Using artificial intelligence to estimate the kink regression to analyze Gross Domestic Product and consumer budget

Tahir R. Dikheel

tahir.dikheel@qu.edu.iq

Rand Abdalriadha

randalwazzan89@gmail.com

University of AL-Qadisiyah

Corresponding Author: Tahir R. Dikheel   Rand Abdalriadha

Abstract : One statistical method for examining data with kink points is kink regression. One artificial intelligence technique, differential evolution, was used to analyze the Gross Domestic Product (GDP) and Consumer budget data for the years 1990–2023. The analysis's outcomes were compared using the Broyden-Fletcher-Goldfarb-Shanot algorithm, which revealed that the data from differential evolution produced superior results.

Keywords: kink regression, Gross Domestic Product ,Differential Evolution, (BFGS)algorithm.

Introduction: One of the most crucial statistical methods a researcher employs to examine data with treatment and assignment variables linked in a way that regression design explains is regression analysis. The analysis aims to examine estimations of its parameters in order to identify the estimated equation used in this process. This arrangement continues the formula E(Y|X) with assignment variables. The discontinuity leads to regression, which produces a single estimated equation for each of the kinked assignment variables, however this assumption may not be met empirically. Using appropriate estimating techniques is necessary to produce successful estimators, which leads to a semi-empirical test design. Furthermore, kink is created by adding randomness to an assignment variable in order to give it a kink. An assignment variable with a kink is considered nonlinear in the context of the regression discontinuity design (RDD). Kink regression has a higher level of sophistication than discontinuity. Furthermore, the regression employs a regression equation for the assignment variable with a kink that contains both positive and negative components. These types of regression models comprise a model and parameters, both of which need to be estimated. Many research have estimated these parameters in different ways, but the following are the most important ones: Regression kink was initially used by Nielsen, H. S., Sørensen, T., and Taber, C. (2010) to examine how educational.

1.1 Kink Regression:

Card et al. (2012) popularized the regression kink model, a variation of the regression discontinuity model. The regression function is continuous in the regression kink model. However, there comes a point at which the slope stops, creating a "kink." Many practical studies have examined this paradigm, including implementations by Ganong and Jager (2015) and Landais (2015) (2014). The cutoff must be approximated in other situations, such as Card, since it is unknown, unlike the conventional regression discontinuity model, which assumes that it is known. Mas and Rothstein (2008) . There are similarities between threshold regression and regression discontinuity models. The latter were first presented by Tong (1983, 1990) in the context of nonlinear autoregression, although they can be used in a variety of nonlinear regression scenarios. The majority of articles about these techniques concentrate on the erratic (unconstrained) threshold model, which separates regression models into two groups according to one or more threshold indicators. Regression kink models may be interesting in empirical contexts where the threshold impact is focused in a single variable and a discontinuous result is not expected. Cox, Hansen, and Jiménez (2004) provide an example of the economic use of the continuous threshold model. Chan's first continuous threshold model is a notable exception. & Tsay (1998), an analog of the regression kink model, uses parts of piecewise linear regression. taking into account the challenges of establishing the regression parameters, threshold effect testing, and regression inference procedures. Similar to Chan and Tsay (1998), there is a large body of literature on discontinuous threshold regression. Hansen (1996), Lee, Seo, and Shin (2011), Chan (1990, 1991), and Chan and Tong (1990) have all contributed to the problem of testing for a threshold effect. Hansen (2000), Seo and Linton (2007), and Chan (1993) are relevant works that address the issue of testing for a threshold effect. (2013). Caner and Hansen (2007) are the authors of instrumental variable techniques.. A paradigm for estimating and inferring regression discontinuity without thresholds was created by Yu and Porter (2015). Related model groups in the statistical literature include the broken stick model, bent cable, two-phase regression, and segmented regression. Important works by Feder (1975) and Hinkley (1969, 1971) are

examples of this literature. See also Chiu, Lockhart, and Routledge (2006) sources. For example, we use the regression kink model on the Reinhart and Rogoff's.

