The primary purpose of this paper is comparing six common models, which were linear, quadratic, Cobb-Douglas, translog, logarithmic, and transcendental, to estimate the supply and demand functions for Saudi Arabian wheat. In addition to estimating the market equilibrium for price and quantity, that led to identifying consumer and producer surplus. Data cover 1990-2014 for all the variables that used to show the effect supply and demand of Wheat. After testing the models using Stepwise and Box-Cox, we came up with the fact that the linear and Cobb-Douglas methods were the best models to show the relationship between variables. On the supply side, we found using the linear model, that wheat price had a negative sign, which represents the impact of government policy number 335. However, in the Cobb-Douglas model, the wheat price had a positive sign. The elasticity coefficient of supply for the wheat price was inelastic. Moreover, the result also showed that all the elasticity coefficients in the supply and demand models were inelastic. The low-income elasticity of demand led the consumption of wheat to increase.

Keywords: Saudi Arabia, wheat, Cobb-Douglas, translog, transcendental.

INTRODUCTION

The primary purpose of this investigation is to determine the factors that affected the supply and demand of Saudi Arabia’s wheat crop over the past three decades. This information will be useful to policymakers in the development of future agricultural policies, as agricultural policies are the most critical indicators of an agricultural policy’s success. To assist in accomplishing the investigation’s goal, this introduction will provide a detailed historical account of Saudi Arabia’s wheat crops.

Wheat production has been an important part of Saudi Arabia’s agricultural production history for many decades. During two decades, the government provided support to farmers to produce wheat. As a result of the government’s support, approximately 535.6 thousand hectares of land, on average, was dedicated to wheat production between 1990–2007, resulting in the production of 2.5 million tons of wheat annually.

In 2008, Saudi Arabia decided to change their wheat cultivation map. As a result, they developed Resolution 335. This resolution stated that the Saudi Grains Organization (SAGO) was required to stop purchasing locally produced wheat for up to eight years, at an annual decline rate of 12.5%. The resolution also prohibited the export of locally produced wheat. Also, the Ministry of Agriculture stopped issuing licenses to produce wheat, barley, and fodder. The agricultural policy changes resulted in some wheat farmers becoming reluctant to grow wheat in Saudi Arabia, due to higher input costs and lower revenues (Al-Hadithi, 2002), (Al-Nashwan, 2010). Consequently, between 2008 and 2016, wheat was only cultivated on approximately 171.97 thousand hectares annually, resulting in the production of 1.05 million tons of wheat, on average, as opposed to the 2.5 million tons produced annually in the previous two decades (ADF, 2017; Al-Nashwan, 2010; MEWA, 2017; SAGO, 2017).

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1 Selected Poster prepared at the Southern Agricultural Economics Association’s 2018 Annual Meeting, Jacksonville, FL, February 3-6, 2018.
Table 1: Wheat area, production, yield, producer and import prices, import quantity and value, and domestic consumption in Saudi Arabia during the period (1990-2016).

<table>
<thead>
<tr>
<th>Year</th>
<th>Area 1000Ha</th>
<th>Production 1000Ton</th>
<th>Yield Ton/ha</th>
<th>Producer Price ($/ton)</th>
<th>Import Quantity 1000Ton</th>
<th>Import Value Million US$</th>
<th>Price Import $/ton</th>
<th>Domestic Consumption 1000Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>414.4</td>
<td>2041.2</td>
<td>5.21</td>
<td>329.3</td>
<td>612.9</td>
<td>189.1</td>
<td>346.6</td>
<td>2450.37</td>
</tr>
<tr>
<td>Max</td>
<td>924.4</td>
<td>4123.7</td>
<td>6.43</td>
<td>445.8</td>
<td>3236.9</td>
<td>1023.6</td>
<td>696.4</td>
<td>4100</td>
</tr>
<tr>
<td>Min</td>
<td>102.6</td>
<td>660.1</td>
<td>4.25</td>
<td>252.9</td>
<td>0.047</td>
<td>0.013</td>
<td>155.6</td>
<td>1550</td>
</tr>
<tr>
<td>% change</td>
<td>-84%</td>
<td>-79%</td>
<td>35%</td>
<td>11%</td>
<td>1311%</td>
<td>1119%</td>
<td>-14%</td>
<td>137%</td>
</tr>
</tbody>
</table>

* General Authority for statistics (GASTAT). Saudi Arabia.
* FOASTAT, the Food and Agriculture Organization of the United Nations (FAO).
* The United States Department of Agriculture (USDA), PSD and GATS.

