Research on the Evaluation and Decision-Making of Product Premium Based on Electroencephalography (EEG) Testing Technology

Xiaheng Zhang

ABSTRACT

This paper aims to investigate the evaluation and decision-making of product premium based on actual materials of product premium in the market. To this end, the management economics was integrated with neuroscience to create an evaluation and decision-making model. Then, the model was applied to examine the evaluation and decision-making of product premium based on the electroencephalography (EEG) testing technology. A total of four premium stimulants were selected for the analysis, namely beverage, food, garment and home appliance. Through the behavior data and EEG data of the recipients, it is concluded that the well-known and little-known products shared a similar linear relationship between the LPW amplitude induced by the initial stimulant and the target stimulant; the premium of beverage products was evaluated much faster than that of food and garment; there is a significant linear relationship between the acceptance rate and response time in product premium similarity evaluation. The research findings shed new light on the evaluation and decision-making product premium.

Key Words: Decision-making Neurology, Product Premium, Management Economics, Electroencephalography (EEG) Testing

DOI Number: 10.14704/nq.2018.16.3.1199 **NeuroQuantology 2018; 16(3):68-74**

Introduction

The "product" is an ancient and time-honored theme in market research. The concept of "product premium" can also be traced far back in time. It is essentially the twin of product exchange (Hagsten, 2015). Classical economists attribute product premium to the imperfect market competition. In their view, the supply-demand balance of a market is undermined when one or more enterprises monopolize the supply end. To reap more profits, the monopolies must set a higher price than that in a perfect competitive market. The extra price is what is defined as the product premium (Zhang *et al.*, 2014; Rogers *et al*., 2016). Information scientists, however, consider the product premium as the result of incomplete market information, that is, information asymmetry between market players. Under information asymmetry, the consumer knows little about the actual quality of a product, and judges the quality solely based on price (Daly *et al*., 2013; Di Natale *et al*., 2016; Du *et al.,* 2015; Malara *et al*., 2016; Student *et al.,* 2017; Inţă and Muntean, 2015). In addition, many other causes of the product premium have been given by welfare economists and psycho-economists (Ponnampalam *et al*., 2017; Mollick *et al*., 2013). Whatever the cause, the product premium

Corresponding author: Xiaheng Zhang
Address: Business School, Northwest University of Political Science and Law, Xi'an 710122, China
e-mail ✉ zhangxiaheng@163.com
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 01 February 2018; **Accepted:** 25 February 2018

provides an incentive for enterprises to sell consistent and high-quality products, and has been willingly accepted by the consumer (Powell and Wagner, 2014). There are three major influencing factors of the product premium: the buyer, the seller and the market (Powell and Wagner, 2014). The effect of these factors is demonstrated as product quality, control standard, the buyer's emphasis on quality, the seller's investment on brand, and the seller's monopoly power (Tienhaara *et al*., 2015). Over the years, various paradigms have been created for the research into product premium. Concerning the market behavior and performance of product premium, the research focus has shifted from qualitative analysis to quantitative research based on economic data (Nuijten, 2016). From the perspective of neuroscience, the neuroscience research into consumer decision-making based on the economic behavior of product premium is still in the initial stage (Sharma *et al*., 2015).

In view of the above, this paper attempts to investigate the evaluation and decision-making of product premium based on actual materials of product premium in the market and the electroencephalography (EEG) testing technology.

Neuroscience Theory of Consumer Decision-Making on Product Premium Behavior

Decision neuroscience and consumer decision-making

Decision-making is the centerpiece of management science. In both management science and economics, the decision-making divided into enterprise decision-making and individual decision-making for actual practice (Olesen *et al*., 2011; Ren, 2009; Zaccone *et al*., 2017). The former aims to minimize the cost and maximize the profit, while the latter evolves with the behavioral and economic theories. With the recent rapid development of behavioral economics, the cognitive science and psychology have been introduced to the traditional decision-making process.

