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Forecasting Saudi Arabia's production and imports of broiler meat chickens and its effect on expected self-sufficiency ratio

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ABSTRACT

This research interested in forecasting Saudi production and imports of broiler meat chicken and compute expected self-sufficiency ratio to the period 2017–2021. The study depended on the time series data, *VARX* (1) model with non-intercept at the first difference was suggested to forecast imports and *ARIMA* (0,1,1) model to forecast production. The results showed that predicated imports from Brazil decreased by annual growth rate 0.52%, and other countries also decreased by annual growth rate 0.20%. The production increasing by annual growth rate 4.2%, expected self-sufficiency ratio increase from 52.9% in 2017 to 57.4% in 2021 by annual growth 2.09%.

1. Introduction

The poultry industry in the Kingdom enjoys the care and attention of the competent authorities represented by the Ministry of Environment, Water and Agriculture and the Agricultural Development Fund, which led to the formation of an organized and successful industry and the increase of production efficiency during the past five years. It also helped to stimulate investment and enter new companies or expand existing companies. The need for such an industry is also increasing due to the change in the consumption pattern of the consumer and the increase in his health awareness to maintain his health by favoring the white meat for its high nutritional value, which led to increased annual consumption of chicken meat about 34.6 kg.

The Saudi poultry sector has witnessed significant growth in production in recent years, registering a growth rate of 2.8% in the period 1990–2016. Chicken is one of the most sought after meals in the Kingdom. The demand for white meat is higher than red meat, especially with the first popular eaters, "Kabsa" Saudi Arabia's consumption of poultry is about 1.5 million tons per year, and it aims to raise the self-sufficiency ratio to 60% over the next five years by encouraging and supporting local production projects.

The increase in the rate of growth of Saudi imports of poultry by 6% during the period 1990–2016. Brazil has the largest share of the poultry import market in the Kingdom, with poultry imports from Brazil alone reaching about 700–750 thousand tons. In addition, Saudi poultry production is concentrated in 12 companies, including 7 medium sized companies and 3 major companies, including National Company, the largest meat producer in the local market, with share by third of domestic production, followed by Fakeeh and Almarai.

Domestic poultry production in Saudi Arabia covers only 50.3% of consumption, while 49.7% of consumption is covered by importation in 2016. Domestic poultry production has developed relatively slowly. Over the period 1990–2016, although the number of poultry farms in the Kingdom is about 400 farms, but they are all described as small except the 12 companies contribute about 80% of the domestic market for poultry. The poultry market also has a geographical concentration of production; the table below

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shows production in different regions of the kingdom during the period (2015–2018), the highest average production was in the Qassim region 259 million chickens represent 34.1%, followed by Makkah region with 155.4 million chickens (15.1%), Riyadh with 110.5 million chickens (14.5%), then Asir and Hail regions with 97.8 and 90. 2 million chickens (12.8% and 11.9%) and the rest of the regions produce 88.5 million chickens (11.6%).

Also from Table 1, the information about the characteristics of a huge investment need in other areas of low production, especially in light of the productive nature that necessitated near production from the areas of consumption, as the proportion of loss of transport is very high, and is not safe in light of the frequent spread of viruses and diseases of avian influenza. The lack of studies on this subject on one hand and the studies on this subject used simple statistical methods, and to provide information with high accuracy to the vision of the Kingdom of 2030.

Due to the lack of consideration appropriate statistical methods to predict production and imports, which in inaccurate results on self-sufficiency ratios, which is an important indicator of food security. Also most researches neglect the relationship between the two dependent variables (production and imports) when forecasting, relied on single equation methods. Hence this study relied on methods of prediction through simultaneous equation system, as one of the multivariate analysis methods, which gives the most efficient estimates in forecasting.

1.1. Research objectives

This research aims to study and analyze the prediction of Saudi imports of broiler meat chicken during the period 2017–2021, and its effect on self-sufficiency ratio through:

1. Forecasting of Saudi imports from Brazil and other countries as the main import sources.
2. Forecasting of local production of broiler meat chicken.
3. Estimation of the expected consumption and self-sufficiency ratio during the period under study.

2. Methodology and data description

One of the objectives of the research the forecasting of imports and production by applying *VARX* model as well *ARIMA* model as tools for analysis.

2.1. Stationary VARX model

Sims (1981) suggested a vector autoregressive *VAR* model, which would treat all variables in one way without deleting some variables from some equations in order to arrive at an acceptable diagnosis of the model. But the *VARX* model is defined as a vector autoregressive with exogenous variables. This model is used in multivariate time series analysis when the analysis includes exogenous variables as independent variables. The forecasting of vector dependent variables underline using the *VARX* model is one of the main objectives in this research. So this model written as:

$$VARX(p): \boldsymbol{Y}_t = \boldsymbol{\alpha D}_t + \boldsymbol{\psi Z}_t + \gamma_1 \boldsymbol{Y}_{t-1} + \gamma_2 \boldsymbol{Y}_{t-2} + \cdots + \gamma_p \boldsymbol{Y}_{t-p} + \boldsymbol{\varepsilon}_t \quad t = p+1, p+2, \cdots, T \tag{2.1}$$