The model of kink regression for one explanatory variable can be written as:

$$y_i = \beta_0 + \beta_1 x_i + e_i \qquad \qquad \text{if } x_i \leq k \quad \dots (1)$$
$$y_i = \beta_0 + \beta_1 * k + \beta_2 (x_i - k) + e_i \qquad \text{if } x_i > k \quad \dots (2)$$
$$e_i \sim N(0, \sigma 2)$$

y_i: is the i_{th} observation of the response variable yi

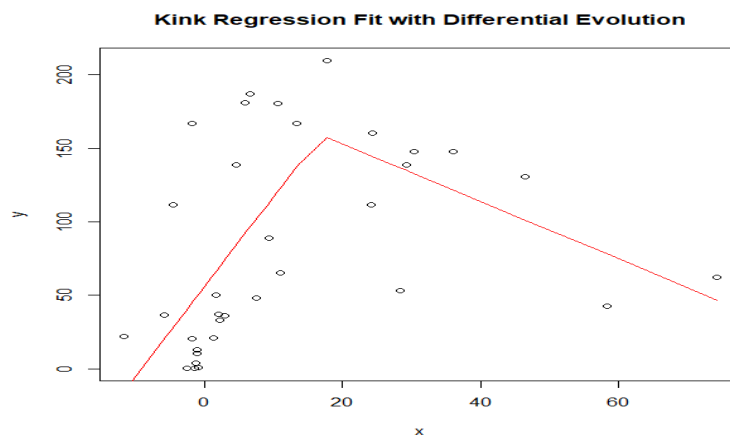x_i : is the i_{th} of observation of explanatory variable

K: kink point

β_1, β_2: parameters of the kink model need to be estimated.

e_i: the error of the i_{th} observation

Differential Evolution (DE):

In order to optimize the real parameter and real valued function by price and storn, it was first put into practice in 1996. By combining stochastic and heuristic components drawn from the biological processes of crossover, mutation, and natural selection, DE, a member of the most widely used class of genetic algorithms (GA), decreases an objective function throughout the duration of the following generation. This technique, which makes use of an easily interchangeable probe, has been used for a few years for global optimization.DE is an extra evolutionary technique that develops the population of possible solutions to answer the optimization problem by using selection and alteration operators. The distinction is that DE employs floating-point encoding, while GA uses bit-string encoding.

Figure(1)Kink point in DE

From the figure above, the kink point for the DE algorithm was equal to(16.9363)

Broyden-Fletcher-Goldfarb-Shanot(BFGS):

In terms of optimizing nonlinear functions, it is regarded as one of the most often utilized techniques. It was created in the seventies. Though it avoids doing derivative calculations directly, the approach is more effective in real-world applications. It is built on the concept of optimizing functions utilizing techniques that rely on predicting second derivatives.

Procedures for the Algorithm

The algorithm consists of multiple primary steps:

1. Establishment

2-Iteration

. Directional Calculation. Advancement Update of Derivatives in Step Five. Update the Matrix

3. Stopping Check

. Benefits of Putting It to Use

Efficiency: Without requiring a direct calculation, the approach yields accurate estimates of a matrix.

- Speed: For big functions, it is faster than more conventional approaches like Newton's technique.

Flexibility: It can be applied to a wide range of optimization tasks.

Gross Domestic Product (GDP) data:

