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CONTENTS

Sr. No.	TITLE & NAME OF THE AUTHOR (S)	Page No.
1.	**THE EXTENT OF THE IMPORTANCE OF PERSONALITY INDICATORS OF INDEPENDENT ENTREPRENEUR THROUGH USING GROUP ANALYTICAL HIERARCHY PROCESS** *MOJGAN RIAZI, DR. YOUNOS VAKIL ALROAIA & DR. ALI AKBAR AMIN BIDOKHTI*	1
2.	**ASSOCIATION OF TRAINING PRACTICES WITH JOB SATISFACTION IN PUBLIC SECTOR ORGANIZATIONS** *RIZWAN BASHIR & FARZANA BASHIR*	8
3.	**STUDYING THE RELATIONSHIP BETWEEN SOCIAL CAPITAL AND TALENT MANAGEMENT IN IRAN STATE MANAGEMENT TRAINING CENTER (SMTC)** *SAYED ALI AKBAR AHMADI, MOHAMMAD ALI SARLAK, MUSA MAHDAVI, MOHAMMAD REZA DARAEI & SAMIRA GHANIABADI*	14
4.	**CONTEMPLATIVE SCRUTINY OF THE ADEQUACY OF HERZBERG'S MOTIVATION-HYGIENE THEORY: A VERDICT OF JOB SATISFACTION IN THE MID LEVEL MANAGER IN TELECOMMUNICATION INDUSTRY** *ABU ZAFAR AHMED MUKUL, SHAH JOHIR RAYHAN & MD. SHAKIB HOSSAIN*	21
5.	**PLANNING AND MANAGING A SCHEDULED SERVICE** *DR. IGNATIUS A. NWOKORO*	29
6.	**REAL INCOME, INFLATION, AND INDUSTRIAL PRODUCTIVITY IN NIGERIA (1970-2005)** *Dr. OWOLABI A. USMAN & ADEGBITE TAJUDEEN ADEJARE*	34
7.	**DEVELOPMENT OF SMALL AND MEDIUM ENTERPRISES IN NIGERIA: A PARADIGM SHIFT** *ADEYEMI, A. ADEKUNLE*	40
8.	**THE EVALUATION OF KNOWLEDGE MANAGEMENT'S EFFECTIVENESS ON E-LEARNING: A CASE STUDY ON PAYAME NOOR UNIVERSITY OF IRAN** *BAHAREH SHAHRIARI & KIARASH JAHANPOUR*	45
9.	**THE RELATIONSHIP BETWEEN ORGANIZATIONAL CULTURE AND JOB SATISFACTION AMONG PROFESSIONAL STAFF IN VIETNAMESE CONSTRUCTION COMPANIES** *NGUYEN PHI TAN*	49
10.	**ANALYSIS OF LIQUIDITY OF SELECTED PRIVATE SECTOR INDIAN BANKS** *SULTAN SINGH, SAHILA CHOUDHRY & MOHINA*	54
11.	**PRODUCTIVITY MEASUREMENT OF PUBLIC SECTORS BANKS IN INDIA** *DR. BHAVET, PRIYA JINDAL & DR. SAMBHAV GARG*	57
12.	**IMBIBE ETHICAL EDUCATION** *DR. T. SREE LATHA & SAVANAM CHANDRA SEKHAR*	63
13.	**MODELING INDIAN MONSOON (RAINFALL) VOLATILITY AS AN INDEX BASED RISK TRANSFER PRODUCT** *D P. SHIVKUMAR, M PRABHU & DR. G. KOTRESHWAR*	66
14.	**THE DEVELOPMENT OF SMALL SCALE INDUSTRIES IN MEGHALAYA** *MUSHTAQ MOHMAD SOFI & DR. HARSH VARDHAN JHAMB*	72
15.	**REGRESSION MODELS** *M.VENKATARAMANAIAH & M.SUDARSANA RAO*	83
16.	**EFFECTIVENESS OF EMPLOYEE RETENTION TECHNIQUES ADOPTED BY BPO COMPANIES WITH REFERENCE TO CHENNAI** *DR. RANJITHAM.D*	86
17.	**ROLE OF FOREIGN DIRECT INVESTMENT IN EDUCATION INSTITUTIONS IN INDIA** *SHABANA, SONIKA CHOUDHARY & DR. M. L. GUPTA*	91
18.	**AN EXAMINATION OF LONG-RUN AND SHORT-RUN RELATIONSHIP BETWEEN CRUDE OIL PRICE, GOLD PRICE, EXCHANGE RATE AND INDIAN STOCK MARKET** *R.KANAKARAJAMMAL, S.PAULRAJ & M.V.ARULALAN*	94
19.	**MYSTERY SHOPPING– THE MIRACLE TOOL IN BUSINESS RESEARCH** *SHAKEEL-UL-REHMAN & A.VELSAMY*	101
20.	**THE EMPIRICAL INVESTIGATION BETWEEN EMOTIONAL COMPETENCE AND WORK PERFORMANCE OF INDIAN SALES PEOPLE** *DR. RITIKA SHARMA*	104
21.	**MARKETING OF BRANDED PRODUCT IN RURAL AREA: A CONCEPTUAL BASED STUDY ON RURAL MARKET** *PANKAJ ARORA & AJITHA PRASHANT*	111
22.	**A STUDY ON EMPLOYEES JOB SATISFACTION WITH SPECIAL REFERENCE TO COACH FACTORY** *P.MANONMANI & V.UMA*	120
23.	**E-CRM APPLICATION IN INSURANCE SECTOR AND RETENTION OF CUSTOMERS** *DASH BISWAMOHAN. & MISHRA RADHAKRISHNA*	123
24.	**THE USAGE OF SIX SIGMA TOOLS IN BRINGING DOWN THE DEFECTS IN THE HR PROCESSES** *SREEJA K & MINTU THANKACHAN*	128
25.	**WOMEN EMERGING GLOBALLY AS THE POTENTIAL MARKET: REASONS, IMPLICATIONS AND ISSUES** *DR. JAYA PALIWAL*	136
26.	**URBAN RESIDENTIAL WATER SUPPLY IN GADAG TOWN IN KARNATAKA STATE** *DR. H H BHARADI*	140
27.	**TECHNICAL ANALYSIS: A TOOL TO MEASURE MARKET VOLATILITY** *G.B.SABARI RAJAN*	144
28.	**CO-BRANDED CREDIT CARD - A TAILOR-MADE PRODUCT NICHE FOR CONSUMERS** *DR. A. JESU KULANDAIRAJ*	150
29.	**A COMPARATIVE STUDY ON CUSTOMER SATISFACTION WITH SERVICE QUALITY IN PUBLIC AND PRIVATE SECTOR BANKS** *DR. SAMBHAV GARG, PRIYA JINDAL & DR. BHAVET*	153
30.	**EMOTIONAL INTELLIGENCE (EI): AN IMPERATIVE SKILL FOR MANAGERS IN THE GLOBAL WORKPLACE** *SMARTY MUKUNDAN*	157
	REQUEST FOR FEEDBACK	160