where $\boldsymbol{Y}_t = (Y_{1t}, Y_{2t}, \cdots, Y_{nt})'$, $t = p+1, p+2, \cdots, T$, denote a n-dimensional time series vector of random variables under study, $\boldsymbol{D}_t = (1, t)'$ is a 2×1 vector of deterministic, $\boldsymbol{Z}_t = (Z_{1t}, Z_{2t}, \cdots, Z_{lt})'$ is $l \times 1$ vector of exogenous variables, $\boldsymbol{\alpha}$, ψ, $\{\gamma_i, i = 1, 2, \cdots, p\}$ are respectively $n \times 2$, $n \times l$, $n \times n$ coefficient matrices, and $\boldsymbol{\varepsilon}_t$ is a sequence of $n \times 1$ independent white noise vectors with zero mean and nonsingular contemporaneous covariance matrix given by $\sum_\varepsilon$. We note that model (2.1) is a system of "seemingly unrelated regression (SUR) equations" with independent variables include lagged vectors $\boldsymbol{Y}_{t-1}, \boldsymbol{Y}_{t-2}, \cdots, \boldsymbol{Y}_{t-p}$ vector of deterministic terms; $\boldsymbol{D}_t$ and vector of exogenous variables; $\boldsymbol{Z}_t$. The VARX(p) model (2.1) based on some assumptions determinant as: (Lütkepohl, 1991) and (Pesaran & Pesaran,1997).

Assumption 1. $\boldsymbol{E}(\boldsymbol{\varepsilon}_t) = 0$, $\boldsymbol{E}(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}'_t) = \sum_\varepsilon$ for all t, where $\sum_\varepsilon = \left\{\sigma_{ij}^2, i, j = 1, 2, \cdots, n\right\}$ is an positive definite matrix, $\boldsymbol{E}(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}'_{t'}) = 0$ for all $t \neq t'$, and $\boldsymbol{E}(\boldsymbol{\varepsilon}_t | \boldsymbol{D}_t, \boldsymbol{Z}_t) = 0$.

Assumption 2. All the roots of $|\gamma(L)| = \left|\boldsymbol{I}_n - \sum_{i=1}^{p} \gamma_i L^i\right| = 0$ fall outside the unit circle, or all eigenvaluees of the $np \times np$ companion matrix have modulus less than one, and $\boldsymbol{I}_n$is $n \times n$ identity matrix.

Assumption 3. $(\boldsymbol{Y}_{t-1}, \boldsymbol{Y}_{t-2}, \cdots, \boldsymbol{Y}_{t-p}, \boldsymbol{Z}_t)$, $t = p+1, p+2, \cdots, T$ are not perfectly collinear.

Under Assumptions 2 and no restrictions on parameters of model (2.1), the general form of the multivariate linear model represented by

$$\underset{(m \times n)}{\boldsymbol{Y}} = \underset{(m \times k)}{\boldsymbol{X}} \underset{(k \times n)}{\boldsymbol{B}} + \underset{(m \times n)}{\boldsymbol{E}} \tag{2.2}$$

where $\boldsymbol{Y} = (\boldsymbol{Y}_{p+1}, \boldsymbol{Y}_{p+2}, \cdots, \boldsymbol{Y}_T)$, $\boldsymbol{X} = (\boldsymbol{X'}_{p+1}, \boldsymbol{X'}_{p+2}, \cdots, \boldsymbol{X'}_T)'$, $\boldsymbol{X}_t = (\boldsymbol{D'}_t, \boldsymbol{Z'}_t, \boldsymbol{Y'}_{t-1}, \boldsymbol{Y'}_{t-2}, \cdots, \boldsymbol{Y'}_{t-p})$, $\mathbf{B} = \left(\boldsymbol{\alpha}, \psi, \gamma_1, \gamma_2, \cdots + \gamma_p\right)'$, $\boldsymbol{E} = (\boldsymbol{\varepsilon}_{p+1}, \boldsymbol{\varepsilon}_{p+2}, \cdots, \boldsymbol{\varepsilon}_T)'$, $(m = T - p)$ and $k = np + l + 2$. Then coefficient matrix $\mathbf{B}$ can be estimated by using the conditional least squares (LS) method which is (Johnson and Wichern, 1992. p.316).

$$\widehat{\mathbf{B}}_{ls} = (\boldsymbol{X'X})^{-1} \boldsymbol{X'Y} \tag{2.3}$$

and this estimation can be used for computing estimation of the covariance matrix of error vector; $\sum_\varepsilon$ which given by $\widehat{\varepsilon}_t = \left(\boldsymbol{Y}_{t-1} - \boldsymbol{X}_t \widehat{\mathbf{B}}_{ls}\right)$, is the residual vector.

