Resources Policy 63 (2019) 101409

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

Modeling steel supply and demand functions using logarithmic multiple regression analysis (case study: Steel industry in Iran)

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ARTICLE INFO

Keywords:
Steel industry
Supply function
Demand function
Logarithmic multiple regression

ABSTRACT

The steel industry is considered as one of the mother industries that serves many large and small industries. Hence, recognizing the market situation of the steel industry both inside and outside the country is very important. Supply and demand are among the most important factors in stimulating the steel market. Usually, supply and demand have complex function. So, modeling and forecasting steel supply and demand require the use of accurate and scientific approaches. This paper presents an approach to identify the steel supply and demand functions and also to forecast the supply and demand trends. In the first step, through reviewing the historical data on the steel supply and demand in Iran, the effective and most important variables will be identified. Then, the supply and demand functions will be fitted using multiple logarithmic regression analysis. Logarithmically transforming variables in a regression model is a very common way to handle situations where a non-linear relationship exists between the independent and dependent variables. The accuracy of estimations is checked through appropriate statistical tests. The analysis is based on data of Iran steel market obtained from a 60 monthly period starting in 2010 and ending in 2014. The results showed that the estimated functions was appropriate in modeling the steel supply and demand behavior. The extrapolation analysis using 24 monthly data from 2017-2018 has also been accomplished to check the performance of the regression analysis.

1. Introduction

The steel industry can be considered as one of the key and infrastructure industries in the economy, and its growth reflects economic growth and the return of a prosperity to the global economy. In fact, economic growth and the steel industry growth are causally related and impacted by one another, because steel demand grows when the economy is in a state of growth and industrial activity increases. On the other hand, when the economy is in full health, industrial activities will grow and steel demand will increase.[2] The steel industry in the developing economies will be out of recession and the number of infrastructure projects will increase in these countries.

Countries such as China, Japan, India, America, Russia, South Korea, German, Turkey, Brazil and Ukraine are top 10 steel producer in 2016, according to the World Steel Association, which was published by the economic deputy of the Tehran Chamber of Commerce. According to statistics, China, the world's largest steel producer, with 808.4 Mt in 2016, accounts for 49.6% of the world's crude steel production. Asia, except China, accounts for about 20%, the Commonwealth of Independent States (CIS) about 6.3%, the European Union about 10%, the Middle East about 2%, North America about 7%, and South Africa about 2.5%, and Africa accounts for about 1% of world steel production. Iran has ranked 14th in this list with 17.9 Mt of steel. IMIDRA institute with the production of 14.02 million tons is in the 25th place among the largest steel producer companies. Comparing steel production in selected countries showed that Iran is largest crude steel producer in April 2017, with a production of around 1.7 Mt in April 2017 that has 65% share among other Middle Eastern countries, such as Qatar, UAE and Saudi Arabia. On the other hand, according to the World Steel Association, China's share of global steel demand will

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[2] https://www.worldsteel.org/media-centre/press-releases/2018/worldsteel-Short-Range-Outlook-2018-2019.html.

https://doi.org/10.1016/j.resourpol.2019.101409
Received 25 January 2019; Received in revised form 20 May 2019; Accepted 20 May 2019
Available online 29 May 2019
0301-4207/

decline in 2017 and 2018, and China, the United States and India will continue to be among the three major steel consuming countries in the world in 2017 and 2018.[3]

Esfahan Steel Company and Khouzestan Steel Company with capacity above 2 Mt are active among currently active steel units, and other existing units and projects under implementation have lower capacity. This indicates a significant difference in the production scale in Iran compared to global norms.[4] Since a basic step to understand the structure of the steel supply and demand functions in the country is the modeling of the above functions by employing the factors affecting them, this paper aimed to model these two functions to identify the determinant factors in the crude steel supply and demand in Iran. This modeling will predict the supply and demand conditions for crude steel in the coming years. Therefore, the modeling and prediction of crude steel demand in the coming years and the analysis of variables that play a more critical role in the crude steel demand, will be considered. For this purpose, we will use historical data analyzes, statistical tests and multiple logarithmic regression analysis.

Next sections of this article are organized as follows. In Section 2, the review of literature and previous research and studies on steel supply and demand and regression-based prediction methods are presented. In Section 3, modeling the steel supply and demand functions is presented. In Section 4, the results of using the models in a 48-month period starting in 2010 and ending in 2014. Finally, in Section 5, the paper is summarized and the main achievements and suggestions for future research are presented.

2. Review of literature and research background

2.1. Studies on the steel supply and demand in Iran

Due to the country's development, the need for steel as one of the most important development materials has always been bullish. The demand for steel represents a range of products that are the ultimate products of the steel industry, such as types of ingots, cores, rebar, steel plates, sheets, etc., mainly for durable consumer goods. The capital is used in the production process. By contrast, demand for steel is dependent on the variables of the building sector (residential and non-residential), industry (in particular automotive, shipbuilding, railways and locomotives, container and packaging, household appliances and Except for these), the factor of technology (the intensity of consumption of steel in a unit of goods), the level of development of the country, the cost of alternative materials, and so on (Azerbaijani and Rezaei, 2001).

In modern economics, all markets in the economy are composed of three main parts of supply, demand and price (which is the result of the previous two). If demand changes, the price responses to demand with delay and increases it (Fernandez, 2018). Fernandez (2018) utilized the Divisia-moment approach to gauge price and income elasticity for seven major metals, i.e., steel, aluminum, copper, lead, nickel, tin, and zinc, in eight geographic regions, i.e., Africa, Asia, CIS, Europe, the Middle East, North and South America, Oceania for the period of 1980–2015, and in the world for the period of 1960–2015. The supply response is in way that the supply does not change with demand changes, but changes with price changes. When the price rises, the supply starts to increase with a bit of delay; on the other hand, price rises will reduce demand. The ratio of supply and demand increases price to its maximum, then the price starts to decrease, which is due to increased supply and lower demand, i.e., at the maximum price, we will have the maximum supply-to-demand ratio (Guo et al., 2019). Guo et al. (2019) calculated the Granger causality relationship between different steel products in different markets and the midstream industry chain. They then constructed the global steel product price transmission network and regional price transmission network.

Suppose we have balance between supply, demand and price, then demand for housing will increase, then the demand for steel will increase, with increasing demand for steel, steel price also increases. This will increase imports and possibly investment to increase capacity; but increasing both capacity and import will be done with delay. This delay will make us even more likely to increase capacity and import, even when prices return to their previous state. Therefore, the price is lower than its equilibrium. On the other hand, the reduction in imports and the decline in capacity will lead to the rise in price and fluctuations will continue (Singhal et al., 2019). Sighal et al. (2019) investigated the dynamic relationship among international oil prices, international gold prices, exchange rate and stock market index in Mexico.

On the other hand, by increasing foreign exchange earnings and consequently domestic demand, especially for steel products, the volume of investment on steel production projects in the country increases, thus there are some limitations for this industry. For example, the restriction of crude steel material or an increase in its price has led to an increase in the steel products cost, and since the smelting industry is time-consuming, costly and risky, it needs a market to grow in line with market demand. Therefore, the market requires serious government support in order to grow in line with demand, but surplus to requirements is provided through imports (Chen et al., 2018). Chen et al. (2018) constructed a theoretical framework for analyzing the effects of financial factors on fluctuations in nonferrous metals prices and employ the Markov-switching vector auto-regression (MS-VAR) model to conduct a nonlinear empirical analysis based on monthly data of international copper futures prices from August 2004 to October 2016.

The domestic and export production (the difference between imports and exports) determines the steel supply in the country. Based on the price of imported products and the retail sales of these products, the amount of imports and exports is determined. This means that with the increase in the prices of imported products compared to domestic prices, imports decrease and exports increase, and vice versa. At the same time, tariff increases reduce imports (Mahmoudi and Minaei, 2013).

Mahmoudi and Minaei (2013) considered the factors affecting the supply and demand of steel in the country, such as investment, labor productivity, consumption structure, production technology, political and economic crises, exchange rate and GDP. Finally Mahmoudi and Minaei (2013) had considered parameters such as per capita income, product price, population, imports and exports, alternative materials, production technology level, investment, political and economic crisis and natural disasters as factors affecting the supply and demand of steel in a country in their comprehensive forecasting model.

There are several research works in the related field of Iran steel supply chain. For instance, Azimifard et al. (2018), proposed a hybrid decision making approach to select sustainable suppliers for Iran's steel industry. Shahabi et al. (2014) proposed a hybrid strategic planning via strengths, weaknesses, opportunities and threats (SWOT) analysis and multiple criteria decision making (MCDM) methods to determine and prioritize the efficient strategic factors for the Iran's steel scrap industry. Shahba et al. (2017) identified SWOT and strategies for waste management in Iran iron mines and provided a quantitative basis to analytically determine the ranking of the factors in SWOT analysis via conventional multi-criteria decision-making methods: Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

In an interesting research, Hailu and Kipgen (2017) developed and proposed an index called Extractives Dependence Index (EDI) in order to check the degree of dependence of a country on the extraction of oil, gas and minerals for export earnings. Understanding the degree of dependence on such non-renewable resources and where the dependence

[3] Towards sustainable and lasting growth, Annual report 2016–2018, Government of India, Ministry of Commerce and Industry, Department of Commerce, Available at: http://commerce.gov.in/writereaddata/uploadedfile/moc_636281140249481285_annual_report_16_17_eng.pdf.

[4] https://en.msc.ir/?

originates from is helpful in crafting the right policies for diversification. It is notable that steel industry is one of the main customers of such non-renewable resources. The EDI includes three indicators: 1) the share of export earnings from non-renewable resources; 2) the share of revenue from non-renewable resources; and 3) the extractive industry value added in GDP. On the basis of EDI, Iran has got the rank 55 out of 81 countries under assessment. This shows that Iran steel supply chain already has a potential capacity for more research.

2.2. International studies on the steel supply and demand

The steel industry starts from the extraction of hard iron ore. The extraction stage involves mining and ore production. In 2010, South African mines produced roughly 54.8 million tons of iron ore. South Africa is one of the top five exporter countries of steel, after which Australia and Brazil account for about one third of the rest of the exports. Soon et al. (2017) examined the market demand and the mechanism of investment and allocation of capacity in the steel industry. The study of dynamic investment characteristics and allocation of capacity in the steel industry as well as the feasibility of investing in the steel industry are among the innovations of this research. The results indicate that when the economic environment is healthy, the development of the real estate industry plays a decisive role and has direct effect on the steel supply and demand market.

Serneho et al. have studied the impact of reducing greenhouse gases in the UK on global steel production. Current stocks of steel and steel inventories were estimated from valid databases and greenhouse gas data was obtained from the World Health Organization. Therefore, the demand for steel as well as the emissions of greenhouse gases by 2050 was estimated using different scenarios.

Yung (2016) states that steel demand in Asia grew by 12%–77.37 Mt in 2016. He says that the steel industry, which is worth about $ 900 billion a year, is a benchmark for measuring the global economy wellbeing. Therefore, the steady increase in steel demand can be beneficial for the maritime trade of ore and coal, as these products are the main components of steel production.

Amora et al. investigated the correlation between price and demand for steel scrap and the demand for steel products. The main idea of this research was taken from Green Spam et al. (1999). Green Spam et al. (1999) used the steel scrap price as an indicator for Japan's vast macroeconomic activity, because steel price is an appropriate estimate of the country's economic indicators. Considering stock returns in predicting steel demand and prices is one of the innovations of this research. Zhuan and Yu examined the access to steel scrap and predicted the steel demand in China. They investigated the steel production process from 1980 to 2012 and proposed a model that predicts the direct impact of factors such as environment, economy, population, technology and national policy on steel production by 2030. The results indicate that due to the increasing steel demand, improving the use of steel scrap reduces the demand for natural resources, which greatly reduces the destructive effects of this metal production on the environment.

Aric et al. examined the factors affecting the price of steel in the Chinese market. A case study is Shanghai Stock Exchange, which includes almost all global business activities. The findings show that factors such as environmental laws and inflation should be considered in the study of steel prices, which could be a realistic estimate of the true steel market.

Azadeh et al. (2013) predicted the consumption of steel using neural network methods, fuzzy regression and linear regression. Finally, variance analysis was used to calculate prediction errors after using the combination of these methods. The combined approach is used to predict United States' (which is among the top 10 consumers in the world) and Iran's (which is the only superior consumer in Asia) steel consumption. The results provide an appropriate estimate for the inherent uncertainty in steel consumption.

