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Research Article

The effects of price explosion and compensatory policies on food security: The Case of chicken meat consumers in Iran

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ABSTRACT- Rising food prices have raised concerns about declining food security and increasing food poverty, thereby increasing the vulnerability of the poor to food insecurity. Chicken meat is highly consumed in Iran and plays a key role in the Iranian food basket. Therefore, the explosion in its price in 2020 has posed a threat to the country's food security. Iran's chicken industry is highly dependent on imported inputs, so any increase in exchange rates, global prices, and import restrictions will increase the final price of chicken. In this context, the current study examined the impact of the chicken price explosion and compensation strategies on the amount of calories consumed by consumers. For this purpose, a multi-market equilibrium simulation model was used. The chicken market is linked to the red meat market (beef and sheep). The results showed that an 84% increase in the price of chicken in 2020 would lead to a 41%, 6%, and 14% decrease in the consumption of chicken, beef, and sheep, respectively. In addition, an increase in the price of chicken meat led to a decrease in per capita calorie intake by around 27%. These results indicate that beef and sheep products are not considered viable alternatives to chicken in Iran. Comparing policies that increase nominal income with policies that increase products on the market, the results show that policies that increase products on the market through increased production or imports have more favorable effects on food security. The results also revealed that improving policies related to the import of products will lead to favorable effects on food security compared to nominal income enhancement policies. The results of this study provide policy and decision makers with appropriate adaptation strategies to deal with price shocks in the food sector of the countries.

INTRODUCTION

Increased purchasing power, population growth, and dietary changes have all contributed to an increase in demand for protein products in recent decades, particularly in developing countries (Deng et al., 2017). A 70 kg person needs 70 grams of protein per day, with around a quarter of that (25 grams) coming from animal protein (Van Campenhout et al., 2018). Households that eat a variety of meats, such as red meat and poultry, consume the most animal protein and calories (Van Campenhout et al., 2018). However, the sudden rise in food prices endangers the food security situation for households that spend a high percentage of their income on food purchases (Hernandez et al., 2014). The FAO Food Price Index (FPI) data show that the World Food Price Index (FPI) reached 133 points in October 2021. This is the highest price since July 2011 (FAO, 2021). Accordingly, concerns have increased about the food security vulnerability of poor households, especially in developing countries such as Iran (Sheriff et al., 2020). However, the availability of animal protein in the food basket is a significant requirement for ensuring community food security (Gómez-Luciano et al., 2019; Harris et al., 2019).

Chicken meat, among meat products, is particularly significant in the household food basket, not only because of its high quality and cost-effective protein supply but also because of the important vitamins and minerals it contains (Kuttappan et al., 2017). FAO statistics show that chicken meat is the second most common source form of protein for urban households. This is because every 100 grams of chicken meat provides 298 calories and accounts for 38.1% of the protein intake in urban households (FAO, 2013). In addition, with the development and expansion of chicken meat production units and the increase in production, chicken meat has become an essential commodity in the food basket of households. Therefore, this product is currently considered one of the most important sources of protein for households (Daghir et al., 2021). Accordingly, the average per capita consumption of chicken meat in Iran has increased from 21.83 kg in 2008 to 32 kg in 2019 (Iran's Ministry of Agriculture, 2020). This is despite the fact that global chicken meat consumption per capita is expected to be approximately 15 kg in 2018 (OECD, 2018). Hence,

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chicken meat is a popular product in Iranian households. Given the importance of protein intake and the role of different types of meat in providing this substance, it is important to calculate calorie intake.

Over the past few decades, Iran's poultry sector has expanded significantly and become a key player in protein supply due to the escalating demand for chicken meat. The country's production of chicken meat increased from an estimated 1.6 million tonnes in 2008 to 2.7 million tonnes in 2019, reflecting significant growth in the industry (FAO, 2020). Despite this progress, the industry faces challenges such as economic volatility and supply-demand imbalances, which increase risks for both producers and consumers. Rezitis and Sassi (2013) predicted that the new millennium would be characterized by price volatility in the agricultural and food sectors. Such price increases, especially for essential commodities such as poultry, have raised concerns about food security, especially among the most vulnerable households (Rad et al., 2021; Wood et al., 2012). A stark illustration of these fluctuations is the 84% increase in chicken meat prices in 2020, highlighting the volatility that characterizes this market (Statistical Center of Iran, 2020a). Iran's economy has an inflationary structure, with significant annual price increases across a wide range of products. Data from the Statistical Centre of Iran show that average expenditure on food quadrupled between 2008 and 2016, marking years when prices rose by more than 40% (Statistical Centre of Iran, 2020b). A notable example is the price evolution of chicken over this period, which recorded a sharp increase of 54% between 2011 and 2012. Similarly, a significant increase of around 40% was recorded between 2016 and 2017, as depicted in Fig. 1. This figure illustrates the average annual price of chicken meat in Iran from 2008 to 2019. After 2017, the rate of escalation of chicken meat prices accelerated. By 2019, the expenditure per kilogram surged from roughly 74,000 Rials ($.325) to 130,000 Rials ($.572). Meanwhile, according to the information of Statistical Center of Iran (2020a), the price of each kilogram of sheep and beef in 2019 compared to 2018 has experienced a growth of 15% and 13%, respectively. Of course, the increase in the price of red meat has been more significant in the years before 2018. According to the consumer price index, the price of each kilogram of sheep meat has increased from 361,000 Rials in April 2016 to 946,000 Rials in November 2018 (an increase of 162%). In the same period, the price of each kilogram of beef has increased from 345,000 Rials to 846,000 Rials (145%). However, in recent years, per capita consumption of red meat has fallen due to the higher expenditure and price of red meat, while per capita consumption of chicken has risen due to the lower price.

