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A Numerical Approach for Quantifying Bi-directional Interactions between Macro Economic Indicators and Construction Industry

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Abstract: This article discusses a numerical approach for quantifying bi-directional interactions between economic indicators and the Turkish construction industry. The construction industry is a significant sector that has a substantial impact on economies, especially in terms of jobs and Gross domestic product (GDP). The article explores the relationship between the construction industry and macroeconomics, and uses macroeconomic models to analyze this relationship. The study focuses on Turkish construction industry and Turkish macro-economic datasets provided by Turkish Statistical Institute (TURKSTAT). The prediction model is constructed using Gradient Boosting algorithm, and sensitivity analysis based on improved Analytic Hierarchy Process (AHP) applied to capture model priority vector. The results show that some indicators can predict changes in construction prices, while others do not have predictive power. The article concludes by discussing the implications of these findings.

İnşaat Sektörü ve Makro Ekonomik Göstergeler Arasındaki Çift Yönlü Etkileşimleri Nicelleştirmek için Sayısal bir Yaklaşım

Anahtar Kelimeler
İnşaat sektörü, Makro ekonomik göstergeler, İnşaat maliyet ve fiyatları, Çift yönlü ilişkiler, XGBoost modelleri, Duyarlılık analizi

Öz: Bu makale, ekonomik göstergeler ve Türk inşaat sektörü arasındaki iki yönlü etkileşimleri nicelleştirmek için sayısal bir yaklaşımı tartışmaktadır. İnşaat sektörü, özellikle iş ve Gayri safi yurtiçi hasıla (GSYİH) açısından ekonomilere yüksek derecede etkisi olan önemli bir sektördür. Makale, inşaat sektörü ve makroekonomi arasındaki ilişkiyi nicelleştirmek ve bu ilişkiyi analiz etmek için geliştirilen makroekonomik modelleri kullanmaktadır. Çalışma, Türk İnşaat Sektörü ve Türkiye İstatistik Kurumu (TÜİK) tarafından sağlanan Türk makro-ekonomik veri setlerine odaklanmaktadır. Tahmin modeli, Gradyan Artırma algoritması kullanılarak oluşturulmuş ve model öncelik vektörünü hesaplamak için geliştirilmiş olan Analitik Hiyerarşi Prosesi (AHP) temelli duyarlılık analizi yöntemi uygulanmıştır. Sonuçlar, bazı göstergelerin inşaat fiyatlarındaki değişiklikleri tahmin edebildiğini, diğerlerinin ise daha az tahmin gücüne sahip olduğunu göstermektedir. Makale, bu bulguların sonuçlarını tartışarak sona ermektedir.

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1. Introduction

Globally, the construction industry is generally regarded as a highly significant and substantial sector. This industry is concerned with the development and maintenance of structures such as houses, hospitals, offices, highways, bridges, and other structures, especially major government infrastructure projects [1,2,3].

The construction industry has a crucial part in shaping the economic landscape of a country. The government is a major customer of construction firms. In addition, construction is an investment in the economy and provides investment goods. The industrialization of construction was started in the 1960s and has grown in size since then and contains a large number of various sizes of construction companies.

The construction industry has a substantial impact on economies, especially by the means of jobs and Gross Domestic Product (GDP). The average percentage of jobs in this sector in Europe is 7%, although it ranges between 5% and 8% in Türkiye. For Türkiye, construction jobs were limited in 2020 due to the pandemic. The rates were at 5.75 percent and, construction turnover ranges from 12 to 16 percent of GDP, with an estimation of 11.9% in 2020. The number of construction companies are 12750 in total. They are distributed as; 99220 micro-scale, 23475 small-scale, 3869 mid-scale and 486 large-scale firms [4-7].

Additionally, comprehending potential trends in construction costs may influence the investment strategies of various stakeholders in the construction industry, such as private and public corporations, building companies, land investors, financial organizations, construction professionals and government policy makers [8,9].

The construction industry and the macroeconomy have a two-way relationship can be observed in nearly all aspects and phases of economic activity. This relationship can be divided into four main categories: demand and output, employment and income, balance of payments, and price levels [10]. These categories are interconnected in such a way that improvements in one area will eventually lead to changes in the others.

The word “macroeconomics” was created by Ragnar Frisch in the early 1930s to refer to the study of the economy as a whole [11]. The most crucial stage is to define the model’s working circumstances, which may be divided into three categories: identities or definitions, function relationships, and model boundaries. A challenge that confronts the field of economic analysis is its intricate nature. The mutual reliance of the elements of the system implies that a minor alteration in one element will entail repercussions or cascades of impacts of diverse magnitudes in most systems. Two major methods of simplification can be used. The first solution is to assume the potential result of a change in one variable while keeping all other variables unchanged except the effect of the change constant. The second principal technique of simplification is consolidation to examine the interconnections of all the primary components of the system simultaneously [12]. If the approach fails to tackle the issues of capital accumulation and disequilibrium arising from temporal discrepancies and error-corrections, it is unsuitable for realistic scenarios. These problems are more important to macro-theory and are treated less fully in standard texts.

In this paper, these dynamic analyses are prioritized over the timeless Keynesian system and important macroeconomic indicators for construction level of prices in Türkiye are derived in a nonlinear model. Alternatives models are developed for construction Economic Growth and Financial Markets [13,14]. Similarly, the indicators rely on two tentative methods both saddle points of the fundamental indicators in relation to construction level of price saddle points and predictive power of lags of the fundamental indicators. Other partial macro-economic models are proposed related to prices, development, sustainability, environment and housing development. [15-18] These models are not capable of dealing complexity of the whole construction sector as well as rarely focus on bidirectional relations. The analyses show that some things can tell us what will happen to construction prices before they change. These things are how many people are out of work, how much construction work is done, how much industry makes, and how prices and costs compare in manufacturing. Two other things change at the same time as construction prices. These are the cost of building and the total value of what the country makes. Some other things that we often look at in the economy did not help us predict construction prices. The interest rate, inflation rate, stock market index, and money supply are all factors to consider.

