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Managing Import Risk in Livestock and Poultry Feed Supply: A Portfolio Approach

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Abstract

Iran depends heavily on imports of livestock and poultry feed, making domestic food production vulnerable to disruptions in international markets. Maize, soybean meal, and barley were selected because they account for approximately 80% of Iran's feed imports during the study period. This study applies Portfolio Theory to decompose import portfolio risk into systematic and specific components. Systematic risk was estimated using OLS regression between Iran's import prices and world prices, while specific risk was calculated from residual variance adjusted by partner-specific risk profiles derived from the International Country Risk Guide (ICRG). An additional OLS model was estimated to identify the determinants of specific risk, including import concentration measured by the Herfindahl–Hirschman Index (HHI), exchange rate movements, oil revenues, economic complexity, and domestic livestock production. The results show that systematic risk follows global price volatility, whereas specific risk is the main source of portfolio vulnerability. Among the selected commodities, maize exhibits the highest import risk due to its larger import volume and higher residual variance. The specific risk index reached its lowest level in 2020, reflecting a more balanced distribution of imports among major producers and relatively low-risk suppliers. Higher import concentration and exchange rate depreciation significantly increase specific risk, whereas higher oil revenues reduce it. The findings suggest that import policies should move beyond simple supplier expansion toward risk-aware diversification and a more balanced distribution of import shares across trading partners to enhance feed supply resilience and national food security.

Keywords: Import, Livestock, Portfolio, Poultry, Specific risk, Systematic risk.

Introduction

Global per capita meat consumption increased from 41.3 kg in 2015 and is expected to reach approximately 45.3 kg by 2030 (FAO, 2003). In Iran, per capita meat consumption is lower, at around 35.5 kg, including 12.5 kg of red meat and 23 kg of chicken (FAO, 2020). Despite

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considerable growth in domestic animal protein production, price volatility remains a major challenge in Iran's livestock and poultry sectors (Statistical Centre of Iran, 2021). This instability is largely driven by feed costs, which account for 60–70% of total red and white meat production costs (Iran Livestock and Poultry Support Company, 2020). Consequently, fluctuations in feed availability and prices are transmitted along the meat supply chain, raising production costs and consumer prices. Due to limited water resources and the lack of comparative advantage in domestic feed production (Maroufpoor et al., 2021), Iran relies heavily on imports to meet livestock and poultry feed demand. Annual feed consumption is approximately 21 million tons, with more than 76% supplied through imports. As shown in Fig. 1, imports of major feed commodities, including maize, soybean meal, and barley, increased from less than 4 million tons in 1992 to over 17 million tons in 2020, resulting in import dependency exceeding 80% (IRICA, 2021). Maize represents the largest share of Iran's feed imports, while soybean meal is among the most important imported agricultural commodities, highlighting the critical role of these commodities in feed supply and food security (International Trade Centre, 2021; Alizadeh et al., 2019).

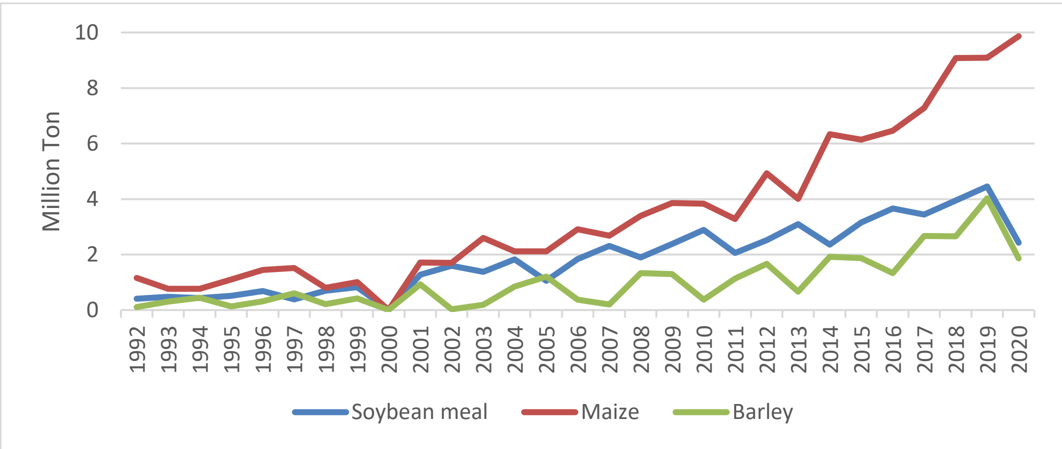

Fig. 1. Import volume of selected livestock and poultry feed commodities in Iran. Source: Islamic Republic of Iran Customs Administration (IRICA).

At the same time, international trade in maize, soybean meal, and barley expanded substantially, with global export volumes increasing from approximately 100 million tons in 2001 to more than 400 million tons in 2020 (Fig. 2). While this expansion has increased the availability of feed commodities, it has also exposed importing countries to greater risks arising from global price volatility, geopolitical disruptions, supplier concentration, and country-specific risks. For highly import-dependent countries such as Iran, ensuring a stable feed supply therefore requires not only securing sufficient import volumes but also selecting an appropriate portfolio of trading partners. Consequently, effective import portfolio risk management has become increasingly important for strengthening food security and supply chain resilience.

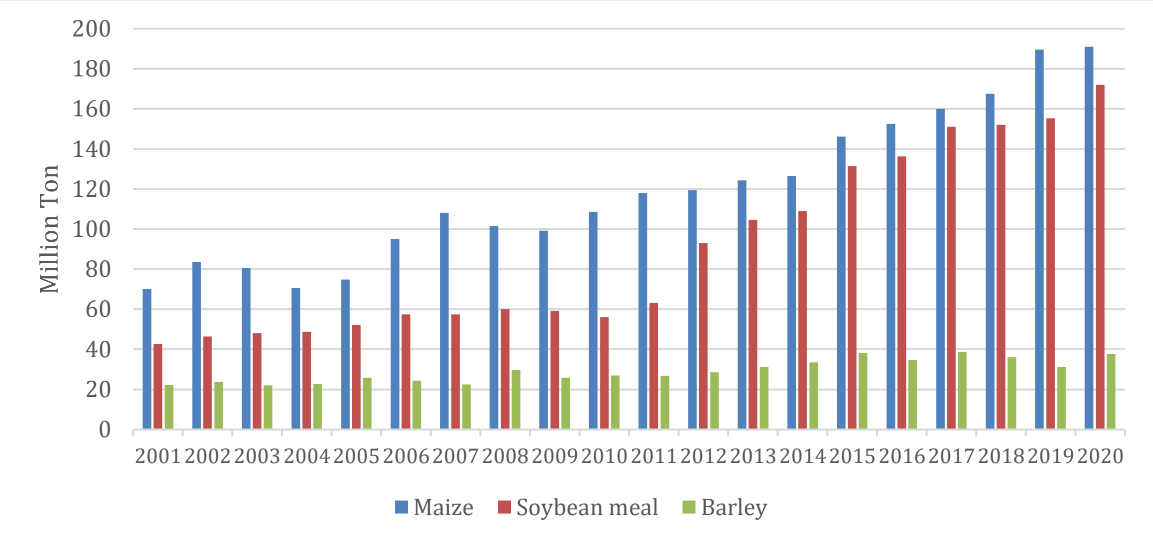

Fig. 2. Global supply of selected livestock and poultry feed commodities. Source: World Trade Organization (WTO).

Import security, defined as the continuous availability of essential commodities at reasonable prices (Baranauskaitė & Jurevičienė, 2021), has become an important concern in international trade. Risk management originated from Markowitz's (1989) portfolio theory, and this theory has since been widely applied in several fields, including international business. Initially, researchers considered diversification to be the primary factor in risk management (Neff, 1997; Yergin, 2006). However, Vivoda (2009) found that diversification alone cannot be the primary factor in risk reduction; rather, the selection of low-risk trading partners is the main driver of risk mitigation in international trade. Ge and Fan (2013) optimized China's crude oil import portfolio by incorporating exporter-specific factors, including export capacity, crude oil price, quality, distance to China, political relations with China, and the exporter's oil export strategy. Within this framework, portfolio risk is decomposed into systematic risk, which arises from fluctuations in international market prices, and specific risk, which reflects the economic, political, and trade-related characteristics of individual trading partners (Chen & Yang, 2021; Ge & Fan, 2013; Ghanizadeh et al., 2022).

Despite these advances, existing studies have largely focused on energy commodities, particularly crude oil and natural gas, while portfolio risk management for agricultural import commodities has received limited attention. Moreover, studies integrating systematic risk, trading-partner-specific risk, and macroeconomic determinants to assess the risk of feed import portfolios remain scarce. To address this gap, this study applies Portfolio Theory to construct import portfolios based on the observed import shares of individual trading partners in each year, thereby assessing the risk associated with the existing supplier structure of Iran's major imported feed commodities throughout the study period.

