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A mathematical model of demand with unpredictable salt supply: a case study in Madura

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ABSTRACT

The proposed mathematical model aims to optimize the amount of demand based on the uncertainty of salt supply to meet the needs of salt in society. This study uses an econometric approach to model the supply and demand for salt based on the uncertainty of the amount of supply. The research results are the salt productivity model used to build a salt availability model. Meanwhile, the salt demand model is built based on past data about the number of requests for each period. The demand and supply functions for salt use a two-variable linear equation system. The salt field productivity models follow a quadratic polynomial pattern according to the difference in seasons at each time. The demand and supply of salt model follows a linear regression. The supply of salt in Indonesia is uncertain at any time. But, the demand for salt increased at the time. It is necessary to model the demand and supply of salt to meet the demand for salt

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INTRODUCTION

Salt is a strategic commodity to meet the needs of the community. The fulfillment of salt needs is determined by the availability of farmers' salt, depending on the season. In addition, the availability of salt is also influenced by land productivity. The average productivity of salt land per hectare is 30-50 tons (Kurniawan 2016). The need for salt in Indonesia is divided into the market for salt consumption and the need for industrial salt. The salt produced by farmers is used for the fulfillment of consumption of salt. The ratio of production capability to salt consumption needs in Indonesia in 2014 – 2018 was 0.357 on average (KKP 2019) The need for salt increases yearly, so the salt supply also increases. The increase in the need and supply of salt should be directly proportional to the price. The price of salt is very volatile; namely, in 2016, in January, the price per kilogram reached IDR5,792, - but in June, it decreased to IDR700. Likewise, in 2017, starting from IDR2,000 - to IDR760. This condition occurs due to imported salt from India and Australia. And the price of imported salt from India is IDR475, and from Australia is IDR600,- (Purnanto et al. 2020)

The supply of salt in Indonesia is uncertain at any time. Some of the causes of unpredictable salt supply are (1) the source of raw materials is only seawater; (2) a short dry season period; (3) high humidity level, so that the productivity of salt production is lower; (4) the scale of production per small and scattered farmer; and (5) low production process technology (Efendi et al. 2013, Rahman et al. 2014, Muhandhis et al. 2019). This problem causes the quality and quantity of salt in Indonesia to be low.

A mathematical model approach is used to describe the demand and supply of agricultural products (Farok 2015, Li dan Yang 2017, Rambe dan Kusnadi 2018, Mousavi et al. 2019, Penkovskii et al. 2019, Barus 2020, Nishanth et al. 2020, Zhuo et al. 2020). The demand for salt is stochastic and normally distributed, as is the demand for other agricultural products (Ferreira et al. 2017, Rambe dan Kusnadi 2018). In general, the demand for salt is uncertain but follows the normal distribution. Salt farmers will meet the demand for salt from merchants. The availability of salt and the price of salt in the market influences the demand for salt. Prices of agricultural commodities, including salt, fluctuate following the seasonal (Gouel 2012). Price fluctuations determine the amount of demand. Price expectations follow the Cobweb theorem, where bidding decisions consider past conditions.

The proposed mathematical model aims to optimize the amount of demand based on the uncertainty of salt supply to meet the needs of salt in society. The mathematical model that is built consists of the supply model of the farmers and the demand model of the middlemen based on the uncertainty of the amount of supply. Farmers' supply is based on the amount of salt land productivity. The productivity of salt land depends on the season and land area. The price of salt will influence the salt supply model. At the same time, the model of demand for salt by middlemen is influenced by the price of salt in the market. The market balance price occurs at the amount of demand equal to the amount of supply. At the time of salt harvest, the supply is more than the demand, so the price decreases, and vice versa. When it is not the salt harvest season, the supply decreases, causing the price to increase.

METHODOLOGY

This study uses an econometric approach to model the supply and demand for salt based on the uncertainty of the amount of supply. The method used is linear equations.