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   FINDINGS

   RECOMMENDATIONS/SUGGESTIONS

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REGRESSION MODELS

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ABSTRACT
In statistics, Regression model is possibly the most important step in the model building sequence. It is also one of the most overlooked Often the validation of a model seems to consist of nothing more than quoting the R^2 statistic from the fit (which measures the fraction of the total variability in the response that is accounted for by the model).

KEYWORD
regression models.

INTRODUCTION
Regression models are used to predict one variable from one or more other variables. Regression models provide the scientist with a powerful tool, allowing predictions about past, present, or future events to be made with information about past or present events. The scientist employs these models either because it is less expensive in terms of time and/or money to collect the information to make the predictions than to collect the information about the event itself, or, more likely, because the event to be predicted will occur in some future time. Before describing the details of the modeling process, however, some examples of the use of regression models will be presented.

PROCEDURE FOR CONSTRUCTION OF A REGRESSION MODEL
In order to construct a regression model, both the information which is going to be used to make the prediction and the information which is to be predicted must be obtained from a sample of objects or individuals. The relationship between the two pieces of information is then modeled with a linear transformation. Then in the future, only the first information is necessary, and the regression model is used to transform this information into the predicted. In other words, it is necessary to have information on both variables before the model can be constructed.

For example, the personnel officer of the widget manufacturing company might give all applicants a test and predict the number of widgets made per hour on the basis of the test score. In order to create a regression model, the personnel officer would first have to give the test to a sample of applicants and hire all of them. Later, when the number of widgets made per hour had stabilized, the personnel officer could create a prediction model to predict the widget production of future applicants. All future applicants would be given the test and hiring decisions would be based on test performance.

A notational scheme is now necessary to describe the procedure:

X_i is the variable used to predict, and is sometimes called the independent variable. In the case of the widget manufacturing example, it would be the test score.

Y_i is the observed value of the predicted variable, and is sometimes called the dependent variable. In the example, it would be the number of widgets produced per hour by that individual.

Y'_i is the predicted value of the dependent variable. In the example it would be the predicted number of widgets per hour by that individual.

The goal in the regression procedure is to create a model where the predicted and observed values of the variable to be predicted are as similar as possible. For example, in the widget manufacturing situation, it is desired that the predicted number of widgets made per hour be as similar to observed values as possible. The more similar these two values, the better the model. The next section presents a method of measuring the similarity of the predicted and observed values of the predicted variable.