As can be expected, a significant part of the Saudi gross domestic product (GDP) consists of wheat-related activities. Between 1990 and 2016, the average Saudi GDP was $343.7 billion, with 87% of GPD belonging to the petroleum sector and 4% ($11.1 billion) belonging to agricultural products (The World Bank, 2017; CIA, 2017). The average per capita GDP and agricultural GDP from 1990 to 2016 was about 13.5 thousand dollars and 468.2 dollars, respectively. The big gap between the two numbers resulted in the government providing more attention to the development of the agricultural sector.

Table 1 illustrates that the average area of wheat cultivation and average wheat production in Saudi Arabia, from 1990 to 2016, was 414.4 thousand hectares and 2.04 million tons, at a rate of decline of about 0.03% and 0.02% annually, respectively. The relative importance of the total area of wheat planted and wheat production was about 38% and 42% in 2016, respectively (MEWA, 2017). Total wheat production in 2016 was estimated at 765.8 thousand tons, a decline of about 79% when compared to 1990.

From 1990 to 2016, the average wheat productivity per hectare was about 5.21 tons per hectare, with a growth rate of about 0.007% per year. Wheat productivity in 2016 was about 6.26 tons per hectare, which was 35% more than that in 1990 (4.65 tons per hectare). Producer prices ranged from $445.8 (2016) to $252.9 (1990) per ton, while the average producer’s wheat price was about $329.3 (1990-2016) per ton.

The average import quantity and value of wheat during the period 1990–2016 in Saudi Arabia accounted for 612.9 thousand tons and $189.06 million, with an annual growth rate of about 0.12% and 0.12%, respectively. When compared to 1990, the Saudi import quantity of wheat was 732% higher in 2008 and 1311% higher in 2016. The average wheat import price during the period of 1990–2016 was about $346.6 per ton, with an annual decline of about 0.002% during that same period.

During the study period, the average annual domestic consumption of wheat was about 2.45 million tons, while the average daily domestic consumption of wheat was about 7 thousand tons per day. The average per capita consumption of wheat in Saudi Arabia was about 104 kg per year.

The research problem arose when the gap between the local production and domestic consumption of wheat encouraged local studies to focus on the most critical factors that led to the growth of this gap. These studies focused on agricultural policies, as well as supply and demand shifter, which did not provide a complete picture of this crop. Therefore, it was not possible to determine the factors affecting the supply and demand of the wheat crop at the same time. Consequently, the primary purpose of this investigation is to determine the factors that affected the supply and demand of Saudi Arabia’s wheat crop over the past three decades.

The rest of this paper is organized as follows. The next section focuses on developing the supply, demand, and market equilibrium models. That section is followed by the estimation results. In the final section, we discuss our conclusions and elaborate upon our policy implications. We also provide recommendations for future research.

METHODOLOGY

The agricultural products market often influenced by a set of external factors of the market mechanism itself, which affects the demand and supply of the agricultural products market. The supply of agricultural produce is affected by natural and disaster factors, such as floods, rainfall, soil fertility, and high or low temperature, among others. The demand for agricultural produce is affected by sudden consumption changes such as wars, diseases, population increase, and more (Debertin, 2012).

To estimate the supply function for the wheat crop during the study period, local production was adopted as a dependent variable; and producer wheat price, the area cultivated by wheat, wheat import price, rice import price, the amount of fertilizer, the amount of rainfall, and the number of tractors per hectare (a variable that reflects the use of technology)

Functions of Wheat Supply and Demand in Saudi Arabia
were adopted as independent variables. Dummy variables were also used (1: production before 2008; 0: production after 2008) to show the impact of government policy number 335.