Ziros examines the steel scrap price and the steel demand. The results indicate that the changes in steel scrap price do not affect the steel consumption, because the scrap price in the global equation is a double-edged sword. When scrap is cheaper, consumer countries have higher economic growth, and if it is expensive, then the producer countries have higher economic growth, and since the global politics is in direction that producer countries rely on this product, these countries have to use the know-how of developed countries to consume surplus income. This case would increase economic growth on both sides of the equation. The relative stability of the global economic growth rate will eventually be created.

Table 1 presents a brief summarization of past research works and current study in the field of steel demand and supply market.

2.3. Multiple logarithmic regression applications in prediction

In statistical models, regression analysis is a statistical process for estimating correlations between variables. This method involves many techniques for modeling and analyzing specific and unique variables, focusing on the correlation between the dependent variable and one or more independent variables. Regression analysis, in particular, helps to understand how the value of the dependent variable varies by changing each of the independent variables and by consistency of other independent variables. The most commonly used regression analysis is estimation of math conditional expectation of the dependent variable from independent determinants, which is equivalent to the mean value of the variable when the independent variables are constant. At least, it is used to focus on multiple or spatial parameters of the conditional distribution of the dependent variable from a given independent variable. In all cases, the goal is to estimate a function of independent variables that is called regression function. In regression analysis, determining the dispersion of the dependent variable around the regression function is considered, which can be explained by a probability distribution.

Regression analysis has been widely used for prediction. Regression analysis is also used to understand the correlation between independent and dependent variables and the form of these correlations. Under certain conditions, this analysis can be used to infer excellent correlations between independent and dependent variables. However, this can cause the correlation to be false or invalid, so caution is advisable. Many techniques have been developed for regression analysis. Familiar methods such as linear regression and least squares, which are parametric, are actually estimated in regression under a limited number of unknown data parameters. Nonparametric regression refers to methods that allow regression functions to be placed in a set of functions with the probability of unlimited parameters.

Soon et al. developed a Mann-Kendall method to predict the amount of water consumed in China. Nonparametric regression is used to predict and analyze the data. Unlike the parametric regression method that is sensitive to the data skewness, nonparametric regression uses only the logarithms, regardless of the data form. The results indicate a very good performance of the proposed approach with a very low level of type 1 error.

Bigrastaf et al. predicted influenza outbreak in 10 districts of the United States. In this research, a logarithmic optimization algorithm is used for prediction. First, the mean scores were evaluated in a period and then logarithmic value was calculated. Data used by the World Health Organization was for 2014 and 2015. The predictions from this study can help improve health and prevent the spread of contagious diseases. She examined calibration tests for Gaussian predictions. The prediction is based on two indices of multivariate David Sebastian and one-variable David Sebastian. The results indicate that the tests have sufficient power to detect false predictions with false mean or variance. But for predictions with false correlation coefficients, only multivariate tests are sensitive to correcting. A case study is expected to predict viral diseases for German female and male patients between 2011 and 2014.

Table 1
Summarization of past research works in the field of steel supply and demand.

Author(s)	Problem	Method	Demand	Supply	Interaction of Supply and Demand	Variables
Ziros (2005)	Steel scrap price and demand	Forecasting	☑	☒	☒	Price, demand, consumption, global policies, economic growth
Godarzi (2007)	Steel Demand	Regression	☑	☒	☒	GDP, Government Investment, Private Investment
Borhani (2007)	Steel Fittings Demand	Regression	☑	☒	☒	Steel demand, Economic factors
Azadeh et al. (2013)	Steel demand	Neural network, fuzzy regression and linear regression	☑	☒	☒	US and Iran steel consumption
Mahmoudi and Minaei (2013)	Factors affecting Steel Demand and Supply	Forecasting model	☑	☑	☒	Investment, labor productivity, consumption structure, production technology, political and economic crises, exchange rate and GDP
Aric et al. (2014)	Price of steel	Regression	☑	☒	☒	Environmental laws and inflation
Serneho et al. (2016)	steel production	Demand Forecasting	☑	☑	☒	Reducing greenhouse gases in global steel production
Amora et al. (2016)	Steel demand and price	Correlation between price and demand	☑	☒	☒	Steel scrap price, steel scrap demand, economic indicator
Zhuan and Yu (2016)	Steel demand	Forecasting	☑	☒	☒	Environment, economy, population, technology and national policy
Soon et al. (2017)	Steel market demand	Capacity Allocation	☑	☒	☒	Mechanism of investment and allocation of capacity
This study	Iran steel demand and supply functions	Regression and statistical analysis	☑	☑	☑	Several micro- and macro-economic indices

Gupta et al. (2017) examined the trends in the prevalence of hypertension in India over a 25-year interval. By the information received from the World Health Organization, the process of changes is predicted by 2030. Logarithmic regression is used for this. Comparison of predicted results and historical data indicate an increase in awareness and rate of improvement of people about the outbreak of various diseases. Chen et al. (2017) predicted demand for the electricity industry. They used regression and machine learning methods to predict the demand by the industry. The case study considered in this research was the predicted demand for chain hotels. Predictive results are compared with historical data and a 1% error indicates the proper performance of the proposed model.

Brentan et al. (2017) forecasted water demand for distribution centers. They used time series and regression methods for forecasting in the short term. The case study in this study was Brazil. One of the goals of this research was to reduce the risks and costs of forecasting. The results of the research indicated the acceptable performance of the proposed model and the average error of 4% was in comparison with historical data. Meng et al. (2017) predicted different scenarios of the Co_2 emissions from Chinese electricity industry. For this purpose, logarithmic regression was used. Considered historical data were information and parameters related to the Co_2 emissions from 2001 to 2013 and its output was prediction for 2016–2030. Sensitivity analysis on the five scenarios suggests that, compared to the non-fossil energy share in electricity production, carbon dioxide gas production from the Chinese electricity industry is more sensitive to overall changes in energy consumption and thermal energy. Meyer et al. predicted the gross domestic product (GDP) in the United States (US), Japan and Germany. Indicators used to predict were interest rates, commodity prices, unemployment rates, and macroeconomic policies. The regression analysis was used. First, non-modified data was used through a regression analysis. Then a logarithmic model was used to convert data. The results represent the exact performance of the models with low error. Confeliti et al. predicted GDP in Euro-zone countries. Unlike the usual method of using combined and equal weights, this study has used weights that minimize the mean squared forecast error (MSFE). The output of research indicates that the use of optimal logarithmic weights can have satisfactory results in terms of input quality.

Miguel et al. (2014), using 168 building projects carried out in Spain, have predicted the required time to carry out the construction of a building. For this purpose, multiple regression analysis has been used. In this research, the logarithmic formulation of manufacturing speed was identified as the most appropriate response variable. Regression analysis shows that the cost of construction is very effective in predicting the required time to carry out the construction of a project. Control of this criterion can help to control the predicted time. Table 2 summarizes the past applications of regression methods in forecasting problems.

2.4. Introducing existing research gap

According to the literature review, in the area of forecasting steel supply and demand, the following research gaps were identified.

- Absence of a comprehensive study to identify the steel supply and demand functions in Iran
- Lack of comprehensive study to predict the steel supply and demand in Iran
- Minor attention to the basic variables related to the steel supply and demand in Iran in previous studies
- Minor attention to the effect of inflation, prices and imports on the steel products supply

In this article, we are going to present a model that will cover some of the gaps identified in this discussion.

Table 2
Past applications of regression in forecasting problems.

Author(s)	Problem	Method	Main Features
Soon et al. (2018)	Prediction of water consumption	Non parametric regression	Not sensitive to data skewness, high performance
Bigrastaf et al. (2018)	Prediction of influenza outbreak in US	logarithmic optimization algorithm	World Health Organization data for 2014 and 2015
She (2017)	calibration tests for Gaussian predictions	Multivariate statistical analysis	Prediction of viral diseases for German female and male patients between 2011 and 2014
Gupta et al. (2017)	trends in the prevalence of hypertension in India over	Logarithmic regression	World Health Organization
Chen and Tan (2017)	Demand prediction for the electricity industry	Regression and Machine learning	Prediction of electricity demand in hotel industry. One percentage error and high performance of proposed method.
Brentan et al. (2017)	Forecasting water demand for distribution centers	Short term time series and regression methods	Reduction of the risks and costs of forecasting
Meng et al. (2017)	Prediction of different scenarios of the Co_2 emissions in electricity industry	Logarithmic regression	Input data for Co_2 emissions from 2001 to 2013, prediction for 2016–2030, Sensitivity analysis on the five scenarios
Meyer et al. (2015)	Prediction of GDP in US, Japan and Germany	Regression and Logarithmic Regression	Using several indices such as interest rates, commodity prices, unemployment rates, and macroeconomic policies
Confeliti et al. (2015)	Prediction of GDP in Euro zone countries	Logarithmic Regression	Optimization of the weights for mean squared forecast error (MSFE)
Guerrero Miguel et al. (2014)	Prediction of the required time to carry out the construction of a building in 168 projects	Logarithmic Regression	Cost of construction is very effective in predicting the required time to carry out the construction of a project
This Study	Formation of demand and supply functions of steel industry in Iran	Multiple logarithmic regression	Considering both macro- and micro-economic indices, interaction of demand and supply functions in steel industry

Table 3
Effective factors on the supply and demand functions.

Country steel production capacity (potential)
Crude steel production (real)
Crude steel export
Crude steel import
The capacity for producing rolled products (such as sheets and rebar, which are produced from crude steel)
Rolled products produced (real)
Total Crude Steel Profit: (Available from financial statements of companies)
Net sales of crude steel
The price of sold goods
The price of energy
The price of consumed scrap
The price of consumed sponge iron
Exchange rate
The price of scrap per ton
The price of sponge iron per ton
The price of crude steel per ton
Gross domestic product growth rate
The growth rate of the building industry
Industry growth rate
The growth rate of industry and mining

3. Modeling steel industry supply and demand functions in Iran

3.1. Identifying variables affecting supply and demand

In the first stage, a list of the variables affecting the steel supply and demand in the country should be identified, which were identified as effective factors by reviewing the articles in this field, and consulting with experts. In general, effective variables are considered on the demand function in accordance with Table 3.

In the second stage, the data was taken from various internal sources (including the Economic Statistics Center of the Ministry of Industry, Central Bank, Statistics Center of Iran, etc.) as well as external sources. At this stage, the monthly supply, demand, import and export of steel, steel products, sheets and rebar were collected. The above mentioned data were collected monthly and in the period from December 2010 to August 2014 and there were 44 data in total. Given the fact that annual data was only available in the last 10 years, and their number was very low for a proper modeling, monthly modeling of supply and demand for crude steel was considered. Therefore, the statistics of other characteristics in this period should be collected. Information on crude steel prices and scrap steel per ton in the country is incomplete and it did not exist within the considered time frame. Therefore, for these two variables, global prices were considered and the error rate was considered to be minimal by taking the exchange rate into account.

The economic variables of inflation and the market price of the dollar were collected -monthly for the above time period. Variables related to industrial production indices and the production of products such as cars that are crude steel consumer in the country were incomplete in monthly periods, and it was virtually impossible to place them in the modeling of supply and demand functions. Due to the existence of variables such as demand for steel products, sheets and rebar used in industries such as automobile and construction, these indicators can be indicative of industrial production indices. And so we will have the information we need.

Regarding the fact that import tariffs on crude steel were constant in the following years, it is not considered in the modeling process. In the case of sponge iron and its production, the required information was very incomplete and therefore not included in the modeling. Finally, the list of variables used in this research and the symbols used for them are presented in Table 4.

Also, prices and economic indices are described in Table 5.

Table 4
List of variables used to estimate supply and demand functions.

Product Name	Total production of public and private sectors	import	export	Apparent consumption
Crude steel	SupplySteel	ImportSteel	ExportSteel	ConsumptionSteel
Steel products	SupplySG	ImportSG	ExportSG	ConsumptionSG
Hot plate	SupplyVaraq	ImportVaraq	ExportVaraq	ConsumptionVaraq
rebar	SupplyMil	ImportMil	ExportMil	ConsumptionM

Table 5
List of variables used to estimate supply and demand functions.

Variable name	Global crude steel prices ($/ton)	global scrap price ($/ton)	The inflation rate	Dollar price
Symbol	ERDollar	Inflation	SteelScrap	Billet Price

Table 6
Regression analysis for crude steel prices and scrap prices.