The salt supply function, in general, follows the theorem Cobweb (Gouel 2012) is as follows:

$$Q_s = a + \beta p \quad (1)$$

Specifically, some farmers' salt availability influences the salt supply at the farmer level. The amount of salt supply (Qs) is the amount of production by farmers; a is a constant; β is the elasticity of prices to the amount of supply, and P is the price of salt.

The function of salt demand by middlemen (Q_D) follows the normal distribution and is formed by the amount of salt demanded by middlemen, which affects the price of salt. The parameter of the change in market price to the amount of salt demand made by the middleman QD, the constant for the middleman a, β is the elasticity of the cost to the amount of demand; and the price offered by the middleman (p) is :

$$Q_D = a - \beta p \quad (2)$$

Testing of the model made will be tested: Classical assumption test and statistical test. Classical assumption tests include normality tests and autocorrelation tests. The normality test intends to assess the distribution of data in a group of data or variables and whether the data distribution is normal. A model is said to be normally distributed when the degree of significance is more than 0.05. The autocorrelation test determines the presence or absence of deviations in the classical autocorrelation assumption, which is the correlation between residual at one observation and another in the regression model. A good regression model is a regression model that is free from autocorrelation. The test method often used in quantitative research uses the Durbin-Watson test (DW). If the result of Durbin Watson's value is between dU and 4-dU, then it says in the data that no autocorrelation occurs

The statistical test is carried out by testing the coefficient of determination (R2) and simultaneously trying the influence (F). The coefficient of determination test (R2) measures how far the model can explain the variations in dependent variables (model accuracy). The coefficient of determination (R2) value ranges from 0 to 1, indicating the magnitude of the combination of independent variables affecting the value of the dependent variable. The closer to number one, the better the model issued by the regression will be.

The F test determines whether independent variables simultaneously affect dependent variables. The significant level used is 0.5 or 5%; if the substantial value in F < 0.05, it can be attractive that the independent variable simultaneously affects the dependent variable or vice versa.

RESULT AND DISCUSSION

Salt Supply Model

A supply model is a static relationship that shows how much a commodity is offered (for sale) at a given place and time at different price levels when other factors do not change (Gouel 2012). Salt supply is influenced by the productivity of salt land and the area of land owned by farmers.

The average salt productivity in Sampang Regency is 80 - 100 tons/ha (KKP 2019). Under normal seasonal conditions, one year is divided into four criteria that distinguish the amount of salt productivity. The criteria for such seasons are the rainy season, the beginning of the dry season, the peak of the dry season, and the transitional season from the dry season to the rainy season. Each of the criteria for the season occurs for three months. For t = 1, 2, 3 is the rainy season; t = 4.5, 6 is the beginning of the dry season; t = 7. 8, 9 is the peak of the dry season; and t = 10, 11, 12 is the transitional season from the dry season to the rainy season. The period t is the month. In the first period (t=1,2,3), salt fields do not produce salt due to the rainy season. In the second period, namely the beginning of the dry season, the productivity of salt land is 20-40 tons /ha. At the peak of the dry season, the productivity of salt land in each sub-district in Sampang Regency reaches 70-100 tons/ha. In the transitional season, from the dry to the rainy season, the productivity of salt land decreases to 20-10 tons/ha. To model the productivity of salt lands using an econometric approach. The quadratic polynomial method produces the following equation of salt field productivity per time :

$$y(t) = -52.626 + 30.037t - 2.066t^2 \qquad (3)$$

The quadratic polynomial model has a p-value of 0.031, so it does not exceed the predetermined tolerance level (α) (α = 5%). Then this model, the regression coefficient, is significant. In addition, this quadratic polynomial regression model produced an R2 value of 53.9% showing significant results. This model is considered capable of representing actual conditions.