The consumer decision-making refers to the entire process from the conception of the idea of purchase to the completion of the purchase. The process is not a linear superposition of the various steps of the purchase (Mcginty *et al*., 2017). Traditionally, the consumer decision-making involves four distinctive starting points: economic view, passive view, cognitive view and emotional view. It is difficult to integrate all these views into the same decision-making model. Compared to such an all-inclusive model, the bounded rationality hypothesis based on behavioral decision-making is a desirable way to describe the real-world decision-making and selection behavior. Another viable tool is the subconscious decision-making model. By this model, the rationality of decision-making is guaranteed through presenting the current factors and future results or utilizing the perceptive experience of similar situations in the past without unconscious prejudice.

Classification theory and product premium evaluation

It is a common cognitive process to categorize the external information into known objects and concepts (Haque *et al.,* 2014). The categorization process can be explained by the classification theory. This theory is a type of cognitive theory based on the associative memory model. The classification is often carried out against such factors as product quality, product efficacy, advertisement, and so on. In general, each category contains a specific group of objects and features a certain kind of structure. Here, the classification theory is gradually improved to explain the exact process of emotional and attitude transfer during the evaluation and decision-making for product premium.

Previous research has shown that the interaction between the automatic and conscious processes of the brain is much more complex than the theoretical models (Bruno *et al*., 2015). The automatic evaluation is critical to the success of human evolution. It has long been integrated with the conscious evaluation to achieve the desired purpose. For example, the same stimulus will trigger both the automatic and conscious evaluations, and the evaluation results will be represented as implicit and explicit behaviors (Figure 1). Some scholars have predicted consumption behaviors through neurological simulation. The results show that the predicted product price is the same with the result of neurological imaging in the lost nerve circuit. When the consumer prefers a product, the nucleus accumbens septi in the brain will be activated; when he/she finds the premium too high (i.e. the product is too expensive), the insula area in the brain will be activated, while the medial prefrontal cortex will be suppressed/deactivated.

Figure 2 shows the theoretical and logical relationship of product premium evaluation and decision-making. It can be seen that the evaluation and decision-making process first follows the associative memory network theory and then the neuroscience theory. In the process, the consumer decision theory determines the extension attitude and decision-making. Figure 3 illustrates the natural property and artificial property of product. As shown in the figure, the success of the product premium hinges on whether the consumer perceives the consistency between the product and the price.

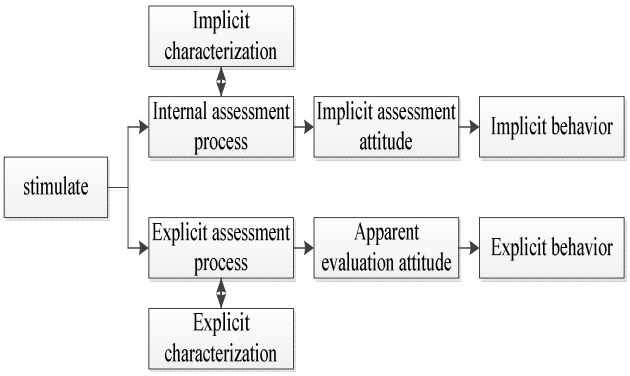

Figure 1. Automatic and conscious evaluations

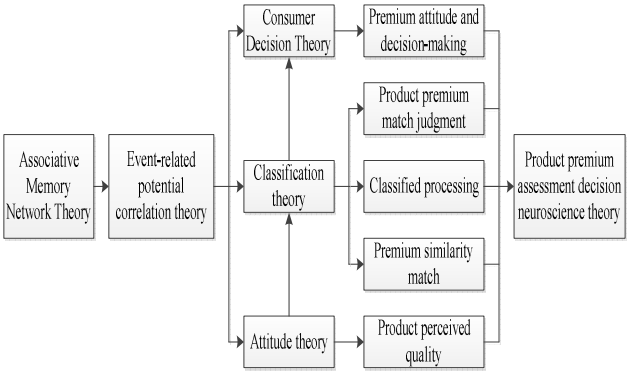

Figure 2. The theoretical and logical relationship of product premium evaluation and decision-making