Y	X	r	r^2	t	Pr(> |t|)
SteelScrap	BilletPrice	0.8392	0.7043	10.0023	0.0000

3.2. Modeling supply and demand functions

A model in the form of a linear logarithmic function or so-called Log-Log Linear model was chosen for modeling the steel supply and demand functions in this paper. The reasons for this selection are described in detail in the results section and they are based on extensive statistical analyzes performed on the relevant variables.

Logarithmic regression is used to model situations where growth or decay accelerates rapidly at first and then slows over time. Logarithmically transforming variables in a regression model is a very common way to handle situations where a non-linear relationship exists between the independent and dependent variables. Using the logarithm of one or more variables instead of the un-logged form makes the effective relationship non-linear, while still preserving the linear model. Estimation of parameters in non-linear models are hard in comparison with linear model. Logarithmic transformations are also a convenient means of transforming a highly skewed variable into one that is more approximately normal. In fact, there is a distribution called the log-normal distribution defined as a distribution whose logarithm is normally distributed but whose untransformed scale is skewed.

In the proposed model, the logarithm of supply and demand (as intrinsic variables) is related to effective factors (as exogenous variables) and is as follows:

$$log\,(SupplySteel) = \alpha + \sum_{i=1}^{N} \beta_i log\,(X_i) + u_i \tag{1}$$

$$log\,(ConsuptionSteel) = \alpha + \sum_{i=1}^{N} \alpha_i log\,(Z_i) + u_i \tag{2}$$

The important assumption in these functions is that the stretch is constant over time. Stretches provide an independent effect of that extrinsic variables have on the intrinsic variables in the model. For example, the stretch of steel demand relative to Zi in a single point is defined as follows:

$$\frac{\partial(ConsuptionSteel)}{\partial(Z_i)} \times \frac{Z_i}{ConsuptionSteel} \tag{3}$$

In a Log-Linear regression model, this value is equal to the coefficient of the regression equation, which is constant at each point, this is why these types of models are called constant stretching.

$$\frac{\partial \log(\mathrm{ConsuptionSteel})}{\partial \log(\mathrm{Z_i})} = \frac{\partial(\mathrm{ConsuptionSteel})}{\partial(\mathrm{Z_i})} \times \frac{\mathrm{Z_i}}{\mathrm{ConsuptionSteel}} \tag{4}$$

The characteristics of Log-Log Linear functions can be summarized as follows:

- The above models modulate the effect of co-linearity between input variables.
- The above models can better illustrate the nonlinear trends among target variables and input variables.
- By logarithmic transformation, the distribution of variables will be closer to the normal distribution, which is one of the key assumptions in regression estimates. Therefore, estimating logarithmic models is more efficient and accurate.

In these models, in order to obtain the change ratio in the target variable Y to P, the change percentage in the variable Xi is as follows:

$$\alpha = \mathrm{Log}\left(\frac{100+\mathrm{P}}{100}\right); \quad \text{Change in} \quad \mathrm{Y} = e^{\alpha\beta_i} \tag{5}$$

For example, if the equation of regression is as follows, then the below interpretations are obtained:

$$\log(\mathrm{Y}) = \alpha + \beta_i \log(\mathrm{X_i}) = 7.088 - 0.498 \log(\mathrm{X_i})$$

- A unit increase in log (Xi) will lead to a −0.498 unit decrease in log (Y).
- 10% increase in the Xi variable will multiply the variable Y in the

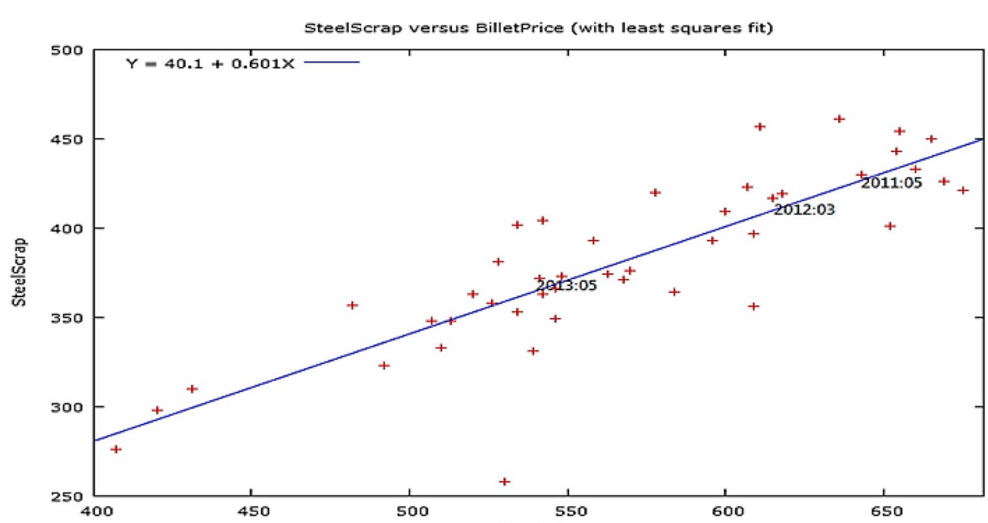

Fig. 1. Changes in scrap and crude steel prices.

value of $e^{-0.498*\log(1.1)} = 0.954$. In other words, it will lead to a 4.6% decrease in the Y variable.

To estimate the coefficients of this model we use the Ordinary Least Squares (OLS) method. The hypotheses in the Ordinary Least Squares method for multiple linear regression modes are as follows:

$$\begin{aligned} &y_i = \sum_{j=1}^{k} x_{ij}\beta_j + u_i = x_i\beta + u_i &&, \quad 1 \le i \le n \\ &E(u_i) = 0 &&, \quad 1 \le i \le n \\ &Var(u_i) = \sigma^2 < \infty &&, \quad 1 \le i \le n \\ &Cov(u_i, u_j) = 0 &&, \quad \forall \quad i, j \quad i \ne j \end{aligned} \tag{6}$$

where, $x_{ij} \quad \forall \quad i, j$ is a definite variable.

4. Results, analysis and discussion

In this section, the results of descriptive statistical analysis of supply and demand data, fitting and modeling supply and demand functions, as well as results obtained from the combination of time series and artificial neural network, are presented to forecast the steel supply and demand.

	Mean	Median	Minimum	Maximum	Std. Dev.
SupplySteel	1.1360e+006	1.1472e+006	8.5714e+005	1.3017e+006	1.0905e+005
ImportSteel	2.9417e+005	2.8718e+005	42053.	6.4516e+005	1.3976e+005
ExportSteel	9760.7	206.05	0.90000	83141.	19854.
ConsumptionSteel	1.4204e+006	1.3894e+006	1.1859e+006	1.7482e+006	1.3814e+005
SupplySG	1.3937e+006	1.3908e+006	1.1598e+006	1.5446e+006	92707.
ImportSG	4.2523e+005	4.3048e+005	1.0087e+005	8.2305e+005	1.5418e+005
ExportSG	1.0256e+005	93162.	29905.	2.0031e+005	44724.
ConsumptionSG	1.7164e+006	1.7291e+006	1.3336e+006	2.0362e+006	1.5610e+005
inflation	20.168	24.250	7.8000	35.056	8.4951
ERDollar	18359.	12838.	10037.	37048.	9607.0
BilletPrice	566.66	560.50	407.00	675.00	66.304
SteelScrap	380.77	375.00	258.00	461.00	47.498

Fig. 2. Descriptive statistics of the data used in the analysis.

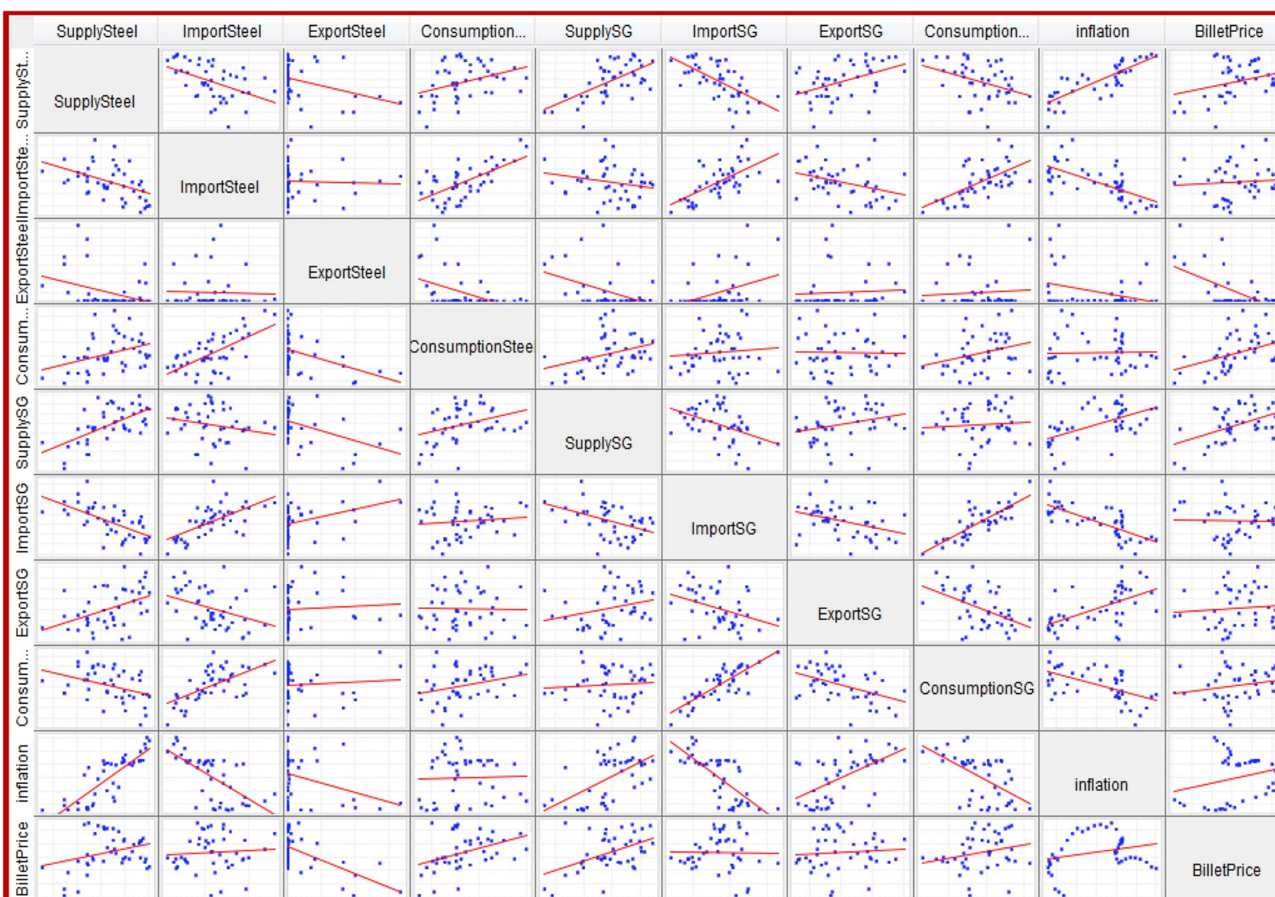

Fig. 3. The dispersion matrix of all the variables used in the analysis.

4.1. Descriptive statistics of supply and demand data

In the first step, we will examine the descriptive statistics of crude steel supply and demand data and other variables. At this stage, the process of changing the above data and the correlation analysis of changes to select the effective variables and their inclusion in the model will be examined. We note that due to the co-existence of the characteristics that affect the crude steel supply and demand, taking into account all the issues in supply and demand models will cause problems, including that the obtained coefficients of the econometric models are likely to have high variance and to be meaningless. Since in the mode of coherence, there is no independent information about each of the independent variables, so it is not possible to estimate the partial effects of the variables on the dependent variable. When there is a strong correlation between the variables, covariance and variance of larger coefficients will be estimated. So choosing the right set of data is an important key for modeling. To verify the coherence between the pair of variables, we use the linear correlation coefficient. Pearson Linear Correlation Coefficient is used to determine the linear correlation between the two variables. Pearson test is also used to test the significance of a linear correlation between two variables, which is a t-statistic. If the value $(Pr > |t|)$ is close to zero, then there is a significant linear correlation between the pair of variables.