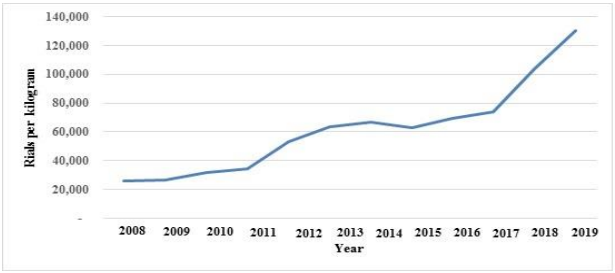

Fig. 1. Price trend of chicken meat in Iran during the years 2008-2019. Source: (Statistical Center of Iran, 2020a)

Despite the Iranian government's efforts to mitigate the effect of price hikes through subsidies, these measures have not been successful (Iran's Ministry of Agriculture, 2019). The chicken meat industry in Iran heavily depends on imported feed and other inputs. Consequently, fluctuations in exchange rates, global prices, or import restrictions directly contribute to increased costs of chicken meat production (Pishbahar et al., 2019). Such sharp price escalations, driven by market disequilibrium, adversely affect both producers and consumers, posing a risk to the food security of the community (Jones and Monsivais, 2016). Therefore, it is imperative to assess how the escalating expenditure on poultry meat affects consumption patterns and overall food security (Ben Abdallah et al., 2021). A review of studies shows that the use of the multi-market equilibrium model to assess the effect of price shocks on food security and household welfare has not received much attention. Indeed, single market equilibrium models have been used to study price shocks and horizontal linkages have not been considered. However, given the advantages of multi-market equilibrium models, including simultaneous attention to the supply and demand of products related to the poultry market, the use of this model is very beneficial. In the 1980s, the World Bank developed multi-market models to study the effect of changes in price policies on production, demand, income, and trade in Senegal, South Korea, and Cyprus (Chilosi and Federico, 2021). Balagtas and Kim (2014) tracked the economic effect of advertising in dairy and milk markets. Given the linkages between dairy markets and the effect of prices and promotions of one product on the demand for another, conventional econometric analyses and models are not appropriate for this purpose. Therefore, an analytical and multi-market model that takes into account horizontal linkages has been presented. Furthermore, the study conducted by Balagtas and Kim (2014) showed that the use of conventional econometric models generally overestimates the effectiveness of dairy advertising. In other words, multi-market equilibrium models reduce the error in measuring the effectiveness of advertising. These models do this by constructing the horizontal relationship between supply and demand in the markets and taking into account substitution and complementarities between goods (Lee, 2021).

A body of research, including works by Croppenstedt et al. (2017), Balagtas and Kim (2014), Haggblade et al. (2017), Yu and Kim (2020), and Fathi and Bakhshoodeh (2021), have used multi-market models to examine the effect of different shocks in agricultural markets, such as those related to prices, production, and income. Specifically, Haggblade et al. (2017) examined how production shocks and fluctuations in global prices affect calorie consumption among vulnerable populations in Sahelian West Africa. The study highlighted that a drought-induced decline in rainfed cereal production, coupled with rising global rice prices, significantly threatens the food security of impoverished households. It found that a 20% reduction in domestic rainfed cereal production could lead to a 15% reduction in calorie intake for these households. At the same time, a 50% increase in global rice prices could lead to an 8% reduction in their calorie consumption. For instance, Fathi and Bakhshoodeh (2021) used a multi-market model including different types of meat in Iran to assess the effect of rising

energy prices on social welfare and the environment. They found that rising energy prices, without a corresponding redistribution of political revenues obtained from policy reform to producers or advances in production technology, would lead to reduced welfare and increased environmental degradation. According to the content discussed, it can be concluded that the multi-market equilibrium model provides a robust framework for analyzing the complex interplay of market forces and policy interventions. This approach not only sheds light on the immediate effects of price volatility and income compensation on household food security but also provides actionable insights for policymakers to mitigate adverse effects and enhance welfare.

