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Role of hybrid forecasting techniques for transportation planning of broiler meat under uncertain demand in thailand

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Abstract

One of numerous problems experiencing in supply chain management is the demand. Most demands are appeared in terms of uncertainty. The broiler meat industry is inevitably encountering the same problem. In this research, hybrid forecasting model of ARIMA and Support Vector Machine (SVMs) are developed to forecast broiler meat export. In addition, ARIMA, SVMs, and Moving Average (MA) are chosen for comparing the forecasting efficiency. All the forecasting models are tested and validated using the data of Brazil's export, Canada's export, and Thailand's export. The hybrid model provides accuracy of the forecasted values that are 98.71%, 97.50%, and 93.01%, respectively. In addition, the hybrid model presents the least error of all MAE, RMSE, and MAPE comparing with other forecasting models. As forecasted data are applied to transportation planning, the mean absolute percentage error (MAPE) of optimal value of forecasted value and actual value is 14.53%. The hybrid forecasting model shows an ability to reduce risk of total cost of transportation when broiler meat export is forecasted by using MA(2), MA(3), ARIMA, and SVM are 50.59%, 60.18%, 68.01%, and 46.55%, respectively. The results indicate that the developed forecasting model is recommended to broiler meat industries' supply chain decision.

Keywords : Hybrid forecasting model, Transportation networks, ARIMA, Support vector machine

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1. Introduction

Nowadays, there are huge demands for agricultural product in order to survive as the world population [1] tends to increase continuously whereas cultivated areas are limited. As mentioned above, an international trading on agricultural produces is very competitive, especially agricultural countries that play both producer and exporter roles. Thailand is an Asian country that plays important roles both producer and exporter in the international agricultural market. The important agricultural products of Thailand [2] are exported to international trading such as rice, cassava, natural rubber, orchid, and so forth are commercially exported. The broiler meat is also exported and ranked as World's top class [15] as Brazil is the number one of broiler meat exporter. Consequently, Thailand government [3] has set many promotion campaigns to enhance broiler industries such as Thailand's strategies for broiler industries during 2012 to 2016. One of weakness that concern to broiler industries is high production cost, including transportation cost. Therefore, improving logistic management should reduce production cost in broiler industries as well. Unfortunately, the actual demands of each country are difficult to be investigated from another country. In addition, the demands of each country depend on their government's strategy also such as subsidies, trade barrier and any other local regulation. Consequently, exports in each year can be represented as demands of the agricultural product. However, future demands as the key factor for decision making are unfortunately uncertain. Therefore, the demand forecasting is a very challenging and useful in agricultural production planning to be achieved. According to the uncertainty, forecasting techniques play important role to predict the future demands as an accuracy of the forecasting technique is also essential to reduce any risk for decision making such as (S. Jaipuria and S.S. Mahapatra, 2014) propose combined model consist of DWT (Discrete wavelet transform) and ANN (Artificial neural networks) to improve demand forecasting in order to reduce bullwhip effect in supply chains. Results of the research indicate that the popular traditional forecasting model (AR, MA, ARMA and ARIMA) are useful forecasting techniques when data series is stationary and follows linear pattern. For forecasting model, [5] propose a research review regarding to the past 25 years of research of time series forecasting. During that period, over one third of all paper published in Journal of Forecasting and International Journal of forecasting concerned time series forecasting. In this research, the results show that time series models are commonly used to forecast. Forecasting techniques are not only the techniques that employ statistical theory to formulate forecasting model such as ARIMA and Holt-Winters but also the techniques that utilize computational intelligence to formulate the forecasting model such as ANNs and SVMs For statistical techniques, there are many researches dealing with ARIMA model as ARIMA model provides good forecasting value when time series dataset are linear pattern and homoscedasticity for instance [6] apply ARIMA model to predict submicron particle concentrations from meteorological factors at a busy roadside in Hangzhou, China. The results of this research indicate that the study can provide a framework that may be applied in future research. [7] apply time series model and neural networks to forecast tourism demand to Catalonia. In this research, the results indicate that ARIMA model outperforms self-exciting threshold autoregressive and artificial neural networks. Moreover, the forecast of tourist are more accurate than forecast of overnight stays. For computational intelligence techniques, machine learning algorithms are introduced to approach in order to forecast in any research fields such as [8] apply statistical techniques and artificial neural networks to forecast Thailand's rice export. The research indicates that Holt-Winters and ARIMA models showed satisfactory goodness of fit while the same models did not perform as well in predicting unseen data during validation. The combined model of ANN and Moving Average outperform statistical techniques. [9] apply SVMs, BNs, ANNs and ANFIS to predict wave height that is one of the most important factors in design and operation of maritime projects. The research indicates that ANN, SVM, and ANFIS can provide acceptable predictions but BNs results are unreliable. [10] apply SVM approach to forecast Thailand's agricultural products by using Pacific white shrimp and produced chicken export. The results show that SVM outperform ARIMA and Holt-Winters models. Moreover, there are many interests to combine more than one technique in order to overcome forecasting error. The combined techniques such as [11] propose improving support vector machine base on genetic algorithm optimization parameters to predict oil price. The research shows that GA-SVM provides accurate forecasting value than traditional SVM. [12] propose a hybrid model of SARIMA and SVM to forecast short-term power of a small-scale grid-connected photovoltaic plant. The results indicate that the proposed model performs better than both the SARIMA and SVM models. [13] propose hybrid forecasting model of ARIMA, it good perform for linear pattern, and SVM, it good perform for nonlinear pattern, to forecast Thailand's orchid export and Thailand's pork product export. The results show that the hybrid model outperforms ARIMA, Holt-Winters, and SVM. [14] propose a hybrid SARIMA and support vector machine to forecast the production values of the machinery industry in Taiwan. The research shows that the hybrid model outperforms SARIMA and SVM models.