The supply production function is as follows:

\[ Q_s = f(P_w, Area, P_{im}, Pr, TFr, RainFall, Tec, D) \]

On the other hand, the individual demand for wheat depends on its price and the prices of alternative commodities such as rice, per capita income, and population. These variables affect the demand; thus, the relationship can be represented in the following form:

\[ Q_d = f(P_w, P_r, Percap, P_{im}, POP, D) \]

### Model Specification

AlSultan (2005) studied the forecasting of wheat productivity in Saudi Arabia using a range of mathematical models. He used six models to predict the values of productivity, such as the linear trend model, quadratic trend model, double moving average, double exponential smoothing, simple moving average, and simple exponential smoothing. Taj Eddin, Khalife, and Al-Batal (1993) used a linear regression method to estimate the production function in Saudi Arabia, while Al-Turkey (1991) estimated many production functions, finding that the quadratic function was the most conciliatory.

In this study, we used a widely different function to estimate the supply and demand function of wheat, as represented in Table 3. Non-linear transformation: made the distribution of the residuals more normal and reduced the multicollinearity and heteroskedastic problems. (Gujarat and Dawn, 2009), (William, 2003).

<table>
<thead>
<tr>
<th>Table 2: Variable Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Qs</strong></td>
</tr>
<tr>
<td><strong>Pw</strong></td>
</tr>
<tr>
<td><strong>Area</strong></td>
</tr>
<tr>
<td><strong>Pr</strong></td>
</tr>
<tr>
<td><strong>Pim</strong></td>
</tr>
<tr>
<td><strong>TFr</strong></td>
</tr>
<tr>
<td><strong>RainFall</strong></td>
</tr>
<tr>
<td><strong>Tec</strong></td>
</tr>
<tr>
<td><strong>D</strong></td>
</tr>
<tr>
<td><strong>Qt</strong></td>
</tr>
<tr>
<td><strong>Percap</strong></td>
</tr>
<tr>
<td><strong>POP</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3: Model Specification for Supply and Demand function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td><strong>linear</strong></td>
</tr>
<tr>
<td><strong>Quadratic</strong></td>
</tr>
<tr>
<td><strong>Cobb-Douglas</strong></td>
</tr>
<tr>
<td><strong>Translog</strong></td>
</tr>
<tr>
<td><strong>Logarithmic</strong></td>
</tr>
<tr>
<td><strong>Transcendental</strong></td>
</tr>
</tbody>
</table>


Where \( y \) is the dependent variables, \( x \)'s are independent variables, and \( \alpha \) and \( \gamma \) are parameters to be estimated.
Market Equilibrium

From the above supply and demand function, we can solve for both price and quantity equilibrium by using simultaneous model. First, we can find the market price equilibrium as \( Q_s = Q_d \).

Therefore, the equilibrium quantity for this market is:

\[
Q^* = \delta_0 - \delta_1 Area - \delta_2 Pr - \delta_4 RainFall - \delta_5 Tec + \delta_6 Pw + \delta_7 Percap + \delta_8 POP + \varphi
\]

Data

The models were estimated using time series data from 1990–2016. We used various sources to estimate our models. Data on area and production came from the Open Source Library at the Ministry of Environment, Water and Agriculture and the General Authority for statistics (GASTAT) in Saudi Arabia. The Food and Agriculture Organization of the United Nations (FAO) and the United States Department of Agriculture (USDA) were used to collect data for import quantity and value for wheat and rice in addition to the domestic consumption and producer wheat price.

The number of tractors and fertilizer consumption collected from FAO as well as the Statistical, Economic and Social Research and Training Centre for Islamic Countries (SESRIC) and the Arab Organization for Agricultural Development (AOAD). GDP, population, and the amount of rainfall collected from available secondary data from the World Development Indicators - World Data Bank.

RESULT AND DISCUSSION

To estimate the supply and demand function, we used six common models, namely linear, quadratic, Cobb-Douglas, translog, logarithmic, and transcendental.

We checked for the correlation matrix between the dependent and independent variables. For the supply variables, \( Pw, Pim, Rainfall, Tec, \) and \( TFr \) were weakly correlated with \( Qs \), whereas \( Area \) and \( Pr \) had highly correlated to \( Qs \). However, there were high correlations between the \( Tfr \) and different types of fertilizer, and between these variables themselves. In demand variables, we found that there were high correlations between \( Pr, Percap, \) and \( POP \) variables with \( Qd \). While \( Pw \) and \( Pim \) had a weak correlation with \( Qd \). The technology sign was negative because of the high decrease in production after 2008 due to government policy number 335, while the cumulative number of machines increased. However, the farm cannot get rid of them or resell them again. One of the important points for estimating the best result is how to choose the function forms, meaning what kind of relationship exists between the dependent and independent variables, whether linear or not linear.