2. Material and Methods

This study focuses on Turkish construction industry and Turkish macro-economic datasets provided by TURKSTAT [19]. The prediction model is constructed using Gradient Boosting algorithm, a suitable machine-learning method for classification tasks. Sensitivity analysis is used to determine the model’s priority vector. This vector is then utilized to create and measure bi-directional relationships.

2.1. Macro-economic Reference Model

This research will narrow its focus to the model and the relation between the economy and the construction industry. The general model can be represented as in Equation 1. In the model Y represents the independent variables such as Construction Supply, Demand, etc. x_i represents the dependent variables for example interest rates, construction materials prices, etc. Details of the parameters are given Table 1. The β_0 represents the biases and β_n are the coefficients of the models. Four specific models Demand-Output, Employment-Incomes, Balance-of-Payments and finally in the Level-of-Prices are constructed using these parameters. These parameters will be used to quantify relationship between the economy and the construction industry.

$$Y_{\mathrm{A}\rightarrow\mathrm{B}} \cong Y_{\mathrm{A}\leftarrow\mathrm{B}} \text{ and } Y = \beta_0+\sum_{i=1}^{n}\beta_i . x_i \quad (1)$$

2.2. The Data and Preprocessing

Turkish macro-economic datasets provided by TURKSTAT. The monthly data periods begin at January 1, 2000 and ends January 1, 2021. The main indicators used in models are given in Table 1. In accordance with the Pareto Principle, a statistical concept widely applied to explain various phenomena in human, machine, and environmental domains, 80% of the data was allocated for training purposes while the remaining 20% was utilized for validation.

Table 1. TURKSTAT indicators used in models

Model Parameters			
Interest Rate	Cru. Petroleum	C. Permission	Housing Num.
Bist100 Vol.	Producer PI	R. Permission	Housing Prices
Consumer PI	Employment	Budget Bal.	C. Employment
Ex. Rates Usd	Balance Pay.	C. Income	Interest Rate
Ex. Rates Eur	C. Materials P.	C. Output	Employment

The Table 1 contains a list of economic indicators. Crude petroleum, stone sand and clay, tubes pipes hollow profiles and related fittings of steel, and coke and refined petroleum products are some of the indicators that measure the performance of the energy sector. Consumer price index, producer price index, and construction materials are some of the indicators that measure the performance of the manufacturing sector. Employment, housing numbers, and construction employment are indicators that measure the performance of the labor market. The performance of the financial sector is measured by indicators such as interest rates and exchange rates. The construction sector's performance is measured by indicators such as budget balance and balance.

Table 2. Summary statistics for various macroeconomic indicators

	Interest Rate	Bist100 Trading Volume	Consumer Price Index	Exchange Rates Usd	Exchange Rates Eur	Petroleum	Producer Price Index	Employment	Supply	Demand
count	252	252	252	252	252	252	252	252	252	252
mean	21.79	3790329	202.13	2.35	2.79	63.57	201.33	43.22	8480	7285
std	12.44	5830956	113.40	1.63	1.83	29.94	120.64	2.65	4506	3149
min	8.42	125799	31.59	0.55	0.55	14.85	28.87	37.30	1450	374
0.25	13.29	916484	115.42	1.40	1.75	39.10	118.73	41.30	5806	5279
0.5	17.28	2245164	177.83	1.60	2.13	59.78	173.37	43.18	8274	7021
0.75	26.08	3924601	264.13	2.86	3.17	81.34	250.14	45.27	10373	8984
max	59.30	39019692	504.81	8.02	9.47	138.40	568.27	48.35	45404	23268

Table 2 presents summary statistics for various macroeconomic indicators and commodities used in Macroeconomic – Construction Models. For example, the mean interest rate is 21.79 and the standard deviation is 12.44. The minimum interest rate is 8.42 and the maximum is 59.30. The 25th percentile is 13.29 and the 75th percentile is 26.08.

Table 3. Correlation coefficients for various macroeconomic indicators

	Interest Rate	Bist100 Trading Volume	Consumer Price Index	Exchange Rates Usd	Exchange Rates Eur	Petroleum	Producer Price Index	Employment
Interest Rate	1.00	0.03	0.14	0.30	0.29	-0.09	0.36	-0.01
Bist100 Trading Volume	0.03	1.00	0.09	0.15	0.11	-0.03	0.14	-0.08
Consumer Price Index	0.14	0.09	1.00	0.30	0.29	0.05	0.59	-0.07
Exchange Rates Usd	0.30	0.15	0.30	1.00	0.87	-0.07	0.57	-0.04
Exchange Rates Eur	0.29	0.11	0.29	0.87	1.00	0.00	0.58	0.01
Petroleum	-0.09	-0.03	0.05	-0.07	0.00	1.00	0.12	0.18
Producer Price Index	0.36	0.14	0.59	0.57	0.58	0.12	1.00	0.06
Employment	-0.01	-0.08	-0.07	-0.04	0.01	0.18	0.06	1.00

Table 3 shows the correlation coefficients between pairs of variables. The correlation values range from -1 to 1. A number of -1 indicates a perfect negative correlation, whereas a value of 1 indicates a perfect positive correlation. A value of 0 means there is no correlation. The diagonal values are always 1 because a variable is perfectly correlated with itself. For example, the correlation between Interest Rate and Bist100 Trading Volume is 0.03, which indicates a very weak positive correlation. On the other hand, the correlation between Exchange Rates Usd and Exchange Rates Eur is 0.87, which indicates a strong positive correlation.

No macro model is sufficiently suitable for realistic scenarios if it fails to tackle the issues arising from temporal discrepancies and error-corrections. These dynamic analyses are prioritized over the timeless Keynesian system in this paper, as they are both more relevant to macro-theory and less explored in research. The proposed model used preprocessed data. The time-lags are log-normalized, other economic variables are normalized between 0 and 1 as well as corrected for stiffness and variations of variables in order to reduce model error and measuring scaled sensitivity. The output parameters binned to 5 classes for sensitivity analysis.

2.3. Macroeconomic – Construction Models and Methodology

A nonlinear Macroeconomic – Construction Models methodology, demand and output, employment and income, and balance of payments, as well as data analysis, the bi-directional relations of models and error rates are given in following sections. The price levels model is out of scope of this study.