LINEAR REGRESSION
In statistics, **linear regression** is an approach to modeling the relationship between a scalar dependent variable y and one or more explanatory variables denoted X. The case of one explanatory variable is called simple regression. More than one explanatory variable is multiple regression. (This in turn should be distinguished from multivariate linear regression, where multiple correlated dependent variables are predicted,[citation needed] rather than a single scalar variable.)

In linear regression, data is modelled using linear predictor functions, and unknown model parameters are estimated from the data. Such models are called linear models. Most commonly, linear regression refers to a model in which the conditional mean of y given the value of X is an affine function of X. Less commonly, linear regression could refer to a model in which the median, or some other quantile of the conditional distribution of y given X is expressed as a linear function of X. Like all forms of regression analysis, linear regression focuses on the conditional probability distribution of y given X, rather than on the joint probability distribution of y and X, which is the domain of multivariate analysis.

Linear regression was the first type of regression analysis to be studied rigorously, and to be used extensively in practical applications. This is because models which depend linearly on their unknown parameters are easier to fit than models which are non-linearly related to their parameters and because the statistical properties of the resulting estimators are easier to determine.

Linear regression has many practical uses. Most applications of linear regression fall into one of the following two broad categories:

- If the goal is prediction, or forecasting, linear regression can be used to fit a predictive model to an observed data set of y and X values. After developing such a model, if an additional value of X is then given without its accompanying value of y, the fitted model can be used to make a prediction of the value of y.
- Given a variable y and a number of variables $X_1, ..., X_p$ that may be related to y, linear regression analysis can be applied to quantify the strength of the relationship between y and the X_j, to assess which X_j may have no relationship with y at all, and to identify which subsets of the X_j contain redundant information about y.

Linear regression models are often fitted using the least squares approach, but they may also be fitted in other ways, such as by minimizing the “lack of fit” in some other norm (as with least absolute deviations regression), or by minimizing a penalized version of the least squares loss function as in ridge regression.

Conversely, the least squares approach can be used to fit models that are not linear models. Thus, while the terms "least squares" and "linear model" are closely linked, they are not synonymous.

SIMPLE AND MULTIPLE REGRESSION

The very simplest case of a single scalar predictor variable x and a single scalar response variable y is known as simple linear regression. The extension to multiple and/or vector-valued predictor variables (denoted with a capital X) is known as multiple linear regression. Nearly all real-world regression models involve multiple predictors, and basic descriptions of linear regression are often phrased in terms of the multiple regression model. Note, however, that in these cases the response variable y is still a scalar.

GENERAL LINEAR MODELS

The general linear model considers the situation when the response variable Y is not a scalar but a vector. Conditional linearity of $E(y|x) = Bx$ is still assumed, with a matrix B replacing the vector β of the classical linear regression model. Multivariate analogues of OLS and GLS have been developed.

HETEROSKEDASTIC MODELS

Various models have been created that allow for heteroskedasticity, i.e. the errors for different response variables may have different variances. For example, weighted least squares is a method for estimating linear regression models when the response variables may have different error variances, possibly with correlated errors. (See also Linear least squares (mathematics)#Weighted linear least squares, and generalized least squares.) Heteroscedasticity-consistent standard errors is an improved method for use with uncorrelated but potentially heteroskedastic errors.

GENERALIZED LINEAR MODELS

Generalized linear models (GLM's) are a framework for modeling a response variable y that is bounded or discrete. This is used, for example:

- when modeling positive quantities (e.g. prices or populations) that vary over a large scale — which are better described using a skewed distribution such as the log-normal distribution or Poisson distribution (although GLM's are not used for log-normal data, instead the response variable is simply transformed using the logarithm function);
- when modeling categorical data, such as the choice of a given candidate in an election (which is better described using a Bernoulli distribution/binomial distribution for binary choices, or a categorical distribution/multinomial distribution for multi-way choices), where there are a fixed number of choices that cannot be meaningfully ordered;
- when modeling ordinal data, e.g. ratings on a scale from 0 to 5, where the different outcomes can be ordered but where the quantity itself may not have any absolute meaning (e.g. a rating of 4 may not be "twice as good" in any objective sense as a rating of 2, but simply indicates that it is better than 2 or 3 but not as good as 5).

Generalized linear models allow for an arbitrary link function g that relates the mean of the response variable to the predictors, i.e. $E(y) = g(\beta'x)$. The link function is often related to the distribution of the response, and in particular it typically has the effect of transforming between the $(-\infty, \infty)$ range of the linear predictor and the range of the response variable.

Some common examples of GLM's are:

- Poisson regression for count data.
- Logistic regression and probit regression for binary data.
- Multinomial logistic regression and multinomial probit regression for categorical data.
- Ordered probit regression for ordinal data.