Let $\widehat{\boldsymbol{\beta}}_{ls} = vec\left(\widehat{\mathbf{B}}_{ls}\right)$ denotes the operator that stacks the columns of the$(k \times n)$ matrix $\widehat{\mathbf{B}}_{ls}$ into a long $(nk \times 1)$ vector. The estimate $\widehat{\boldsymbol{\beta}}_{ls}$is consistent and asymptotically normally distributed with asymptotic covariance matrix; $avar\left(\widehat{\boldsymbol{\beta}}_{ls}\right) = \widehat{\sum}_\varepsilon \otimes \left[(\boldsymbol{X'X})^{-1}/m\right]$ (Hamilton,1994) and (Lütkepohl, 1991). From the statistical properties of $\widehat{\boldsymbol{\beta}}_{ls}$, all important statistical hypothesis tests as well the predicted values to dependent variables in *VARX*(p) model can be performed.

First; Statistical hypothesis tests: Test statistics, such as t-test; $t = \widehat{\beta}_{ij} / S.E_{\widehat{\beta}_{ij}}$ can be computed to test the null hypotheses$H_0: \beta_{ij} = 0$ against alternative hypotheses $H_1: \beta_{ij} \neq 0$, to verify the significant effect of independent variable X_j in equation number i. As well gen-

Table 1
Average Poultry Production and Relative Importance during the period (2015–2015).
Source: General Authority for Statistics (2017).

Region	Mean (Million chicken)	Percentage
Al-Qaseem	259,405	34.1%
Makkah	115,365	15.1%
Al-Riyadh	110,450	14.5%
Asir	97,763	12.8%
Hail	90,245	11.9%
Other Regions	88,548	11.6%

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eral linear hypotheses; $H_0 : \mathbf{C\beta} = \boldsymbol{r}$, which includes coefficients across different equations of the $VARX(p)$ can be tested using the Wald statistic; $Wald = \left(\mathbf{C}\widehat{\boldsymbol{\beta}}_{ls} - \boldsymbol{r}\right)'\left[\boldsymbol{C}\left(avar\left(\widehat{\boldsymbol{\beta}}_{ls}\right)\right)\boldsymbol{C}'\right]^{-1}\left(\mathbf{C}\widehat{\boldsymbol{\beta}}_{ls} - \boldsymbol{r}\right)$, which has a limiting χ^2_q distribution under the null hypotheses, where $q = rank(\boldsymbol{C})$ gives the number of linear restrictions.

Second; Prediction of dependent variables: With given independent variables matrix; $\boldsymbol{X}_{T+h|T} = \left(\boldsymbol{D}'_{T+h}, \boldsymbol{Z}_{T+h}, \widehat{\boldsymbol{Y}}'_{T+h-1|T} \cdots, \widehat{\boldsymbol{Y}}'_{T+h-p|T}\right)'$, the best linear predictor with period has h length;$\boldsymbol{Y}_{T+h}$ is

$$\widehat{\boldsymbol{Y}}_{T+h|T} = \widehat{\mathbf{B}}'_{ls}\boldsymbol{X}'_{T+h|T}, \qquad h = 0, -1, \cdots, \qquad Furthermore \tag{2.4}$$

where $\boldsymbol{D}'_{T+h} = (1, T+h)$, $\boldsymbol{Z}_{T+h}$ is the predicted value of exogenous variables in vector $\boldsymbol{Z}_t$ at time$T+h$, and $\widehat{\boldsymbol{Y}}_{T+j|T} = \boldsymbol{Y}_{T+j}$ $forj \leq 0$. Conditioned on the full set of information and on forecasts of exogenous variables;$\boldsymbol{Z}_{T+h}$. The mean square error matrix MSE of the h-step forecast is given in Green (2003, p.578) by $\widehat{\sum}(h) = \sum(h) + MSE\left[\left(\mathbf{B} - \widehat{\mathbf{B}}_{ls}\right)'\boldsymbol{X}'_{T+h|T}\right]$. In practice, the second term; $MSE\left[\left(\mathbf{B} - \widehat{\mathbf{B}}_{ls}\right)'\boldsymbol{X}'_{T+h|T}\right]$ is often ignored and $\widehat{\sum}(h)$ is computed as

$$\widehat{\sum}(h) = \sum_{s=0}^{h-1}\widehat{\Lambda}_s \sum\nolimits_{\varepsilon}\widehat{\Lambda}'_s \tag{2.5}$$

Were $\widehat{\Lambda}_s = \sum_{j=1}^{s-1}\widehat{\Lambda}_{j-1}\widehat{\gamma}_j$, $\Lambda_0 = \mathbf{I}_n$, $s = 1, 2, \cdots, p$. Asymptotic $(1-\alpha)\%$ confidence intervals for the individual elements of $\widehat{\boldsymbol{Y}}_{T+h|T}$ are then computed as

$$\widehat{\mathbf{Y}}_{k,T+h|T} - Z_{\left(1-\frac{\alpha}{2}\right)}.\widehat{\sigma}_k(h) < \mathbf{Y}_{k,T+h} < \widehat{\mathbf{Y}}_{k,T+h|T} + Z_{\left(1-\frac{\alpha}{2}\right)}.\widehat{\sigma}_k(h) \tag{2.6}$$

where $Z_{(1-\alpha/2)}$ is the $(1-\alpha/2)$ quartile of the standard normal distribution and $\widehat{\sigma}_k(h)$ denotes the square root of the k^{th} diagonal element of $\widehat{\sum}(h)$.