2.3.1 *Gradient Boosting Model*

Gradient Boosting is a machine learning technique that uses many simple models to create a more accurate prediction model [20]. It can be used for both classification and regression tasks. The algorithm builds an ensemble of weak models in a stage-wise manner and allows for the optimization of any differentiable loss function. The aim is to interactively teach a model F to predict values of the form $\hat{y} = F(x)$ by minimizing the mean square error $\frac{1}{n}\sum_i(\hat{y_i} - y_i)^2$. This is done by calculating the difference between the predicted and actual values for each sample in the training set, where i is the indexes of training set and n is the number of samples in y. In addition, $\hat{y_i}$ is the predicted value of $F(x_i)$ and y_i is the observed value. The algorithm with M week estimators for each iteration $F_{m+1}(x_i) = F_m(x_i) + h_m(x_i) = y_i$ adds a new estimator to the imperfect model F_m to improve the error. The Mean-Squared-Error (MSE) loss with respect to $F(x_i)$ is calculated as in Equation 3. Gradient boosting optimizes prediction accuracy for various problems and provides a solution to multicollinearity. It allows for model design freedom and is an advantage over conventional fitting methods.

2.3.2 *Bi-directional Relations of Models*

In economic models the input-output table measures transactions and relations between industries in an economy [21]. An alternative model used in this study is the Analytic Hierarchy Process (AHP), which involves qualitative data and deals with uncertainty. AHP models provide mathematical means to associate relations and priorities of parameters. The AHP method computes the priority vector, ranking the importance of factors. The only inputs required are pair-wise comparisons of relative importance of factors [22].

The AHP approximates a matrix $A = (a_{ij}), (a_{ij}) = {}^1/_{a_{ij}}, i, j = 1, \dots, n$ by a vector $W \in R_+^n$, where R_+^n so that the matrix of ratios is the best approximation $(w_i/w_j), i, j = 1, \dots, n$ to the original matrix A. The eigenvector method $A.W = \lambda_{max}.W$ results in a priority vector $W \in R_+^n$ and an inconsistency number λ_{max}. The eigenvector method for AHP given in Equation 2.

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \vdots & & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} = \begin{bmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \vdots & & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{1\,2} & \cdots & a_{1\,n} \\ & \vdots & \ddots & \vdots \\ \frac{1}{a_{1\,n}} & \frac{1}{a_{2\,n}} & \cdots & 1 \end{bmatrix} \tag{2}$$

Rather than employing an expert-provided judgment matrix as in the AHP model, Feature Importance derived from Gradient Boosting algorithms may be employed. One advantage of this approach is that it's easy to obtain importance scores for each attribute after constructing the weak models. This doesn't require complex expertise and can be derived from existing data. The significance of each attribute is determined by how much its split point enhances the performance metric, which is weighted by the number of observations for which the node is responsible. Each attribute has an impact on the performance of the node, and the significance of it is determined how much it enhances its performance. The final Macro-economic Reference Model is a linear model, thus approximating the XGBoost model *F* for a specific input *x*, the local accuracy gives the priority vector of the model to match the output of *F* for the simplified input *x'*. This priority vector can be used to define the coefficients of the refence model [23].

2.3.3 *Model Validation*

The model performance in terms of SoftMax error is used for defined model parameters. The given equations are provided to compute the above-mentioned factors as provided in Equation 3.

$$L_{\mathrm{MSE}} = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - F(x_i)\right)^2 \tag{3}$$

2.4. Macroeconomic – Construction Demand and Output Model Application

Based on the methodology suggested in previous section a Construction Demand and Output Model developed. The model parameters Interest Rate, Bist100 Trading Volume, Consumer Price Index, Exchange Rates Usd, Exchange Rates Eur, Petroleum, Producer Price Index, Employment data is used as input given in Figure 1. The model output was *Supply and Demand* data.

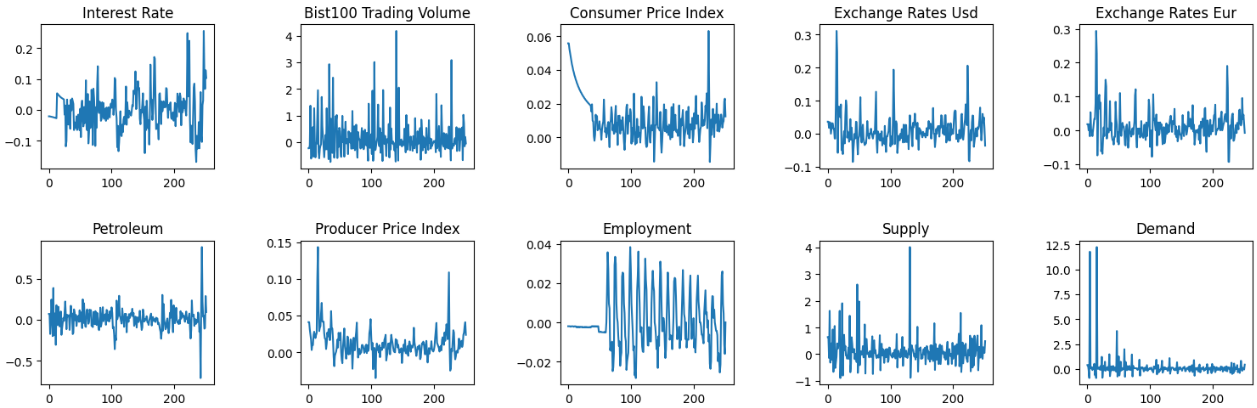

Figure 1. Macroeconomic – Construction Demand and Output Model data

Table 4 shows the correlation coefficients between different economic indicators. A correlation coefficient is used to compute the magnitude and direction of a linear association between two parameters. Some of the strongest positive correlations in this table are between Exchange Rates USD and Exchange Rates EUR (0.87), and between Consumer Price Index and Producer Price Index (0.59). This means that when one of these indicators increases, the other is likely to increase as well. There are also some moderate positive correlations between Interest Rate and Producer Price Index (0.36), Exchange Rates USD and Producer Price Index (0.57), and Exchange Rates EUR and Producer Price Index (0.58). There are no strong negative correlations in this table. The strongest negative correlation is between Petroleum and Exchange Rates USD (-0.07), but this is still a very weak correlation. Overall, this table shows that some economic indicators are more closely related than others. For example, exchange rates seem to be more closely related to each other and to the Producer Price Index than to other indicators.

