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# An application of neural networks in microeconomics: Input–output mapping in a power generation subsector of the US electricity industry

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**Abstract**

The use of the artificial neural networks in economics and business goes back to 1950s, while the major bulk of the applications have been developed in more recent years. Reviewing this literature indicates that the field of business benefits from the neural networks in a wide spectrum from prediction to classification, as most of the applications in economics primarily focus on the predictive power of the neural networks. Time series analysis and forecasting, econometrics, macroeconomics constitute the main areas of economics, where there is an increasing interest in application of neural networks. Although their promising contributions to the area of microeconomics, the applications of neural networks in this area are limited in number. This study provides a microeconomic application of an artificial neural network by input–output mapping for 82 US major investor-owned electric utilities using fossil-fuel fired steam electric power generation for the year 1996. We construct a multilayer feed-forward neural network (MFNN) with back-propagation to represent the relationship between a set of inputs and an electricity production as an output. The network is trained and tested by using approximately 80 percent and 20 percent of the data, respectively. The network is trained with 97% accuracy and performance of the network in testing is 96%. Therefore, this network can be used in calculating electricity output for the given inputs in this subsector of the US electricity market, and these estimations can be employed in policy design and planning.


*Keywords:* Microeconomics; Input–output mapping; Electricity industry; Multilayer feedforward neural networks

## 1. Introduction

The applications of neural networks in business and economics have been increasing for the last decades. Within this literature, the studies are mostly concentrating on business-related problems. Wong, Bodnovich, and Selvi (1997) reviewed 213 journal articles in business from 1988 to 1995 and classified them into the following fields: accounting/auditing, finance, human resources, information systems, marketing/distribution, production/operations, and others. Among the reviewed articles, production/operations and finance were the top two fields in which the neural networks are used as application tools, with the shares of 25.4% and 53.5%, respectively. Neural networks were compared with the traditional methods in related fields in 38.5% of the 213 studies. Similar to Wong et al. (1997), a more updated rather concentrated literature review was provided by Vellido, Lisboa, and Vaughan (1999) on the applications of neural networks in business between 1992 and 1998. The study reviewed research related to management, marketing and decision making finding a particular interest in financial forecasting and planning since the early 1990s and the application of neural networks in these fields

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were relatively large in number. Consequently, surveys find strong evidence that there has been a significant effort to use neural networks in mathematical forecasting and time-series prediction.

While the applications in various fields entail the use of prediction, estimation and classification power of the neural networks, most of the applications in economics focus on prediction power. Time series modeling and forecasting, non-parametric estimation, learning by economic agents, finance, macroeconomics and econometrics are some of the areas in economics studying the possible uses and associated benefits of neural networks. Noting considerable interest in application of neural networks in economics particularly in financial statistics and exchange rates, Kuan and Liu (1995) used feed-forward and recurrent neural networks to investigate nonlinear patterns in exchange rates and test the performance of the selected networks in forecasting. In another area addressing economic prediction, Tkacz (2001) employed neural networks to determine more accurate leading indicator models of Canadian output growth by analyzing the forecast performance of multivariate neural networks and finding that there are gains in the short-run forecast accuracy of the neural networks in comparison to the best linear model due to the neural networks' ability to capture non-linear relationships in the data. Heravi, Osborn, and Birchenhall (2004) used neural networks and linear models to forecast seasonally unadjusted monthly real industrial production data of important sectors of German, French and UK economies. They compared the forecast performance of the neural networks with linear models and found that while linear models outperform the neural networks up to a year forecasts, the neural networks perform better than the linear models in predicting the direction of change. Nakamura (2005) assessed the usefulness of neural networks in inflation forecasting and found that the neural networks outperform univariate autoregressive models in predicting short-horizon of one and two quarters inflation rates.

In the light of the literature review of the recent publications, there are a relatively small number of applications of neural networks in economics (relative to business), mostly in macroeconomic forecasting, econometrics and time series analyses, and there is still a lack of both theoretical and empirical studies in microeconomic applications. There are few applications of neural networks in microeconomics. Hippert, Bunn, and Souza (2005) used neural networks in forecasting electricity load profile. In comparison to conventional regression-based models, the authors find that the large neural networks perform well. Another interesting application of neural networks is in forecasting of employment at regional level (Longhi, Nijkamp, Reggianni, & Maierhoffer, 2005). Longhi et al. compared neural networks with commonly used methods in panel data analysis. Santin, Delgado, and Valino (2004) reviewed the application of the neural networks in measuring the technical efficiency and compare traditional approaches, econometric models and non-parametric methods with neural networks. Upon comparing traditional methods in efficiency analysis, parametric and non-parametric techniques, with neural networks, they found that the neural networks are possible alternatives to the existing tools in measuring technical efficiency. Similarly, Delgado (2005) employed the neural networks for efficiency analysis in public sector, refuse collection services, and found that it was useful to employ the neural networks as complementary tools in efficiency analysis. In addition to the aforementioned studies, the neural networks are employed in few other areas such as productivity analysis (Boussabaine & Duff, 1996), identifying market structures (Gruca & Klemz, 1998), and estimating marketing margins (Mainland, 1998). As these studies indicate, the neural networks can be useful tools in mapping and estimation problems in microeconomics.

### 1.1. Estimating relationships in economics

In the theory and practice of econometrics, the model, the method and the data are interdependent associations in both information recovery and inference. How to develop "reasonable" quantification of economic relationships is the challenge facing the applied business and economic analysts. Oftentimes, the economic analysts are dealing with a non-experimental data generation process and the models that are used involve forces that are unobserved and even not capable of direct observation.[2] Classical econometric approaches pose a parametric form, $y = X\beta$, where the covariates $X$ determine the level of $y$ which is measured noisily, with $\beta$ being the unknown weights to be determined. To account for the indirect measurements and forces that are not measured, a noise component, $\varepsilon$, is appended linearly. The probabilistic structure of $\varepsilon$ is a critical focal point in econometric specification and estimation (Greene, 2007). This classical approach to generalizing estimates of the unknown parameters $\beta$ focus on the statistical inference of the estimated parameters.

When there is not enough information contained in the covariates, $X$, and the noisy data $y$ to permit recovery of estimates of $\beta$ by classical regression techniques, the model is said to be ill-posed and maximum entropy methods emerge as an alternative. Ill-posed problems may arise when the number of unknown parameters exceeds the number of data points. In this case, traditional estimation methods cannot be used unless restrictions on a sufficient number of parameters are imposed so that the remaining ones can be estimated (Golan, Judge, & Miller, 1996). However, these restrictions may lead to erroneous interpretations and conclusions. The maximum entropy (ME) formalism reveals a powerful tool that provides the "best" conclusions possible based on the data at hand (Golan et al., 1996). When one knows little about the functional

[2] For example, we can observe inputs and outputs, but we cannot observe managerial ability which surely impacts the technical efficiency of production.