In general, the fluctuations in chicken prices in Iran in 2020 were unprecedented, in line with the increase in world food prices in recent years. Accordingly, the results of the evaluation of the effect of the sudden price increase in Iran on the household food security situation can be attractive for other countries with similar situations in Iran and provide reliable findings at the international level. Meanwhile, to the best of our knowledge, the simultaneous evaluation of the effects of the increase in chicken prices and the effects of the nominal income compensation policy on the amount of calories received by households has not been investigated in any study. Moreover, the use of the multi-market equilibrium model to track the effects of these policies is one of the strengths of this study, and awareness of the effects of price increases and income compensation policies on household calorie status can be useful for policymakers at the national level. Furthermore, the results of the multi-market equilibrium model used in this study can be extended to other countries and other products.

The aim of this study was to evaluate the effects of the increase in chicken meat prices on food security of Iranian households. A multi-market equilibrium simulation model was utilized in this study since the chicken meat market is linked to the red meat market (beef and sheep). Furthermore, an amount proportional to the inflation rate is added to the income of the people of Iran every year to compensate for the decline in consumer purchasing power. Therefore, the present study simulates a multi-market equilibrium model to examine the simultaneous effects of the price explosion in the chicken market, the increase in the nominal income of consumers and the level of product in the market on the amount of calories received by consumers as an indicator of food security. This study stands out for its use of an advanced and comprehensive multi-market equilibrium simulation model to examine the impact of chicken price fluctuations on the calorie consumption of Iranian families. It also pioneers the study of how rising nominal incomes affect household food security, specifically through calorie availability. This study seeks to answer the following questions:

What effect will the sudden increase in poultry prices in 2020 have on meat consumption and consequently calorie intake?

Can rising consumer incomes mitigate the negative effects of the poultry price explosion on household calorie intake?

METHODS

Study area

In recent decades, Iran has faced macroeconomic problems such as high inflation, insignificant economic growth, and high unemployment (Rad et al., 2021). Thus, the decrease in per capita income and increase in household expenditures due to inflation has led to a decrease in the consumption of many food items among Iranian households. Indeed, the devaluation of the national currency and rising food prices have weakened consumers' purchasing power and ultimately increased food poverty and insecurity (Statistical Center of Iran, 2020b). As a result, rising food prices and declining consumer incomes have directly threatened food security.

Model specification

Different models such as input-output analysis, computable general equilibrium (CGE) and partial equilibrium models are used to determine and evaluate the effects of agricultural policies around the world (Van Campenhout et al., 2018). General equilibrium models and input-output analysis are appropriate for scenarios where researchers want to trace the effects of policies in the agricultural sector on other sectors and the economy as a whole (Czyżewski and Grzelak, 2018). Furthermore, the consumption elasticity is severely limited in CGE models using the linear expenditure system (Haggblade et al., 2017). However, partial equilibrium models, including multi-market models, can be used to show the effect of policies on single or multiple domestic markets (Helseth et al., 2018). Multi-market equilibrium models skilfully navigate the complexities of interlinked markets by adjusting supply and demand functions. This allows for a comprehensive examination of how price shocks affect consumption patterns, economic welfare, and food security (Croppenstedt et al., 2017). On the demand side, however, the markets for different types of meat are interlinked. As a result, if the price of one type of meat changes, the demand for other types of meat changes as well. Thus, multi-market models can be used to consider these relationships (Balagtas and Kim, 2014). The multi-market model is a flexible framework that uses the best available estimates of consumer demand characteristics to measure how consumer food security responds to price and income shocks (Haggblade et al., 2017). In this study, the effect of recently raised chicken prices on consumer food security was explored using a multi-market model. In order to prepare and implement a multi-market model, four general steps are considered (Arulpragasam and Conway, 2003; Croppenstedt et al., 20017):

1) The first step is to identify and define the relevant markets. In this step it is necessary to determine the geographical level (national, regional, sub-regional, etc.) and the appropriate level of disaggregation in terms of household types (poor, rich, etc.). Additional detail in terms of markets, household groups, temporal, or regional disaggregation increases the validity of model calibration and simulation. In this study, the market for three relevant food commodities (chicken, sheep, and beef) was designed and simulated at the national level and for all Iranian households without differentiation based on income levels in the year 2019.

2) The second step is dedicated to the extraction of demand side information for the food commodities. In this step, the parameters of the demand functions are measured by using

the own and cross-price and income elasticities of demand. In this study, the own- and cross-price and income elasticities of demand were taken from Fathi and Bakhshoodeh (2016; 2021) (using the AIDS model), and the methods of calculating the parameters of the demand functions were taken from Minot (2009).