Product Premium Evaluation and Decision-Making

Instruments and methodology

The EEG test took place in a sound-proof, magnetic-isolated and light-adjustable confined event-related potential (ERP)/behavioral lab. The test instrument is a NeurOne EEG/ERP system (Sampling frequency: 500Hz). The system consists of EEG signal amplifiers and EEG electrode caps (Ag/AgCl64). Two reference electrodes (zero potential) were placed on either side of the chest. In addition, two electrodes were arranged 10mm above and below the eyes, respectively, to measure the EEG signals vertical to the eyes, and another two were arranged 5mm outside each eye to capture the EEG signals horizontal to the eyes. To ensure the data quality and signal to noise ratio (SNR), the impedance of all electrodes was maintained below 5kΩ. The EEG data were recorded and analyzed in the process shown in Figure 4. The test recipients received visual stimuli from the computer screen, and their EEG signals were collected and superimposed into EEG waveform and topographic images via the amplifiers.

Four stimuli were selected for evaluating the similarity of product premiums, namely, beverage premium, food premium, garment premium and home appliance premium. During the test, each product and its price were presented in pictures for a duration of 1s. The pictures appeared at an interval of about 500ms. The EEG stimuli were recorded continuously, and the behavioral choices were made by the recipients.

Data analysis of product premium evaluation

During the test, the behavior data were recorded according to the keystrokes by the recipients. These data include the acceptance rate of product premium, and the response time of product premium. The former refers to the range of product premium accepted by the consumer, and the latter means the time needed for the consumer to make evaluation decisions. The length of the response time demonstrates the consumer's specific cognitive and emotional processing.