As shown in Fig. 1, there is a very high linear correlation between crude steel prices and scrap prices. These two variables change together. So, we expect a high correlation coefficient with a positive sign between these two variables. Table 4 shows the result of regression analysis for the correlation between crude steel prices and scrap prices. The correlation coefficient between these two variables is r = 0.84 and is quite significant. So, we can conclude that with 84% confidence, the $SteelScrap = 40.1 + 0.601 Billetprice$ correlation exists between the above two variables. By having a variable, we can obtain the necessary information for another variable. We note that the number 0.601 achieves the paired relation between the variables, and in order to achieve a more precise effect of the variable, the collective effects of the variables in the form of a multivariate regression model should be seen. Therefore, the two above-mentioned variables cannot be considered as influential variables in the crude steel supply or demand function, since in this case we will encounter co-linearity problem.

The zero correlation coefficient shows only the absence of a linear correlation between the two variables, but it cannot be concluded that the two variables are independent. Fig. 2 shows the descriptive statistics of the key variables used in modeling. The data obtained from this research is related to the steel industry in Iran, from 2010 to 2014 with a monthly breakdown.

As you can see, the standard deviation of the variables is due to the high fluctuations in the above series. Dispersion matrices are created by dispersion charts. The dispersion matrix of all the variables used in the

Table 7
Paired correlation matrix between variables..

Attribute	SupplySteel	ImportSteel	ExportSteel	Consumption Steel	Supply SG	Import SG	Export SG	ConsumptionSG	inflation	ERDollar	BilletPrice	SteelScrap
SupplySteel	1.00											
ImportSteel	-0.47	1.00										
ExportSteel	-0.35	-0.03	1.00									
Consumption Steel	0.36	0.64	-0.45	1.00								
SupplySG	0.63	-0.22	-0.45	0.34	1.00							
ImportSG	-0.63	0.64	0.37	0.10	-0.45	1.00						
ExportSG	0.45	-0.36	0.06	-0.01	0.26	-0.36	1.00					
Consumption SG	-0.38	0.61	0.08	0.30	0.08	0.83	-0.48	1.00				
inflation	0.83	-0.67	-0.33	0.03	0.58	-0.75	0.57	-0.56	1.00			
ERDollar	0.67	-0.63	-0.20	-0.08	0.34	-0.83	0.48	-0.76	0.79	1.00		
BilletPrice	0.30	0.07	-0.59	0.40	0.47	-0.02	0.09	0.23	0.27	-0.15	1.00	
SteelScrap	0.23	0.16	-0.55	0.42	0.40	-0.04	0.09	0.18	0.11	-0.16	0.84	1.00

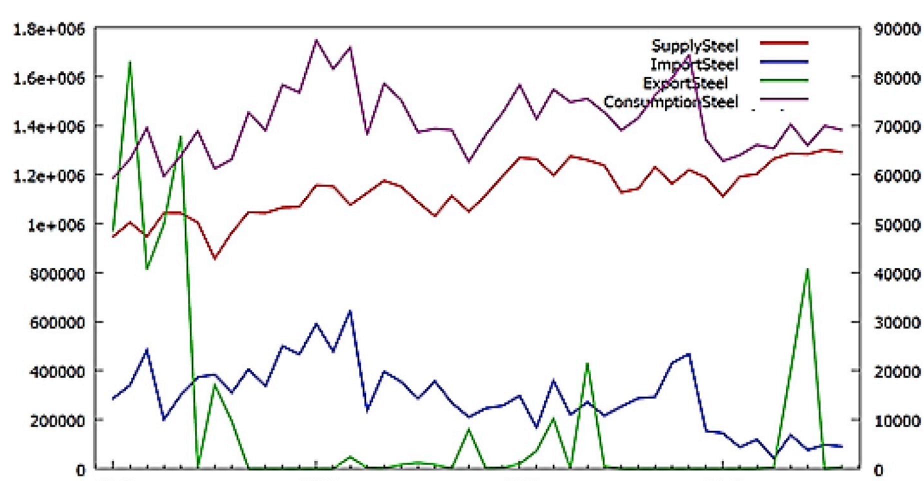

Fig. 4. Changes in time series of supply, demand, import and export of crude steel.

analysis is shown in Fig. 3. Each graph in this matrix displays the paired variations. Each data point in this graph shows the pair (x, y) in the data. Given that the correlation is merely an index used to ensure a linear correlation between the two variables, we use the dispersion matrix to measure the numerical value of angular coefficient of that line. Fig. 3 shows the dispersion matrix of variance, which can be used to examine the coherence of paired changes in the variables (see Table 6).

The paired correlation matrix between variables that shows the home (i, j) of the correlation coefficient between variables i, j is presented in Table 7. Paired correlation matrix between variables is symmetric and therefore only the numbers below the original diameter are shown.

Table 7 shows the significant correlation between pairs of variables in homes marked with yellow. The larger the number is, the more confident it is to have a linear correlation between the variables. To obtain a linear correlation between variables, the regression line between each variable pair is achieved. The correlation coefficient is merely indicative of the existence of a linear correlation between the pair of variables and cannot be used as the effect of a variable on another. In this analysis, by obtaining the regression line $Y = a + bX$, we consider the value of b, which is the angular coefficient of the regression line, as an approximation of the effect of X on Y. In order to obtain the exact amount of effect, we must obtain all the influential factors in the form of a regression model for supply and demand functions that will be presented in this analysis.

4.2. Investigating the trend of changes in the crude steel supply of and its variables

Fig. 4 shows the changes in time series of supply, demand, import and export of crude steel during the analysis period.

As can be seen from the figure above, since 2011, the import trend has been downward and negative, while the production trend has been positive. Crude steel exports also fluctuate a lot, given the fact that in our country, there has always been more demand than supply, it is natural because, except for certain cases in steel exports, the produced steel will be consumed internally. Table 8 shows the correlation values between demand-supply variables and other variables. In this table, according to Pearson test, the correlation coefficient has been investigated. The more $(Pr > |t|)$ is close to zero, the more meaningful is the linear correlation between the pair of variables.

In the following, we will investigate the type of convergence of variables that affect the crude steel supply.

4.2.1. Affecting factors on crude steel supply

Fig. 5 shows the effect of crude steel imports, supply and steel products import, exchange rate and inflation on crude steel supply. As it is known, from 2010 to 2014, import trends for steel products and crude steel decreased. This is due to an increase in the exchange rate during this period. Also, as can be seen, there was a significant negative correlation between import variables and exchange rate that justifies the decline in import trends over the above time period.

Another point that can be seen from Fig. 5 is the effect of decline in the crude steel and steel products imports on domestic production (crude steel supply and steel supply). As the figure shows, the amount of production was facing a growing trend during the analysis period when import trends were declining.

Table 9 also shows that an increase in the price of the dollar will have a greater impact on the declining steel products imports, and the slope of this decline will be higher than that of decline in crude steel. Given that the volume of steel products import to the country is generally higher than the crude steel imports, then the above mentioned result is normal. There is also a very meaningful negative correlation between import and supply variables, as shown in Table 10.

As it is seen, the crude steel supply will increase as imports of crude

Table 8
Correlation between the amount of crude steel supply and other variables.

Y	X	r	t	Pr(> |t|)	Interpretation
SupplySteel	ImportSteel	−0.4733	−3.4821	0.0012	A meaningful and negative correlation: In real data, the crude steel supply and steel imports moved in the opposite direction
SupplySteel	ExportSteel	−0.3529	−1.4447	0.0288	A non-significant linear correlation between the crude steel supply and export
SupplySteel	ConsumptionSteel	0.3613	2.5111	0.0160	A significant and positive correlation: In real data, steel consumption and the crude steel supply have been matched with each other.
SupplySteel	SupplySG	0.6260	5.2027	0.0000	There is a very significant and positive correlation between the crude steel supply and the steel products supply. These two variables have varied in the same direction
SupplySteel	ImportSG	−0.6294	−5.2496	0.0000	There is a very significant and negative correlation between the crude steel supply and the steel products import. These two variables have varied in the same direction.
SupplySteel	ExportSG	0.4540	3.3026	0.0020	There is a very significant and positive correlation between the crude steel supply and the steel products supply. These two variables have varied in the same direction.
SupplySteel	ConsumptionSG	−0.3800	−2.6623	0.0110	There is a significant difference between the steel products consumption and the crude steel supply. These two variables have varied in the opposite direction
SupplySteel	inflation	0.8313	9.6931	0.0000	There is a very significant and positive correlation between the crude steel supply and the inflation rate. These variables have varied in the same direction.
SupplySteel	ERDollar	0.6687	5.8286	0.0000	There is a very significant correlation between crude steel supply and dollar rates. These variables have varied in the same direction.
SupplySteel	BilletPrice	0.3014	2.0488	0.0468	A somewhat significant and positive correlation between the crude steel supply and the global crude steel price
SupplySteel	SteelScrap	0.2335	1.5565	0.1271	The lack of a linear correlation between these two variables

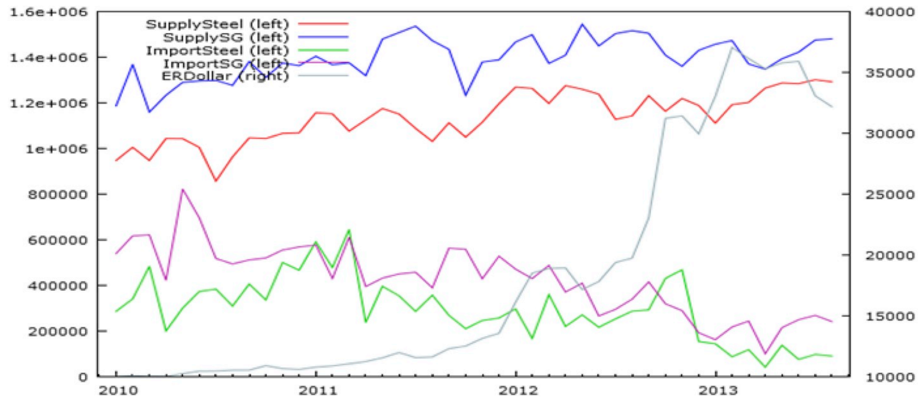

Fig. 5. Affecting factors on crude steel supply.

Table 9
Correlation coefficient between the variables of steel products and crude steel imports and dollar price.

Y	X	r	r^2	t	Pr(> |t|)	a
ImportSteel	ERDollar	−0.6273	0.3935	−5.2205	0.0000	−9.12
ImportSG	ERDollar	−0.8333	0.6944	−9.7698	0.0000	−13.37

Table 10
Correlation coefficient between supply and import variables.

Y	X	r	r	t	Pr(> |t|)	a
SupplySteel	ImportSteel	−0.4733	0.2240	−3.4821	0.0012	−0.369
SupplySteel	ImportSG	−0.6294	0.3962	−5.2496	0.0000	−0.445
SupplySteel	ERDollar	0.6687	0.4472	5.8286	0.0000	7.59
SupplySG	ImportSG	−0.4451	0.1981	−3.2210	0.0025	−0.267

steel and steel products decrease. Table 8 shows that the decrease in the steel products import with a great slope (−0.44) has an effect on the increase in crude steel (compared to a decrease in crude steel imports of −0.36). Regarding the high volumes of steel imports compared to crude steel import, we can expect that the lower the import of steel products, steel producers produce higher volumes, which increases their demand for crude steel, and therefore the effect will have a positive impact on the crude steel supply and production in the country. Therefore, with policies to reduce the steel products import, we can have more influence on the increase of crude steel production in the country. As it is seen, rising dollar price in the country and sanctions and, consequently, reduced imports have had a positive impact on steel production in the country.

4.2.2. The effect of inflation on the steel products supply

There is a direct and significant correlation between the inflation rate and the steel products supply, which is 0.83. Fig. 6 shows the correlation between these two.