Table 4. Macroeconomic – Construction Demand and Output Model correlation coefficients

	Interest Rate	Bist100 Volume	Consumer Price Index	Exchange Rates Usd	Exchange Rates Eur	Petroleum	Producer Price Index	Employment	Supply	Demand
Interest Rate	1.00	0.03	0.14	0.30	0.29	-0.09	0.36	-0.01	0.02	0.03
Bist100 Vol.	0.03	1.00	0.09	0.15	0.11	-0.03	0.14	-0.08	-0.09	0.02
Consumer PI	0.14	0.09	1.00	0.30	0.29	0.05	0.59	-0.07	0.02	0.15
Ex. Rates Usd	0.30	0.15	0.30	1.00	0.87	-0.07	0.57	-0.04	-0.01	0.19
Ex. Rates Eur	0.29	0.11	0.29	0.87	1.00	0.00	0.58	0.01	0.00	0.15
Petroleum	-0.09	-0.03	0.05	-0.07	0.00	1.00	0.12	0.18	-0.01	0.12
Producer PI	0.36	0.14	0.59	0.57	0.58	0.12	1.00	0.06	0.00	0.26
Employment	-0.01	-0.08	-0.07	-0.04	0.01	0.18	0.06	1.00	0.02	-0.02
Supply	0.02	-0.09	0.02	-0.01	0.00	-0.01	0.00	0.02	1.00	0.26
Demand	0.03	0.02	0.15	0.19	0.15	0.12	0.26	-0.02	0.26	1.00

Many weak learners used in Construction Demand and Output Model in order to make a more accurate predictor. A sample week model is given in Figure 2. The accuracy of the final model is calculated by using Equation 3. The model's validation SoftMax accuracy is on average 75.21.

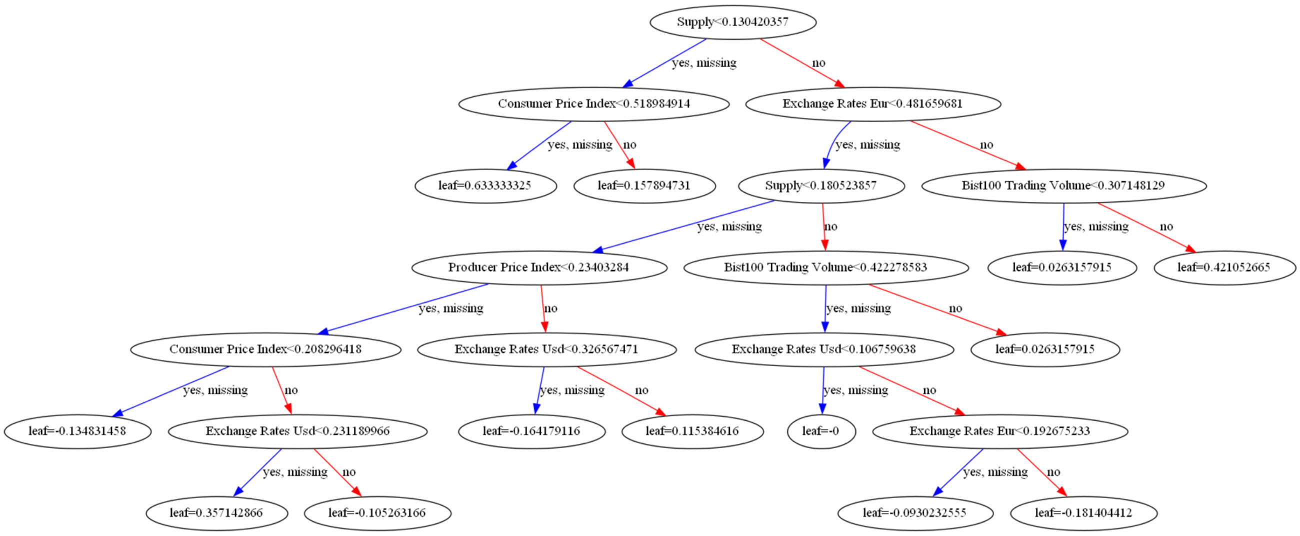

Figure 2. A sample boosting tree for Construction Demand and Output Model

The sample priority vector (Figure 3) of the given model by calculating the contribution of that feature to the prediction by comparing the prediction when all features in the model are present to the prediction. Based on this priority vector table in Figure 4 is formed.

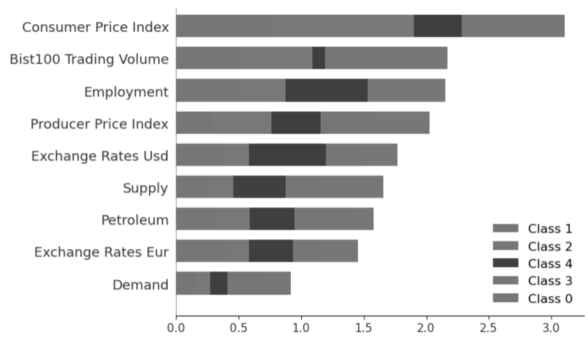

Figure 3. A sample Feature Importance vector for Macroeconomic – Construction Demand and Output Model

The reference model discussed at section 2.1 applied to Demand and Output model $Y_{\text{Supply}} \cong Y_{\text{Demand}}$ by using input and output parameters given above represented as x_i and the weights β_i both $Y_{\text{Supply}} = \beta_0 + \sum_{i=1}^{n} \beta_i . x_i$ and $Y_{\text{Demand}} = \beta_0 + \sum_{i=1}^{n} \beta_i . x_i$ models can be obtained using boosting model. The bidirectional relations given in below Figure 4 represents β_i. The upper triangular matrix gives β_i the weights of $Y_{\text{Supply}} \rightarrow Y_{\text{Demand}}$ and lower triangular matrix gives β_i the weights of $Y_{\text{Supply}} \leftarrow Y_{\text{Demand}}$ respectively.