This research is interested to develop hybrid forecasting model of ARIMA-SVM in order to forecast Brazil's broiler export, Canada's broiler export, and Thailand's broiler export. The forecasted export of Brazil and Canada may be used as marketing information for decision making. The forecasted export of Thailand is used as demand in order to compare optimal costs that obtain from each forecasting model using linear programming.

2. Numerical data

The numerical data are obtained from the following steps:

i. Export data of each country [15] are obtained from The U.S. Department of Agriculture (USDA) from 1999 to 2013 as presented Figures 1 to 3.

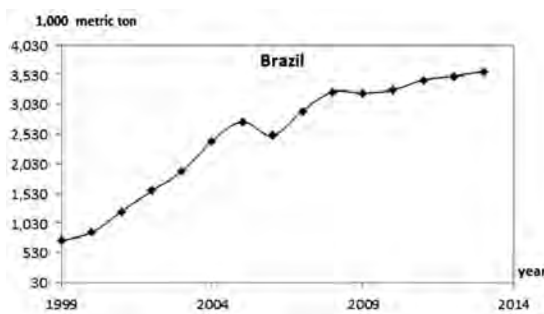

Figure 1 Brazil's broiler meat export

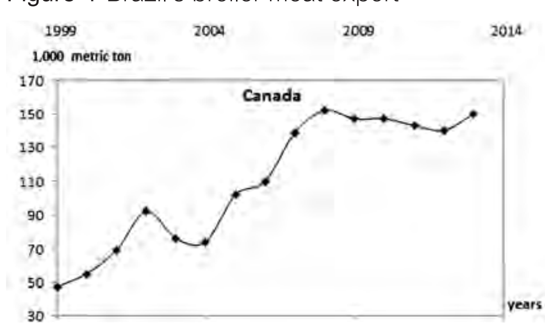

Figure 2 Canada's broiler meat export

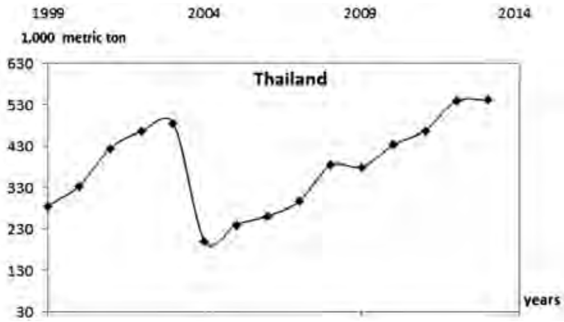

Figure 3 Thailand's broiler meat export

Exports of Brazil and Canada are grouped into two dataset. 70% of dataset is used to formulate forecasting model and the rest is used to test and validate the forecasting model. For Thailand's export, the data are separated into three datasets. For the first dataset, 70% of export data is used to formulate forecasting model. For the second dataset, 15% of export data is used to validate the forecasting model and for the third dataset, 15% of export data is used to compare the optimal values obtained from the mathematical model of the transportation.