As it was seen in the previous section, due to the rise in the dollar price over the analysis period, the volume of crude steel and steel products imports has been decreased. This has led to crude steel mills be eager to increase production, which, as we can see, has an effect on increasing the steel and its steel products supply. Therefore, the existence of a positive correlation between the inflation rate and the

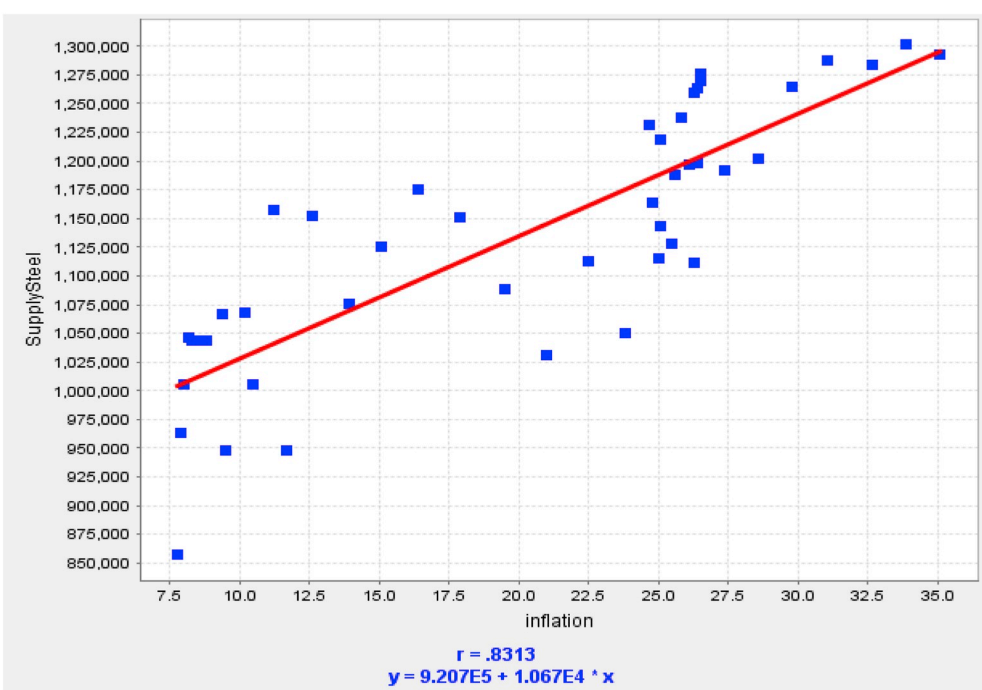

Fig. 6. The correlation between inflation and the steel products supply.

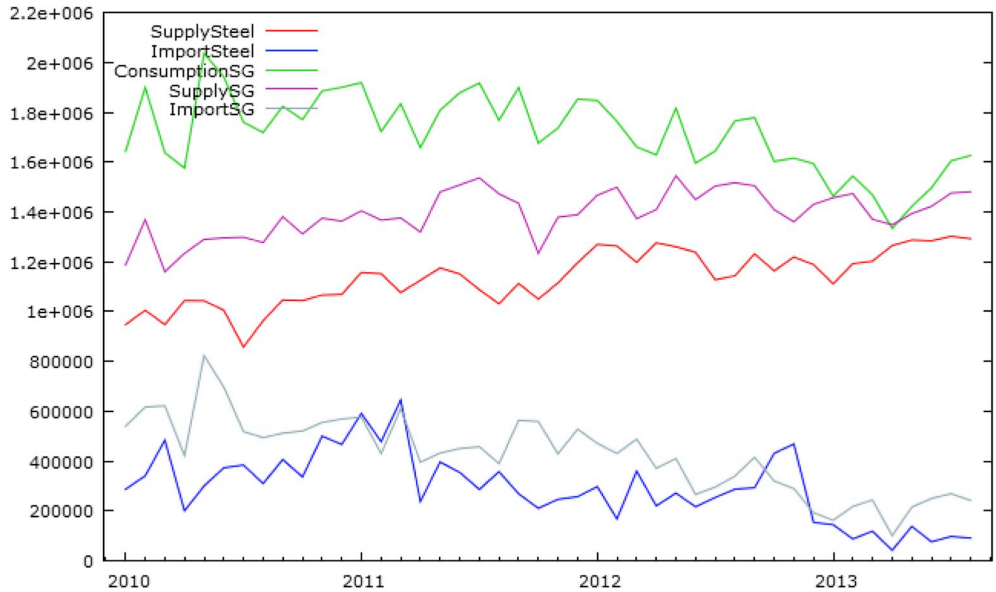

Fig. 7. Changes in the variables of imports and steel products consumption and the crude steel supply.

Table 11
Correlation between variables of steel products import and consumption.

Y	X	r	r	t	Pr(> |t|)	a
ConsumptionSG	SupplySteel	−0.3800	0.1444	−2.6623	0.0110	
ConsumptionSG	ImportSteel	0.6073	0.3688	4.9540	0.0000	0.678
ConsumptionSG	SupplySG	0.0788	0.0062	0.5122	0.6112	
ConsumptionSG	ImportSG	0.8254	0.6813	9.4745	0.0000	0.835

Table 12
Correlation between crude steel imports and steel products imports.

Y	X	R	r	t	Pr(> |t|)
ImportSteel	ImportSG	0.6409	0.4108	5.4111	0.0000

amount of crude steel production can be justified. An increase in the inflation rate was a direct result of the rise in the dollar price, which led to a decrease in imports, an increase in production and an upward trend in the production of crude steel (thus, a positive correlation between the inflation rate and the amount of crude steel production is normal).

4.2.3. The effect of crude steel import variables, steel products import on steel products consumption

As can be seen in Fig. 7, the trend of steel products demand in the analysis period is very similar to that of steel products imports and crude steel imports, all of which are decreasing. So we expect a high and positive correlation between these three variables.

As Table 11 and Fig. 7 show, the decline in demand for steel products did not have a significant effect on the steel products production, but it had great effect on steel products imports and has decreased the gap between steel products supply and demand, and supply is roughly equal to demand. In fact, during this period, manufacturing plants were producing steel products in an incremental manner, and these products

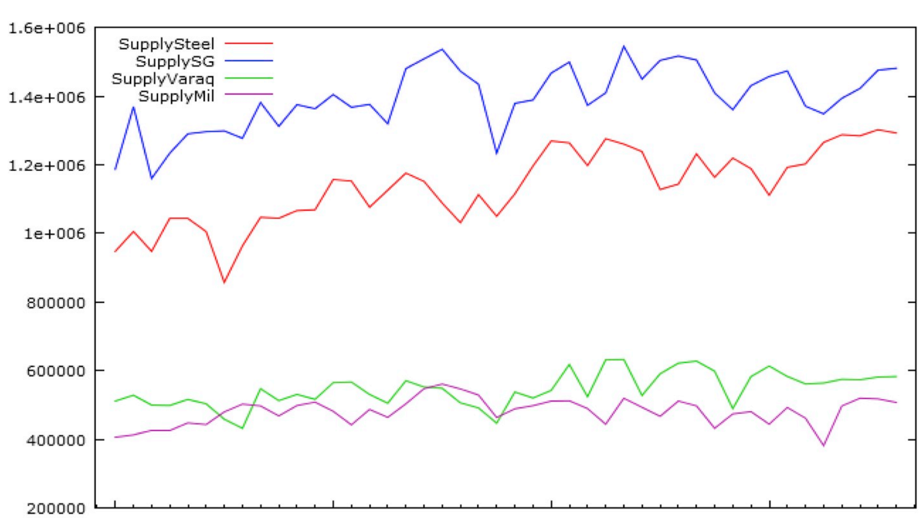

Fig. 8. Changes in supply quantities of steel and other steel products.

Table 13
Correlation between variables related to steel products with hot plate and rebar.

Y	X	r	r^2	T	Pr(> |t|)
SupplySG	SupplyVaraq	0.7030	0.4942	6.4062	0.0000
SupplySG	SupplyMil	0.6479	0.4198	5.5124	0.0000
Y	X	r	r^2	T	Pr(> |t|)
ImportSG	ImportVaraq	0.8749	0.7654	11.7068	0.0000
ImportSG	ImportMil	0.6379	0.4070	5.3687	0.0000
Y	X	r	r^2	t	Pr(> |t|)
ExportSG	ExportVaraq	0.8056	0.6489	8.8107	0.0000
ExportSG	ExportMil	0.6701	0.4490	5.8507	0.0000
Y	X	r	r^2	t	Pr(> |t|)
ConsumptionSG	ConsumptionVaraq	0.6497	0.4221	5.5385	0.0000
ConsumptionSG	ConsumptionMil	0.7049	0.4969	6.4410	0.0000

replaced a significant amount of steel imports. Also, due to the high and significant correlation between crude steel import and steel products import at the analysis time interval indicated in Table 12, and as both were decreasing with the same trend, only the crude steel import variable has entered the function modeling of crude steel supply.

4.2.4. Correlation between steel products and changes sheet metal and rebar

In Fig. 8, changes in the variables of the steel supply, steel products, rebar and sheets have been shown, indicating a high positive correlation between them. Therefore, it will suffice to consider only one of these variables as the variables that affect the crude steel supply.

Also, given that the steel products include the rebar and the hot plate, it is not appropriate to consider the information in all three categories in the crude steel supply function (also demand function) and it will cause problems such as convergence, and in practice, the stretch coefficients will be meaningless in the regression equations. Table 13 shows the high correlation between the components of steel products, rebar and sheets. Therefore, it is sufficient to consider the information about steel products in the modeling (we note that if there is a linear correlation between the input variables in a regression, the model will not function properly and the coefficients of the model will be meaningless).

Table 14
Correlation coefficient of crude steel prices and scrap prices.

Y	X	r	r	t	Pr(> |t|)
SteelScrap	BilletPrice	0.8392	0.7043	10.0023	0.0000

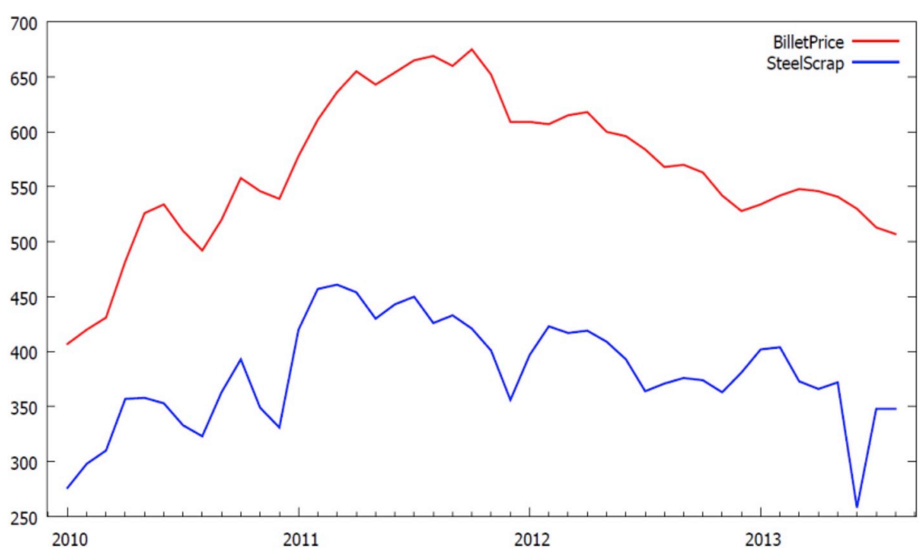

Fig. 9. Changes in scrap prices and crude steel prices.

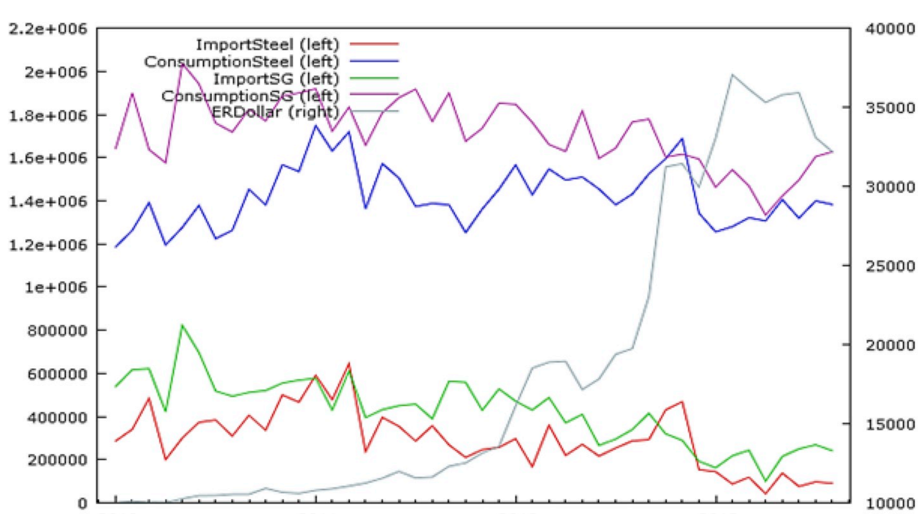

Fig. 10. Crude steel and steel products import and supply along with the dollar price.