	Interest Rate	Bist100 Trading Volume	Consumer Price Index	Exchange Rates Usd	Exchange Rates Eur	Petroleum	Producer Price Index	Employment	Supply	Demand
Interest Rate	1.00	0.10	0.09	0.09	0.09	0.09	0.13	0.13	0.08	0.07
Bist100 Trading Volume	0.10	1.00	0.10	0.09	0.10	0.11	0.13	0.09	0.08	0.08
Consumer Price Index	0.14	0.11	1.00	0.12	0.10	0.10	0.17	0.17	0.09	0.09
Exchange Rates Usd	0.13	0.12	0.11	1.00	0.29	0.11	0.12	0.09	0.10	0.09
Exchange Rates Eur	0.12	0.10	0.10	0.28	1.00	0.12	0.08	0.09	0.12	0.11
Petroleum	0.09	0.10	0.11	0.11	0.08	1.00	0.11	0.12	0.09	0.09
Producer Price Index	0.11	0.14	0.20	0.09	0.10	0.13	1.00	0.10	0.10	0.10
Employment	0.11	0.11	0.12	0.07	0.07	0.11	0.09	1.00	0.07	0.09
Supply	0.10	0.11	0.08	0.08	0.09	0.12	0.09	0.11	1.00	0.29
Demand	0.10	0.12	0.09	0.08	0.09	0.10	0.08	0.10	0.28	1.00

Figure 4. Bidirectional Macroeconomic – Construction Demand and Output Model weights

2.5. Macroeconomic – Construction Employment and Income Model Application

A Construction Employment and Income Model developed. The Interest Rate, Bist100 Trading Volume, Consumer Price Index, Exchange Rates Usd, Exchange Rates Eur, Petroleum, Producer Price Index, *Employment, Turnover, Costs, Income, Construction Balance* data is used as input and output given in Figure 5.

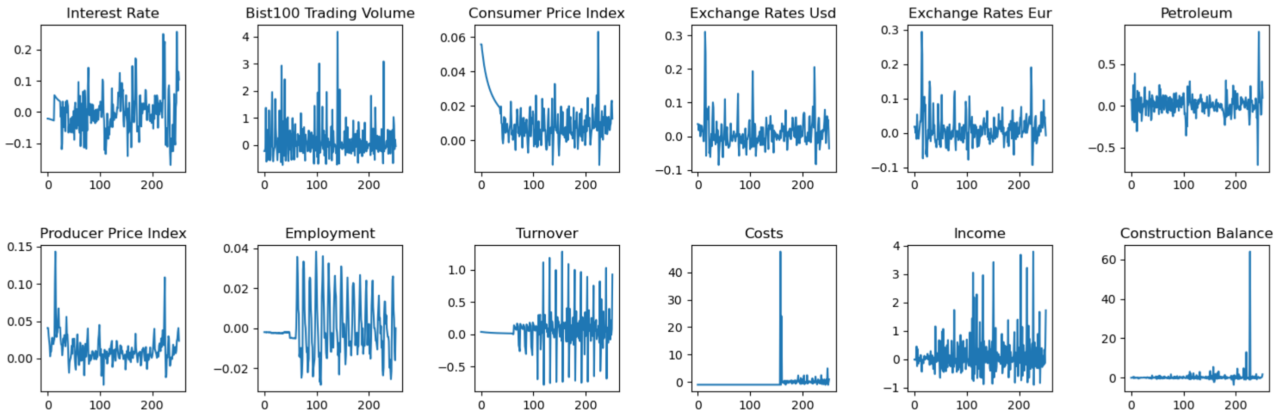

Figure 5. Construction Employment and Income Model data

From the Table 5, we can see that there is a moderate positive correlation between Turnover and Income (0.58), as well as between Construction Balance and Income (0.48). There is also a weak positive correlation between Costs and Employment (0.09). On the other hand, there is a weak negative correlation between Employment and Turnover (-0.21), as well as between Employment and Construction Balance (-0.11). The correlations between the other indicators you mentioned are close to 0, indicating little to no correlation.

Table 5. Construction Employment and Income Model correlation coefficients

	Int. Rate	Bist 100 Vol.	Cons. PI	Ex. Rates Usd	Ex. Rates Eur	Petro-leum	Producer PI	Employ-ment	Turn-over	Costs	Income	Cons. Balance
Interest Rate	1.00	0.03	0.14	0.30	0.29	-0.09	0.36	-0.01	0.02	0.03	-0.01	-0.03
Bist100 Vol.	0.03	1.00	0.09	0.15	0.11	-0.03	0.14	-0.08	-0.09	0.02	-0.14	-0.10
Consumer PI	0.14	0.09	1.00	0.30	0.29	0.05	0.59	-0.07	0.02	0.15	-0.12	-0.09
Ex. Rates Usd	0.30	0.15	0.30	1.00	0.87	-0.07	0.57	-0.04	-0.01	0.19	-0.04	-0.01
Ex. Rates Eur	0.29	0.11	0.29	0.87	1.00	0.00	0.58	0.01	0.00	0.15	-0.06	-0.02
Petroleum	-0.09	-0.03	0.05	-0.07	0.00	1.00	0.12	0.18	-0.01	0.12	0.05	-0.05
Producer PI	0.36	0.14	0.59	0.57	0.58	0.12	1.00	0.06	0.00	0.26	-0.10	-0.10
Employment	-0.01	-0.08	-0.07	-0.04	0.01	0.18	0.06	1.00	0.02	-0.02	-0.02	-0.11
Turnover	0.02	-0.09	0.02	-0.01	0.00	-0.01	0.00	0.02	1.00	0.26	0.58	0.26
Costs	0.03	0.02	0.15	0.19	0.15	0.12	0.26	-0.02	0.26	1.00	0.04	-0.03
Income	-0.01	-0.14	-0.12	-0.04	-0.06	0.05	-0.10	-0.02	0.58	0.04	1.00	0.48
Con. Balance	-0.03	-0.10	-0.09	-0.01	-0.02	-0.05	-0.10	-0.11	0.26	-0.03	0.48	1.00

A sample week Construction Employment and Income model is given in Figure 6. The accuracy of the final model is calculated by using Equation 3. The model's validation SoftMax accuracy is on average 75.21. The priority vector represented in Figure 7 of the given model by calculating the contribution of that feature to the prediction by comparing the prediction when all features in the model are present to the prediction. Based on this priority vector table in Figure 8 is formed.