Given Iran's heavy dependence on imported livestock and poultry feed commodities, import security depends not only on import volume but also on the diversification and composition of trading partners. Although administratively managed or preferential exchange-rate policies may temporarily reduce exchange-rate uncertainty, import security remains vulnerable to supplier-specific risks, country risk, global price volatility, trade concentration, and geopolitical disruptions. Therefore, understanding the structure of import portfolio risk is essential for strengthening food security and improving supply chain resilience.

Unlike conventional studies that primarily emphasize import costs or exchange-rate effects, this study evaluates import portfolio risk from a portfolio composition perspective. The import portfolio of each feed commodity is constructed based on the observed import shares of individual trading partners in each year, allowing the risk associated with the existing supplier structure to be assessed over the study period. Accordingly, the study quantifies the relative contributions of systematic and specific risks to Iran's import portfolio of selected livestock and poultry feed commodities.

Accordingly, this study contributes to the literature by developing an integrated framework for agricultural import risk assessment that conceptualizes feed suppliers as a risk-bearing portfolio under conditions of market uncertainty, trade restrictions, and macroeconomic instability. Unlike previous studies that mainly emphasize diversification or cost minimization, the proposed framework jointly evaluates supplier concentration, systematic and specific risks, and the macroeconomic determinants associated with import risk. By examining the observed composition of trading partners over time, the framework provides a basis for understanding how changes in supplier structure are associated with variations in import portfolio risk and for identifying factors that can inform import-risk management policies.

Given the substantial volume of livestock and poultry feed imports and their significant implications for environmental sustainability and food security, a robust understanding of import-related risks is essential. Accordingly, the primary objective of this study is threefold: to assess the portfolio risk of selected feed commodities under the observed structure of trading partners over the study period, to identify the key factors associated with variations in portfolio risk, and to derive policy implications for import risk management. By evaluating portfolio risk based on the actual distribution of import shares across trading partners in each year, this study provides empirical evidence on the relationship between supplier composition and import portfolio risk and identifies key economic factors that can inform risk-management strategies.

2. Methodology

This study assesses supplier concentration in Iran's imports of selected livestock and poultry feed commodities, decomposes import portfolio risk into systematic and specific components, and identifies the determinants of specific import risk. Portfolio theory is employed as the analytical framework, distinguishing systematic risk, which reflects market-wide price fluctuations beyond individual actors' control (Sukrianingrum & Manda, 2020; Chen & Yang, 2021), from specific risk, which results from partner-specific financial, economic, political, institutional, production, and climate-related shocks and can be reduced through diversification (Tang et al., 2023; Dai et al., 2023). Each supplier country of maize, soybean meal, and barley is considered an asset in Iran's import portfolio, with its annual import share representing the portfolio weight. The overall research framework and methodological sequence are presented in Fig. 3.

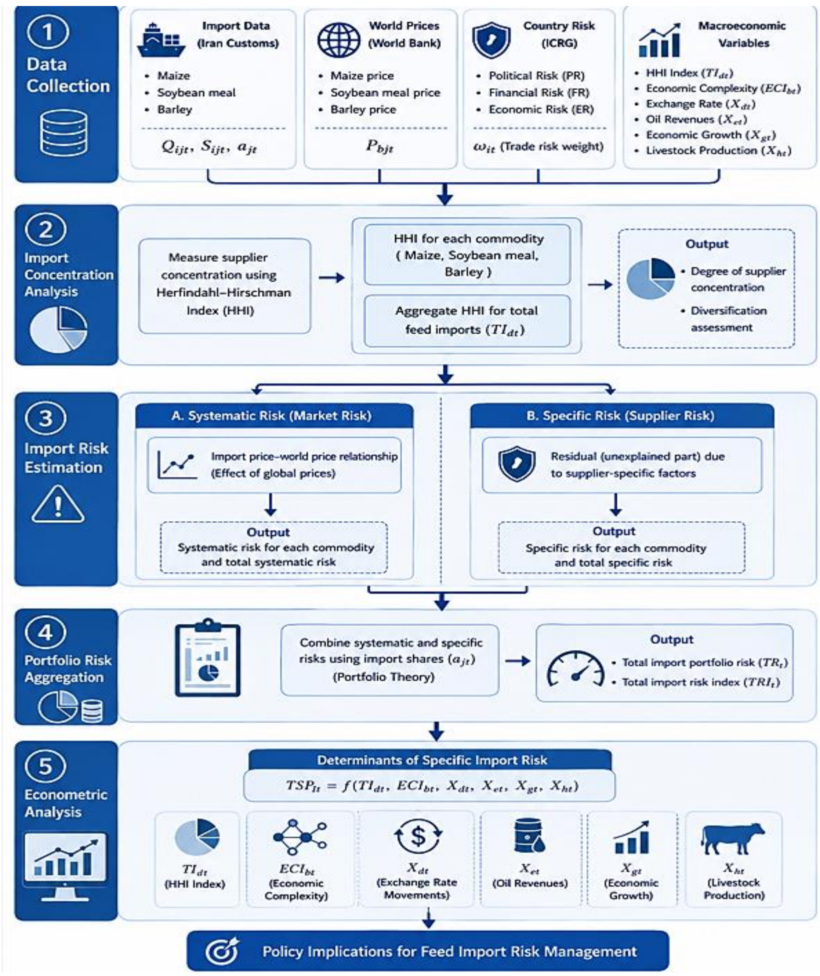

Fig. 3. Research framework and research steps.

2.1. Import Concentration Index (Herfindahl–Hirschman Index, HHI)

The Herfindahl–Hirschman Index (HHI) was used to measure the degree of supplier concentration in Iran's imports of selected livestock and poultry feed commodities. Because supplier concentration is the inverse of diversification, lower HHI values indicate a more diversified import portfolio with a more balanced distribution of imports across trading partners, whereas higher HHI values indicate greater concentration and dependence on a limited number of suppliers. An HHI value of 1 represents complete concentration, where all imports originate from a single trading partner, while progressively lower values indicate greater diversification of import sources (LeeKaivo-oja et al., 2023; Bayramov et al., 2021). During the study period, Iran imported maize, soybean meal, and barley from more than 20 trading partners with varying import shares. The HHI was calculated as follows (Eq. 1).

$$I_{dtj} = \sqrt{\sum_{i=1}^{n} S^2{}_{ijt}} \qquad \forall\, j: Maize, Soybean\ meal, Barely \tag{1}$$

where, I_{dtj} represents the Herfindahl–Hirschman concentration index (HHI) for imports of livestock and poultry feed commodity j in year t, $S^2{}_{ijt}$ displays the squared share of the imports of j commodity of Iran from country i in year t, and n number of countries supplying the commodity to Iran. The HHI concentration index was calculated separately for maize, soybean meal, and barley imports.

The aggregate HHI concentration index (TI_{dt}) for Iran's imports of livestock and poultry feed commodities was then calculated as the weighted average of the HHI concentration indices for the three commodities, with weights a_{jt} corresponding to each commodity's annual share in total imports (Eq. 2).

$$TI_{dt} = \sum_{j=1}^{3} a_{jt} I_{dtj} \tag{2}$$

2.2. Import price and world price relationship

The import prices of selected livestock and poultry feed commodities in Iran are influenced not only by international market prices but also by supplier-specific factors, including transportation distance, transaction costs, and product quality. To decompose import price risk into its systematic (market) and specific (partner) components, the relationship between Iran's import prices and world prices for each commodity was estimated using Eq. (3).

$$P_{cjt} = \alpha_j + \beta_j\, P_{bjt} + \varepsilon_{jt} \qquad \forall\, j: Maize, Soybean\ meal, Barely \tag{3}$$

where P_{cjt} the annual import price of j commodity in Iran in year t (USD/kg), which is calculated by dividing the import value by the import volume of the selected commodity in that year, and P_{bjt} represents the corresponding annual world price (USD/kg), of j commodity in year t, obtained from the World Bank commodity price database. Furthermore, ε_{jt} , α_j, and β_j illustrate the residual term, intercept, and the estimation coefficient of j commodity which is a parameter for calculating systematic risk. The residual term (ε_{jt}) represents the portion of fluctuations in Iran's import prices for the commodity that cannot be explained by changes in world prices. This unexplained component reflects supplier factors and forms the basis for estimating the specific risk of the import portfolio.

Financial theory provides the conceptual framework for decomposing risk into systematic (market-driven) and specific (non-systematic) components. International trade theory, in turn, provides the exogenous benchmark by treating world prices as given for a small open economy such as Iran (Salvatore & Tripathi, 2025). Accordingly, movements in world prices are used to identify the systematic component of import-price risk, while the residual variation in Iran's actual import prices that is not explained by world-price movements represents the non-systematic component. This residual component may reflect factors beyond global market movements, including exchange costs, tariffs, supplier heterogeneity, trade disruptions, logistics, domestic policy interventions, and other unobserved factors.