2.2. Data and empirical VARX model

One of the main objectives of this research is to use $VARX(p)$ model (2.1) to forecast the imports of broiler meat chicken from Brazil; Y_{1t} and other countries; Y_{2t}. The $VARX$ model was set up for those two series. The applied study depends on the time series data from 1990 to 2016. These data, collected from different numbers of the annual statistical book, were published by ministry of agriculture in KSA as a secondary source for data. So the total number of observations can be set $T = 27$. According to rule $p_{max} = ineger\left(T^{1/3}\right)$ suggested by Lütkepohl and Saikkonen (1999), $p_{max} = 3$, so $plag = 1, 2, 3$, and the empirical $VARX(3)$ model in matrices form denoted as.

$$\begin{aligned} VARX(3) : \begin{pmatrix} Y_{1t} \\ Y_{2t} \end{pmatrix} = &\begin{pmatrix} \alpha_{10} & \alpha_{11} \\ \alpha_{20} & \alpha_{21} \end{pmatrix}\begin{pmatrix} 1 \\ t \end{pmatrix} + \begin{pmatrix} \psi_{11} & \psi_{12} \\ \psi_{21} & \psi_{22} \end{pmatrix}\begin{pmatrix} Z_{1t} \\ Z_{2t} \end{pmatrix} \\ &+ \begin{pmatrix} \gamma_{111} & \gamma_{121} \\ \gamma_{211} & \gamma_{221} \end{pmatrix}\begin{pmatrix} Y_{1t-1} \\ Y_{2t-1} \end{pmatrix} + \begin{pmatrix} \gamma_{112} & \gamma_{122} \\ \gamma_{212} & \gamma_{222} \end{pmatrix}\begin{pmatrix} Y_{1t-2} \\ Y_{2t-2} \end{pmatrix} \\ &+ \begin{pmatrix} \gamma_{113} & \gamma_{123} \\ \gamma_{213} & \gamma_{223} \end{pmatrix}\begin{pmatrix} Y_{1t-3} \\ Y_{2t-3} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} \end{aligned} \tag{3.1}$$

where Y_{1t} and Y_{2t} imports from Brazil and other countries respectively at time t, Z_{1t} and Z_{2t} its import prices at time t, $t = p+1, p+2, \cdots, 27$, ε_{1t} and ε_{2t} are disturbances error term, α_{ij}, $i = 1, 2$, $j = 0, 1$ coefficients of constant and linear trend, ψ_{ij}, $i = 1, 2$, $j = 1, 2$ coefficients of import prices, γ_{ijp}, $i = 1, 2$, $j = 1, 2$, $p = 1, 2, 3$ autoregressive coefficients of import from Brazil and other countries at $plag = 1, 2, 3$.

The empirical $VARX(3)$ model (3.1) is a system includes two equations, each of them has ten coefficients; defined in equation number i as:

$$\boldsymbol{\beta}_i = (\alpha_{i0}, \alpha_{i1}, \psi_{i1}, \psi_{i2}, \gamma_{i11}, \gamma_{i21}, \gamma_{i12}, \gamma_{i22}, \gamma_{i13}, \gamma_{i23})', i = 1, 2 \tag{3.2}$$

And the (10×2) coefficients matrix; $\mathbf{B} = (\boldsymbol{\beta}'_1, \boldsymbol{\beta}'_2)$ can be estimated by using the conditional least squares (LS) method in (2.3).

3. Analysis of results

3.1. Data description

The variables understudy in this research are determined in import of broiler meat chicken from Brazil and other countries, its import prices, and local production, Table 2 displays some descriptive statistics of these variables during 1990–2016.

From Table 1, we note that, Saudi Arabia's imports of broiler meat chicken ranged from a minimum of 28.53 thousand tons and a maximum of 509.77 thousand tons, with an average of 254.3 thousand tons and an annual growth rate of 8.3%. Saudi Arabia's imports of broiler meat chicken from other countries ranged between a minimum of 28.36 thousand tons and maximum of 161.98 thousand tons, with an average of 102.7 thousand tons and an annual growth rate of 2.1%. Saudi Arabia's production of broiler meat chicken ranged from a minimum of 270 thousand tons to a maximum of 644.9 thousand tons, with an average of 466.91 thousand tons and an annual growth rate of 2.8%.

As for import prices, the prices of Saudi imports of broiler meat chicken from Brazil ranged between a minimum of 3.56 thousand riyals and a maximum of 8.67 thousand riyals, with an average of 5.67 thousand riyals and an annual growth rate of 2.2%. The prices of Saudi imports of broiler meat chicken from other countries ranged from a minimum of 3.97 thousand riyals to a maximum of 8.42 thousand riyals, with an average of 5.67 thousand riyals and an annual growth rate of 2%.

3.2. Results of application empirical VARX(p)

Available data has been transformed to natural logarithm, which are $Ln(Y_{1t})$, $Ln(Y_{2t})$, $Ln(Z_{1t})$, $Ln(Z_{2t})$and $Ln(Q_t)$, and SAS program version (9.2) was used for obtaining the initial results that concerned with testing stationarity of these transformed data, as well selecting appropriate lag order in empirical model $VARX(p)$, $p = 1, 2, 3$ using Schwarz information criterion (BIC) (Schwarz, 1978).