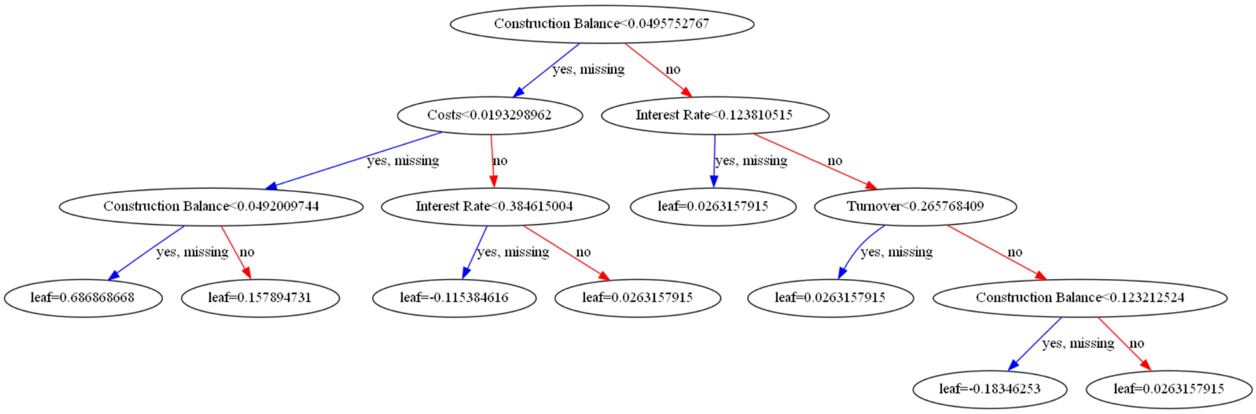

Figure 6. A sample boosting tree for Construction Employment and Income Model

The for Construction Employment and Income Model $Y_{\text{Employment}} \cong Y_{\text{Income}}$ by using input and output parameters given above represented as x_i and the weights β_i both $Y_{\text{Employment}} = \beta_0 + \sum_{i=1}^{n} \beta_i . x_i$ and $Y_{\text{Income}} = \beta_0 + \sum_{i=1}^{n} \beta_i . x_i$ models can be obtained using boosting model. The bidirectional relations given in below Table 3 represents β_i. The upper triangular matrix gives β_i the weights of $Y_{\text{Employment}} \rightarrow Y_{\text{Income}}$ and lower triangular matrix gives β_i the weights of $Y_{\text{Employment}} \leftarrow Y_{\text{Income}}$ respectively.

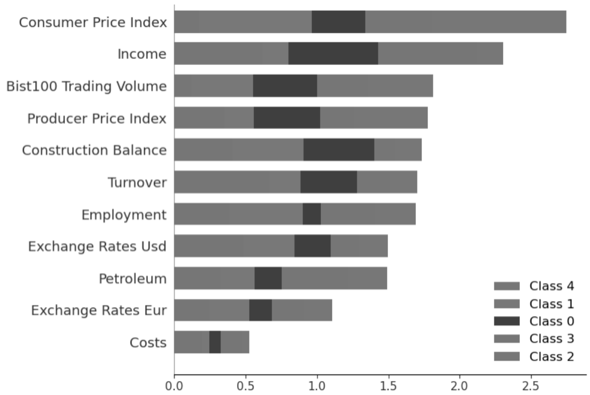

Figure 7. A sample Feature Importance vector for Construction Employment and Income Model

The priority vector (Figure 7) of the given model by calculating the contribution of that feature to the prediction by comparing the prediction when all features in the model are present to the prediction. Based on this priority vector table is formed given in Figure 8.

	Interest Rate	Bist100 Trading Volume	Consumer Price Index	Exchange Rates Usd	Exchange Rates Eur	Petroleum	Producer Price Index	Employment	Turnover	Costs	Income	Construction Balance
Interest Rate	1.00	0.09	0.08	0.07	0.05	0.07	0.10	0.09	0.05	0.10	0.07	0.04
Bist100 Trading Volume	0.08	1.00	0.07	0.06	0.07	0.08	0.09	0.06	0.08	0.07	0.03	0.04
Consumer Price Index	0.12	0.09	1.00	0.09	0.07	0.09	0.15	0.15	0.14	0.07	0.03	0.04
Exchange Rates Usd	0.12	0.09	0.10	1.00	0.26	0.08	0.10	0.06	0.07	0.07	0.03	0.05
Exchange Rates Eur	0.08	0.10	0.06	0.23	1.00	0.09	0.09	0.05	0.08	0.08	0.07	0.04
Petroleum	0.07	0.09	0.07	0.10	0.08	1.00	0.08	0.09	0.07	0.05	0.03	0.03
Producer Price Index	0.09	0.09	0.19	0.08	0.08	0.10	1.00	0.07	0.07	0.05	0.06	0.05
Employment	0.10	0.10	0.08	0.08	0.06	0.08	0.07	1.00	0.12	0.09	0.05	0.02
Turnover	0.08	0.11	0.11	0.07	0.09	0.10	0.09	0.18	1.00	0.17	0.06	0.07
Costs	0.09	0.10	0.07	0.11	0.07	0.12	0.11	0.10	0.13	1.00	0.17	0.13
Income	0.10	0.10	0.08	0.06	0.11	0.10	0.08	0.10	0.07	0.07	1.00	0.47
Construction Balance	0.08	0.05	0.09	0.04	0.05	0.08	0.04	0.05	0.13	0.17	0.42	1.00

Figure 8. Bidirectional Construction Employment and Income Model weights

2.6. Macroeconomic – Construction Balance of Payments Model Application

A Construction Balance of Payments Model developed. The Interest Rate, Bist100 Trading Volume, Consumer Price Index, Exchange Rates Usd, Exchange Rates Eur, Petroleum, Producer Price Index, *Turnover, Construction Balance, Income, Construction Employment* data is used as input and output given in Figure 11.