ii. Expected broiler production [16] is obtained from the Office of Agricultural Economics (OAE) by using selected provinces that have high production rate from 2007 to 2012. The selected provinces are presented in Table 1.

Table 1 Expected production from 2007 to 2012

Province	Production(broiler)
Chon Buri	250,958,309
Chachoengsao	79,864,904
Prachinburi	72,900,029
Nakhon Nayok	56,016,631
Lopburi	41,580,661
Saraburi	29,277,729
Nakhon Ratchasima	39,565,918

iii. Suppose that a chicken provides 1.5 kilogram of expected broiler meat.

iv. Routes of transportation are obtained from Google map and the distances are shown in Table 2.

Table 2 Distance from producer to port

Province	Distance (km.)
Chon Buri	38.5
Chachoengsao	84.8
Prachinburi	194
Nakhon Nayok	205
Lopburi	252
Saraburi	214
Nakhon Ratchasima	306

v. Suppose that broiler meats are exported at Laem ChaBang port.

vi. Suppose that the location of provincial government office is the location of production area.

vii. Average cost of transportation [17] by road is 1.72 Baht per ton-km.

viii. Durbin-Watson method is used to test of Autocorrelation.

ix. R programming Language and AMPL are used to obtain the decision variables.

3. Methodologies

The Durbin-Watson statistic is a statistical test for detecting the presence of autocorrelation in the residuals from regression analysis. The Durbin-Watson is as equation (1).

$$d = \frac{\sum_{i=2}^{r}\left(e_i - e_{i-1}\right)^2}{\sum_{i=1}^{r} e_i^2} \qquad (1) \qquad (1)$$

Where H_0: There are not autocorrelation

H_a: There are autocorrelation

ARIMA model is composed of moving average (MA) and autoregressive (AR) as equation (2).

$$\left(1-\sum_{i=1}^{p}\varphi_i L^i\right)(1-L)^d X_t = \left(1-\sum_{i=1}^{q}\theta_i L^i\right)\varepsilon_t \qquad (2)$$

Where L is Lag operator

φ_i is a parameter of autoregressive part

θ_i is a parameter of moving average part

The fit ARIMA model is appropriately selected by AIC (Akaike's Information Criteria), which provides the lowest value.

SVM algorithm was invented by Vladimir N. Vapnik and the current standard materialization was proposed by Vapnik and Corinna Cortes in 1995. The SVM can be applied to linear or nonlinear separation by using kernel function in order to map a set of points x in the feature space into the hyperplane are defined by the kernel function. The kernel function used in training and predicting as following.

Linear: $u'v$

Polynomial: $(\gamma u'v + coef0)^{\text{degree}}$

Radial basis: $\exp\left(-\gamma|u-v|^2\right)$

Sigmoid: $\tanh\left(\gamma u'v + coef0\right)$

The hybrid model is made up of linear model and nonlinear model for forecasting linear and nonlinear parts. ARIMA is used to forecast linear part while SVM is used forecast linear or nonlinear part that remains from ARIMA. The model is as equation (3).

$$y = \hat{L} + \hat{N} + \varepsilon \qquad (3)$$

Where y is Actual value

$\hat{L}$ is Linear value

$\hat{N}$ is Nonlinear value

ε is White noise

The procedure of ARIMA-SVM is presented in Figure 4.