3) In this step, the supply-side parameters of food commodities are calculated based on the information of supply elasticities and production functions (Cobb-Douglas, Translog, etc.). In this study, the supply elasticities were taken from the studies of Fathi and Bakhshoodeh (2016; 2021) and methods of calculating the parameters of supply functions were taken from Minot (2009).

4) The final step involves establishing market equilibrium for food commodities. This equilibrium is achieved when the sum of domestic supply plus imports equals the sum of domestic demand plus exports for each commodity. Tradable quantities and prices are bounded by set upper and lower limits. The model's outcomes for a given period must align with observed macroeconomic data. Subsequently, it becomes possible to assess the effects of various policies and shifts in food commodity prices, household real income, income distribution, and production levels. In particular, this study examined the impact of a sudden rise in chicken prices and the implementation of an income compensation policy. Therefore, Eq. (1) to Eq. (3) representing demand functions, Eq. (4) to Eq. (6) representing supply functions, and Eq. (7) to Eq. (9) indicating market equilibrium for chicken, sheep, and beef meat as markets related to the chicken meat market are presented for this purpose (Minot, 2009; Nasr Ahmed et al., 2021).

$$Q_b = \alpha_b + \beta_{bb}(P_b + F) + \beta_{bv}P_v + \beta_{bl}P_l + \mu_b Y0 \quad \text{Eq. (1)}$$

$$Q_v = \alpha_v + \beta_{vb}(P_b + F) + \beta_{vv}P_v + \beta_{vl}P_l + \mu_v Y0 \quad \text{Eq. (2)}$$

$$Q_l = \alpha_l + \beta_{lb}(P_b + F) + \beta_{lv}P_v + \beta_{ll}P_l + \mu_l Y0 \quad \text{Eq. (3)}$$

$$S_b = \delta_b + \gamma_{bb}(P_b + F) + \gamma_{bv}P_v + \gamma_{bl}P_l \quad \text{Eq. (4)}$$

$$S_v = \delta_v + \gamma_{vb}(P_b + F) + \gamma_{vv}P_v + \gamma_{vl}P_l \quad \text{Eq. (5)}$$

$$S_l = \delta_l + \gamma_{lb}(P_b + F) + \gamma_{lv}P_v + \gamma_{ll}P_l \quad \text{Eq. (6)}$$

$$S_b + M_b = X_b + Q_b \quad \text{Eq. (7)}$$

$$S_v + M_v = X_v + Q_v \quad \text{Eq. (8)}$$

$$S_l + M_l = X_l + Q_l \quad \text{Eq. (9)}$$

In Eq. (1) to Eq. (9), Q, P, S, M, X, $Y0$, and F represent the level of product demand, price, domestic supply, imported products, product exports, consumer income in the year in question, and the market price shock for chicken meat, respectively. Chicken, beef, and sheep meat are also represented by the markers b, v, and l, respectively. Own-price, cross-price, and income elasticities were used to determine the parameters of the demand functions. However, the price elasticity of supply was used to calculate the parameters of the supply functions (Minot, 2009).

$$\alpha_i = Q0_i - (\beta_{ij} * P0_i) - (\mu_i * Y0) \; for\; i = j = b, v, l \quad \text{Eq. (10)}$$

$$\beta_{ij} = \varepsilon_{ij} * \left(\frac{Q0_i}{P0_j}\right) \quad for\; i = j = b, v, l \quad \text{Eq. (11)}$$

$$\mu_i = \theta_i * \left(\frac{Y0}{P0_i}\right) \quad for\; i = b, v, l \quad \text{Eq. (12)}$$

$$\gamma_{ij} = \varepsilon s_{ij} * \left(\frac{S0_i}{P0_j}\right) \quad for\; i = j = b, v, l \quad \text{Eq. (13)}$$

$$\delta_i = S0_i - (\gamma_{ij} * P0_i) \quad for\; i = j = b, v, l \quad \text{Eq. (14)}$$

In Eq. (10) to Eq. (14), α, β, and μ denote the intercept, coefficients related to product price variables and coefficients related to consumer income variable in demand functions, respectively. It should also be noted that δ and γ are the width coefficients of origin and coefficients related to the price of products in the supply functions, respectively. ε, θ, and εs denote the price elasticity of demand (including own and cross-price), the income elasticity of demand, and the price elasticity of supply (including own and cross-price), respectively. The values of $Q0$, $P0$, $Y0$, and $S0$ are also examined in terms of demand, price, income, and supply in the base year.

The model was written in the General Algebraic Modelling System (GAMS) software and solved using the Mixed Complementarity Programming (MCP) technique, and the equilibrium values of consumption and price were obtained with and without price shocks (GAMS codes are provided in Appendix 1). Finally, household calorie intake was calculated on the basis of calories using the equilibrium consumption levels.

$$CAL = (Q_b * cal_b) + (Q_v * cal_v) + (Q_l * cal_l) \quad \text{Eq. (15)}$$

In Eq. (15), Cal is the overall calorie gained from the eating of meat products, and CAL is the calorie received from the consumption of each unit (kg) of products.