Accordingly, the total import price risk of the selected feed commodities can be decomposed into two components: (i) systematic risk (SR_{jt}), which is attributable to fluctuations in world market prices, and (ii) specific risk (SP_{jt}), which captures supplier shocks represented by the residual term (ε_{jt}). Consequently, Eq. (3) can be reformulated as Eq. (4) (Ge & Fan, 2013).

$$R_{jt} = SR_{jt} + SP_{jt} \tag{4}$$

R_{jt} demonstrates the total import price risk of Iran's portfolio of selected livestock and poultry feed commodities in year t, which is the sum of the systematic risk (SR_{jt}) and specific risk (SP_{jt}) (Ge & Fan, 2013; Wabiri & Amusa, 2010).

2.3. Systematic risk

The systematic risk component captures the influence of global market movements on import prices. It is determined by the monthly variance of world prices and the estimated price transmission coefficient from Eq. (3). The systematic risk of commodity *j* in year *t*, denoted by (SR_{jt}) , was calculated using Eq. (5).

$$SR_{jt} = \sum_{i=1}^{n} Q_{ijt}^{2}\, \sigma_{jt}^{2}\, \beta_{j}^{2} \quad \forall\, j: Maize, Soybean\ meal, Barely \tag{5}$$

β_j^2 is the square of the estimated global price and import price of the selected feed commodity in Iran, obtained from Eq. (3). Q_{ijt}^2 displays the squared volume of j commodity imports from country i in year t, and n refers to the number of countries from which Iran imports the commodity. Additionally, σ_{jt}^2 denotes the monthly variance of the global price of the j commodity in t year.

The total systematic risk of feed commodity imports in year *t*, denoted by TSR_t, was then calculated as the weighted sum of the systematic risk of each commodity (SR_{jt}), as shown in Eq. (6), where the weights a_{jt} represent each commodity's annual share in total feed commodity imports.

$$TSR_t = \sum_{j=1}^{3} a_{jt} SR_{jt} \tag{6}$$

The various effects of import volume in different years were eliminated to calculate the risk index. Therefore, the squared imported share of the selected livestock and poultry feed commodities from country i in year t (S_{ijt}^2) was used as a substitute for the squared import quantity (Q_{ijt}^2) to make the systematic risk index (SRI_{jt}) as Eq. (7). (Wabiri & Amusa, 2010; Ge & Fan, 2013). $TSRI_t$ is the total systematic risk index of feed commodity imports. The total systematic risk index was defined based on Eq. (8).

$$\mathrm{RI}_{\mathrm{jt}} = \sqrt{\sum_{\mathrm{i=1}}^{\mathrm{n}} \beta_j^2\, \sigma_{jt}^2\, S_{ijt}^2} \quad \forall\, j: Maize, Soybean\ meal, Barely \tag{7}$$

$$\mathrm{TSRI_t} = \sum_{\mathrm{j=1}}^{3} a_{jt}\, \mathrm{SRI_{jt}} \tag{8}$$

2.4. Specific risk

The specific risk component implicitly captures exogenous shocks that are not explained by world price movements, such as trade disruptions, international sanctions, and other country-specific factors. These effects are reflected through the residual variance and the International Country Risk Guide (ICRG) country risk ratings incorporated into the risk assessment framework.

The specific risk was calculated in three sequential steps. First, the unexplained component of import price fluctuations was obtained from the residual variance of Eq. (3). Second, use the inverse of the ICRG country risk rating to account for the financial, economic, and political risk associated with each trading partner. Finally, the risk contribution of each exporting country was weighted according to its share in Iran's imports and aggregated across all trading partners to obtain the annual specific risk. SP_{jt} is used to calculate the specific risk rate each year for importing j commodity in year t as Eq. (9). TSP_t is the total specific risk of feed commodity imports. The total specific risk was defined based on Eq. (10), the weights a_{jt} represent each commodity's annual share in total feed commodity imports.

$$SP_{jt} = \sum_{i=1}^{n} \frac{Q_{ijt}^2 \ \varepsilon_j{}^2}{\omega_{it}} \qquad \forall\, j: Maize, Soybean\ meal, Barely \tag{9}$$

$$TSP_t = \sum_{j=1}^{3} a_{jt}\, SP_{jt} \tag{10}$$

Q_{ijt}^2 denotes the squared import quantity of j commodity from country i in year t. $\varepsilon_j{}^2$ is the variance of the residual term of estimating the world price and import price of commodities in Iran using Eq. (3). ω_{it} indicates the trade risk-adjustment factor assigned to trading partner i in year t, representing the influence of each exporting country on the import risk of Iran's selected livestock and poultry feed commodities, as Eq. (11).

$$\omega_{it} = \frac{1}{\mathrm{ICRG}_{it}} \tag{11}$$

Accordingly, the contribution of each trading partner to portfolio-specific risk depends jointly on its relative importance in Iran's import structure and its country-risk profile. Countries with higher import shares have greater exposure within the portfolio, while countries with lower ICRG scores (indicating higher risk) receive larger risk-adjustment factors. The ICRG index was selected because it provides a comprehensive assessment of country risk by incorporating political, financial, and economic dimensions that are directly relevant to international trade relationships and import reliability. Because the original ICRG index is positively oriented, with higher values representing lower country risk, the direct use of the original score would assign a larger risk contribution to safer countries and underestimate the contribution of riskier suppliers. Therefore, the inverse transformation of the ICRG score was applied to construct country-specific risk-adjustment factors. This transformation converts the index into a risk-oriented measure in which countries with higher country risk receive larger risk-adjustment values, providing a consistent interpretation of country risk exposure within the import portfolio framework. ICRG index is based on 22 variables grouped into three dimensions: political risk (PR), financial risk (FR), and economic risk (ER). The PR, FR, and ER components are scored on scales of 100, 50, and 50 points, respectively. The combined risk score is calculated by aggregating these components, with PR, FR, and ER accounting for 50%, 25%, and 25% of the total score, respectively. The resulting index ranges from 0 to 100, where higher values indicate lower country risk. Based on the ICRG classification, countries are categorized from very low risk o very high risk. Finally, the inverse of the composite ICRG score was then used to derive the country-specific risk-adjustment factors employed in Eq. (9). After calculating the contribution of each trading partner, the weighted risks are aggregated to derive the specific risk index of the import portfolio**.** The specific risk index was defined based on Eq. (12), ${S^2}_{ijt}$ is the square of the imported share of j commodity from country i in year t, which is replaced by the square of the import quantity (Q_{ijt}^2). $TSPI_t$ denotes the total specific risk index of feed commodity imports in year t, while the weights a_{jt} represent the annual import share of commodity j in total feed commodity imports in year t, calculated according to Eq. (13).

$$SPI_{jt} = \sqrt{\sum_{i=1}^{n} \frac{{S^2}_{ijt}\ {\varepsilon_j}^2}{\omega_{it}}} \quad \forall\, j: Maize, Soybean\ meal, Barely \tag{12}$$

$$TSPI_t = \sum_{j=1}^{3} a_{jt}\, SPI_{jt} \tag{13}$$

The portfolio risk (TR_t) was calculated as the sum of the systematic (TSR_t) and specific risk values (TSP_t) presented in Eqs. (14) , whereas the portfolio risk index (TR_tI) was calculated as the sum of the corresponding systematic ($TSRI_t$) and specific risk indixes ($TSPI_t$), as presented in Eqs. (15):

$$TR_t = TSR_t + TSP_t \tag{14}$$

$$TR_tI = TSRI_t + TSPI_t \tag{15}$$

2.5. Variables affecting the specific risk index

The total specific risk index of Iran's feed commodity imports is affected by several factors beyond global price fluctuations. Therefore, the effects of selected macroeconomic variables and the import diversification index on the total specific risk index ($TSPI_t$) were investigated. Accordingly, the following regression model was estimated:

$$TSPI_t = \beta_0 + \beta_1 TI_{dt} + \beta_2 ECI_{bt} + \beta_3 X_{dt} + \beta_4 X_{et} + \beta_5 X_{gt} + \beta_6 X_{ht} + \varepsilon_t \tag{16}$$

In Eq. (16) where β_0 is the intercept, TI_{dt} refers to the Herfindahl–Hirschman Concentration Index (HHI) of selected livestock and poultry feed commodities. Import concentration, measured by the Herfindahl–Hirschman Index (HHI), was treated as an explanatory variable because it represents the observed structure of Iran's import portfolio in each year. The objective of the analysis is to examine the association between portfolio structure and the specific risk index rather than to estimate a simultaneous causal relationship. ECI_{bt} represents the economic complexity index (ECI), which measures the characteristics of the products produced in economic systems in the countries. The ECI seeks to explain the knowledge accumulated in the population of a country (networks formed by people to produce goods) ,and its result can be observed in the industrial composition of countries. A combination of product diversity and comprehensiveness criteria are used to measure the relative export complexity of countries. ECI was developed by Cesar Hidalgo from the Massachusetts Institute of Technology (MIT) and Ricardo Hausmann from Harvard University. Iran's Economic Complexity Index (ECI) was included as an explanatory variable because it reflects the country's productive capabilities and structural sophistication. Greater economic complexity enhances the economy's ability to diversify production, adapt to external trade shocks, and improve supply chain resilience. Consequently, changes in economic complexity are expected to influence the specific risk associated with the feed import portfolio. X_{dt} represents the variable for real exchange-rate depreciation, while X_{et} represents the variable for real exchange-rate appreciation. These two variables are constructed based on the annual change in the real exchange-rate index relative to the previous year. Specifically, X_{dt} takes the value of the positive change in the real exchange-rate index when the index increases relative to the previous year, and zero otherwise. Conversely, X_{et} takes the value of the negative change when the real exchange-rate index decreases relative to the previous year, and zero otherwise. Under the definition of the real exchange-rate index used in this study, an increase in the index represents a depreciation of the Iranian rial, whereas a decrease represents an appreciation. Since Iran is an oil-dependent country, X_{gt}, as the oil revenue logarithm of Iran is considered in that year. X_{ht} is the growth of domestic livestock and poultry production in Iran. Because both the HHI and the constructed specific-risk index are based, in part, on the observed distribution of import shares across trading partners, a potential mechanical relationship exists between these measures. Therefore, the estimated regression relationships are interpreted as associations rather than causal effects.