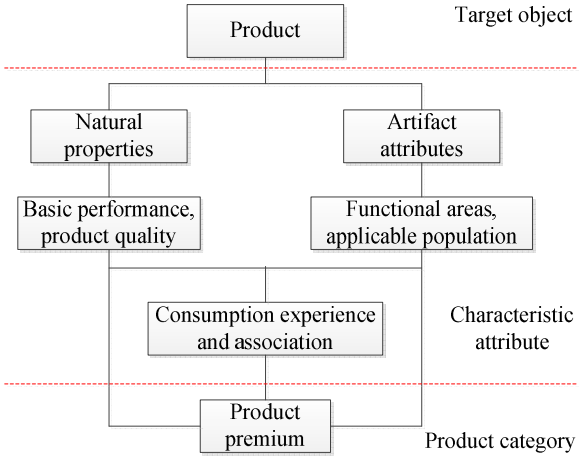

Figure 3. Natural property and artificial property of a product

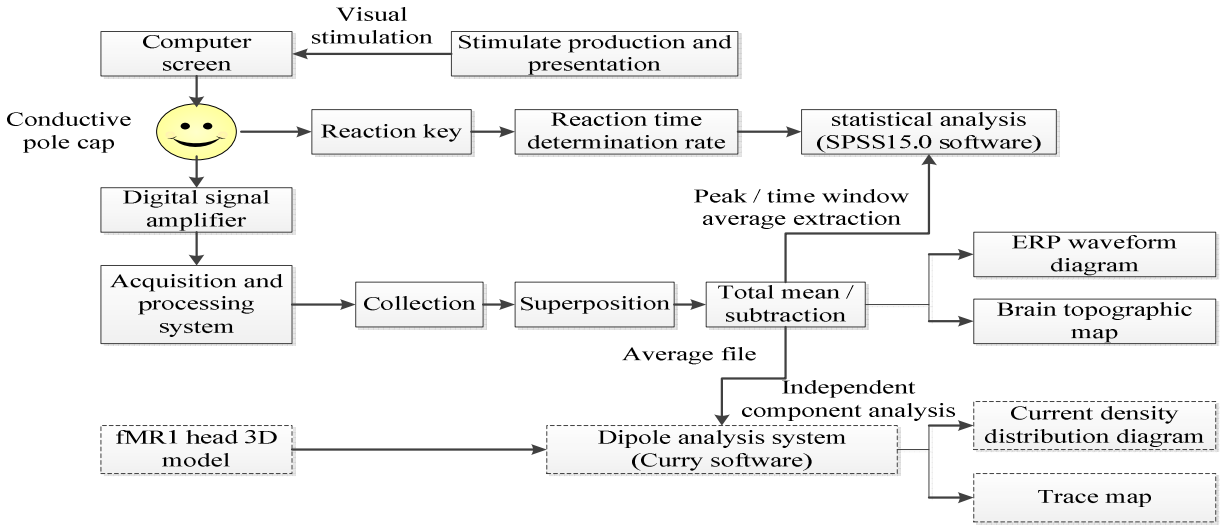

Figure 4. EEG data recording and analysis

Table 1. Behavior data under different product conditions

	Number of valid samples	Mean acceptance rate	Standard deviation of acceptance rate	Mean response time	Standard deviation of response time
Well-known product premium	50	0.1877	0.16899	809.5239	212.45482
Little-known product premium	50	0.2435	0.19384	874.8042	237.07162

Table 1 lists the behavior data of the recipients facing product premium of well-known product and little-known product. It is clear that the product premium of well-known product had a lower acceptance rate and a shorter response time than that of little-known product. In other words, it took a longer time for the consumer to make a decision about the little-known product.

Figure 5 shows the correlation potential waveforms of well-known and little-known products at three electrodes (CP3, P3 and PO3). It can be seen that the well-known product exhibited an obvious late positive wave (LPW) in 300ms~600ms. By contrast, the same wave only appeared near the occipital region for the little-known product; the wave moved to the negative direction with the decrease in the distance to the forebrain; unlike the well-known product, obvious negative potential was observed in the little-known product.

The linear relationship between the amplitude of the LPWs induced by the product name (initial stimulant) and the product premium (target stimulant). It is learned that the well-known and little-known products shared a similar linear relationship between the LPW amplitude induced by the initial stimulant and the target stimulant. Overall, whenever the initial stimulant created a large LPW amplitude, the target stimulant will induce a big LPW.

Product Premium Similarity Evaluation

Behavior data analysis

The behavior data under similar product premiums were also analyzed based on the recipients' behavior record, and also from the dimensions of acceptance rate and response time. According to the data in Table 2, the beverage premium had the highest average acceptance rate and the shortest response time. This means the recipients made a rapid evaluation of the premium of beverage products. The slow evaluation of the premium of food and garment indicates these two types of products are heavily influenced by market monopoly.

Figure 7 depicts the linear relationship between the response time and the acceptance rate under similar product premiums. It is observed that the correlation coefficient between the response time and the acceptance rate was $\gamma=0.500$, $P=0.041<0.05$ for beverage products, $\gamma=0.519$, $P=0.033<0.05$ for food products, $\gamma=0.846$, $P=0.00<0.05$ for garments, and $\gamma=0.502$, $P=0.04<0.05$ for home appliances. Hence, there is a significant linear correlation between the acceptance rate and the response time in the premium evaluation of the four types of products.