Data

The Central Bank of Iran, the Statistical Center of Iran, and the Customs Organization of Iran provided data for the study, including product prices, demand (consumption), consumer income, and exports and imports of products. Own price, cross price, and income elasticities of demand were adapted from the studies of Fathi and Bakhshoodeh (2016; 2021). It should be noted that supply price elasticities were also calculated by Fathi and Bakhshoodeh (2016; 2021) according to price information and production of products between 2008 and 2016. The elasticities of demand and supply as well as price and consumption of chicken, sheep, and beef for determining the parameters of the supply and demand functions and solving the model are presented in Tables 1 to Table 3. It is noteworthy that in 2020, the price of chicken in Iran escalated from 130,495 Rials ($0.574) to 240,000 Rials ($1.057), marking an approximate 84% increase (Statistical Center of Iran, 2020a). At the same time, nominal consumer income-adjusted as per Iran's regulations-along with the annual inflation rate, which historically fluctuates between 15% and 40%, rose by increments of 15%, 30%, and 40%. As part of a compensatory strategy, the study evaluated the effects of bolstering the market presence of chicken through enhanced domestic production or increased imports.

In this section, first, the effects of an increase in the price of chicken meat on the equilibrium of other meat products were determined. In the following, while assessing the effects of scenarios of increasing nominal income on the consumption of meat products, the results of using different scenarios on the per capita calorie intake were explained.

Table 1. Equilibrium market quantities and prices of meat products obtained from the multi-market equilibrium model

Meats	Demand[b] (Kg per capita)	Price[b] (Rial per Kg)	Income elasticity of demand[a]
Chicken	32	130,495	0.81
Beef	7	810,000	0.76
Sheep	4	870,000	1.1

[a] Fathi and Bakhshoodeh (2016; 2021).
[b] Statistical Center of Iran (base year = 2019).

Table 2. Price elasticities of demand

Meats	Price elasticities of demand[a]		
	Chicken	Beef	Sheep
Chicken	-1.17	0.17	-0.10
Beef	0.32	-0.93	0.14
Sheep	-0.17	0.08	-0.79

[a] Fathi and Bakhshoodeh (2016; 2021).

Table 3. Price elasticities of supply

Meats	Price elasticities of supply[a]		
	Chicken	Beef	Sheep
Chicken	0.67	0.02	0.01
Beef	0.01	0.35	0.03
Sheep	0.02	0.02	0.62

[a] Fathi and Bakhshoodeh (2016; 2021).

RESULTS AND DISCUSSION

The amount of consumption and the equilibrium price of meat products in Iran were calculated using data from the base year 2019 and the price, cross-price, and income elasticities obtained from the study of Fathi and Bakhshoodeh (2016). In addition, the supply elasticity was calculated based on the output and price in different years. The results of these calculations are shown in Table 4.

Table 4. Equilibrium market quantities and prices of meat products obtained from the multi-market equilibrium model

Meats	Equilibrium quantity (thousand tonnes)	Equilibrium price (Rials per kilogram)
Chicken	2638	154200
Beef	486	923000
Sheep	355	1015400

According to Table 4, the market equilibrium quantity of chicken meat is expected to be around 2638 thousand tonnes with a market equilibrium price of 154,200 Rials ($0.679). This means that at 154,200 Rials ($0.679), the supply and demand of chicken meat will be equal to 2638,000 tonnes and the chicken market will be in equilibrium. The market equilibrium for beef and sheep products was around 486 and 355 thousand tonnes, respectively. Furthermore, the equilibrium prices for beef and sheep products are predicted to be around 923,000 and 1,015,400 Rials ($4.066 and $4.473), respectively. The effect of an increase in the price of chicken meat by about 84% (equivalent to 110,000 Rials ($0.485)) on the meat market was then examined and the results are presented in Table 5.

Table 5. The effects of the 84% increase in the price of chicken meat on the equilibrium consumption of meat products

Meats	Equilibrium consumption in the base year (thousand tonnes)	Equilibrium consumption under the scenario (thousand tonnes)	Changes (%)
Chicken	2638	1556	-41
Beef	486	457	-6
Sheep	355	305	-14