For the supply model, we tested for the best function that prefers to use the Box-Cox test for each variable, and we found that linear function was the preferred function. However, we tested for all variables together to check for the preferred function, and we rejected the null hypothesis for all three forms (linear, log, inverse). Therefore, we were unable to decide which one was preferred. For the demand function, we found that logarithmic function is the preferred function, these results was different than Al-Turkey (1991) who found that quadratic function was favorable (using survey data). However, we tested for all variables together to check for the preferred function and found that logarithmic function is the preferred function. Although several models were estimated, we tried to prove that the Box-Cox test generated a best-predicted function form. Our result indicates that what we found in the Box-Cox test was the best function form when compared to the others.

We estimated more than 70 equations for supply and 30 equations for demand to find the best function. Also, we used stepwise regression to get a useful and reasonable regression model. We used the Enter and Stepwise methods since we are interested in some of the independent variables not omitted from our function.

Estimating the Supply Function

For the fertilizer variables, we tried to collect different types, but since we were unable to gather complete data, we used what was available in our sources. We included Nitrogenous (N), Phosphate (PH), Potash (PO), and Urea (UR). However, we tried to estimate the model by including all these variables, but none were significant. We dropped each variable one by one, but they were still not significant. Therefore, we included total fertilizer as representative of these four types, and we found somewhat that the variables of our models improved.

As a result of the high R2 and the fact that some of the coefficients were not significant and got the opposite sign, we were worried about facing multicollinearity problems. We, therefore, tested for multicollinearity using the variance inflation factors (VIF) test and variance-covariance matrix of the fitting coefficient. For the VIF test, we tested for any coefficient more than 10, and we displayed high multicollinearity between the variables with quadratic, translog, logarithmic, and transcendental forms. The quadratic and translog models were not of full rank. The least-squares solutions for the parameters were not unique. Some statistics will be misleading, and some parameters had been set to 0 since the variables were a linear combination of other variables. This problem leads to face the multicollinearity problem. Therefore, we ignored these forms. Also, some of these functions had no significance with prices. We also used a variance-covariance matrix of the appropriate coefficient test to show the correlation between variables, as in the regression. Then we omitted the highly correlated independent variables (which had more than 0.80) or those variables that had opposite signs.
in the regression from our hypothesis. Also, we checked for heteroskedasticity by using the Breusch-Pagan test, and we found that the null hypothesis was not significant, which means there was no heteroskedasticity problem.

Table 4 represents a coefficient table of the best functional form. All the models had a high value of F-test (p<0.001) and R2 (got more than 0.9), which confirms the high explanatory power of the model statistically. When we included the dummy variable, we did not get any significant variables for prices. Therefore, we chose the models that didn’t include a dummy for a linear function. However, the Cobb-Douglas with a dummy variable had a significant price, which was the only form.

The Linear function had two models. The T-test indicated that all the coefficients had a significant result at the 10% significance level, except for rice import price. All the variables received the same sign as what expected; the mean problem sign was the price of wheat, which was negative and reflected the supply law. However, since the government interfered with this market until 2008, this led to the farmers facing the market price (lower than the government price), and many of farmers refrained from cultivating wheat. The sign of Tec was negative, and the only aspect apparent to affect this was that the reluctance of the farmers to grow wheat led to the accumulation of machinery on farms, with a decline in cultivating wheat and a higher number of annual machinery. Therefore, as a result from the linear model, wheat production was expected to increase with more units in the area and wheat import price, but a decrease in units of producer wheat price and the number of machines per hectare.

Second, the results of the Cobb-Douglas production function as log-linear (by including time to capture the impact of technical change) presented in Table 3. All the variables had a significant t-test at the 10% significance level. With different estimated functions, we chose the first model, Cobb-Douglas, which had the economy sign we expected. The results showed that the production of wheat was a positive function of producer wheat price, area, wheat import price, and time, but decreased with the number of machines per hectare. To estimate the marginal effect, we took the derivative of our function and found that all the variables were positively associated with wheat production and negatively associated with the number of machines per hectare. We found that the first and third models represent the increasing return to scale (which means that the function is homogenous of degrees higher than one), while the second model represents the decreasing return to scale.