Figure 11. Construction Balance of Payments Model data

From the Table 6, we can see that there is a strong positive correlation between Employment and Construction Employment (0.54). There is also a moderate positive correlation between Turnover and Income (0.58), as well as between Construction Balance and Income (0.48). On the other hand, there is a weak negative correlation between Employment and Turnover (-0.21), as well as between Employment and Construction Balance (-0.11). The correlations between the other indicators you mentioned are close to 0, indicating little to no correlation.

Table 6. Macroeconomic – Construction Balance of Payments Model correlation coefficients

	Int. Rate	Bist100 Vol.	Consumer PI	Ex. Rates Usd	Ex. Rates Eur	Petro-leum	Producer PI	Employ-ment	Turnover	Con. Balance	Income	Con. Employ.
Int. Rate	1.00	0.03	0.14	0.30	0.29	-0.09	0.36	-0.01	-0.01	-0.03	-0.01	0.05
Bist100 Vol.	0.03	1.00	0.09	0.15	0.11	-0.03	0.14	-0.08	-0.21	-0.10	-0.14	-0.19
Consumer PI	0.14	0.09	1.00	0.30	0.29	0.05	0.59	-0.07	-0.13	-0.09	-0.12	-0.08
Ex.Rates Usd	0.30	0.15	0.30	1.00	0.87	-0.07	0.57	-0.04	0.01	-0.01	-0.04	-0.07
Ex.Rates Eur	0.29	0.11	0.29	0.87	1.00	0.00	0.58	0.01	0.00	-0.02	-0.06	-0.01
Petroleum	-0.09	-0.03	0.05	-0.07	0.00	1.00	0.12	0.18	-0.03	-0.05	0.05	0.04
Producer PI	0.36	0.14	0.59	0.57	0.58	0.12	1.00	0.06	-0.07	-0.10	-0.10	0.02
Employment	-0.01	-0.08	-0.07	-0.04	0.01	0.18	0.06	1.00	0.04	-0.11	-0.02	0.54
Turnover	-0.01	-0.21	-0.13	0.01	0.00	-0.03	-0.07	0.04	1.00	0.26	0.58	0.24
Con. Balance	-0.03	-0.10	-0.09	-0.01	-0.02	-0.05	-0.10	-0.11	0.26	1.00	0.48	0.00
Income	-0.01	-0.14	-0.12	-0.04	-0.06	0.05	-0.10	-0.02	0.58	0.48	1.00	0.04
Con. Empl.	0.05	-0.19	-0.08	-0.07	-0.01	0.04	0.02	0.54	0.24	0.00	0.04	1.00

A sample week Construction Balance of Payments model is given in Figure 12. The accuracy of the final model is calculated by using Equation 3. The model's validation SoftMax accuracy is on average 75.21. The priority vector given in Figure 13 of the given model by calculating the contribution of that feature to the prediction by comparing the prediction when all features in the model are present to the prediction. Based on this priority vector table in Figure 14 is formed.

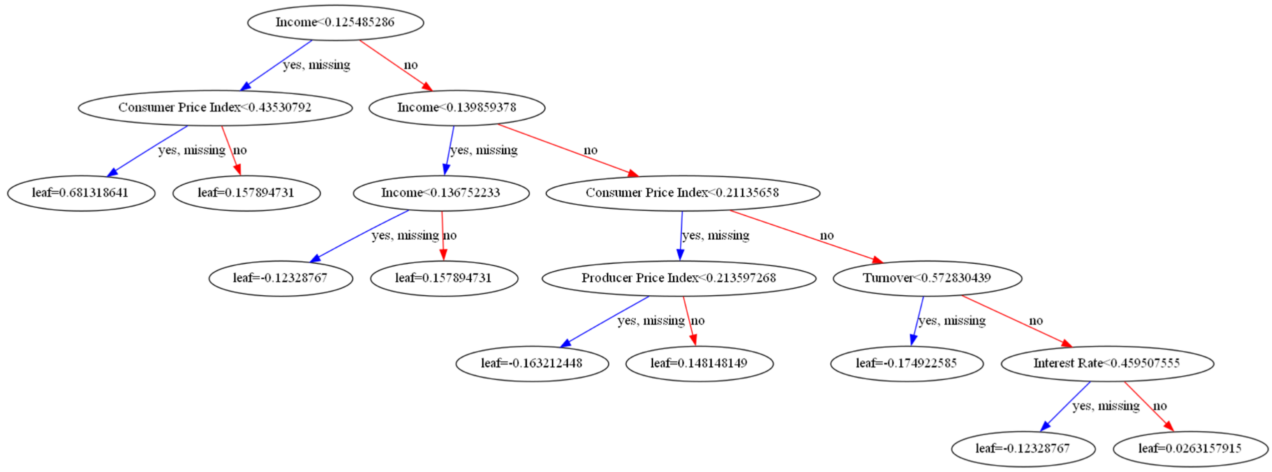

Figure 12. A sample boosting tree for Macroeconomic – Construction Balance of Payments Model

Figure 13. A sample Feature Importance vector for Construction Balance of Payments Model

The for Construction Balance of Payments Model $Y_{\text{Balance}} \cong Y_{\text{Turnover}}$ by using input and output parameters given above represented as x_i and the weights β_i both $Y_{\text{Balance}} = \beta_0 + \sum_{i=1}^{n} \beta_i . x_i$ and $Y_{\text{Turnover}} = \beta_0 + \sum_{i=1}^{n} \beta_i . x_i$ models can be obtained using boosting model. The bidirectional relations given in below Table 3 represents β_i. The upper triangular matrix gives β_i the weights of $Y_{\text{Balance}} \rightarrow Y_{\text{Turnover}}$ and lower triangular matrix gives β_i the weights of $Y_{\text{Balance}} \leftarrow Y_{\text{Turnover}}$ respectively.