The results show that an 84% increase in the price of chicken meat on the market has reduced the equilibrium consumption from around 2638 thousand tonnes per year to around 1556 thousand tonnes per year, indicating a 41% decrease in the consumption of chicken meat on the market. The beef market has decreased from about 486 thousand tonnes per year to 457 thousand tonnes per year (a decrease of about 6%). As a result, these two types of meat are not substitutes on the market. The market equilibrium consumption of sheep has decreased from around 355 tonnes per year to around 305 thousand tonnes per year (a decrease of around 14%). As a result, the notion of market substitution between chicken meat and sheep meat is also ruled out. Bakhshoodeh and Fathi (2009) and Ataei and Mohammadi (2018) found that there is little substitution of meat types in Iran. The cross-demand elasticity was calculated by Bakhshoodeh and Fathi (2009), who found that chicken and red meat (sheep and beef) are not only substitutes but also complements. Ataei and Mohammadi (2018) supported the findings of the present study regarding the low cross coefficients of meat demand in Iran. They found that a change in the price of one type of meat is not expected to dramatically affect the demand for other types of meat. According to the findings of this study, an increase in the price of chicken meat in 2020 will reduce the market consumption of chicken meat and will result in a lack of substitution of chicken meat by red meat (such as beef and sheep meats). Several studies have shown that an increase in product prices leads to a decrease in consumption (Bakhshoodeh and Fathi, 2009; Chavas, 2017; Haggblade et al., 2017; Hill and Porter, 2017).

Compensation policy and consumption of meat products

To analyze the adaptability of the situation, scenarios of increased consumer income were examined. The results of this section are presented in Table 6. Accordingly, a 15%, 30%, and 40% increase in nominal consumer income was used as the main scenarios. This increase in nominal income was determined based on the existing laws in the country and according to the annual inflation rate, which is estimated to be between 15% and 40%.

According to the results, a 15% increase in nominal income combined with an 84% increase in the price of chicken would lead to a 34% reduction in chicken consumption, a 2% reduction in beef consumption and a 7% reduction in sheep consumption on the market. Therefore, with this rate of increase in the price of chicken in 2020 and a 15% increase in nominal income, it is impossible to improve the consumption of chicken and other meat products.

Table 6. The effects of nominal income growth scenarios with rising chicken prices on equilibrium consumption of meat products (%)

Meats	Increase (%)		
	15	30	40
Chicken	-34	-16	+6
Beef	-2	+8	+16
Sheep	-7	+1	+11

The quantities represent the percentage change compared to the equilibrium consumption values of the base year.

According to the results, a 30% rise in nominal income combined with an 84% increase in the price of chicken meat reduced the consumption of chicken meat by around 16%, beef by about 8%, and sheep by about 1%. Thus, a 30% rise in nominal income can considerably mitigate the effects of increasing the price of chicken flesh on lowering the consumption of this product. An 84% increase in the price of chicken meat led to a 41% decrease in the consumption of this product in the market. However, a 30% increase in income has reduced the consumption of chicken meat by about 16%. This result represents a 25% improvement in the consumption of chicken in the market. Despite a 30% increase in the nominal income of consumers in the market, the 84% increase in the price of chicken meat in 2020 has a diminishing influence on the consumption of this product. For both beef and sheep products, the results showed that a 30% increase in nominal income could mitigate the negative effects of rising chicken prices, and that this 30% increase could improve the consumption of beef and sheep. Eventually, a 40% increase in nominal income could lead to a 6% rise in chicken meat consumption, a 16% increase in beef consumption, and an 11% increase in sheep consumption.

The policy of increasing the supply for chicken meat was also examined through policies that supported domestic producers as well as policies that increased imports of this commodity. The results are presented in Table 7. The results show that a 10% increase in the product on the market, either through increased production or imports, can play a significant role in minimizing the effect of price increases on consumption reduction. For example, in the case of a price explosion, combined with a market policy of a 10% increase in chicken meat with no change in nominal income, chicken meat consumption will increase by about 44% compared to consumption under the price explosion scenario. However, compared to the baseline without price explosion, consumption under this policy is 15% lower. According to the results of this section, a 10% increase in the product's market share has the same effect on improving chicken consumption as a 30% increase in nominal income. Therefore, increasing the market share of the product by increasing production or imports is a more efficient policy than increasing nominal income.

The amount of calories per capita consumed from meat products in one year was predicted to be 62.00, 73.28, and 86.58 kcal for scenarios with an 84% increase in the price of chicken meat and nominal income increases of 15%, 30%, and 40%, respectively. Comparing the results of alternative scenarios of nominal income increases, it is clear that only a 40% increase in nominal income can offset and even improve the negative effect of an 84% increase in the price of chicken meat on the amount of calories obtained. Furthermore, a 10% increase in the price of chicken in the market was predicted to increase the amount of calories gained from meat product consumption per capita in one year to around 70.13 kcal. This research shows that by modifying the product on the market and responding quickly to price increases, the risk of consumers' nutritional welfare being reduced by price increases can be mitigated.