The Ministry of Oil is one of the key institutions that is necessary to the administration of the oil sector, which is one of the major economic pillars in many countries, especially those that heavily depend on energy resources. Oil contributes significantly to the GDP and affects the trade balance.
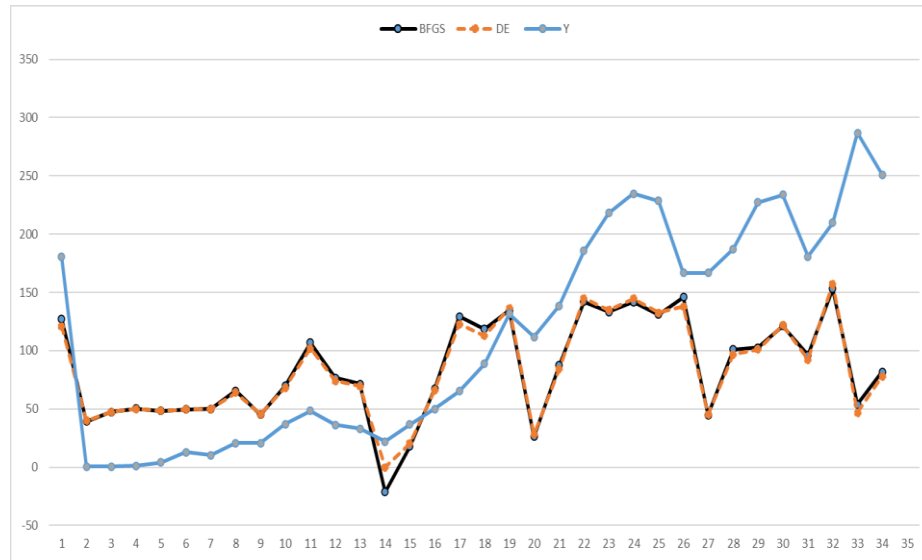
Oil plays a major impact in the gross domestic product and trade balance of countries that produce it. Therefore, monitoring global markets and price swings is essential to stability and economic advancement. The Ministry of Oil assists in formulating policies to boost output and attain the right trade balance

Consumer budget :

When a consumer allocates his budget among different goods and services, he reaches a point where he is most satisfied. This is known as consumer equilibrium. This equilibrium is reached when the marginal utility of each unit of products equals its costs, meaning that the customer cannot alter the quantity of things he purchases to enhance his level of satisfaction. Significance: Oil profits help fund public spending plans, build infrastructure, and raise living standards.

Table 1: The table shows the value of GDP and its estimates using artificial intelligence algorithms. We note from the results of the table that the DE algorithm yields the best results

i	Y	$\hat{y}$ DE	$\hat{y}$BFGS
1	180.4080	120.8607	127.4104
2	0.4077	40.0307	39.2202
3	0.5536	47.4646	47.3311
4	1.0319	50.0487	50.1505
5	3.9913	48.3158	48.2597
6	12.8940	49.4853	49.5358
7	10.4336	49.8650	49.9500
8	20.76485	64.0531	65.4301
9	20.6174	45.2663	44.9326
10	36.8816	68.0885	69.8329
11	48.3642	101.9698	106.79937
12	36.1764	74.1936	76.4940
13	32.9284	69.4785	71.3495
14	21.9215	-15.4909	-21.3570
15	36.6336	20.4478	17.8542
16	50.0651	65.8228	67.3609
17	65.1470	122.6794	129.3947
18	88.8370	112.7103	118.5179
19	131.6144	136.6419	134.5984
20	111.6575	28.0225	26.1187
21	138.5167	84.1443	87.3507
22	185.7496	144.9169	142.0411
23	218.0024	134.9814	133.1049
24	234.6376	144.4699	141.6391
25	228.4156	132.7386	131.0877
26	166.7741	137.9146	146.0172
27	166.7435	45.2234	44.8858
28	187.2176	96.68523	101.0336
29	227.3674	101.10298	102.6338
30	233.6360	121.73077	121.1869
31	180.8987	92.31306	96.2633
32	209.6919	157.3265	153.2026
33	286.6403	46.7261	53.7260
34	250.8427	78.1089	81.952

Figure(2) The actual values and estimated values for the DE, BFGS approach are displayed in the following figure.

Table 2: The values of the parameters and MSE For methods.

	b_0	b_1	b_2	tau	MSE model
DE	55.4864	6.1234	-1.9604	16.9363	2513.19
BFGS	56.0833	6.6810	-1.7632	15.2367	2524.65

Conclusion:

It is clear that the kink point that amounts to (16.9363), in which there is a strong correlation between the two variables, the effective value is (6.1234). In other words, there is a direct relationship between the gross domestic product and the consumer budget i.e., there is an increase in consumer's budget whenever there is an increase in the domestic product. However, there is an indication of an inverse weak relationship after kink point in which the effective value becomes (-1.960443). This means that an increase in the gross domestic product leads to a decrease in the consumer budget. According to the findings, the differential evolution algorithm is more effective in providing more valuable result.

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