Table 1 summarizes the variables used in this study, including their definitions, units of measurement, data sources, and time coverage. The empirical analysis is based on annual data for the period 1992–2020. Following the small-country assumption in international trade theory, Iran is assumed to be a price taker in the international market for the selected livestock and poultry feed commodities. Accordingly, the import price of each commodity in Iran is measured as its annual import unit value, calculated by dividing the total import value by the corresponding import quantity, using data from the Islamic Republic of Iran Customs Administration (IRICA). The corresponding world prices reported by the World Bank are used as the international reference prices in the empirical analysis and are treated as exogenous to Iran.

Table 1. Description of variables used in this study.

Variable	Description	Unit	Data Source	Reference
Q_{it}	Annual imports of soybean meal, maize, and barley by trading partner	10 e4 tons	Iran Customs Administration (IRICA)	Iran Customs Administration (2021)
S_{it}	Annual share of each exporting country in Iran's imports	Percentage (%)	Calculated from IRICA data	Author's calculations
a_{jt}	The share of commodities of soybean meal, barley, and maize from the total import volume of livestock and poultry feed commodities	-	Calculated from IRICA data	Author's calculations
P_{cjt}	Domestic imported price: Import value divided by import quantity	US$/kg	Calculated from IRICA data	Author's calculations
P_{bjt}	World price: Annual international market price of selected commodity	US$/Kg	World Bank Commodity Price Data	World Bank (2021)
σ_{jt}	Monthly variance of the global price of the selected commodity	US$/Kg	World Bank Commodity Price Data	Author's calculations
ω_{it}	Trade risk-adjustment factor: Political, economic, and financial risk of trading partners	Index	International Country Risk Guide (ICRG)	PRS Group (2021)
ECI_{bt}	Iran's Economic Complexity Index	Index	Atlas of Economic Complexity	Harvard Growth Lab (2021)
X_{dt}	Real exchange rate reduction	Percentage	Central Bank of Iran	Author's calculations
X_{et}	Real exchange rate enhancement	Percentage	Central Bank of Iran	Author's calculations
X_{ht}	Annual fluctuations in domestic livestock and poultry production	Tons	Statistical Centre of Iran	Statistical Centre of Iran (2021)
X_{gt}	logarithm of oil export revenue of Iran	Million Dollar	World Bank	World Bank (2021)

3. Results and discussion

3.1. Herfindahl–Hirschman Concentration Index (HHI) of Iran's livestock and poultry feed import portfolio

Figure 4 presents the evolution of the Herfindahl–Hirschman Index (HHI) for Iran’s livestock and poultry feed import portfolio over the period 1992–2020. The results show a general decline in the HHI, indicating that the number of supplying countries increased over time, resulting in lower supplier concentration and a more balanced distribution of import shares among trading partners. This section therefore examines the evolution of import concentration and identifies the major suppliers that shaped Iran's feed import portfolio during the study period.

During the early period (1992–2002), Iran's imports remained highly concentrated in Brazil and Argentina, despite the entry of additional suppliers. The portfolio HHI reached its highest value of 0.73 in 2002, while the lowest value (0.33) occurred when imports were distributed among several suppliers, including the United States, Argentina, Australia, India, and South Africa. Although China and India entered the import portfolio during this period, their relatively small shares had a limited effect on overall diversification

Between 2003 and 2011, the import portfolio changed substantially due to the increasing role of intermediary trading countries, particularly Switzerland and the United Arab Emirates. However, the reduction in concentration was limited, as the portfolio HHI remained between 0.37 and 0.61, reflecting the continued dominance of a few major suppliers. In some years, more than half of total imports came from a single country, indicating persistent supplier concentration.

During 2012–2020, import volumes increased significantly, exceeding 17 million tonnes in 2019, and the number of trading partners reached fourteen. Although the HHI declined to its lowest value of 0.32 in 2020, the import portfolio remained concentrated. Major suppliers, including the United Kingdom, Turkey, the United Arab Emirates, the Netherlands, and Switzerland, still accounted for most imports. These results show that portfolio expansion was mainly achieved through increased imports from a limited number of dominant suppliers rather than a more balanced distribution among trading partners.

Commodity-level results show a similar pattern. Soybean meal had the largest decline in supplier concentration, with the HHI decreasing from 0.93 in 1997 to 0.37 in 2016. Maize concentration also declined, with the HHI falling from 1.00 in 2000 to 0.32 in 2020, while barley showed a smaller reduction from 1.00 to 0.34 during the study period.

Overall, all three commodities experienced lower supplier concentration and greater diversification over time, however, the results indicate that increasing the number of trading partners alone is not enough to reduce concentration. The level of concentration mainly depends on the distribution of import shares among suppliers. Therefore, despite expanding Iran's trading network, imports remained concentrated among a few major exporters in many years, limiting the formation of a more balanced import portfolio.

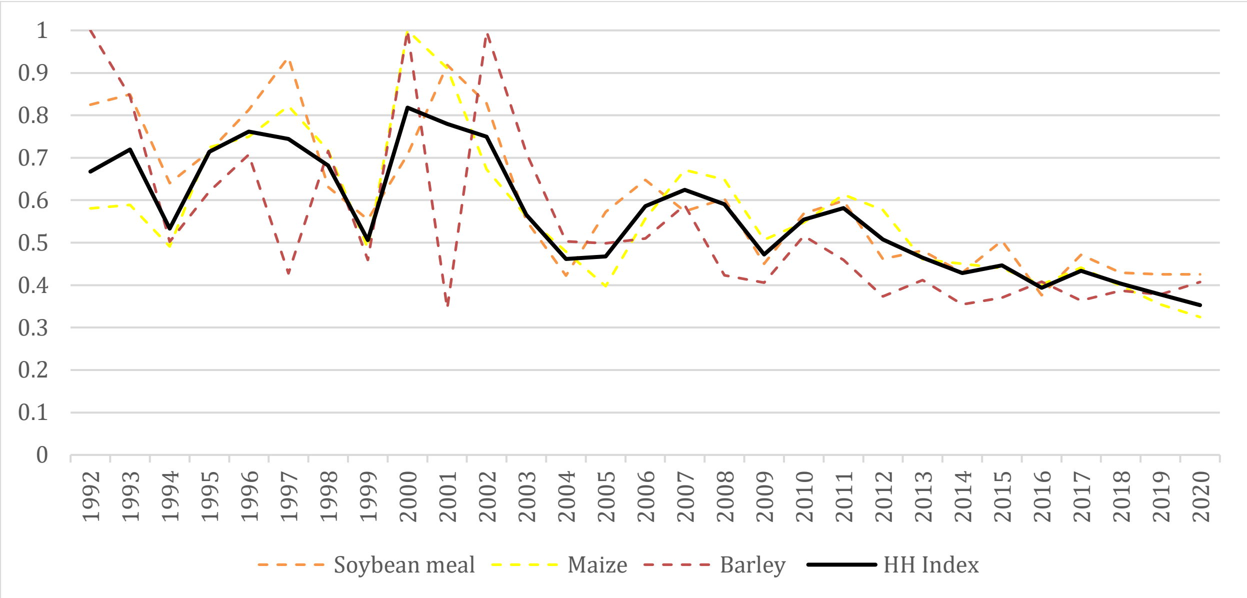

Fig. 4. HH Index of import of Soybean meal, Barley, Maize (I_{dt}), and aggregate HHI (TI_{dt}) in Iran**.**

3.2. Price Analysis and Relationship Between Iran's Import Prices and World Prices of Selected Livestock and Poultry Feed Commodities During 1992–2020

Figure 5 shows the trends in Iran's import prices and world prices for soybean meal, maize, and barley during 1992–2020. For all three commodities, import prices were consistently higher than world prices due to transportation, insurance, transaction, and intermediary costs. A common pattern across the three markets was the sharp price increase during 2007–2013, followed by a gradual decline after 2014 as global supply conditions improved and international markets became more stable.