The function of land productivity in each season, assuming t is 12 months so that the land productivity function of each t is as follows:

$$y(t) = \int_{t=0}^{12} -52.626 + 30.037t - 2.066t^2 \qquad (4)$$

The salt supply of farmers is not only determined by the seasons but also influenced by the area of land owned by farmers. Where Ws is the amount of supply, y is the productivity of the land, t is the time, and L is the area of salt land, then the function of the number of supply of the farmer is as follows:

$$W_s = y(t) * L \qquad (5)$$

The salt supply amount model is not only influenced by the land area's productivity but also by the price of salt. The salt supply function (QS) affected by the price (p) is as follows :

$$Q_s = W_s + \beta p \quad (6)$$

Sampang Regency is one of Indonesia's regions with a high salt productivity level, which is 80-100 tons/ha. One of the areas in Sampang Regency, namely Pangarengan District, has a salt land area of 1,866 ha (KKP 2019). The price range of salt starts from IDR475 up to IDR2000 (Purnanto et al. 2020). Based on these data, the salt supply function is as follows:

$$Q_s = 17.971 + 61{,}369P \quad (7)$$

Salt Demand model

The demand function shows the relationship between the number of products requested by the consumer and the product's price. In economic theory, the law of demand says if the price goes up, then the quantity of requested products goes down, and vice versa. If the price falls, then the amount of goods requested goes up. The influence of the demand function results in the supply function, which occurs due to the market balance. The bidding function shows the relationship between the number of products the manufacturer offers and the product's price. In economic theory, there is an explanation of the law of supply: if the price increases, then the number of goods offered increases and vice versa. If the price falls, then the number of goods offered falls.

Table 1 Salt Price and Quantity Demand

Price (IDR)	Quantity Demand (kilograms)
300	306,333
400	276,072
600	255,675
800	222,126
1,000	188,578
1,200	155,029
1,300	121,482
1,400	87,933
1,500	54,385

Based on these data, the model of salt demand by middlemen is as follows:

$$Q_D = 369{,}261 - 194.793p \quad (8)$$

The normality and autocorrelation tests are analyzed based on the salt supply model produced (equation (7)). The normality test is based on the Asymp.sig value at the Kolmogorov-Smirnov test level is worth 0.867. The significant rate used is %%, so the Asymp.sig value is 0.867 > 0.05, so it can be concluded that the data is normally distributed.

Durbin Watson's value (1,739). The free regions in this data are 1.3197(dU) to 2.6803 (4-dU) so that Durbin Watson values are within dU values and (4-dU) or 1.3197 < 1.739 < 2.6803, then it can be concluded the model is not autocorrelated.

The salt supply model shows the value of R2 is 0.933 indicating a significant result. This model is considered capable of representing the actual conditions. In addition, the simultaneous effect test showed a p_value value (sig.) of 0.000 less than α = 5%, so the accompanying free variable (price) had a significant effect on the dependent variable (amount of salt).

Based on classical assumption and statistical tests, it shows that the salt supply model that has been produced is feasible to use to determine the amount of salt supply based on productivity and land area affected by salt prices.

Based on the model of salt demand by middlemen (equation (8)), an analysis of the normality test and an auto-correlation test were produced. The normality test is based on the Asymp.sig value at the Kolmogorov-Smirnov test level is worth 0.988. The significant rate used is %%, so the Asymp.sig value is 0.988 > 0.05, so it can be concluded that the data is normally distributed.

Durbin Watson value (1.6 39) and the free regions in this data are 1.3199 (dU) to 2.681 (4-dU) so that the Durbin Watson values are within the dU values and (4-dU) or 1.319 9 < 1.639 < 2.681, it can be concluded that the model did not undergo autocorrelation.

The salt supply model shows the value of R2 is 0.971 indicating a significant result. This model is considered capable of representing the actual conditions. In addition, the simultaneous effect test showed a p_value value (sig.) of 0.000 less than α = 5%, so the simultaneous free variable (price) had a significant effect on the dependent variable (amount of salt).

Based on classical assumption and statistical tests, it is shown that the salt supply model that has been produced is feasible to use to determine the amount of salt demand by middlemen influenced by salt price.

