventions are proposed to reduce Eswatini's milk import dependency and enhance the dairy sector's import substitution ratio.

5.2.1 Strengthen Domestic Dairy Production Capacity

The Ministry of Agriculture and Eswatini Dairy Board (EDB), in collaboration with the Ministry of Finance, should restructure subsidy programs to redirect funds towards dairy intensification. Given the significant positive impact of domestic milk production on import substitution ($\beta = 0.1955$, $p < 0.001$), policies that expand domestic production capacity are the most effective means of improving the substitution ratio. Specific interventions include:

- **Investment in High-Yield Breeds:** Expand the adoption of improved cattle breeds (Friesian and Jersey crossbreeds) through subsidized artificial insemination programs and breed improvement initiatives. A 1% increase in domestic milk production yields a 0.00196-point improvement in the import substitution ratio, so targeted investments in breed improvement will yield measurable returns.
- **Climate Adaptation Subsidies:** Implement subsidies for drought-resistant fodder and irrigation systems, particularly for smallholder farmers. Climate variability has been identified as a significant constraint on domestic production, and building resilience to climate shocks will stabilize production and reduce import dependency.
- **Mobile Veterinary Networks:** Establish mobile veterinary extension services to reduce disease losses and improve herd health. This intervention aims to reduce mortality and morbidity losses, increasing the effective milk yield per animal and contributing to overall production growth.

5.2.2 Strategic Import Management and Rationalization

The Ministry of Commerce, Industry and Trade, in conjunction with the Ministry of Finance, should implement strategic import management mechanisms. Given the significant negative impact of milk imports on the substitution ratio ($\beta = -0.1975$, $p < 0.001$), managing import volumes is critical to improving import substitution. Specific interventions include:

- **Variable Tariff Mechanism:** Implement variable tariffs tied to quarterly domestic output levels (e.g., zero tariffs when production falls below a strategic supply buffer threshold, and higher tariffs when

domestic production is adequate). This mechanism protects domestic producers during periods of adequate supply while ensuring affordable imports during production shortfalls.

- **Domestic Supply Buffers:** Establish and manage a national dairy reserve holding a strategic stock of UHT/powdered milk. The reserve should be released when local output drops significantly (e.g., more than 10% year-over-year) to stabilize the market and reduce import price volatility.
- **Local Content Requirements:** Enforce rules requiring processors to source a majority of raw milk domestically for subsidy eligibility. This creates a non-negotiable incentive for processors to invest in local supply chains and reduces the structural preference for imported milk.

5.2.3 Invest in Dairy Value Chain Infrastructure

The Ministry of Agriculture and EDB, in partnership with private sector stakeholders, should prioritize investments in strengthening milk processing and cold-chain infrastructure. This is vital to reduce spoilage, enhance local value addition, and ensure that increased domestic production effectively reaches consumers. Specific interventions include:

- **Cold-Chain Expansion:** Invest in cold storage facilities and refrigerated transport to reduce post-harvest losses, particularly in rural areas where spoilage rates are highest. Improved cold-chain infrastructure will increase the effective supply of domestic milk and reduce the need for imports during peak demand periods.
- **Processing Capacity Enhancement:** Support the development of domestic processing capacity for value-added products such as UHT milk, cheese, and yoghurt. The theory of imperfect substitution suggests that consumer preferences for processed products may drive import demand; expanding domestic processing capacity can substitute for these imports.
- **Smallholder Integration:** Develop programs to integrate smallholder farmers into formal dairy value chains through cooperative models and contract farming arrangements. This improves market access for smallholders, increases their production incentives, and contributes to overall production growth.

5.2.4 Align Population Growth with Dairy Supply Planning

While population growth was not statistically significant in the long-run model, the short-run analysis revealed significant effects of changes in population growth on the import substitution ratio ($D(POP) = -0.0213$, $p < 0.01$; $D(POP(-1)) = 0.0270$, $p < 0.01$). To address population-driven demand pressures, the Ministry of Agriculture and EDB should:

- **Integrate Population Forecasts:** The Central Statistical Office should regularly provide population forecasts to the Ministry of Agriculture and EDB to integrate into 5-year dairy development plans. This allows for proactive planning of domestic supply capacity to meet projected demand increases.
- **Targeted Investments:** Prioritize farm investments in regions experiencing significant annual population growth (e.g., exceeding 2%) to align local production with localized demand increases. This reduces the regional demand-supply gap that drives import dependency.
- **Dietary Diversification:** Promote alternative protein sources in high-growth urban zones to diversify dietary habits and reduce the pressure on dairy demand. This is a long-term strategy to moderate the growth of dairy import demand.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. The supplementary materials include:

1. **Excel Data.xlsx** – Contains the complete annual time series dataset for Eswatini from 1981 to 2023, including raw variables (YEAR, IR, DM, MI, RGDP, POP, REER) and their natural logarithmic transformations (INDM, INMI, INRGDP, INREER) as used in the econometric analysis. The file includes a "READ ME" sheet with a comprehensive data dictionary.
2. **DATA DICTIONARY.docx** – A standalone document providing detailed variable definitions, descriptions, units of measurement, data sources, and transformation details.
3. **EVIEWS ANALYSIS OUTPUTS.docx** – A consolidated document containing all EViews analytical outputs, organized into the following sections: Unit Root Tests (ADF), ARDL Bounds Test for Cointegration, Long-Run Coefficients, Error Correction Model (ECM), and Post Estimation Diagnostic Tests.

All supplementary files will be made available alongside the published article. The data are aggregated at the national level and do not contain any identifying or confidential information. The econometric analysis was conducted using EViews 14 Student Version. All analytical outputs are fully documented for complete transparency and replication.

Data Sources:

Variable	Data Source
Milk Import Substitution Ratio (IR)	Calculated from EDB data
Domestic Milk Production (INDM)	Eswatini Dairy Board (EDB)
Milk Imports (INMI)	Eswatini Dairy Board (EDB)
Real Gross Domestic Product (INRGDP)	International Monetary Fund (IMF)
Population Growth Rate (POPGR)	World Bank Open Data
Real Effective Exchange Rate (INREER)	World Bank Open Data

Source: Output generated by the author

The econometric analysis was conducted using **EViews 14 Student Version**. All analytical outputs are fully documented in the supplementary files provided for complete transparency and replication. All data are aggregated at the national level and do not contain any identifying or confidential information.

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