	Interest Rate	Bist100 Trading Volume	Consumer Price Index	Exchange Rates Usd	Exchange Rates Eur	Petroleum	Producer Price Index	Employment	Turnover	Construction Balance	Income	Construction Employment
Interest Rate	1.00	0.07	0.06	0.08	0.04	0.08	0.10	0.05	0.05	0.05	0.08	0.05
Bist100 Trading Volume	0.08	1.00	0.06	0.07	0.08	0.09	0.08	0.07	0.07	0.03	0.05	0.04
Consumer Price Index	0.12	0.08	1.00	0.10	0.06	0.10	0.14	0.11	0.13	0.06	0.04	0.08
Exchange Rates Usd	0.12	0.08	0.07	1.00	0.23	0.07	0.11	0.06	0.07	0.05	0.03	0.06
Exchange Rates Eur	0.07	0.09	0.07	0.23	1.00	0.09	0.09	0.06	0.06	0.04	0.06	0.05
Petroleum	0.08	0.09	0.07	0.09	0.07	1.00	0.10	0.07	0.07	0.05	0.04	0.04
Producer Price Index	0.08	0.09	0.15	0.09	0.07	0.09	1.00	0.06	0.05	0.05	0.03	0.08
Employment	0.08	0.09	0.08	0.07	0.06	0.08	0.08	1.00	0.07	0.05	0.06	0.19
Turnover	0.09	0.11	0.11	0.08	0.08	0.11	0.09	0.13	1.00	0.07	0.06	0.18
Construction Balance	0.07	0.08	0.08	0.05	0.08	0.09	0.05	0.05	0.12	1.00	0.48	0.10
Income	0.09	0.08	0.05	0.07	0.10	0.09	0.07	0.10	0.06	0.47	1.00	0.13
Construction Employment	0.10	0.13	0.20	0.07	0.13	0.11	0.08	0.25	0.26	0.09	0.07	1.00

Figure 14. Bidirectional Macroeconomic – Construction Balance of Payments Model weights

3. Results

In a free market economy, building supply and demand are interdependent and serve as the primary determinants of one another. This relationship is confirmed through this study, with a bidirectional correlation between building supply and demand being the most significant parameter (28-29%). Energy is a crucial input for developing countries to achieve their economic growth targets. However, non-renewable energy sources constitute a significant portion of the energy mix. As such, the relationship between building supply and demand and oil prices is noteworthy. Given that oil is a primary raw material in building construction and the production of building materials, there exists a strong correlation between these variables.

In Türkiye, the relationship between building supply and demand and the exchange rate in the construction sector is significant. When considering the factors that influence construction prices, companies often opt to price housing in Euros. Per se, a 12% correlation was found between building supply and the Euro exchange rate. Similarly, an 11% correlation was found between building demand and the Euro exchange rate. This is primarily attributed to expatriate citizens residing in EU member countries seeking to purchase housing in their home countries. In the income and employment model, analogous to the supply and demand model, the relationship between the Euro and construction income is a notable parameter. Given that construction income prices are denominated in Euros, fluctuations in the Euro exchange rate directly impact income.

A positive and upward trend in the BIST 100 index positively impacts building supply and demand. This is due to increased participation from foreign investors in the stock market, which bolsters confidence in the country's economy and stimulates additional investments and demand in the housing sector. Analysis confirms this relationship, with an 11% correlation between building supply and the BIST 100 index and a 12% correlation between building demand and the BIST 100 index. Furthermore, an increase in building supply is known to drive up labor demand. In this context, similar to the BIST 100 results, an increase in building supply positively affects employment (11%) and reduces unemployment. As with the supply and demand model, the BIST 100 index is influential in the income and employment model (10%). As previously stated, developments in the BIST 100 index positively affect construction income and employment.

A 10% correlation has been observed between building demand and the producer price index (PPI). An increase in housing demand is expected to drive up the housing stock, leading to increased demand and prices for building materials, thereby affecting the PPI. In another model, the income and employment model, a 15% correlation was determined between the consumer price index (CPI) and employment. As such, an increase in the CPI will drive up construction prices, which in turn will impact employment through an increase in building supply.

In the income and employment model, interest rates and costs are influential factors. Fluctuations in interest rates directly impact both construction income (10%) and employment (10%), as changes in interest rates are considered the most significant development in both the establishment and sale of buildings. Decreases in interest rates, a key economic indicator, stimulate housing demand and subsequently increase housing supply. Conversely, rising costs lead to a decrease in income (17%) and a corresponding decrease in employment (9%). The inverse of this relationship is also theoretically valid.

In the income and employment model, the income-expenditure balance is the most influential parameter (42%) affecting construction income. Turnover is the most significant parameter (18%) impacting employment. Based on these results, a Construction Balance model was estimated. Analysis revealed that Income (48%), Turnover (12%), Euro, BIST and CPI (8%), Oil prices (9%), and Interest rates (7%) are all correlated with construction balance. The strong relationship between the balance of payments and construction income is expected. The relationship between economic outcomes and parameters expressed in previous models was also found to be valid within this model.

4. Discussion and Conclusions

This paper discusses the bi-directional interactions between economic indicators and the Turkish construction industry that shapes the economic landscape of a country and has a substantial impact on economies through jobs and GDP. The paper developed nonlinear macroeconomic models and data from the Turkish Statistical Institute to analyze the relationship between the construction industry and the economy. The study focuses on three main categories: demand and output, employment and income, and balance of payments. The proposed model is using a machine learning technique called gradient boosting. Gradient boosting is a nonlinear method that builds an ensemble of weak models in a stage-wise manner and allows for the optimization of any differentiable loss function. The advantage of using a nonlinear method is that it can capture complex and nonlinear relationships between the variables, which may not be possible with linear methods. The paper also uses sensitivity analysis to determine the priority vector of the model, which represents the relative importance of each variable in the model. This helps to quantify and measure the bi-directional relations between the economic indicators and the construction sector. The results show correlations between various economic indicators and the construction industry. Some key findings of the study are also discussed in details such as interest rates, exchange rates, oil prices, BIST 100 index, CPI, PPI, and the construction industry in terms of supply and demand, income, employment, balance of payments, and price levels.

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