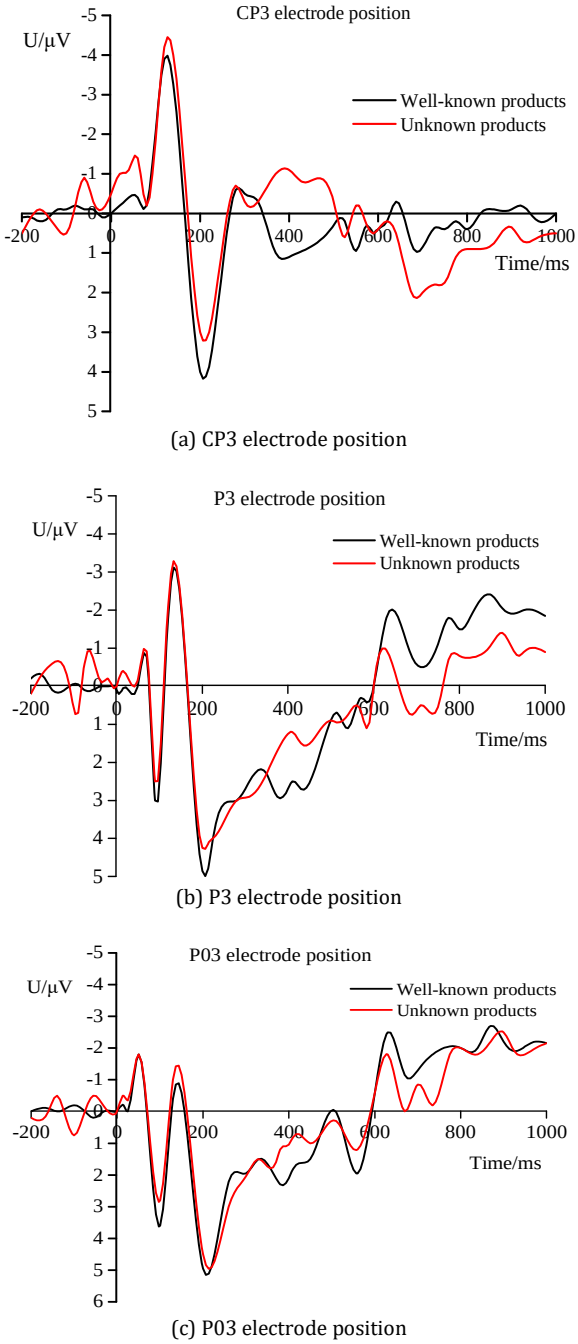

Figure 5. ERP waveform of well-known products and little-known products of the left electrode

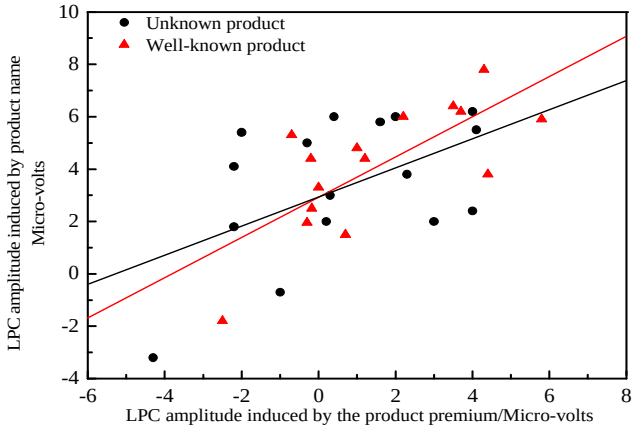

Figure 6. The linear relationship between the amplitude of the LPWs induced by the product name (initial stimulant) and the product premium (target stimulant)

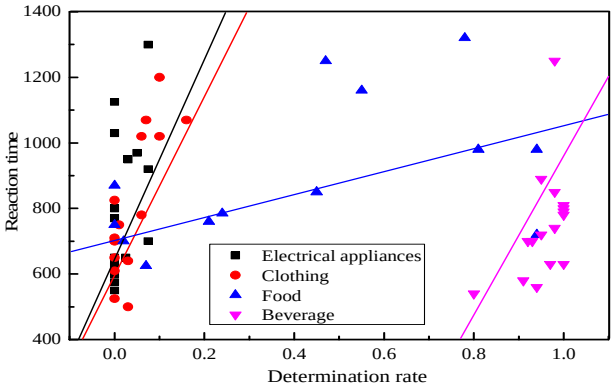

Figure 7. The linear relationship between the response time and the acceptance rate under similar product premiums

EEG data analysis

The EEG data were tested in the same procedure as above. The EEG signals recorded from the 200ms before stimulation to 1,000ms after stimulation were divided into different segments. With the EEG data in the stimulant-free 200ms as the baseline, the EEG segments were subject to mean superposition according to the similarity between different products. After that, the EEG-related potentials were filtered by a low pass filter at 30 Hz. When the stimulant appeared, a significant potential band was recorded by the test instrument.