Maize prices remained relatively stable until 2005 but increased sharply after 2007, reaching their highest level in 2013. The decline after 2014 was associated with higher global exports, particularly from Brazil, the United States, Argentina, and Ukraine, which are major players in the international maize market (WTO, 2021). However, Iran's import prices remained above world prices and declined more slowly, indicating the continued impact of transportation, transaction, and intermediary costs.

Soybean meal had the highest price level and the greatest volatility among the three commodities. Prices increased significantly during 2007–2013, with the largest gap between world and import prices occurring around 2013. Since the global soybean meal market is highly concentrated, with Brazil, the United States, and Argentina accounting for most exports, supply shocks and export policies in these countries strongly affect world prices (WTO, 2021). Despite declining global prices after 2014 due to increased production and exports, Iran's import prices remained substantially higher, suggesting incomplete transmission of global price reductions.

Barley showed a similar pattern, with stable prices before 2007, a sharp increase during 2007–2013, and a decline afterward. Unlike soybean meal and maize, barley trade is less concentrated, with exports shared among France, Australia, Ukraine, and the Russian Federation, making prices more sensitive to production and export changes in these countries (WTO, 2021). Although both world and import prices decreased after 2014, Iran's import prices remained above global levels, indicating the continued role of import-related costs.

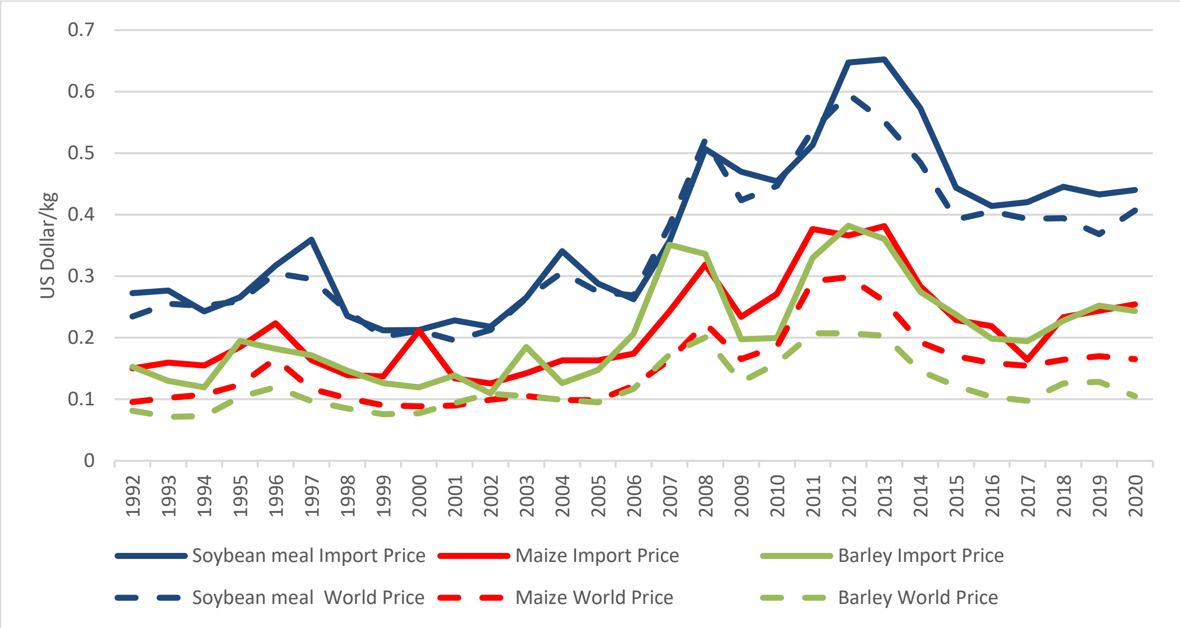

Fig. 5. World price and import price of Soybean meal, Barley, and Maize.

Before estimating the regression model, the stationarity properties of the variables were examined. The detailed results of the unit root tests are reported in Appendix Table 1A. The relationships were estimated using OLS (Table 2). As no ARCH effect was detected, GARCH estimation (Engle, 1982; Engle et al., 1986) was unnecessary. The estimated coefficients indicate strong price transmission from international to domestic markets. Among the three commodities, barley exhibited the strongest price transmission from world markets, whereas soybean meal and maize experienced comparatively lower transmission effects. A one-dollar increase in the world price increased Iran's import price by approximately 1.1 US dollars for soybean meal, 1.7 US dollars for barley, and 1.2 US dollars for maize. The soybean meal estimate is consistent with the law of one price and supports the findings of Martignone et al. (2022), indicating a high degree of market integration. The relatively high price transmission coefficient estimated for barley suggests that Iran's import price is more sensitive to fluctuations in world market prices than those of soybean meal and maize. This greater sensitivity may reflect differences in trading arrangements, procurement timing, intermediary trading channels, and transaction and logistics costs associated with barley imports. In addition, institutional arrangements related to import procurement and market regulation may amplify the transmission of international price shocks to domestic import prices. Therefore, the estimated coefficient should be interpreted as reflecting not only global price movements but also the characteristics of the import supply chain and trading arrangements.

Given the limited number of annual observations (29 observations), the estimated OLS models were evaluated using standard diagnostic tests for model adequacy. The Jarque–Bera test was used to assess the normality of the residuals, the Ramsey RESET test to examine potential functional-form or specification errors, and the Breusch–Godfrey LM test to detect serial correlation. The results provided no evidence of significant non-normality, specification error, or residual autocorrelation. In the price-transmission equations, an AR(1) specification was incorporated to account for first-order serial correlation in the disturbance process. These diagnostic tests support the adequacy of the estimated specifications.

Table 2. The results of estimating the relationship between the import price and the world price of selected livestock and poultry feed commodities.

	Soybean meal		Barley		Maize	
Variable	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
C	0.0001	0.02	0.005	0.02	0.02**	0.01
World Price	1.1***	0.02	1.7***	0.19	1.2***	0.05
AR(1)	0.31	0.18	0.4	0.2	0.06	0.21
SIGMASQ	0.0008***	0.0002	0.0008	0.0002	0.0002***	0.000006
R^2	0.95		0.85		0.95	
F statistic	159.38***		49.33***		177.45***	
DW	1.77		1.89		1.96	
Test	**Value**	**Prob**	**Value**	**Prob**	**Value**	**Prob**
ARCH effect	0.90	0.35	0.01	0.91	0.11	0.73
LM test	2.89	0.11	2.22	0.12	0.15	0.85
Ramsey RESET Test	0.5	0.61	0.04	0.96	0.68	0.98

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

3.3. The systematic and specific risk of the portfolio

After estimating the price relationships, total import portfolio risk was decomposed into systematic and specific components. Figure 6 illustrates the changes in total portfolio risk for selected feed commodities during the study period. Overall, portfolio risk increased substantially from 42.23 in 1992 to 1,021.28 in 2020, reaching a maximum of 1,425.73 in 2017 (Fig. 6). Although annual fluctuations reflected changes in international markets and import composition, the long-term increase was mainly driven by the expansion of feed imports after 2001, which increased Iran's exposure to global markets.

The decomposition results show that specific risk was the main contributor to total portfolio risk during most of the study period. After 2001, supplier-related risk increased significantly and accounted for the largest share of total risk, with maize contributing the most due to its dominant import share and higher commodity-specific risk. In contrast, systematic risk showed greater annual fluctuations, particularly after 2007 during the 2008 global financial crisis and the 2010–2012 climate-related shocks, but remained lower than specific risk, indicating the main role of supplier-related factors in overall import vulnerability.

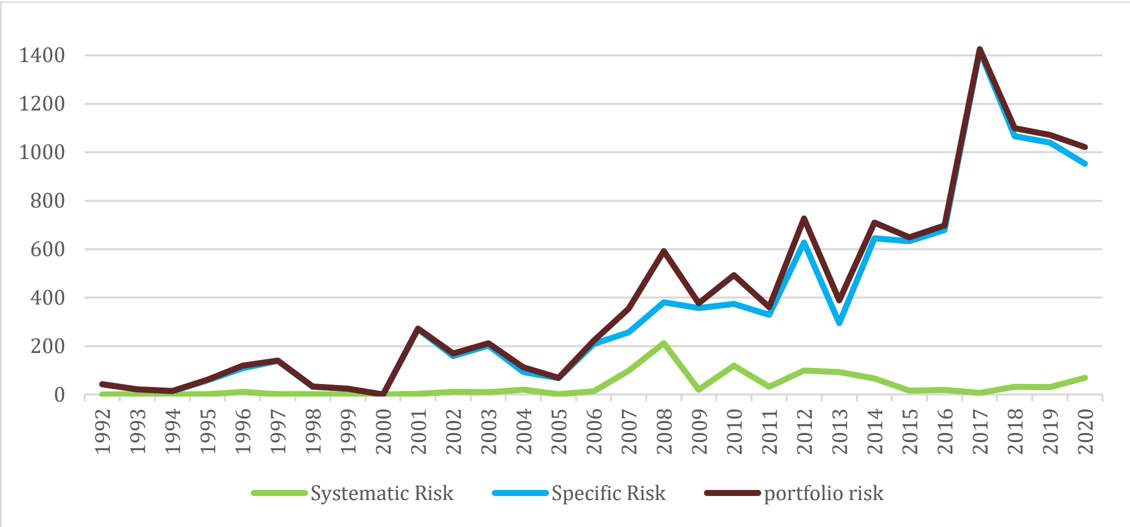

Fig. 6. The systematic and specific risk of the portfolio in Iran of feed commodities import during the period 1992-2020.