Table 7. The effects of price explosion with the policy of increasing the supply of chicken meat in the market by 10% without changing the nominal income

Meats	Equilibrium consumption in the base year (thousand tonnes)	Equilibrium consumption under the price explosion scenario (thousand tonnes)	The quantity of equilibrium consumption under the price explosion and a 10% increase in product in the market
Chicken	2638	1556	2237
Beef	486	457	448
Sheep	355	305	301

Changes in calorie received by consumers

Finally, the effect of different scenarios on consumers' calorie intake, as a measure of food security, was examined and the results are presented in Table 6. Table 8 shows that under the current situation, the per capita calorie intake from meat products is 77.37 kcal in 2020. With an 84% increase in the price of chicken, the amount of per capita calorie intake from meat products in one year has decreased to 56.76 kcal (a decrease of about 27%). Several studies (e.g., Bakhshoodeh and Fathi, 2009; Ghazali and Bakhshoodeh, 2014; Fathi and Bakhshoodeh, 2016; Wossen et al., 2018) have shown that rising food expenditures have a negative effect on food security.

Table 8. The effects of different scenarios on per capita calorie intake per year (Kcal = 1000 calories)

Scenario	Calorie intake per capita per year
Base year	77.37
Rising prices for chicken meat	56.76
Price increase accompanied by a 15% increase in nominal income	62
Price increase with a 30% increase in nominal income	73.28
Price increase with a 40% increase in nominal income	86.58
Price increase with a 10% increase chicken meat in the market.	70.13

CONCLUSION

In this study, the influence of the chicken price explosion and compensation strategies on the amount of calories consumed by consumers was investigated. Given the elasticities of demand, supply, and the share of meat

products in the consumer basket of Iranian households, the trend of rising prices in recent years is not in line with food security policies. In recent years, especially in 2020, there has been a sharp increase in the price of chicken meat, which poses a serious threat to food security due to the high dependency on chicken meat in Iran (twice the global average). This study assessed the effect of a chicken price increase on meat product consumption and calories per capita. A multi-market equilibrium model in the base year 2019 was used, taking into account the markets for chicken, beef, and sheep products. The results showed that beef and sheep products are not suitable substitutes for chicken. Therefore, increasing the price of chicken will not increase the consumption of beef and sheep. The results also showed that an 84% increase in chicken prices in 2020 will lead to a 41% decrease in chicken consumption and a 27% decrease in calorie intake per capita. Furthermore, the analysis of nominal income increase scenarios showed that a nominal income increase of more than 30% could compensate for the negative effects of a chicken price increase in 2020 on consumers' food security. Therefore, the compensatory policy results showed that policies aimed at improving nominal income cannot be considered as appropriate policies to improve calorie intake and consequently household food security. Annual consumer income growth should be at least 30% to reduce the negative effect of price shocks. This is the case despite a nominal increase in consumer income of 20% in 2020. In this context, the introduction of a Supplemental Nutrition Assistance Program (SNAP) targeted at low-income families is likely to increase per capita calorie consumption. Moreover, given that Iranian households do not typically switch from red meat to chicken, it is clear that consumers' financial flexibility in response to escalating chicken prices is limited. Therefore, targeted financial assistance should be specifically aimed at improving consumer's ability to afford chicken. In addition, the government can facilitate this through strategies such as increasing production capacity, using advanced technical expertise, and regulating market supply to ensure stable prices and availability.

Future research is encouraged to explore the socio-economic and environmental implications of changes in household meat consumption patterns. Such complexities can be well captured by multi-objective modelling. Unexpected food price spikes can have different effects on food security, depending on a household's wealth, income dynamics, and role in food production. A major limitation of the current model is the lack of granular, household-specific data. This absence precludes the calculation of household-level demand elasticities, thus preventing a nuanced assessment of how price spikes affect food security across different demographic groups. Examining the effect of price inflation on food security across different income brackets, occupations, and urban versus rural dwellers will enrich the discussion initiated in this study. While this analysis used price and income elasticities as described by Fathi and Bakhshoodeh (2016) to define elasticity cut-offs, the use of alternative benchmarks suggested by other scholars did not result in significant differences in findings. Nevertheless, it is expected that shifts in these cut-offs could alter the results. Consequently, dedicated studies are recommended to determine the substitution and complementarity relationships between different types of meat in the Iranian context.

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CRediT AUTHORSHIP CONTRIBUTION STATEMENT

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Abbas Mirzaei, Hassan Azarm, Naser Valizadeh, and Seyed Mohammad Javad Sobhani. The first draft of the manuscript was written by Abbas Mirzaei and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare no conflicts of interest.

ETHICAL STATEMENT

Prior to starting the work, the study design was fully explained to the organizations providing the required data. No false promise such as remuneration and or per diem, food and financial aids was given. Information was collected after securing consent from organizations. Data obtained from each organization were kept confidential, and all organizations participated in the study were acknowledged. The consent form has been read to me and voluntarily I agree to participate in this study.

DATA AVAILABILITY

Data will be made available on request.