3.3. The unit root test

Augmented Dickey-Fuller (ADF_n) statistics computed in order to test the stationarity of these transformed data at its level $Ln(.)$ as well as at the first difference $\Delta(Ln(.))$. Table 3 displays the values of ADF in the cases (zero mean, single mean and linear trend).

From the values of test statistics ADF in the table above, we note that the transformed time series (logarithm values) related to each of Brazil import; $Ln(Y_{1t})$, Other countries import; $Ln(Y_{2t})$, Brazil import price; $Ln(Z_{1t})$, Other countries import price; $Ln(Z_{2t})$, and local production; $Ln(Q_t)$, has a unit root; this indicates non stationary of all transformed time series at the same level. After taking the first difference; $\Delta(Ln(Y_{1t}))$, $\Delta(Ln(Y_{2t}))$, $\Delta(Ln(Z_{1t}))$, $\Delta(Ln(Z_{2t}))$ and $\Delta(Ln(Q_t))$, we note that all difference does not have a unit root at 5% significant level, and it means that the time series are stationary at the first differences. So the empirical $VARX(3)$ model (3.1) that can be suggested for forecasting the imports rewritten as:

Table 2
Some descriptive statistics for import of broiler meat and production from year 1990 to 2016 in kingdom of Saudi Arabia. (Quantity in tons and import price in thousands riyals). *Source:* Computed from time series data collected from the annual statistical book, published by ministry of agriculture in kingdom of Saudi Arabia.

Series	Mean	St.Dev.	Min	Max	Growth rate
Imports from Brazil (Y_{1t})	254,343	152,057	28,530	509,772	0.083
Imports from other countries (Y_{2t})	102,700	33,181	28,358	161,979	0.021
Brazil import price (Z_{1t})	5.669	1.555	3.564	8.671	0.022
Other countries import price (Z_{2t})	5.673	1.384	3.969	8.415	0.020
Production (LQ_t)	466,907	106,962	270,000	644,902	0.028

Table 3
The results of (ADF_n) test statistics for testing unit root in time series under study. *Source:* Computed from time series data published by source mentioned in previous table.

Cases		*P Lag*	Quantity of imports		import prices		Production $Ln(Q_t)$
			Brazil $Ln(Y_{1t})$	Other countries $Ln(Y_{2t})$	Brazil $Ln(Z_{1t})$	Other countries $Ln(Z_{2t})$	
At level $Ln(.)$	Zero Mean	1	0.12	0.01	0.08	0.09	0.066
		2	0.13	0.03	0.11	0.08	0.061
		3	0.13	0.04	0.12	0.12	0.054
	Single Mean	1	−2.16	−7.48	−4.02	−2.44	−3.435
		2	−1.43	−5.51	−4.78	−3.74	−3.570
		3	−1.42	−10.98	−7.07	−5.86	−3.111
	Trend	1	−24.05**	−12.78	−8.86	−6.80	−10.968
		2	−25.14**	−11.30	−11.45	−10.60	−13.671
		3	−80.40**	−22.56**	−19.60*	−14.77	−15.406
First Difference $\Delta(Ln(.))$	Zero Mean	1	−60.58**	−54.64**	−32.87**	−26.24**	−20.513
		2	−63.20**	−35.25**	−29.69**	−23.04**	−18.548
		3	180.29	106.50	−24.82**	−9.52*	−13.619
	Single Mean	1	−68.62**	−54.95**	−34.01**	−27.32**	−32.774
		2	−127.0**	−36.64**	−33.22**	−26.52**	−47.630
		3	47.98	91.59	−30.89**	−11.29	−53.397
	Trend	1	−68.61**	−58.33**	−33.90**	−27.53**	−36.176
		2	−125.3**	−39.50**	−32.05**	−24.63**	−60.729
		3	49.40	64.77	−27.43**	−7.21	−75.321

* The series has not a unit root at 5% significance level.
** The series has not a unit root at 1% significance level.

$$VARX(3):\begin{pmatrix}\Delta(Ln(Y_{1t}))\\ \Delta(Ln(Y_{2t}))\end{pmatrix}=\begin{pmatrix}\alpha_{10}&\alpha_{11}\\ \alpha_{20}&\alpha_{21}\end{pmatrix}\begin{pmatrix}1\\ t\end{pmatrix}+\begin{pmatrix}\psi_{11}&\psi_{12}\\ \psi_{21}&\psi_{22}\end{pmatrix}\begin{pmatrix}\Delta(Ln(Z_{1t}))\\ \Delta(Ln(Z_{2t}))\end{pmatrix}+\begin{pmatrix}\gamma_{111}&\gamma_{121}\\ \gamma_{211}&\gamma_{221}\end{pmatrix}\begin{pmatrix}\Delta(Ln(Y_{1t-1}))\\ \Delta(Ln(Y_{2t-1}))\end{pmatrix}+\begin{pmatrix}\gamma_{112}&\gamma_{122}\\ \gamma_{212}&\gamma_{222}\end{pmatrix}\begin{pmatrix}\Delta(Ln(Y_{1t-2}))\\ \Delta(Ln(Y_{2t-2}))\end{pmatrix}+\begin{pmatrix}\gamma_{113}&\gamma_{123}\\ \gamma_{213}&\gamma_{223}\end{pmatrix}\begin{pmatrix}\Delta(Ln(Y_{1t-3}))\\ \Delta(Ln(Y_{2t-3}))\end{pmatrix}+\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix} \tag{4.1}$$