Table 2. Behavioral data under similar product premiums

	Number of valid samples	Mean acceptance rate	Standard deviation of acceptance rate	Mean response time	Standard deviation of response time
Beverage premium	50	0.9506	0.04087	752.6603	170.31920
Food premium	50	0.3743	0.37638	840.0430	208.07121
Garment premium	50	0.0415	0.06651	820.8410	244.60537
Home appliance premium	50	0.0218	0.03618	776.0454	216.07063

Figure 8 shows the waveforms of the central region potentials under the premium similarity of different products. It is evident that, after 200ms, the maximum negative potential appeared at 270ms. This occurred to all four types of products. Hence, the stable EEG component was

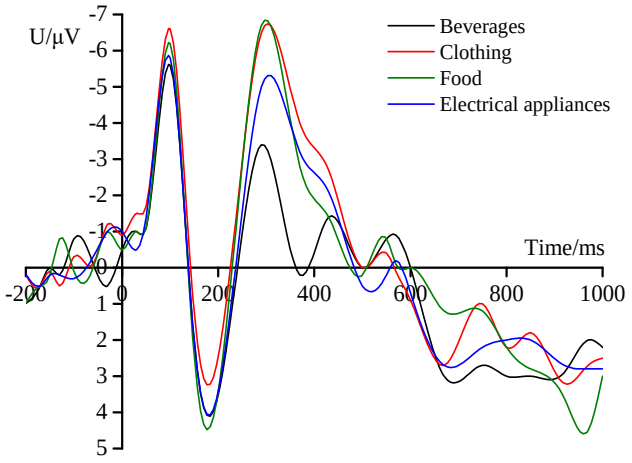

Figure 8. Central region ERP waveforms under similar product premiums

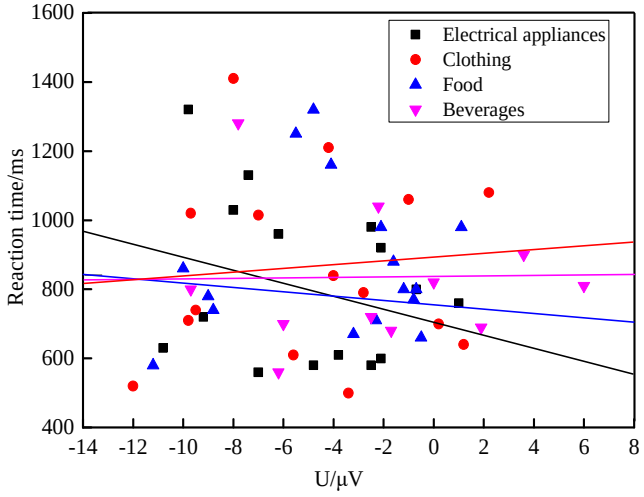

Figure 9. Linear relationship between amplitude and response time at 270ms under the premium similarity of different products

named 270ms negative wave. Figure 9 gives the linear relationship between amplitude and response time at 270ms under the premium similarity of different products. It can be seen that the four types of products exhibited significant correlations between the difference wave and the response time difference at 270ms. In summary, the EEG test reveals the significant linear relationship between the acceptance rate and response time in product premium similarity evaluation.

Conclusions

Inspired by decision neuroscience, this paper applies the EEG testing technology in the evaluation and decision-making of product premium. Through the analysis of the behavioral data and EEG data, the following conclusions were drawn:

(1) The predicted product price is the same with the result of neurological imaging in the lost nerve circuit. the success of the product premium hinges on whether the consumer perceives the consistency between the product and the price.
(2) The well-known and little-known products shared a similar linear relationship between the LPW amplitude induced by the initial stimulant and the target stimulant. Overall, whenever the initial stimulant created a large LPW amplitude, the target stimulant will induce a big LPW.
(3) There is a significant linear relationship between the acceptance rate and response time in product premium similarity evaluation. The four types of products exhibited significant correlations between the difference wave and the response time difference at 270ms.

Acknowledgement

Supported by the special research program of Shaanxi provincial department of education of the “Operational Mechanism and Implementation Path of E-commerce in Rural Areas under the Precision Poverty Reduction Strategy” (17JK0795).