CONCLUSION

The salt field productivity model follows a quadratic polynomial pattern according to the difference in seasons at each time. The salt demand and supply model follows a linear regression model. The managerial impact obtained by modeling land productivity, demand, and supply of salt can be used as a reference for predicting the supply and demand for salt in each region. In addition, it can be used as reference material by the government regarding salt procurement policies

REFERENCE

Barus, M. D. B. 2020. Analisis Aplikasi Dan Penerapan Matematika Pada Ilmu Ekonomi Fungsi Permintaan Dan Penawaran. Akutansi Bisnis Dan Publik 11:1–11.

Efendi, M., Y. Rochwulaningsih, M. P, P. Gumilar, T. . Asih, D. . Dyspriani, dan K. Baekhaki. 2013. Pugar: Momentum Kebangkitan Usaha Garam Rakyat (Pugar: a Momentum for Local Salt Empowerement). Halaman UTM Press. UTM Press, Bangkalan.

Farok, G. M. G. 2015. Transaction of the Mechanical Engineering Division, The Institution of Engineers. Journal of Mechanical Engineering 45:96–117.

Ferreira, K. J., J. Goh, dan E. Valavi. 2017. Intermediation in the Supply of Agricultural Products in Developing Economies. SSRN Electronic Journal.

Gouel, C. 2012. Agricultural price instability: A survey of competing explanations and remedies. Journal of Economic Surveys 26:129–156.

KKP. 2019. Kelautan dan Perikanan dalam Angka 2018 (Marine and Fisheries in Number 2018). Indonesia.

Kurniawan, B. A. 2016. Implementasi Program Dana Bantuan Pemberdayaan Usaha Garam Rakyat (PUGAR) dalam Rangka Pengembangan Wirausaha Garam Rakyat (Studi Pada Dinas Kelautan Dan Perikanan Kabupaten Sumenep) (Implementation of Financial Aid for PUGAR in Order to Develop Salt b. AJIE - Asian Journal of Innovation and Entrepreneurship 1(1).

Li, Y. C., dan H. Yang. 2017. A mathematical model of demand-supply dynamics with collectability and saturation factors. International Journal of Bifurcation and Chaos 27:1–14.

Mousavi, B. A., R. Azzouz, dan C. Heavey. 2019. Mathematical modelling of products allocation to customers for semiconductor supply chain. Procedia Manufacturing 38:1042–1049.

Muhandhis, I., H. Susanto, dan U. Asfari. 2019. Development of system dynamics model to increase salt fulfillment ratio. Procedia Computer Science 161:867–875.

Nishanth, B., S. Priyanka, V. Kannan, A. Muhammad Raheel Basha, J. Dinesh, A. Muhammad Raheel Basha, R. Muruganandham, V. Harish, dan R. Muruganandham. 2020. Mathematical modelling of supply chain under current COVID'19 business scenario with the review study on the fuzzy logic based supply chains. European Journal of Molecular and Clinical Medicine 7:4972–4981.

Penkovskii, A., V. Stennikov, dan I. Postnikov. 2019. Unified heat supply organization: Mathematical modeling and calculation. Energy Procedia 158:3439–3444.

Purnanto, S. H., S. Suadi, dan U. Ustadi. 2020. Salt Supply Chain Management at Regional Level: Case Study of Salt Processing Industry and Salt Consumer Industry in Central Java. Jurnal Perikanan Universitas Gadjah Mada 22:63.

Rahman, A., S. Raharja, dan D. Kadarisman. 2014. Evaluasi Kinerja Usaha Petani Garam Rakyat di Kabupaten Bima , Nusa Tenggara Barat (Performance Evaluation of Salt Farmers Business People in Bima District , West Nusa Tenggara Province). Manajemen IKM 9:106–118.

Rambe, K. R., dan N. Kusnadi. 2018. Permintaan Dan Penawaran Minyak Goreng Sawit Indonesia. Forum Agribisnis 8:61–80.

Zhuo, Z., K. Y. Chau, S. Huang, dan Y. K. Ip. 2020. Mathematical modeling of optimal product supply strategies for manufacturer-to-group customers based on semi-real demand patterns. International Journal of Engineering Business Management 12:1–8.