where $\Delta(Ln(Y_{1t}))$, $\Delta(Ln(Y_{2t}))$, the first differences of logarithm time series for Brazil import and other countries sequentially.

3.4. Information criteria for selecting optimal lag period

Schwarz information criterion (BIC) has been computed for $VARX(p)$ model at $plag = 1, 2, 3$ for selecting optimal lag period and summarized in the following Table 4.

Table 4
Schwarz information criterion (BIC) for empirical $VARX(p)$model. *Source:* Computed from data mentioned in Table 2.

model Type	*p lag*	*BIC*
Non intercept	1	−4.234
	2	−3.976
	3	−4.050
With intercept	1	−4.098
	2	−3.914
	3	−3.999
Linear trend	1	−3.868
	2	−3.799
	3	−3.786

From Table 3 above we note that (BIC) has smallest values (-4.234) in the case no intercept at $plag = 1$. So we can suggest using $VARX(1)$ with non-intercept to forecast the imports of broiler meat chicken from Brazil and other countries given the predicted values of import prices. During the period (2017–2030) in Saudi Arabia. The suggested empirical model $VARX(1)$ can be determined by reducing the model (4.1) as follows:

$$VARX(1):\begin{pmatrix}\Delta Ln(Y_{1t})\\ \Delta Ln(Y_{2t})\end{pmatrix}=\begin{pmatrix}\psi_{11}&\psi_{12}\\ \psi_{21}&\psi_{22}\end{pmatrix}\begin{pmatrix}\Delta Ln(Z_{1t})\\ \Delta Ln(Z_{2t})\end{pmatrix}+\begin{pmatrix}\gamma_{111}&\gamma_{121}\\ \gamma_{211}&\gamma_{221}\end{pmatrix}\begin{pmatrix}\Delta Ln(Y_{1t-1})\\ \Delta Ln(Y_{2t-1})\end{pmatrix}+\begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix} \tag{4.2}$$

where the system Eq. (4.2) contains two equations, each of them single equation includes 4 parameters; $\boldsymbol{\beta}_i = (\psi_{i1}, \psi_{i2}, \gamma_{i11}, \gamma_{i21})'$, $i = 1, 2$.

4. Results and discussion

The parameters of $VARX(1)$ model (4.2) estimated by using conditional (LS) method, then some statistical tests were performed as well the prediction of broiler meat chicken imports to achieve the objectives of the research, the following are analysis of the results and its discussion.

4.1. Results of conditional (LS) estimates

Table 5 displays conditional (LS) estimates for coefficients of $VARX(1)$ in (4.2); $\boldsymbol{\beta}_i = (\psi_{i1}, \psi_{i2}, \gamma_{i11}, \gamma_{i21})$.

From Table 4, we note the following

Table 5
Results of the (*LS*) estimates for coefficients of *VARX*(1) model. *Source:* Computed from data mentioned in Table 3.

Eq.	*Coefficients* β	Estimates $\hat{\beta}$	St.Error $S.E(\hat{\beta})$	*t*	Pr > |*t*|	*Independent Variables*
Brazil Import $\Delta(Ln(Y_{1t}))$	ψ_{11}	−2.858	0.631	−4.53	0.000	$\Delta(Ln(Z_{1t}))$
	ψ_{12}	2.450	0.841	2.91	0.008	$\Delta(Ln(Z_{2t}))$
	γ_{111}	−0.384	0.230	−1.67	0.110	$\Delta(Ln(Y_{1t-1}))$
	γ_{121}	0.087	0.300	0.29	0.775	$\Delta(Ln(Y_{2t-1}))$
	$R^2 = 0.623$ F $value = 11.55$ p $value = Pr > 11.55 = 0.0001$					
Other countries Import $\Delta(Ln(Y_{2t}))$	ψ_{21}	−1.483	0.599	−2.47	0.022	$\Delta(Ln(Z_{1t}))$
	ψ_{22}	1.781	0.798	2.23	0.037	$\Delta(Ln(Z_{2t}))$
	γ_{211}	−0.182	0.219	−0.83	0.416	$\Delta(Ln(Y_{1t-1}))$
	γ_{221}	−0.249	0.284	−0.88	0.391	$\Delta(Ln(Y_{2t-1}))$
	$R^2 = 0.448$ F $value = 5.69$ p $value = Pr > 5.69 = 0.0052$					