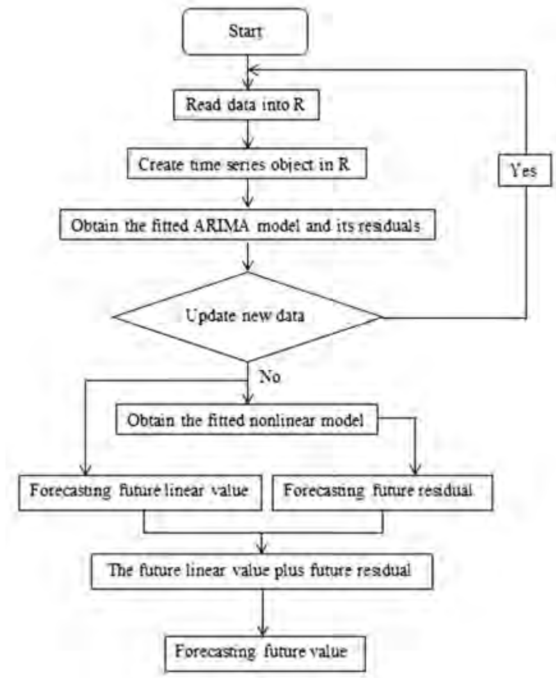

Figure 4 Algorithm of data preparation of hybrid model

Candidate models are validated using MAE, RMSE, and MAPE with the lowest as equations (4) to (6).

$$\text{MAE} = \frac{\sum_{i=1}^{n}|\hat{y}_i - y_i|}{n} \qquad (4)$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}} \qquad (5)$$

$$\text{MAPE} = \frac{\sum_{i=1}^{n}|\hat{y}_i - y_i| / y_i}{n} \times 100 \qquad (6)$$

Mathematical model is used to determine optimal transshipment volume in each lane and minimize total cost presented in equation (7).

$$\text{Min } z=\sum_{i=1}^{m}\sum_{j=1}^{m}c_{ij}x_{ji}$$
$$\text{subject to } \sum_{j=1}^{m}x_{ij}\ \sum_{j=1}^{m}x_{ji}=\bar{\omega}_i \qquad (7)$$
$$0\le x_{ij}\le u_{ij}$$

Where c_{ij} is transportation cost, c_{ij} is decision variables that are shipping amount, and $\bar{\omega}_i$ is the demand, which is uncertain. The index i represents the origin while the index j represents the destination, respectively.

4. Research results

The results of Durbin-Watson test at 0.05 significance levels are presented in Table 3.

Table 3 Durbin-Watson test of export

Export	Brazil	Canada	Thailand
p-value	< 0.001	0.00169	0.00184

Since all p-values of each country are less than 0.05, it can be concluded that there are autocorrelation in series data of export.

All forecasting models are validated using statistical criteria that are MAE, RMSE, and MAPE. The validations of broiler meat export are presented in Tables 4 to 6.

Table 4 The validations of Brazil's export

Forecasting model	Criteria		
	MAE	RMSE	MAPE
MA(2)	122.75	135.63	3.69%
MA(3)	177.25	178.61	5.41%
ARIMA	140.08	149.01	4.08%
SVM	175.91	180.99	5.10%
ARIMA-SVM	43.47	54.92	1.29%

The ARIMA-SVM model provides lowest MAE, RMSE, and MAPE as kernel function of SVM is used to forecast as radial basis. The Brazil's export consists of linear and nonlinear pattern.

Table 5 The validations of Canada's export

Forecasting model	Criteria		
	MAE	RMSE	MAPE
MA(2)	5.00	5.47	3.46%
MA(3)	4.75	5.24	3.26%
ARIMA	9.23	10.00	6.43%
SVM	15.92	19.53	10.95%
ARIMA-SVM	3.66	4.21	2.50%

The ARIMA-SVM model provides lowest MAE, RMSE, and MAPE as kernel function of SVM is used to forecast as linear. The Canada's exports consist of only linear pattern. But ARIMA model cannot be able to predict overall linear pattern so the SVM enhance the forecasted value by forecasting the residual.

Table 6 The validations of Thailand's export

Forecasting model	Criteria		
	MAE	RMSE	MAPE
MA(2)	56.25	56.49	14.28%
MA(3)	74.17	74.35	19.92%
ARIMA	104.71	105.60	23.21%
SVM	103.61	104.40	22.97%
ARIMA-SVM	30.37	40.19	6.99%

The ARIMA-SVM model provides lowest MAE, RMSE, and MAPE as kernel function of SVM is used to forecast as linear. The Thailand's exports consist of only linear pattern. Nevertheless ARIMA model cannot be able to forecast overall linear pattern thus the SVM is employed to enhance the forecasted value by forecasting the residual.