Specific risk was very low in the early years and reached its minimum in 2000, when import volumes were lowest. After 2000, it increased considerably, with differences across commodities showing the important role of both import volumes and supplier composition. Figures 7–9 present the changes in specific risk for Iran's maize, soybean meal, and barley import portfolios during 1992–2020 and the contribution of each trading partner. Trading partners with less than 1% of annual imports were excluded for clarity.

Among the three commodities, maize consistently had the highest specific risk. After increasing to 250.7 in 2001, maize-specific risk remained high and reached a maximum of 1,381.8 in 2017. Although it declined slightly afterward, it remained above 900 during 2018–2020. At its peak, maize-specific risk was approximately 37 and 46 times higher than the peak values of soybean meal and barley, respectively, indicating that maize was the main source of specific risk in Iran's feed import portfolio.

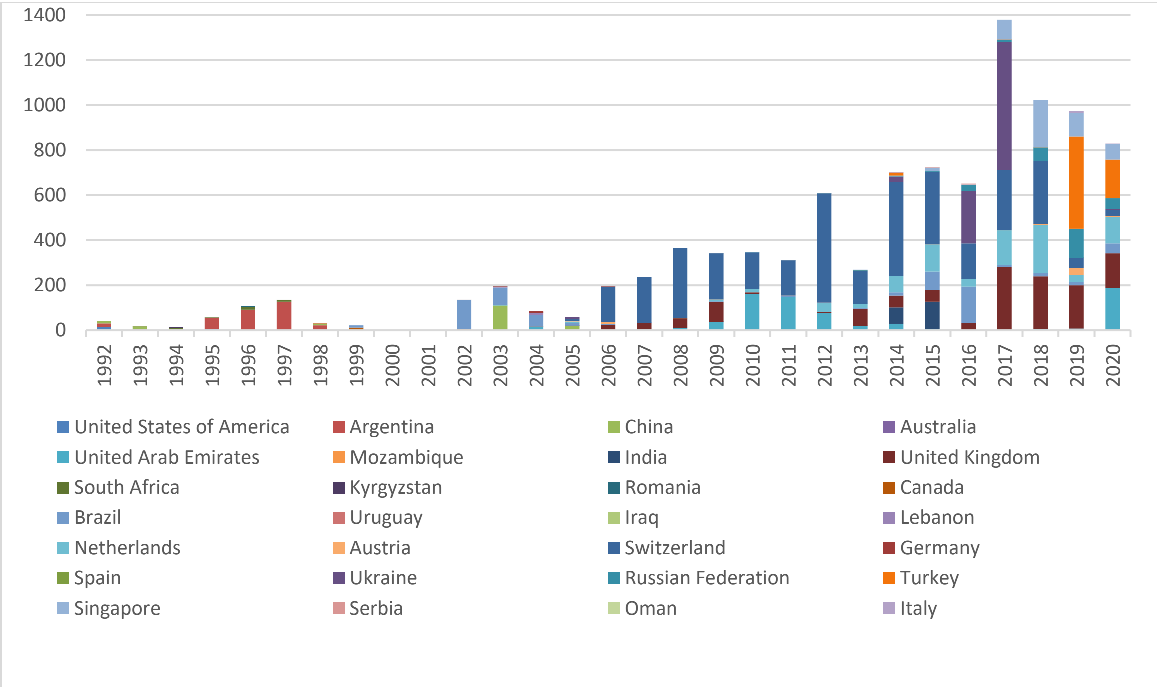

Fig. 7. The specific risk of the maize import portfolio during 1992-2020.

Soybean meal showed a lower but increasing specific risk. After remaining below 3 throughout the 1990s, its risk increased after 2001, with peaks in 2010, 2013, 2015, and 2017–2019. The highest value was recorded in 2019 (37.02), declining to 13.29 in 2020. Compared with maize, soybean meal showed a smoother risk pattern, suggesting a relatively more stable supplier structure.

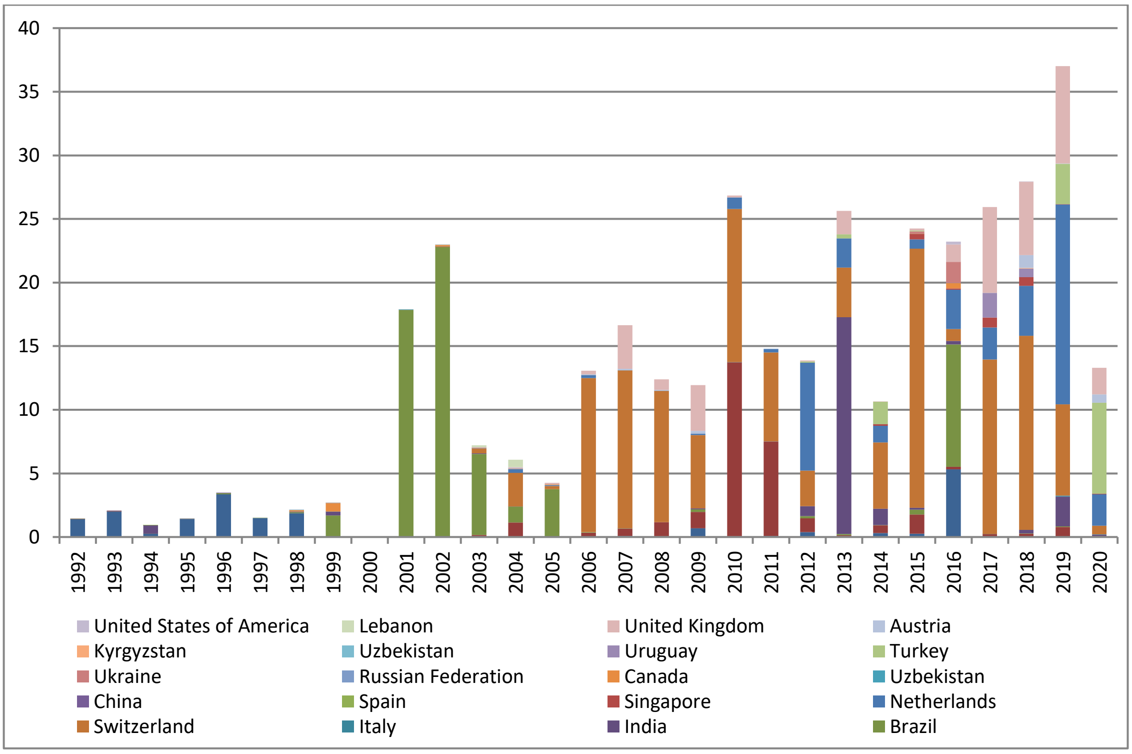

Fig. 8. The specific risk of the soybean meal import portfolio during 1992-2020.

Barley had the lowest specific risk during most of the study period. Its risk remained close to zero until the early 2000s and generally below 6 through 2016. However, it increased after 2017, reaching a maximum of 30.00 in 2019 before declining to 7.54 in 2020. Despite having the lowest absolute risk level, the increase after 2017 indicates growing vulnerability of barley imports to supplier-specific risks.