First: In equation related to first difference of logarithm Brazil import, the effect of the first difference of logarithm Brazil and other countries import prices on the dependent variable (first difference of logarithm Brazil imports; $\Delta(Ln(Y_{1t}))$ is significant at 5% level. But first difference of logarithm Brazil import at lag period one; $\Delta(Ln(Y_{1t-1}))$ has significant effect at 20% level. The estimated equation is given by

$$\Delta\widehat{Ln(Y_{1t})} = -2.858\Delta Ln(Z_{1t}) + 2.450\Delta Ln(Z_{2t}) - 0.384\Delta Ln(Y_{1t-1}) + 0.087\Delta Ln(Y_{2t-1}) \tag{4.3}$$

The independent variables which are $\Delta Ln(Z_{1t})$, $\Delta Ln(Z_{2t})$, $\Delta Ln(Y_{1t-1})$, $\Delta Ln(Y_{2t-1})$ explain 62.3% from deviations in the dependent variable; $\Delta(Ln(Y_{1t}))$, also $p value = Pr > 11.55 = 0.0001$ indicates that the Eq. (4.3) is appropriate at 5% level.

Second: In equation related to first difference of logarithm other countries import, the effect of the first difference of logarithm Brazil and other countries import prices on the dependent variable (first difference of logarithm other countries imports; $\Delta(Ln(Y_{2t}))$ is significant at 5% level. The estimated equation is given by

$$\Delta\widehat{Ln(Y_{2t})} = -1.483\Delta Ln(Z_{1t}) + 1.781\Delta Ln(Z_{2t}) - 0.182\Delta Ln(Y_{1t-1}) - 0.249\Delta Ln(Y_{2t-1}) \tag{4.4}$$

The independent variables $\Delta Ln(Z_{1t})$, $\Delta Ln(Z_{2t})$, $\Delta Ln(Y_{1t-1})$, $\Delta Ln(Y_{2t-1})$, explain 44.8% from deviations in the dependent variable; $\Delta Ln(Y_{2t})$, $p value = Pr > 5.69 = 0.0052$ indicates that the Eq. (4.4) is appropriate at 5% level.

Third: From the values of conditional (*LS*) estimates, the *VARX* (1) model (4.2) can be written as

$$\begin{pmatrix} \Delta\widehat{Ln(Y_{1t})} \\ \Delta\widehat{Ln(Y_{2t})} \end{pmatrix} = \begin{pmatrix} -2.858 & 2.450 \\ -1.483 & 1.781 \end{pmatrix} \begin{pmatrix} \Delta Ln(Z_{1t}) \\ \Delta Ln(Z_{2t}) \end{pmatrix} + \begin{pmatrix} -0.384 & 0.087 \\ -0.182 & -0.249 \end{pmatrix} \begin{pmatrix} \Delta Ln(Y_{1t-1}) \\ \Delta Ln(Y_{2t-1}) \end{pmatrix} \tag{4.5}$$

4.2. The analysis of Results about restriction test

In order to test the null hypothesis related to linear restriction, the values of Wald statistics computed and set in Table 6.

From Table 5 we note from computed $(p value = Pr > \chi^2)$ the following:

1. The estimated *VARX*(1) model (4.5) is appropriate for prediction the logarithm imports from Brazil and other countries at 5% significant level.
2. The equation related to the first difference of logarithm Brazil import is appropriate at level 5%.
3. The equation related to the first difference of logarithm other countries import is appropriate at level 5%.
4. The addition of import prices as exogenous independent variable $\Delta(Ln(Z_{1t}))$, $\Delta(Ln(Z_{2t}))$ improve ability of prediction for *VARX*(1) at 5%.
5. The addition of endogenous independent variable at lag one $\Delta(Ln(Y_{1t-1}))$, $\Delta(Ln(Y_{2t-1}))$ improve ability of prediction for at 10%.

5. Discussion of the forecasting results

To forecast the import quantities from 2017 to 2021 using *VARX* (1) model (4.5), it must be predicate the logarithm of import prices for each of Brazil and other countries as exogenous variables through this period. According to method of (Box and Jenkins, 1976) which is also mentioned by (Kirchgässner and Wolters, 2007), the researchers applied autoregressive and moving average with integrated series *ARIMA*(*p,d,q*) models for forecasting the value of two exogenous variables, according to Schwarz information criterion (*BIC*). The optimal model for forecasting logarithm of Brazil import price $Ln(Z_{1t})$ is *ARIMA*(1,1,0), where the minimum value of (*BIC*) is −8.68, also the optimal model for forecasting logarithm of other countries import price $Ln(Z_{2t})$ is *ARIMA*(1,1,0), where the minimum value of (*BIC*) is −25.59. The results of predication using these two models displayed in table 6. So *VARX*(1) model (4.5) was used in predication of Brazil and other countries imports given the predicted values of the two exogenous variables $[Ln(Z_{1t}), Ln(Z_{2t})]$ and summarized in Table 7.

From Table 7 we note that in the future period 2017–2021, we expected that import prices of broiler meat chicken from Brazil increases by annual growth rate 0.98%. And from other countries increases by annual growth rate 0.64%. Therefore the expectation of import from Brazil decreases by annual growth rate 0.52% and

Table 6
The values of Wald test statistics.