Single index models [clarification needed] allow some degree of nonlinearity in the relationship between x and y, while preserving the central role of the linear predictor β′x as in the classical linear regression model. Under certain conditions, simply applying OLS to data from a single-index model will consistently estimate β up to a proportionality constant.[6]

HIERARCHICAL LINEAR MODELS

Hierarchical linear models (or multilevel regression) organizes the data into a hierarchy of regressions, for example where A is regressed on B, and B is regressed on C. It is often used where the data have a natural hierarchical structure such as in educational statistics, where students are nested in classrooms, classrooms are nested in schools, and schools are nested in some administrative grouping such as a school district. The response variable might be a measure of student achievement such as a test score, and different covariates would be collected at the classroom, school, and school district levels.

ERRORS-IN-VARIABLES

Errors-in-variables models (or "measurement error models") extend the traditional linear regression model to allow the predictor variables X to be observed with error. This error causes standard estimators of β to become biased. Generally, the form of bias is an attenuation, meaning that the effects are biased toward zero.

OTHERS

- In Dumpster–Shafer theory, or a linear belief function in particular, a linear regression model may be represented as a partially swept matrix, which can be combined with similar matrices representing observations and other assumed normal distributions and state equations. The combination of swept or un swept matrices provides an alternative method for estimating linear regression models.

Evaluating Regression Models

i. *Good Models and "Explaining" Variance*
   - What do we mean when we say a model is "good" or "explains" the dependent variable?
     - Explanation exists in our theory, not in any data we might observe.
     - Thus "explained" variance cannot be measured with a statistic (or with data).
   - What do we mean when we say we have a "good model" of our data?
     - Changes in X have a large impact on changes in Y (That is, b is large)
     - Remaining error terms are small (That is, σ_u^2 is small)

ii. *A Composite Measure of Model Quality*
   - Developed an overall measure of these concepts that is insensitive to the scale measuring X & Y
     - Measure is based on fundamental goal of the OLS estimator – minimize squared errors.
     - Take the ratio of "Explained" Sum of Squares (ESS) to Total Sum of Squares (TSS)
   - This ratio is known as the "coefficient of determination" or R^2
     - R^2 is literally just the correlation between Y and Yhat, squared

$$R^2 = \frac{ESS}{TSS} = 1 - \frac{USS}{TSS}$$

iii. *What IS R^2 Really? The R^2 Stew*
   - Want a measure of model quality to compare across samples
     - Like correlation coefficients – R^2 cannot generalize
     - It depends on the variance of X and the variance of the errors

$$R^2 = \frac{ESS}{TSS} = \frac{ESS}{ESS + USS}$$

- R2 for bivariate regression can be written as:

$$R^2 = \frac{b^2 * \sigma_x^2}{b^2 * \sigma_x^2 + \sigma_u^2}$$

iv. *Don't Drink the R^2 Kool Aid*
- Thus R^2 conflates our two aspects of a "good model," combines them with σ_x^2, and places them on a dimensionless scale
- The resulting value is nearly uninterruptable
- Basically measures the shape of the cloud of observations around our regression line.
- R^2 tells us little we want to know – pay it no heed
    - Also avoid standardized regression coefficients
- We must make substantive evaluations of our models:
    - Size of Coefficients (hypothesis tests)
    - Size of Substantive Effects
    - Ability to forecast out-of-sample

v. *Standards of Model Evaluation*
- Statistical Significance of Coefficients
    - T-tests
- Substantive Size of Effects
    - Generate predictions from the model
- Size of Residuals
    - Compare to substantive effects
- Forecasting Out-of-Sample

vi. *Statistical Significance of Regression Coefficients*
- In general, our theories give us hypotheses that B>0 or B<0
    - We can estimate b, but we need a way to assess the validity of statements that B is positive or negative
    - We can rely on our estimate of b and its variance to use probability theory to test such statements.
- T-tests (or Z-scores) give us confidence that relationships we observe generalize to the population
    - Don't get too focused on .05 as a "magical" threshold for significance

vii. *Z-Scores & Hypothesis Tests*
- This variable is a "z-score" based on the standard normal distribution.
    - 95% of cases are within 1.96 standard deviations of the mean.
- If $b / \sigma_b > 1.96$ then there is a 95% chance that B>0
    - Conversely if $b / \sigma_b < -1.96$ then there is a 95% chance that B<0
- Recall that since we don't know σ_b we estimate it
    - Thus we rely on the t distribution for small samples (N<100)

CONCLUSION

Regression models are powerful tools for predicting a score based on some other score. They involve a linear transformation of the predictor variable into the predicted variable. The parameters of the linear transformation are selected such that the least squares criterion is met, resulting in an "optimal" model. The model can then be used in the future to predict either exact scores, called point estimates, or intervals of scores, called interval estimates.

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