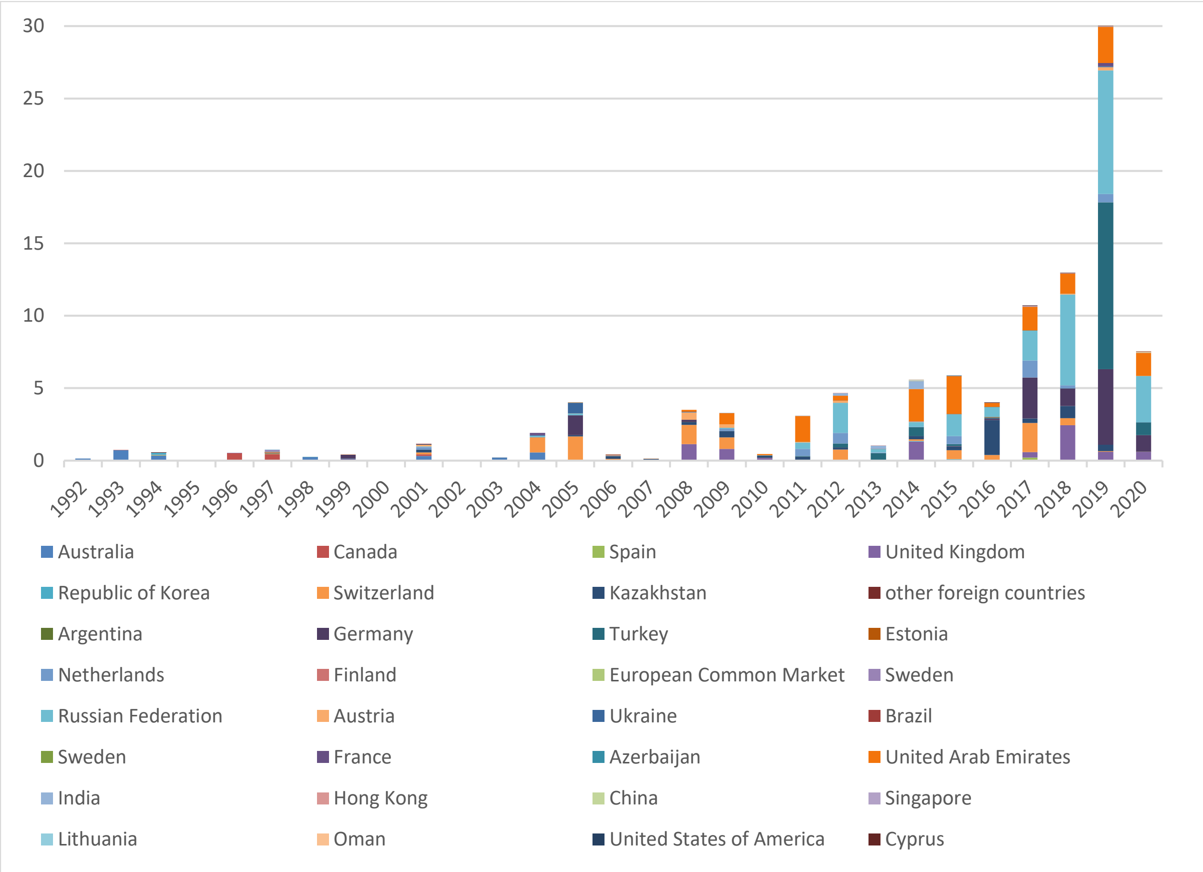

Fig. 9. The specific risk of the barley import portfolio during 1992-2020.

3.4. The systematic and specific risk index of the portfolio

The absolute systematic risk, specific risk, and total portfolio risk measures presented earlier reflect the magnitude of risk in Iran's livestock and poultry feed imports. Since these measures are based on import quantities, they are affected by changes in import scale, meaning that higher import volumes can increase absolute risk even without changes in supplier composition. To allow comparisons across years and commodities, standardized risk indices were developed using the import shares of trading partners instead of import quantities. These indices remove the effect of import size and measure the relative structure and distribution of portfolio risk, allowing consistent comparisons of systematic and specific risk over time.

Figure 10 presents the systematic risk index, specific risk index, and total portfolio risk index of Iran's soybean meal, maize, and barley import portfolio during 1992–2020. The total portfolio risk index remained relatively stable over the study period, ranging from 0.080 to 0.206, despite the increase in absolute portfolio risk. The highest value (0.206) was observed in 2008, while the lowest (0.080) occurred in 2019.

The systematic risk index showed greater fluctuations over time, reaching its maximum value (0.117) in 2008 during the global financial crisis and remaining relatively high during the climate-related food price shocks of 2010–2012. Its subsequent decline, with moderate increases including in 2020, suggests that systematic risk was mainly driven by external market shocks rather than structural changes in the import portfolio. Risk decomposition shows that specific risk constituted the dominant component of total portfolio risk. Despite the substantial growth in livestock feed imports, the specific risk index remained relatively stable, ranging from 0.061 to 0.181, and exceeded the systematic risk index in most years.

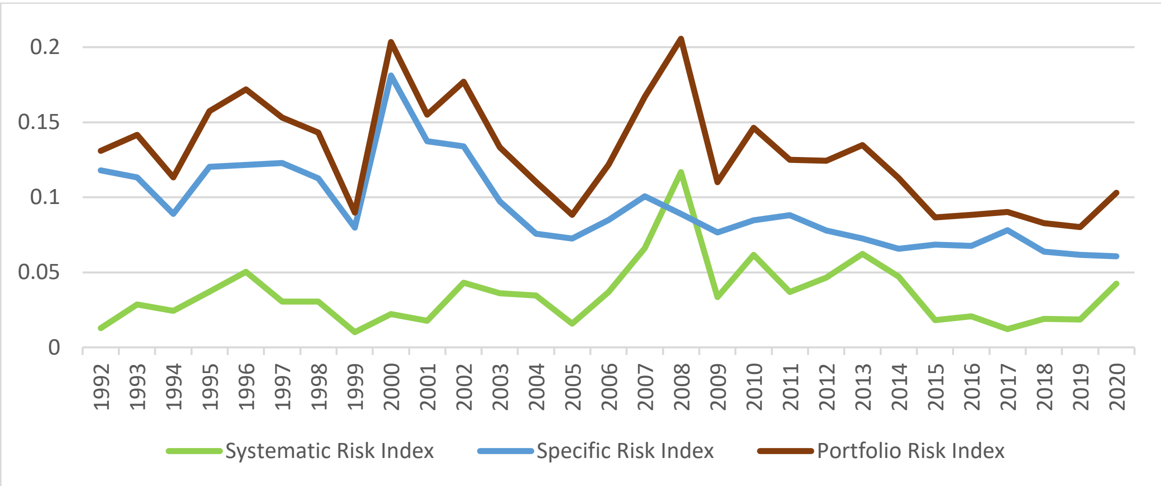

Fig. 10. Systematic and specific risk indexes of Iran's import portfolio for selected livestock and poultry feed commodities during 1992–2020.

Figure 11 presents the systematic risk index for Iran's imports of soybean meal, maize, and barley during 1992–2020. The systematic risk index remained relatively low during most of the study period but increased substantially during episodes of global market instability, particularly in 2008. Soybean consistently exhibited the highest systematic risk index among the three commodities, while maize generally recorded the lowest values. Barley showed an intermediate level of systematic risk, with notable increases during the 2008 food price crisis and again in 2013–2014.

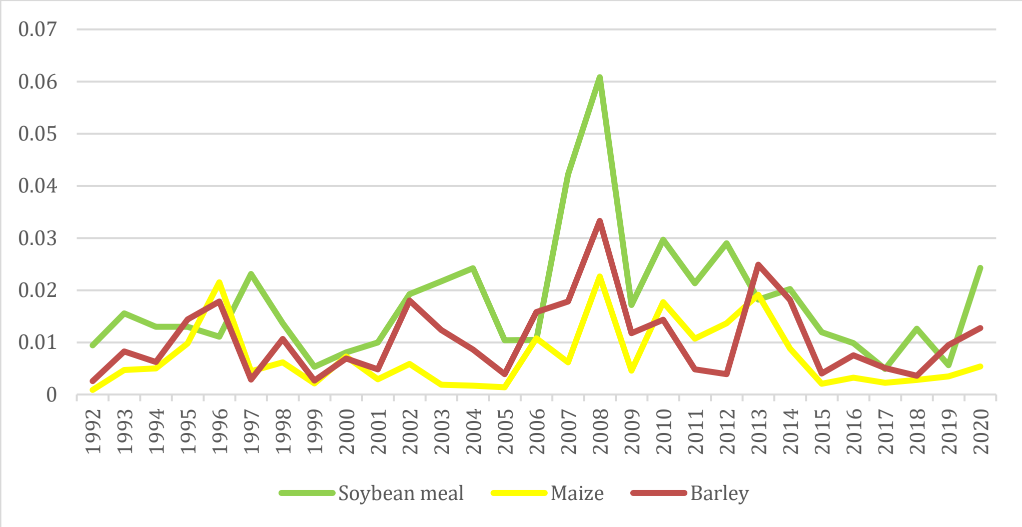

Fig. 11. Systematic risk index of Iran's import portfolio for selected livestock and poultry feed commodities during 1992–2020.

Figure 12 presents the specific risk index of Iran's soybean meal, maize, and barley import portfolios during 1992–2020. Among the three commodities, maize consistently showed the highest specific risk index, ranging from 0.031 to 0.119, with the maximum value recorded in 2000 (0.1186). Although maize-specific risk declined after 2013, it reached 0.0309 in 2020. Soybean meal exhibited an intermediate level of specific risk index, fluctuating between 0.013 and 0.033, with the highest value observed in 2001 (0.0332), followed by a decline and stabilization at approximately 0.014–0.016 after 2014. Barley had the lowest specific risk index in most years, ranging from 0.012 to 0.037, with a peak of 0.0374 in 2000, and remained relatively stable during the last decade.