References

Bruno RL, Douarin E, Korosteleva J, Radosevic S. Technology choices and growth: testing new structural economics in transition economies. Journal of Economic Policy Reform 2015; 18(2): 131-52.
Daly I, Sweeney-Reed CM, Nasuto SJ. Testing for significance of phase synchronisation dynamics in the EEG. Journal of Computational Neuroscience 2013; 34(3): 411-32.
Di Natale F, Carotenuto C, Manna L, Esposito M, La Motta F, D'addio L, Lancia A. Water electrified sprays for emission control in energy production processes. International Journal of Heat and Technology 2016; 34(Special Issue 2): S597-602.
Du Y, Chen Q, Mao N. The research of varıable productıon lıne ınto multı-channel. Academic Journal of Manufacturing Engineering 2015; 13(4): 6-12.
Hagsten MFE. Exporter productivity premium for european smes. Applied Economics Letters 2015;22(12):930-33.
Haque M, Biermacher JT, Kering MK, Guretzky JA. Economic evaluation of switchgrass feedstock production systems tested in potassium-deficient soils. Bioenergy Research 2014;7(1):260-67.
Inţă M, Muntean A. Application of lean principles to optimize production. case study- connectors department of the

harting company, Academic Journal of Manufacturing Engineering 2015; 13(2):42-47.

Malara A, Marino C, Nucara A, Pietrafesa M, Scopelliti F, Streva G. Energetic and economic analysis of shading effects on PV panels energy production, International Journal of Heat and Technology 2016; 34(3): 465-72.

Mcginty R, Bianchi G, Zaher O, Woolass S, Oliver D, Williams C. Techno-economic survey and design of a pilot test rig for a trilateral flash cycle system in a steel production plant. Energy Procedia 2017;123:281-88.

Mollick AV, Ibarra-Salazar J. Productivity effects on the wage premium of mexican maquiladoras. Economic Development Quarterly 2013;27(3):208-20.

Nuijten M. Valuation of healthcare innovation: a decision analytic valuation model for the assessment of the economic value of an innovative medicinal product. Journal of Biotechnology 2016; 231: S13-S13.

Olesen SS, Graversen C, Hansen TM, Blauenfeldt RA, Hansen JB, Steimle K. Spectral and dynamic electroencephalogram abnormalities are correlated to psychometric test performance in hepatic encephalopathy. Scandinavian Journal of Gastroenterology 2011; 46(7-8): 988-96.

Ponnampalam EN, Linden NP, Mitchell ML, Hopkins DL, Jacobs JL. Production systems to deliver premium grade lambs to the growing international and australian markets. Small Ruminant Research 2017;157:32-39.

Powell D, Wagner J. The exporter productivity premium along the productivity distribution: evidence from quantile regression with nonadditive firm fixed effects. Review of World Economics 2014; 150(4):763-85.

Pozharliev R, Verbeke WJMI, Strien JWV, Bagozzi RP. Merely being with you increases my attention to luxury products: using eeg to understand consumers' emotional experience of luxury branded products. Journal of Marketing Research 2015; 52(4): 546-58.

Ren YL. Electroencephalogram recognition of imaginary right and left hand movements by brain-computer interface. Journal of Clinical Rehabilitative Tissue Engineering Research 2009; 13(17): 3370-74.

Rogers JM, Johnstone SJ, Aminov A, Donnelly J, Wilson PH. Test-retest reliability of a single-channel, wireless eeg system. International Journal of Psychophysiology Official 2016; 106:87-96.

Sharma R, Pachori RB, Acharya UR. An integrated index for the identification of focal electroencephalogram signals using discrete wavelet transform and entropy measures. Entropy 2015; 17(8): 5218-40.

Student TKPSR, Sriraam N. Comparison of t-test ranking with pca and sepcor feature selection for wake and stage 1 sleep pattern recognition in multichannel electroencephalograms. Biomedical Signal Processing & Control 2017; 31: 499-512.

Tienhaara A, Ahtiainen H, Pouta E. Consumer and citizen roles and motives in the valuation of agricultural genetic resources in finland. Ecological Economics 2015;114:1-10.

Zaccone R, Sacile R, Fossa M. Energy modelling and decision support algorithm for the exploitation of biomass resources in industrial districts, International Journal of Heat and Technology 2017; 35(S1): S322-S29.

Zhang P, Su Q, Li C, Wang T. An economically designed sequential probability ratio test control chart for short-run production. Computers & Industrial Engineering 2014; 78(C):74-83.