Table 15
Correlation between crude steel demand and other affecting factors.

Y	X	r	r	t	Pr(> |t|)
ConsumptionSteel	SupplySteel	0.3613	0.1305	2.5111	0.0160
ConsumptionSteel	ImportSteel	0.6423	0.4125	5.4308	0.0000
ConsumptionSteel	ExportSteel	−0.4517	0.2041	−3.2815	0.0021
ConsumptionSteel	SupplySG	0.3404	0.1159	2.3465	0.0237
ConsumptionSteel	ConsumptionSG	0.3025	0.0915	2.0567	0.0460
ConsumptionSteel	BilletPrice	0.3986	0.1589	2.8170	0.0074
ConsumptionSteel	SteelScrap	0.4243	0.1801	3.0370	0.0041

As we see in Table 13, there is a very high correlation between the steel products supply and the rebar and hot plate supply (which is consistent with reality). There is also a high correlation between variables such as import, export and demand. Therefore, in modeling the crude steel supply and demand, we will only use variables related to steel products, and the rebar and hot plate will not be included in the modeling.

4.2.5. Correlation between the crude steel price and the scrap price

Correlation analysis was performed on variables of crude steel price and scrap price. As Fig. 9 shows, both variables change in nearly identical direction and their behavioral correlation is high. As shown in Table 14, the correlation coefficient between these two variables is very high and very significant, so considering both of these variables in the modeling of the crude steel supply and demand function will lead to the emergence of the convergence problem in the estimate. Therefore, only the scrap price variable will be used in the estimation of the above functions.

Finally, the variables that will be considered in the steel products supply function are described in Equation (7).

$$\begin{aligned} \text{SupplySteel} \\ &= F(\text{ConsumptionSteel, ImportSteel, ExportSG, ConsumptionSG} \\ &\quad \text{, inflation, BilletPrice, ERDollar}) \end{aligned} \tag{7}$$

Fig. 11. The trend of crude steel and steel products supply and demand.

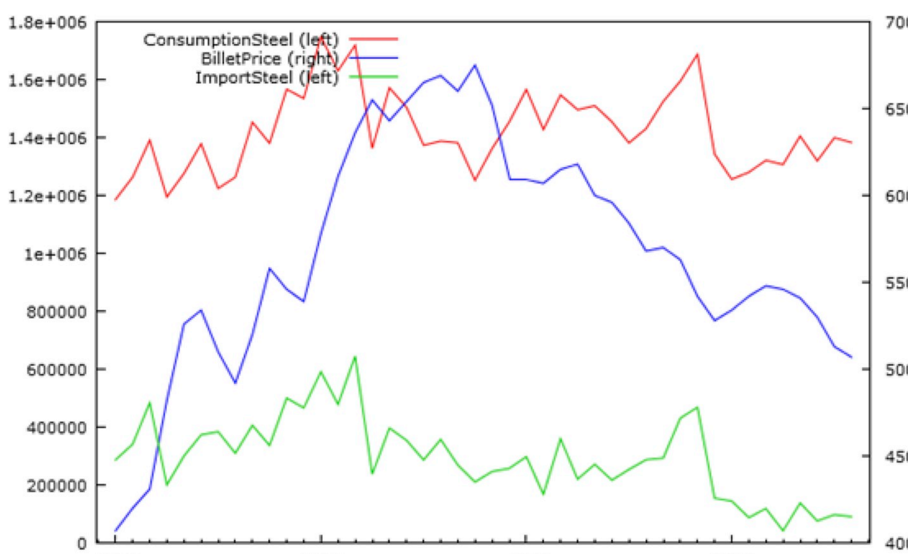

Fig. 12. Changes in steel prices and steel consumption.

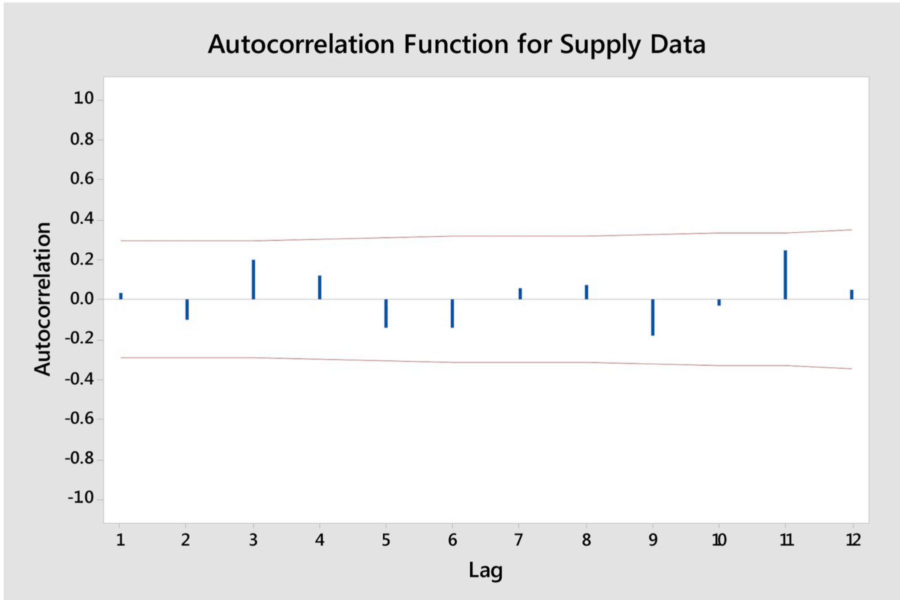

Fig. 13. Autocorrelation analysis with different lags for steel supply time series.

4.3. Review of changes in crude steel demand (consumption) and other affecting factors

As Fig. 10 shows, the trend of changes in crude steel demand and steel products demand during the analysis period is relatively similar, and as the table shows, there is a positive correlation of 0.3 between them, which is a natural correlation. But there is a strong correlation between the crude steel demand and the crude steel import, which is 0.64. It can be seen that the a decline in crude steel demand has led to a dramatic decline in crude steel imports, while crude steel production in the country was changing positively. Therefore, it can be seen that decline in crude steel demand has affected the crude steel import and reduced it. Meanwhile, declining crude steel demand reduced the gap between the crude steel supply and demand.

Table 15 shows the correlation between crude steel demand and other factors affecting it.

Fig. 11 shows the trends of changes in crude steel and steel products supply and demand.

As shown in Fig. 11, there is a steady downward trend in the steel products consumption over the time period, and the gap between steel products supply and demand is shrinking with the decline in imports. Considering that during this period, the trend of steel products production is relatively increasing, so we expect a positive effect on the amount of crude steel production, and therefore, there is a significant positive correlation between these two variables (since during this time the crude steel import was decreasing, and this increase in steel products production should be supplied with increased crude steel production). Due to the high correlation between the crude steel supply and the steel products supply, only one of these variables will be used in the demand function. There is also a relatively significant correlation of 0.4 between crude steel prices and crude steel demand. Fig. 12 shows the trend of changes in these two variable along with the crude steel

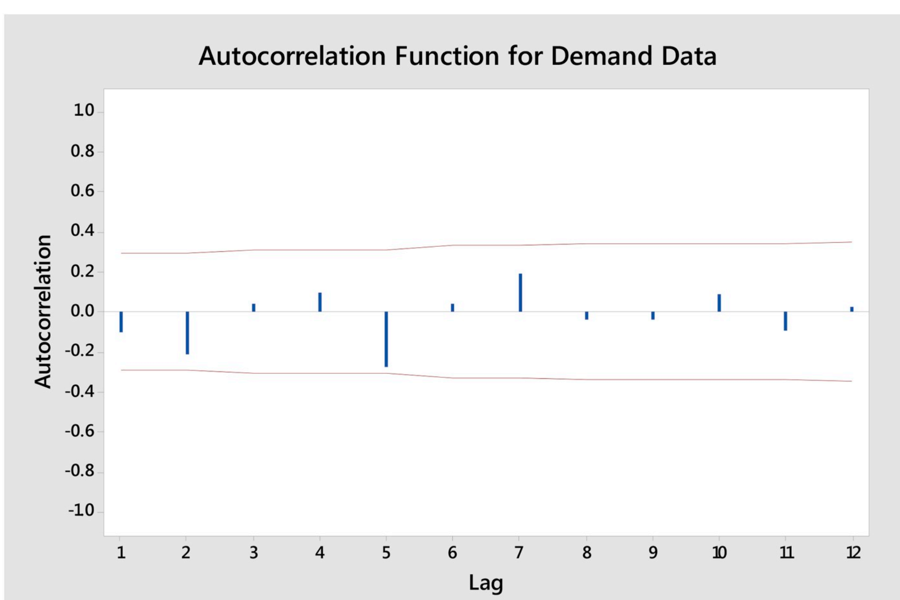

Fig. 14. Autocorrelation analysis with different lags for steel demand time series.

import.

As shown in Fig. 12, by mid-2011, despite the fact that steel prices were rising, steel consumption was also increased, and these two have the same behavior. During this period, crude steel import declined as a result of the rise in global crude steel price and the dollar price. Considering that during the above period from mid-2011 onwards, the trends of changes in these two variables have been less correlated with each other; this is the reason for the low correlation coefficient between these two. Finally, the variables considered in the steel products demand function are described in Equation (8).

$$\begin{aligned} \mathit{Consumption}\mathrm{Stee} &= F(\mathrm{SupplySteel},\ \mathrm{ImportSteel},\ \mathrm{SupplySG},\ \mathrm{ExportSG},\ \mathrm{ConsumptionSG} \\ &\quad ,\ \mathrm{inflation},\ \mathrm{BilletPrice},\ \mathrm{ERDollar}) \end{aligned} \tag{8}$$

In the next section, we will address the fitness of the supply and demand functions.

4.4. Structure of supply and demand functions

Therefore, considering the variables described in the descriptive statistics analysis, the general form of crude steel supply and demand functions is presented as the correlations between linear logarithmic regression models of (9) and (10).

$$\begin{aligned} \mathrm{LSupplySteel} &= \alpha_1 \mathrm{LConsumptionSteel} + \alpha_2 \mathrm{LImportSteel} + \alpha_3 \mathrm{LExportSG} \\ &\quad + \alpha_4 \mathrm{LConsumptionSG} + \alpha_5 \mathrm{Linflation} + \alpha_6 \mathrm{LBilletPrice} \\ &\quad + \mathrm{Constant} \end{aligned} \tag{9}$$

$$\begin{aligned} \mathrm{LConsumptionSteel} &= \alpha_1 \mathrm{LSupplySteel} + \alpha_2 \mathrm{LImportSteel} + \alpha_3 \mathrm{Linflation} \\ &\quad + \alpha_4 \mathrm{LBilletPrice} + \alpha_5 \mathrm{LERDollar} + \mathrm{Constant} \end{aligned} \tag{10}$$

It is worth noting that the term “L” at the beginning of the independent and dependent variables in the supply and demand functions of the steel industry is the symbol of logarithm.

We remind that due to the high correlation between the crude steel supply and the steel products supply, only one of them is considered in each function. In the same way, we have done the same for crude steel import and the steel products import.