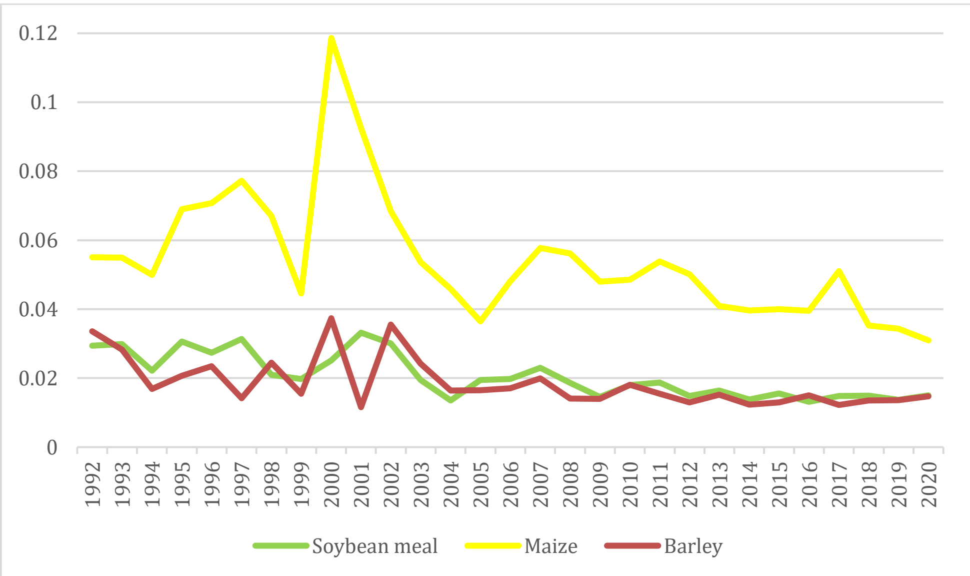

Fig. 12. Specific risk index of Iran's import portfolio for selected livestock and poultry feed commodities during 1992–2020.

3.5. Examining the variables affecting the specific risk index of Iran's import portfolio for selected livestock and poultry feed commodities

As a prerequisite for the regression analysis, unit root tests were conducted to examine the stationarity of the variables (Appendix Table 2A). The results indicate that all variables are stationary in levels (I(0)), confirming the appropriateness of the subsequent OLS estimation. Table 3 presents the estimation results for the determinants of the specific risk index of Iran's import portfolio for selected livestock and poultry feed commodities. The estimated model exhibits strong explanatory power ($R^2 = 0.85$) and is statistically significant overall ($F = 19.87$, $p < 0.01$), indicating that the selected variables explain a substantial proportion of the variation in specific risk.

The real exchange rate also has a significant influence on the specific risk index. The estimated positive coefficient indicates that real exchange rate depreciation increases the specific risk index, whereas a 1% appreciation of the real exchange rate reduces it by approximately 0.02 units. This finding is consistent with Iran's heavy dependence on imported livestock and poultry feed commodities. Currency depreciation raises the domestic cost of imports, reduces importers' purchasing power in international markets, and increases uncertainty in procurement decisions. As a result, importers have less flexibility to diversify sourcing or select lower-risk trading partners, leading to a higher level of supplier-specific risk within the import portfolio.

Oil revenues exhibit a negative and statistically significant relationship with the specific risk index. Specifically, a 1% increase in oil revenues reduces the specific risk index by approximately 0.003 units. Higher oil revenues improve the availability of foreign exchange, facilitate import financing, and provide greater flexibility in selecting reliable trading partners. Consequently, importers can avoid excessive dependence on a limited number of suppliers, thereby reducing supplier-specific risk within the import portfolio.

In contrast, the Economic Complexity Index (ECI), real exchange rate appreciation, and changes in domestic livestock production had no statistically significant effects on the specific risk index. The results indicate that specific risk was mainly driven by import concentration (HHI), exchange rate dynamics, and foreign exchange availability, rather than broader economic structures or short-term production changes. Diagnostic tests confirmed model reliability, as the ARCH, Breusch–Godfrey LM, and Ramsey RESET tests showed no evidence of heteroskedasticity, serial correlation, or functional form problems. Moreover, the Durbin–Watson statistic (1.9) confirmed that residual autocorrelation was not a concern.

Table 3. Determinants of the specific risk index of Iran's imports of selected livestock and poultry feed commodities.

Variable	Coefficient	Std. Error
C	***0.085	0.03
TI_{dt}	***0.069	0.00
ECI_{bt}	-0.004	0.00
X_{dt}	*0.021	0.01
X_{et}	-0.002	0.00
X_{gt}	*-0.003	0.00
X_{ht}	0.002	0.00
R^2	0.85	
F statistic	19.87***	
DW	1.9	

Test	Prob	Value
ARCH Effect	0.64	0.22
LM	0.8	0.22
Ramsey RESET	0.14	2.18

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Conclusions

This study examined Iran's livestock and poultry feed import portfolio during 1992–2020 by analyzing import concentration, price transmission, and the determinants of import risk. The findings show that although import volumes increased substantially, the Herfindahl–Hirschman Index (HHI) declined and the number of trading partners increased, indicating gradual diversification of import sources. However, Iran's import network includes both producing and intermediary (re-exporting) countries, highlighting the complexity of supplier relationships. Therefore, the resilience of the feed import portfolio depends not only on global market conditions but also on domestic economic factors and supplier composition.

The results indicate that all three feed commodities are strongly affected by international prices, confirming Iran's role as a price taker in global feed markets. Among the commodities, barley showed the highest price transmission, suggesting greater exposure to external price shocks and the need to improve supply chain efficiency and reduce vulnerability to international market fluctuations.

Portfolio risk analysis shows that specific risk is the main source of total import risk, while international price fluctuations contribute less. This finding highlights the importance of supplier characteristics and portfolio structure in determining import vulnerability. Among the commodities, maize showed considerably higher specific risk than soybean meal and barley, indicating the need for commodity-specific risk management strategies.

Although absolute import risk increased over the study period, the decline in the specific risk index suggests improvements in supplier selection and portfolio management. However, during periods of intensified economic sanctions, import concentration, specific risk, and price transmission increased, demonstrating the negative impact of geopolitical constraints on import resilience.

The determinants of specific risk provide important policy implications. A diversified portfolio based on reliable and lower-risk suppliers can reduce import risk. In addition, exchange-rate stability is essential for improving the resilience of agricultural imports. The negative relationship between oil revenues and specific risk suggests that improving market efficiency and strengthening market-based supplier selection mechanisms can contribute to better allocation of import sources.

However, diversification strategies should consider Iran's trade restrictions, sanctions, financial limitations, and logistical constraints. Therefore, the objective should not be unrestricted replacement of suppliers, but rather improving the composition of feasible and reliable suppliers. Establishing a dedicated import risk monitoring unit within the Ministry of Agriculture or related institutions could support continuous assessment of supplier concentration, country risk, exchange-rate exposure, and global market conditions. Monitoring indicators such as HHI, specific risk indexes, and supplier risk profiles, together with a formal ranking system for trading partners, would improve procurement decisions and strengthen the resilience of the feed import system.

Several limitations should be noted. First, specific risk was estimated using the residual component, which may include unobserved factors and other sources of uncertainty. Although the determinants of specific risk were examined, future studies could incorporate additional supplier-level characteristics. Second, exchange-rate effects were captured using separate variables for appreciation and depreciation; future research could apply nonlinear models or structural-break approaches to examine possible asymmetric effects across different exchange-rate regimes. Third, the analysis covers the period 1992–2020; therefore, the findings should be interpreted within this historical period and not as direct evidence of current import-policy conditions. Future research should update the database and examine post-2020 developments, while higher-frequency data (daily, monthly,...) could be used to capture short-term risk dynamics and temporary supply disruptions.

For future import planning, suppliers with established trading relationships and lower country-risk profiles should be considered. Although the 2020 import portfolio had the lowest specific-risk index during the study period, its supplier structure should be viewed only as a historical reference for comparison with import portfolios in subsequent years, rather than as an optimal portfolio.

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Table 1A. The results of the stationarity test of the variables with the Augmented Dickey-Fuller test.

Variable		t-Statistic	Prob	Result
Soybean meal	Import price	-3.03^{***}	0.00	I(0)
	World price	-3.6^{**}	0.05	I(0)
Barley	Import price	-3.35^{*}	0.07	I(0)
	World price	-1.9^{*}	0.06	I(0)
Maize	Import price	-3.26^{**}	0.02	I(0)
	World price	-2.47^{*}	0.09	I(0)

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively

Table 2A. The results of the stationarity test of the variables with the Augmented Dickey-Fuller test.

Variable	t-Statistic	Prob	Result
$I_{c\varepsilon tj}$	-2.93^{**}	0.01	I(0)
ECI_{bt}	-2.94^{***}	0.00	I(0)
X_{dt}	-3.54^{**}	0.05	I(0)
X_{et}	-5.3^{***}	0.00	I(0)
X_{gt}	-1.71^{*}	0.09	I(0)
X_{ht}	-4.78^{***}	0.00	I(0)

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.