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APPENDIX 1

```
SET    i  products    /chicken, beef, sheep /;
ALIAS (i,j);
TABLE P0(i) Original price (LC per kg)
$call=xls2gms i=E:\price.xlsx r=sheet1!A1:B4 o=pard.inc
$include pard.inc;
TABLE QUOTA(i,*) Trade quota (1000 tons)
$call=xls2gms i=E:\quota.xlsx r=sheet1!A1:C4 o=pard.inc
$include pard.inc;
TABLE E(i,j) Price elasticity of demand
$call=xls2gms i=E:\pelas.xlsx r=sheet1!A1:D4 o=pard.inc
$include pard.inc;
TABLE Teta(i) Income elasticity of demand
$call=xls2gms i=E:\inelas.xlsx r=sheet1!A1:B4 o=pard.inc
$include pard.inc;
TABLE ES(i,j) Price elasticity of supply
$call=xls2gms i=E:\selas.xlsx r=sheet1!A1:D4 o=pard.inc
$include pard.inc;
TABLE Q0(i) Original demand (1000 tons)
$call=xls2gms i=E:\demand.xlsx r=sheet1!A1:B4 o=pard.inc
$include pard.inc;
TABLE S0(i) Original supply (1000 tons)
$call=xls2gms i=E:\supply.xlsx r=sheet1!A1:B4 o=pard.inc
$include pard.inc;
TABLE  Px(i)    Export price (LC per kg)
$call=xls2gms i=E:\pexport.xlsx r=sheet1!A1:B4 o=pard.inc
$include pard.inc;
TABLE  Pm(i)   Import price (LC per kg);
$call=xls2gms i=E:\pimport.xlsx r=sheet1!A1:B4 o=pard.inc
$include pard.inc;
Parameter shock(i) Shock price
/ chicken  1
  beef     1
  sheep    1
/;
Scalar Y0      Total expenditure in base year (LC per capita)
/48738900.95/;
PARAMETERS
alfa            Intercept of demand equation
beta(i,j)          Price coefficient of demand equation
mu              Income coefficient of demand equation
gamma        Intercept of supply equation
lambda         Price coefficient of supply equation
ner             Nominal exchange rate (LC per US$)
beta(i,j) = E(i,j)*Q0(i)/P0(j);
mu(i) = Teta(i)*Y0/P0(i);
alfa(i) = Q0(i) – sum(j, beta(i,j)*P0(j)) - mu(i)*Y0;
lambda(i,j) = ES(i,j)*S0(i)/P0(j) ;
gamma(i) = S0(i) – sum(j, lambda(i,j)*P0(j)) ;
VARIABLES
P(i) Equilibrium price (LC per kg)
Q(i) Quantity demanded (thousand tons)
S(i) Quantity supplied (thousand tons) ;

POSITIVE VARIABLES
X(i) Exports (thousand tons)
M(i) Imports (thousand tons)
IXT(i) Implicit export tax (LC per kg)
IMT(i) Implicit import tax (LC per kg);

EQUATIONS
DEMAND Demand equation
SUPPLY Supply equation
IN_OUT Equilibrium
EXPORTS Export price relationships
IMPORTS Import price relationships
XQUOTA Export quota
MQUOTA Import quota ;
DEMAND(i)..              Q(i)  =E=  (alfa(i)  +  sum(j,
beta(i,j)*P(j)*shock(j)) + mu(i)*Y0)/1000000;
SUPPLY(i)..              S(i)  =E=  (gamma(i)  +  sum(j,
lambda(i,j)*P(j)*shock(j)))/1000000;
IN_OUT(i)..       S(i) + M(i) =E= Q(i)+X(i);
EXPORTS(i)..     P(i) + IXT(i) =G= Px(i) ;
IMPORTS(i)..     Pm(i) + IMT(i) =G= P(i) ;
XQUOTA(i)..     QUOTA(i,'X') =G= X(i) ;
MQUOTA(i)..    QUOTA(i,'M') =G= M(i) ;
MODEL MARKET / DEMAND
                        SUPPLY
                        IN_OUT
                        EXPORTS.X
                        IMPORTS.M
                        XQUOTA.IXT
                       MQUOTA.IMT / ;
SOLVE MARKET USING MCP ;
Parameter cal(i)  Calorie of products (per Kg)
Parameter calobj   objective;
Sum(i, Q(i)*cal(i))=calobj;
*-------------------------------------------------------------------
----------------
*Simulation scenario: (84% increase of chicken price)
*-------------------------------------------------------------------
-------------------
parameter shock(i)   shock to production;
shock('chicken') =1.84;
MODEL MARKET1 / DEMAND
                        SUPPLY
                        IN_OUT
                        EXPORTS.X
                        IMPORTS.M
                        XQUOTA.IXT
                       MQUOTA.IMT /;
SOLVE MARKET1 USING MCP;
```