Our perspective for estimation of demand function of steel in Iran is on the basis of the both macro- and micro-economic variables used in

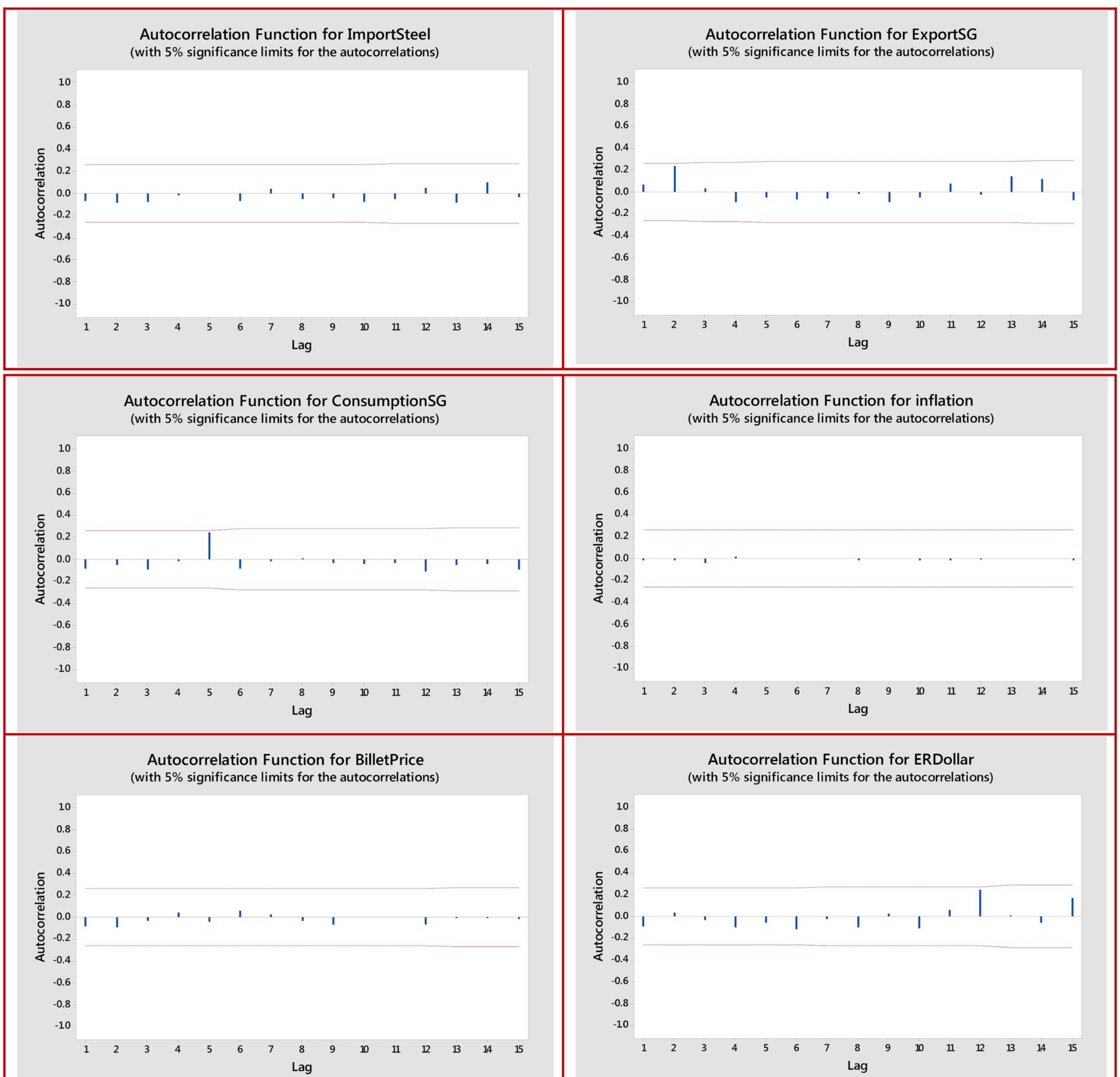

Fig. 15. Autocorrelation analysis with different lags for explanatory variables.

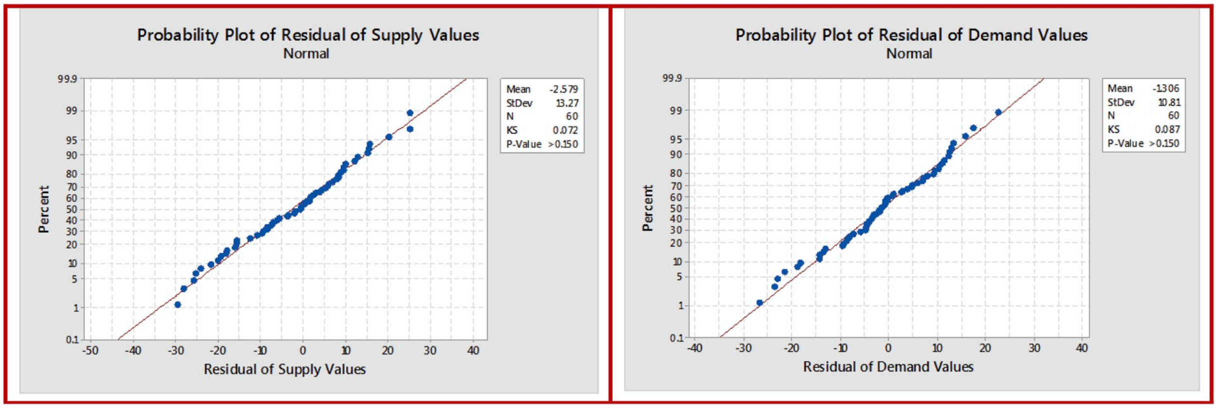

Fig. 16. Normality test of Residuals of Demand and Supply Values.

the trading of steel market and in the economy as a whole. Steel market trading variables, as micro-economic variable, which drive the steel market to move are the focus of our study. Moreover, we have also considered the effect of supply of steel on demand of steel and vice versa. As the supply of steel is a macro-economic variables and is related to several variables in turn, so we have considered both micro- and macro-economic variables in our study, concurrently. Please check Equation (9) and Equation (10) in the revised manuscript.

4.4.1. *Analysis of statistical stationary of time series data*

The statistical properties such as mean, variance and autocorrelation are all constant over time in stationary time series. Statistical prediction methods, including logarithmic regression, are based on the assumption that the statistical properties of the time series are stationary or can be rendered approximately stationary through the application of mathematical transformations. A stationary time series is relatively easy to predict as its statistical properties will be the same in the future as they have been in the past. In this section, first we check if the time series data for steel supply and demand functions are stationary. If required, some transformations such as differencing or seasonal differencing may be applied in order to render to time series data approximately stationary. In the latter case, reverse transformation may be applied to, to obtain predictions for the original series. Fig. 13 presents the autocorrelation analysis with different lags for steel supply time series data during 2010–2014.

Fig. 13 shows no significant spike at lag one. Moreover the spike at lag one does not suddenly decreases after a few lags. On the other hand the spikes are increasing and decreasing through lags. This result indicates that the steel supply time series is stationary over time periods and statistical properties such as mean, variance and autocorrelation are approximately constant over time. So, there is no need to check the partial autocorrelation function and time series is relatively easy to predict using logarithmic regression.

Fig. 14 presents the autocorrelation analysis with different lags for steel demand time series data during 2010–2014.

Fig. 14 also shows no significant decreasing spike over sequential lags. So, the steel demand time series is stationary over time periods and is relatively easy to predict using logarithmic regression.

We have also tested the stationary of all explanatory variables. The results have been presented in Fig. 15.

Fig. 15 shows no significant decreasing spike over sequential lags. So, the explanatory variables of the time series are stationary over time periods.

Moreover, we have implemented Kolmogorov-Smirnov test to check whether the residuals of demand and supply follow normal distribution function. Fig. 16 presents the results of normality test for residuals of demand and supply values.

As the p-values for both cases in Fig. 16 are larger than the significance level, i.e., 0.05, so, we do not have enough evidence to conclude that the residual of supply and demand values do not follow a normal distribution. This proves that the estimation of demand and supply is good enough to be considered.

Table 16
The results of the regression of the steel industry supply function.

Endogenous attribute	l_SupplySteel
Examples	44
R^2	0.911687
Adjusted- R^2	0.897366
Sigma error	0.031608
F-Test (6,37)	63.6605 (0.000000)

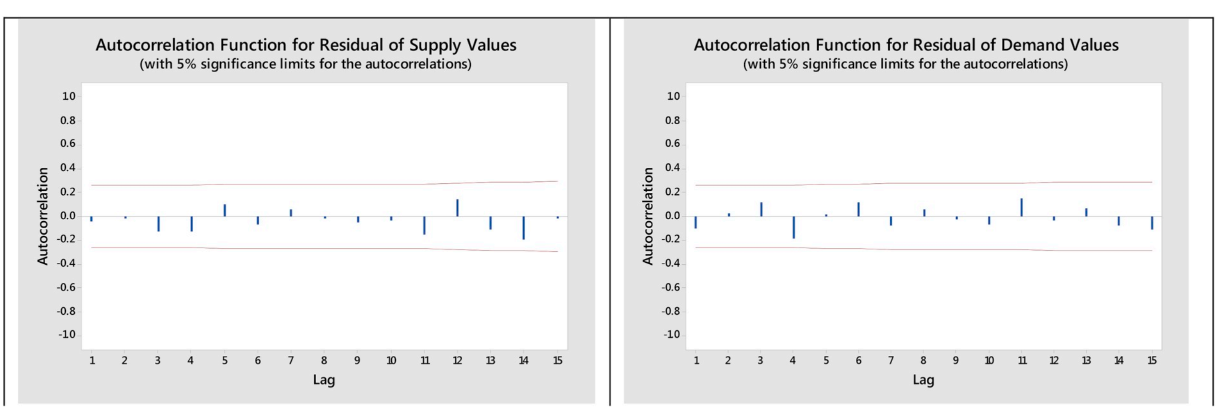

Fig. 17. Autocorrelation analysis with different lags for Residual Values of Demand and Supply.

Table 17
Analysis of the variance of the regression for the steel industry supply function.

Source	SS	d.f.	MSS	F	p-value
Regression	0.3816	6	0.0636	63.6605	0.0000
Residual	0.0370	37	0.0010		
Total	0.4186	43			

Table 18
Significance testing of regression coefficients of steel industry supply function.

$$\begin{aligned} LSupplySteel &= 0.753LConsumptionSteel - 0.129LImportSteel + 0.004LExportSG \\ &+ 0.162LConsumptionSG + 0.07Linflation - 0.035LBilletPrice \\ &+ 2.539 \end{aligned} \tag{11}$$

Attribute	Coef.	Std	t(37)	p-value
Intercept	2.539041	1.424339	1.782611	0.082857
l_ImportSteel	−0.129952	0.017185	−7.562062	0.000000
l_ConsumptionSteel	0.753171	0.076388	9.859863	0.000000
l_ExportSG	0.003943	0.011994	1.328736	0.094209
l_ConsumptionSG	0.161931	0.080711	2.006312	0.052174
l_inflation	0.069568	0.018725	3.715176	0.000668
l_BilletPrice	−0.034663	0.052189	−0.964191	0.210686

Hence, the final formula of steel supply function is proposed as follows.

At the end, the existence of sequence of correlation for residuals has also been tested. The results are presented in Fig. 17.

Fig. 17 also shows no significant decreasing spike over sequential lags. So, the residual values of demand and supply are stationary over time periods.

4.4.2. Estimating the steel industry supply function

In this section, the estimation of the steel industry supply function in the country is carried out using the least squares method. Tables 16–18 show the results of regression analysis.

As Table 16 shows, R^2 is a high number regression, indicating that the above regression model has been estimated with a proper accuracy. Table 17, which is related to the analysis of variance, also shows that the above regression equation is quite significant and is acceptable at each level. However, for the regression coefficients presented in Table 18, firstly, the significance of most of the coefficients is high. Moreover, low standard deviation of the estimated coefficients indicates that the regression is not collinear Therefore, the above coefficients can be used in analyzes. In Fig. 18, we can see the performance of the regression model in estimating the crude steel supply curve versus actual data. As it is known, the model has been able to accurately simulate the supply curve.

In Fig. 19, to determine the level of the accuracy of the fitted function of the regression for the steel supply function, the actual data difference (error) values and the proposed value of the fitted regression equation for all data are presented during the analysis horizon. As

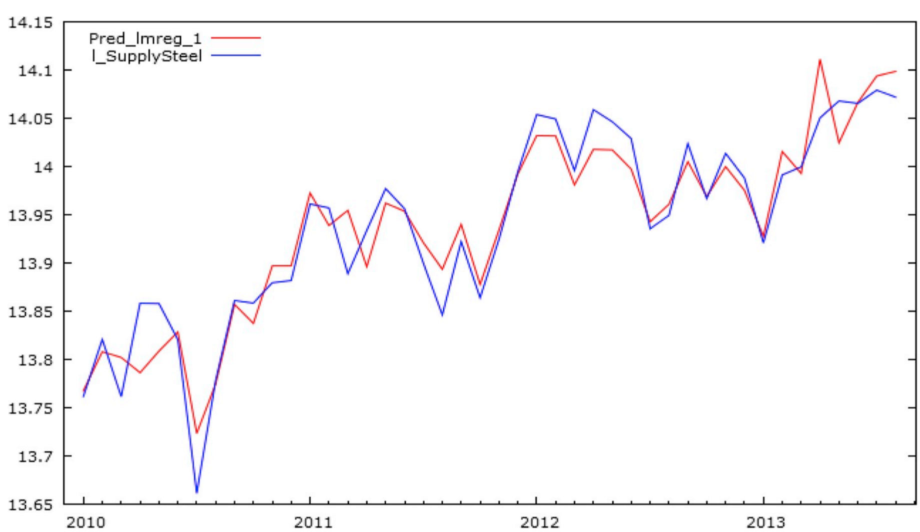

Fig. 18. Actual and forecasted quantities of steel supply by model.