The forecasted value and actual value in cross-validation procedure are presented in Figures 5 – 7.

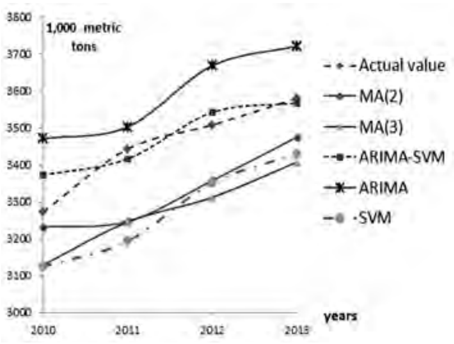

Figure 5 Forecasted export of Brazil

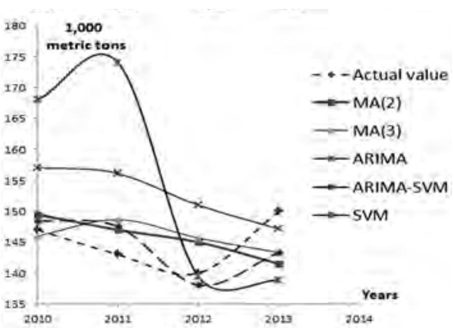

Figure 6 Forecasted export of Canada

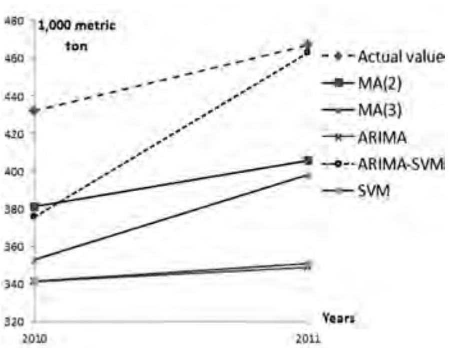

Figure 7 Forecasted export of Thailand

The optimization model presented in equation (7) is used to determine minimum total cost with satisfied shipping amounts. The input values are both forecasted and actual and the results are presented in Tables 7 to 11.

Table 7 Optimal value of MA(2)

Years	Forecasted value	Actual value	Absolute percentage error
2012	35,584.39	56,336.36	36.84%
2013	44,490.72	57003.72	21.95%

Table 8 Optimal value of MA(3)

Years	Forecasted value	Actual value	Absolute percentage error
2012	32,156.68	56.336.36	42.92%
2013	39,887.26	57,003.72	30.03%

Table 9 Optimal value of ARIMA

Years	Forecasted value	Actual value	Absolute percentage error
2012	23,686.23	56,336.36	57.96%
2013	38,276.96	57,003.72	32.85%

Table 10 Optimal value of SVM

Years	Forecasted value	Actual value	Absolute percentage error
2012	35,231.41	56,336.36	37.46%
2013	47,373.72	57,003.72	16.89%

Table 11 Optimal value of ARIMA-SVM

Years	Forecasted value	Actual value	Absolute percentage error
2012	40,208.15	56,336.36	28.63%
2013	56,763.47	57,003.72	0.42%

The absolute percentage errors in Table 7 to 11 imply that the accuracy of forecasting model has an effect to reduce risk of total transportation cost. The appropriate forecasting model provides 14.52% of average error. In addition, the hybrid model provides 13.15% of average error in cross-validation. The average error of cross-validation and test of optimal value is relatively indifferent.

5. Conclusion

The hybrid model of ARIMA-SVM provides lowest error in term of MAE, RMSE, and MAPE comparing with other models when the forecasted values are tested in the mathematical model of the transportation. The combination of forecasting techniques is able to enhance performance of forecasting and can be applied to real situation in order to predict future information. The forecasted exports of Brazil and Canada may be used to provide decision making in order to create strategies of broiler meat export. Moreover, the forecasted export provides reliability for applying forecasting techniques in supply chain management. In addition, all procedures are potential for applying to enhance broiler industries in the future.

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