We calculated the elasticity for each variable. However, all the elasticity coefficients were inelastic for all models. We calculated the elasticity for the first linear function of the own price, wheat import price, and rice import price, and the technology elasticity, which were 0.16, 0.07, 0.05, and 0.13, respectively. Since the own price was less than one, the supply was less responsive to changes in price. The cross prices were positive referring to the increasing supply of wheat as the cross-price rose. We also calculated a second linear function of the own price elasticity, which was -0.19, and the cross-price elasticity for wheat import price was 0.07, while the technology elasticity was -0.12%. The coefficient elasticity for the first Cobb-Douglas function of the own price, cross-price, and technology elasticity were 0.68 and 0.12, respectively. Also, the third Cobb-Douglas function result showed that the own price, wheat and rice import price, and technology elasticity were 0.12, 0.08, 0.03, and 0.05, respectively.
Table 5: Estimating Demand function

<table>
<thead>
<tr>
<th>Variables</th>
<th>Linear Coefficient</th>
<th>Linear t</th>
<th>Cobb Douglas Coefficient</th>
<th>Cobb Douglas t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pw</td>
<td>1.38*</td>
<td>2.41</td>
<td>-0.188*</td>
<td>-1.8</td>
</tr>
<tr>
<td>IPw</td>
<td>0.04</td>
<td>2.63</td>
<td>0.407*</td>
<td>0.66</td>
</tr>
<tr>
<td>PerCap</td>
<td>50.8</td>
<td>3.99</td>
<td>0.220*</td>
<td>2.9</td>
</tr>
<tr>
<td>IPercap</td>
<td>45.06*</td>
<td>3.99</td>
<td>0.022*</td>
<td>4.75</td>
</tr>
<tr>
<td>t</td>
<td>40.6</td>
<td>3.99</td>
<td>5.174*</td>
<td>4.95</td>
</tr>
<tr>
<td>Cons</td>
<td>-968.43*</td>
<td>-3.95</td>
<td>-36.61*</td>
<td>-4.47</td>
</tr>
<tr>
<td>F</td>
<td>103.47</td>
<td></td>
<td>106.12</td>
<td>157.37</td>
</tr>
<tr>
<td>R²</td>
<td>0.931</td>
<td></td>
<td>0.9326</td>
<td>0.9535</td>
</tr>
</tbody>
</table>

* Significant at 10% significant level, t statistics in parentheses

Estimating the Demand Function

Six functions form were used to estimate the demand function for wheat crops: linear, quadratic, Cobb-Douglas, translog, logarithmic, and transcendental. We tested for multicollinearity and found that we were facing this problem. By using the VIF test, we found that some variables had more than 10, and we dropped it from our regression. After that, we checked for heteroskedasticity. By using the Breusch-Pagan test, we found that our model survived this potential issue. The results indicated that the best function representing the demand function was linear and Cobb-Douglas, whereas the signs for the coefficient were compatible with economic theory, and the R adjusted square was higher than the other functions.

We chose the Cobb-Douglas function, the third equation in Table 4, which had the expected sign for all variables and had a significant t-test at the 10% significance level. The results indicate that the consumption of wheat increased with more units of per capita income but decreased with more units of producer wheat price.

In demand elasticity, we found that the elasticity was less than one (inelastic), which indicates that the demand was less responsive to the change of these variables. We calculated the first linear function elasticity of the own price elasticity, which was 0.19. The income elasticity was 0.22, which shows that the wheat commodity was normal and necessary. Also, for the first Cobb-Douglas function, the own price and income elasticity were 0.188 and 0.407, respectively. The elasticity of the second Cobb-Douglas function found that the own price and income elasticity were 0.123 and 0.193, respectively.

Estimating Market Equilibrium

At market equilibrium, the demand is exactly equal to supply, which meant that at the equilibrium price the buyers who are willing to buy at this price would get the quantity they need, and the sellers who are willing to sell their product at that price will also get their quantity. (Gujarati and Dawn, 2009), (William, 2003).