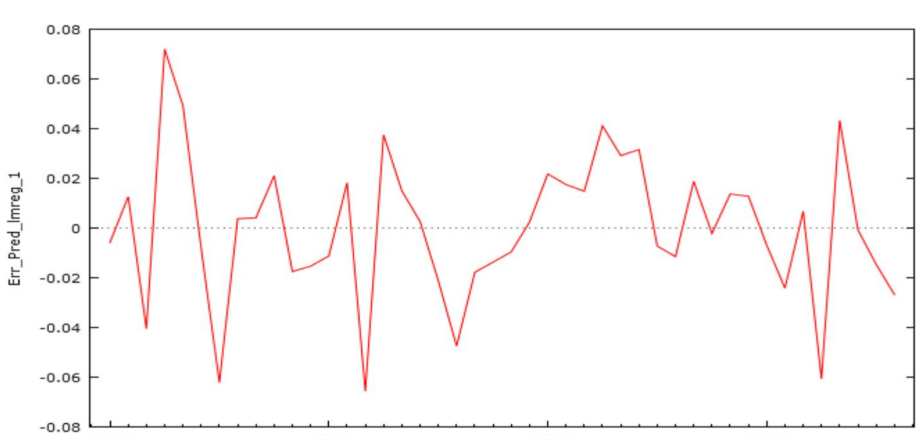

Fig. 19. Chart of predicted error values by the steel supply function model.

shown in Fig. 19, first, the error values are analyzed throughout the entire period, and for all courses it is less than 0.07. In the other hand, the error behavior is symmetric near zero, which indicates the accuracy of the fit function.

Regarding the nature of the logarithmic models, the regression coefficients obtained show the stretches of the variables. The stretching of each of the variables related to the steel supply function is given in Table 19.

Also, with respect to Equation (5), we calculate the value of $e^{\alpha\beta_i}$ to obtain the direct effect of the change in input variables on the steel supply target variable. Table 20 shows the change in the crude steel supply in terms of an increase of 10% in each of the influential factors. As can be seen, the above quantities are approximately equal to the stretches.

As it is deduced from the stretches, the effect of crude steel imports on the crude steel production is a relatively large number, and a 10% increase in the imports, crude steel production will decrease by 1.23%. Increasing steel products exports also has a positive effect on the crude steel production in the country. Meanwhile, the inflation rate is also an influential variable that has positive effect. An increase of 10% in inflation will increase crude steel production by 0.66% in the country. Given the strong positive correlation between the inflation and the appreciation of the dollar during the analysis period, and also according to an analysis that the rise in the dollar price reduced the amount of crude steel imports, the increase in the crude steel production is normal. Consuming steel products also has a major effect on the crude steel production.

4.4.3. Estimating the crude steel demand

The results of estimating the steel industry demand function in the country using the least squares method and its statistical analysis are presented in Tables 21–23.

Table 19
Stretching the variables of the steel supply function model.

Affecting Factor	Attraction Coefficient
l_ImportSteel	−0.129952
l_ConsumptionSteel	0.753171
l_ExportSG	0.003943
l_ConsumptionSG	0.161931
l_inflation	0.069568
l_BilletPrice	−0.034663

Table 20
The effect of direct change in input variables on supply variable.

The factor of change	Coefficient of change in supply	Change percentage in the amount of steel supply
l_ImportSteel	−0.129952	−1.23094
l_ConsumptionSteel	0.753171	7.442417
l_ExportSG	0.003943	0.037588
l_ConsumptionSG	0.161931	1.555339
l_inflation	0.069568	0.665257
l_BilletPrice	−0.034663	−0.32983

Table 21
Results obtained from the regression of the steel industry demand function.

Endogenous attribute	l_ConsumptionSteel
Examples	44
R	0.890054
Adjusted-R	0.875587
Sigma error	0.033851
F-Test (5,38)	61.5247 (0.000000)

Table 22
Analysis of regression variance of steel industry demand function.

Source	xSS	d.f.	xMS	F	p-value
Regression	0.3525	5	0.0705	61.5247	0.0000
Residual	0.0435	38	0.0011		
Total	0.3960	43			

As Table 21 shows, R^2 is the highest number of regression indicating the accuracy of the regression estimation. Table 22 also shows that the above regression equation is quite significance and is acceptable at any significant level. But in the case of regression coefficients, firstly, the significance of the most coefficients are high. Moreover, low standard deviation of the estimated coefficients indicates that the regression is not collinear Therefore, the above coefficients can be used in analyzes.

Hence, the final formula of steel demand function is proposed as follows.

$$\begin{aligned} \text{LConsumptionSteel} = {} & 0.867\text{LSupplySteel} + 0.162\text{LImportSteel} \\ & - 0.066\text{Linflation} + 0.119\text{LBilletPrice} \\ & + 0.068\text{LERDollar} - 1.155 \end{aligned} \tag{12}$$

In Fig. 20, we can see the performance of the regression model in estimating the crude steel demand curve versus actual data. As can be seen, the above model has been able to simulate the demand curve.

In Fig. 21, to determine the level of the accuracy of the fitted function of the regression for the steel demand function, the actual data difference (error) values and the proposed value of the fitted regression equation for all data are presented during the analysis horizon. As shown in Fig. 21, first, the error values are analyzed throughout the entire period, and for all courses it is less than 0.1. In the other hand, the error behavior is symmetric near zero, which indicates the accuracy of the fit function.

Also, with respect to Equation (5), we calculate the value of $e^{\alpha\beta_i}$ to obtain the direct effect of the change in input variables on the steel demand target variable. Table 24 shows the change in the crude steel demand in terms of an increase of 10% in each of the influential factors. As can be seen, the above quantities are approximately equal to the stretches.

The factor changing the coefficient of change in demand is the percentage change in the amount of steel demand. As it is known, the demand for crude steel in the country is highly dependent on the crude steel supply. The crude steel import also has an impact on demand. In the meantime, inflation has a negative effect. Considering that during the inflation analysis period, we were in recession and that the industrial goods supply remained the same as cars and so on, so it was natural that crude steel demand had also reduced. An increase of 10% in global steel prices also boosts 1.14% crude steel demand. Given that rising crude steel prices and rising dollar prices over the analysis period have led to a reduction in the steel and steel products import rate, it is natural that the factories demand to buy steel from domestic companies also increases somewhat.

4.4.4. Extrapolation for testing the reliability of regression analysis

We have provided new data from different period in order to check

Table 23
Significance testing of regression coefficients of steel industry demand function.

Attribute	Coef.	std	t(38)	p-value
Intercept	−1.154679	1.245924	−1.426765	0.159897
l_SupplySteel	0.866998	0.095741	9.055664	0.000000
l_ImportSteel	0.161766	0.013012	12.431956	0.000000
l_inflation	−0.066159	0.025874	−2.557004	0.014674
l_ERDollar	0.067776	0.024921	2.719603	0.009799
l_BilletPrice	0.118772	0.062309	1.906184	0.064211

Fig. 20. Actual and forecasted quantities of steel demand.

the performance of the regression analysis. On the other hand, we have used 60 monthly data from 2010-2014 in order to estimate the coefficients of supply and demand functions. Now, we are going to check the fitting performance of regression using data not used in the estimation procedure.

Regression models predict value of the dependent variable (i.e., supply and demand in this study) given known values of the dependent variables (i.e., inflation, dollar rate, Supply SG, Billet Price and etc. in this study). Prediction within the range of values in the dataset used for model-fitting is known informally as interpolation. Prediction outside this range of the data is known as extrapolation. Performing extrapolation relies strongly on the regression assumptions. The further the extrapolation goes outside the data, the more room there is for the model to fail due to differences between the assumptions and the sample data or the true values. By the way, we have used 24 monthly data from 2017-2018 to accomplish extrapolation for supply and demand values and to check the fitting performance of regression. Fig. 22 presents the results of extrapolation for supply and demand values.

It is clear that extrapolation analysis for both demand and supply values have been laid down in acceptable ranges, which suggest suitable performance of regression analysis.

Table 24
The amount of changes in steel demand in terms of 10% increase in each of the factors.

The factor of change	Coefficient of change in supply	Change percentage in the amount of steel supply
SupplySteel	1.086144	8.614392
ImportSteel	1.015537	1.553742
inflation	0.993714	−0.62858
ERDollar	1.006481	0.648065
BilletPrice	1.011384	1.13845

5. Conclusions and recommendations for future research

The steel industry is considered as one of the mother industries that serves many industries. Hence, recognizing the market situation of this industry both inside and outside the country is very important. The main drivers of market stimulation are industries such as price, supply and demand. Usually supply and demand have complex functions which are hard to model or forecast. In this paper, identifying the steel supply and demand functions as well as forecasting the steel supply and

Fig. 21. Chart of predicted error values by the steel demand function model.

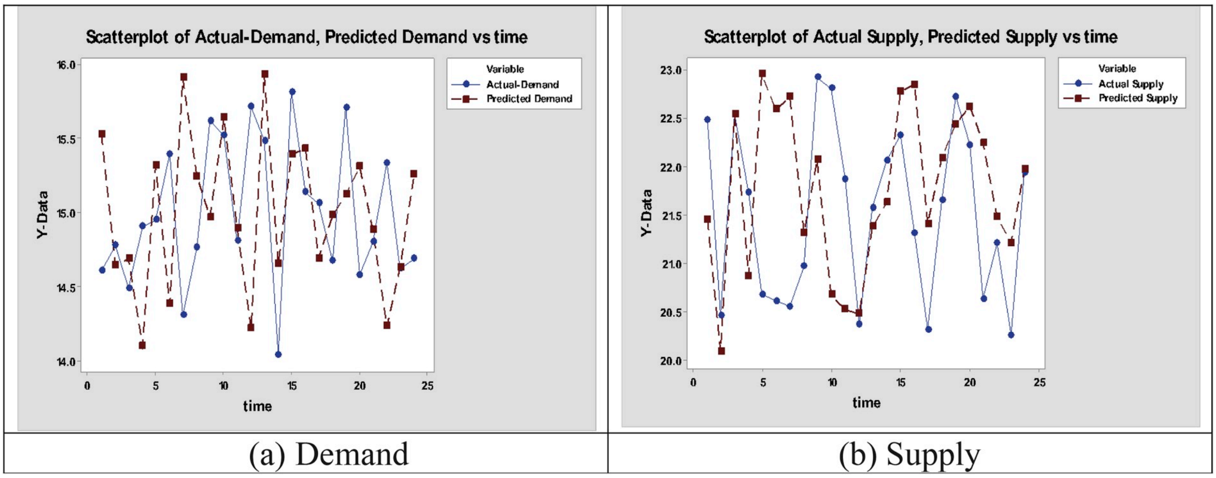

Fig. 22. Actual and predicted values for extrapolation analysis.

demand trends were studied by analyzing the historical supply and demand data and other variables that affected the steel industry. In the first step, most important and influential variables were identified. Then, supply and demand functions were fitted using multiple logarithmic regression analysis. Accuracy of fittings was evaluated by appropriate statistical tests. Finally, using supply and demand functions, some forecasts were made about the steel supply and demand conditions.

The study was conducted using data from a 48-month period starting in 2010 and ending in 2014. The results indicated the appropriate accuracy of supply and demand functions in modeling the steel supply and demand behavior and forecasting the future trend of steel supply and demand in Iran.

For future research, considering the effects of other economic variables such as the effect of industrial progress, the products export related to the steel industry, including cars, household appliances and agricultural implements on supply and demand functions can be interesting. This study focused on steel demand and supply functions, although the price, economic growth, GDP and technological changes, steel scrap demand and price may be considered in the future study. Also, the interactive effect of supply and demand functions and the consideration of the price function that is related to both supply and demand functions can make the analysis more interesting. Also, using approaches such as time series and machine learning techniques such as artificial neural networks can be subjects for future research.

Acknowledgments

The authors would like to thank you the editor and reviewers for their insightful comments. This paper has been written in partial fulfilment of a PhD thesis by Farhad Mehmanpazir at Department of Industrial Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resourpol.2019.101409.

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