Test	*Null Hypothesis*	*Wald* (χ^2)	*df*	$Pr > \chi^2$
VARX(1) Model	$H_0: \psi_{11} = \psi_{12} = \gamma_{111} = \gamma_{121} = \psi_{21} = \psi_{22} = \gamma_{211} = \gamma_{221} = 0$	41.2	8	<0.0001
Brazil import equation	$H_0: \psi_{11} = \psi_{12} = \gamma_{111} = \gamma_{121} = 0$	35.37	4	<0.0001
Other countries import equation	$H_0: \psi_{21} = \psi_{22} = \gamma_{211} = \gamma_{221} = 0$	17.06	4	0.0019
Price import	$H_0: \psi_{11} = \psi_{12} = \psi_{21} = \psi_{22} = 0$	25.38	4	<0.0001
Import at Lag 1	$H_0: \gamma_{111} = \gamma_{121} = \gamma_{211} = \gamma_{221} = 0$	9.33	4	0.0533

Table 7
Forecasting of Imports prices and quantities using *ARIMA*(*p*,*d*,*q*) and *VARX*(1).

Case	Years	Predicted values of Import prices		Predicted quantities of Brazil import			Predicted quantities of other countries import		
		Brazil	Other countries	Brazil import	Lower	Upper	Other countries import	Lower	Upper
Logarithm	2017	1.890	1.890	13.052	12.351	13.752	11.814	11.149	12.479
	2018	1.877	1.868	13.074	12.228	13.920	11.796	11.010	12.582
	2019	1.899	1.890	13.055	12.052	14.058	11.803	10.872	12.734
	2020	1.909	1.896	13.048	11.917	14.179	11.800	10.756	12.844
	2021	1.923	1.908	13.039	11.792	14.285	11.802	10.653	12.951
Normal	2017	6.616	6.620	465,795	231,191	938,464	135,104	69,487	262,682
	2018	6.533	6.477	476,394	204,516	1,109,811	132,707	60,470	291,239
	2019	6.678	6.622	467,474	171,493	1,274,163	133,653	52,702	338,947
	2020	6.746	6.661	464,167	149,837	1,438,052	133,239	46,892	378,549
	2021	6.844	6.740	459,778	132,138	1,599,817	133,479	42,298	421,258

Table 8
Percentage of self - sufficiency ratio of poultry meat in Saudi Arabia and some regional countries during the period 2009–2016. *Source:* Agricultural Statistical Yearbook, Volume 37, Arab Organization for Agricultural Development, Khartoum, Sudan.

Country	2009–2013	2014	2015	2016
Saudi Arabia	45.8	46.7	45.1	46.6
Kuwait	23	27.9	30.5	31.3
Emirates	12.5	12.3	9.2	9.7
Egypt	95.7	98.9	93.2	94.7

Table 9
The Predicted total import and production, expected domestic consumption and expected Self Sufficient ratio.

Years	Predicted total import	Predicted Production using *ARIMA*$(0,1,1)$	Domestic consumption	Self Sufficient ratio
2017	600,899	674,819	1,275,718	52.9
2018	609,101	705,174	1,314,275	53.7
2019	601,127	736,084	1,337,212	55.0
2020	597,406	767,582	1,364,988	56.2
2021	593,258	799,706	1,392,964	57.4

imports from other countries decreases by annual growth rate 0.20%.

5.1. The expectation of domestic consumption and sufficient ratio

First: Presentation of the results of self-sufficiency ratios for Saudi Arabia and some countries, for the period 2009–2016 (see Table 8) Agricultural Statistical Yearbook (2017).

Secondly: Prediction of domestic consumption and self-sufficiency ratios for the period (2017–2023):

We note that the domestic consumption includes production plus import, where: the predicted quantities of import displayed in Table 9, then the optimal model for forecasting logarithm of production is *ARIMA*$(0,1,1)$ model, where the minimum value of (BIC) is -49.82. Table 9 displays the predicated quantities of imports, production quantities, computed expected domestic consumption and sufficient ratio which is (production / domestic consumption).

From Table 9 Saudi Arabia's broiler meat chicken self-sufficiency ratio is expected to increase from 52.9% in 2017 to 57.4% in 2021 by growth rate 2.09%. This is due to increase in production during the period 2017–2021 by growth rate 4.2%, from above results.

5.2. Reasons for low imports and production increased

Saudi Arabia aims to raise the self-sufficiency rate to 60% over the next five years by encouraging and supporting local production projects. The report also predicted that Saudi poultry imports would decline by 2%, equivalent to 940 thousand tons in 2016, and to 930 thousand tons in 2017, the decline attributed to the high prices of frozen poultry meat from Brazil, which accounts for 85% of the Kingdom's imports.

6. Recommendations

From the results of the study:

- we recommend the economic policy to reduce imports from broiler meat chickens in the following period by setting restrictions on imports, at the same time to increase production through the expansion of national projects to achieve the following:
- Meeting local market needs.
- Raise self-sufficiency ratio.
- Reduce the competitiveness of imports to domestic production and non-dumping of markets.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Further reading

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