The Saudi Arabian government used the price support program for wheat producers. Under this program, the government can raise the price of wheat by buying it from the producer. In our cases, the government interfered the wheat market, represented by the Saudi Grains Organization, buying domestic wheat from the producer at a high price and then sell the quantity back to the market at lower prices, after converting the wheat to other products (since it had a higher price than the market, producers will sell their product to the government to get a high profit). As a result, we face the problem of estimating the market price and quantity equilibrium, and the market shows distortions.

We used the simultaneous equation model to estimate the equilibrium price for the wheat market. Therefore, we need Qs=Qd for equilibrium, and then we solve for the price $P_w$, as follow:

$$lnP_w = 77.65 - 3.23lnArea + 0.21lnTec - 0.28lnPim + \frac{1.41lnPerCap}{-0.03t - 0.76D}$$

The average equilibrium price for the period 1990–2016 was $322.5/ton^2. It was lower than the average producer price, which was $329.3/ton. This gap in prices (which was $6.8/ton) resulted because of the government intervention in determining wheat prices within markets. The quantity equilibrium from the supply side equaled 1788.7 thousand tons, and from the demand side equaled 2361.1 thousand tons. Consumers saw the benefit from the government intervention in this case, with the lower-priced consumer surplus increase. The losses from changing the price for the consumer was $526.02 thousand, and the benefit for producers were equal at $576.9 thousand. The total social surplus was $50.8 thousand, and the government's cost was $187.6 thousand. These results were different from AL-Kahtani (1994), who determined the optimum quantity of wheat production under the government subsidy policy for wheat prices ($533.3 per ton). He found that the optimal production of wheat should be 1.004 million tons. Thus, the benefits of the producer and the consumer amount to $30.03 and $12.8 million, respectively, while the government and social costs were $44.32 and $1.5 million, respectively.

\(^2\) To find the price equilibrium, we used the standard Generalized Reduced Gradient (GRG) provides from Excel programming. This method can control for non-linear models to find the optimal solution.

Using the predicted value, we could find the equilibrium price and quantity by minimizing the sum of squares error.
CONCLUSION

In 2008, Saudi Arabia decided to implement government policy number 335, which changed the map of wheat cultivation significantly. The government programs contributed to supporting wheat cultivation and then stopped this support, which led to a rapid decrease in the area used for wheat cultivation and domestic production.

The research problem showed that when the gap occurred between local production and domestic consumption of wheat expansion, local studies were encouraged to focus on the most important factors that led to the growth of this gap.

The aims of this research were estimating the supply and demand functions for Saudi Arabian wheat, in addition to estimating the market equilibrium for price and quantity that led to identifying consumer and producer surplus. The results showed that the most important factor for wheat supply was producer wheat price, area cultivated, rice import price, wheat import price, the total amount of rainfall, and the number of machines per hectare. Furthermore, wheat demand factors were producer wheat price, rice import price, wheat import price, per capita GDP, and total population. We used a widely different function to estimate the supply and demand function of wheat. We chose the linear and Cobb-Douglas methods to estimate supply and demand relationships between variables.

On the supply side, we found using the linear model that wheat price had a negative sign, which represents the impact of government policy number 335. However, in the Cobb-Douglas model, the wheat price had a positive sign. In both models, the cumulative of the area and wheat import price had a positive impact on the production. The proxy of technology had a negative relation with production, which shows the accumulation of machinery in farms after the government decision. The elasticity coefficient of supply for the wheat price was inelastic, which represents that supply was less responsive to changes in price. Moreover, the result also showed that all the elasticity coefficients in the supply and demand models were inelastic (less than one). The low-income elasticity of demand led the consumption of wheat to increase. However, the positive sign indicates that wheat was a normal and necessary commodity. The equilibrium amount was $322.5/ton. Therefore, the consumer losses was $526.02 thousand and producer benefit was $576.9 thousand, while the government cost was $187.6 thousand.

The study recommends focusing on the period after the government's decision to stop subsidizing wheat. It also recommends reviewing the decision by presenting the benefits and costs carried by society. The orientation of foreign investment in wheat cultivation is a solution in case of stability of that country.

REFERENCES


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