

APPLICATION OF DATA ENVELOPMENT ANALYSIS FOR EXPLORING BILATERAL TRADE POTENTIALS

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| **Madiha Riaz, Nausheen Syed, Zia-Ur-Rahman, Saeed-Ur-Rahman, Shafqat Abbas. Application Of Data Envelopment Analysis For Exploring Bilateral Trade Potentials-- Palarch’s Journal Of Archaeology Of Egypt/Egyptology 18(1), 4906-4921. ISSN 1567-214x****Key words; Gravity model, DEA, Trade Partners, Trade Potentials, Optimum utilization. JEL codes: F10, F11, F14, F1** |

**ABSTRACT**

Global Economy has been completely transformed since the last few decades because of momentous growth is trade. Export led economic growth has transformed the direction of policy makers in almost every country. Trade relations escort to economic growth. Therefore, this study is structured to grasp the picture of bilateral trade relations of Pakistan with other countries. To analyze the strength of trade relations, the theoretical and empirical concept of the gravity model has been utilized in the study. Further trade partner’s countries are ranked. Ranking of the countries is made by applying the Data Envelopment Analysis (DEA). Gravity model concept is employed to select the input and output for the DEA model, in order to rank the countries in reference to the utilization of their bilateral trade potential with Pakistan. Gross Domestic Product, Total Population, Per capita gross domestic product and distance between Partner country and Pakistan are used as input variables. Bilateral trade flows (Export+ Import) between Pakistan and it relevant Partner is taken as output. Finding of the study depicts the ranking of the trade partners of Pakistan in reference to the optimum utilization of trade potentials. The counties that are ranked lower represents that they are not exploiting their trade potentials optimally with Pakistan. Hence, following the proposition of the study, Policy makers can get direction to revise their trade policies in order to utilize the potential and get the maximum gain from trade.

**INTRODUCTION**

Global economy has been transformed completely due to the miracles of trade and technology. Trade has increased global production on one hand and transformation as well as distributional effect on other hands. Trade connections between countries comprise of both tangible and intangible commodities. That has generated a complex production chains for these goods and services. Moreover, production chains have increased the flow of trade between countries.

The gravity model of international trade flows is a common approach to modeling bilateral trade flows and has been considered as the workhorse for cross country empirical analysis since last five decades or more (Baier and Bergstrand, 2006). Though, gravity model has been criticized due to weak theoretical base and poor micro foundation yet several efforts of researchers retorted the model serious disparagement. The first attempt to prove the theoretical justification was made by Anderson (1979). Further the same proposition was used by Bergstrand in (1985), Helpman and Krugman (1985), and Deardoff (1995); they constructed the international trade theory consistent gravity equation for the microeconomic foundations of the model. A large number of theoretical works was done with aggregated data providing empirical application of gravity model for heterogeneous firms. However, Feenstra et al. (2001) was first that applied disaggregated data and empirically found the home-market effect in the gravity equation. Further, Helpman, Melitz and Rubinstein (HMR, 2008); derived a theoretical model and suggested the trade flows at the extensive and intensive margins, estimated the composition of exports and trade flows geographically.HMR work provided the ground to deal with asymmetry and selection biases of the model. Whereas, border puzzle by introducing the dummy variable was studied by Manchin and Pinna (2003), and adding multilateral resistance in McCallum’s equation by Anderson and van Wincoop (2003). Further, McCullum (1995), Anderson and van Wincoop (2003) suggested a tedious system of nonlinear equations. Rutherford (2007) explained McCullum’s model in reference to border puzzle effect and pointed out the presence of structural bias. Egger (2001) concentrated on econometric issues and, in its turn, looked for an unbiased estimator for the analysis of trade volumes. In spite of all the discussed shortcomings and weaknesses of the model, researches around the world used the model to evaluate trade patterns. Maryanchyk (2005) applied the gravity theory of trade to estimate two specifications of the model for Ukraine. To investigate bilateral trade flows of Poland with 181 trade partners, Brodzicki (2009) employed the gravity model of trade. Similarly; Shepotylo (2009) estimated trade potential of countries incorporating disaggregated data, zero trade flows and heterogeneity of firms at the industry level. After the remarkable use of gravity model for trade flows, the same modeling tools were applied to other types of flows and interactions. Head et al. (2009) adapted the Eaton and Kortum (2002) model to the case of service off shoring. Anderson (2011) presented a migration gravity model drawing on discrete choice techniques. Ahlfeldt et al. (2012) drew on Eaton and Kortum (2002) to specify a commuting gravity model. Portes et al. (2001) and Portes and Rey (2005) established that gravity equations can explain cross border portfolio investment patterns. Okawa and van Wincoop (2012) suggested an alternative foundation for gravity in international finance. Gravity equations have also been shown to do a good job fitting stocks of foreign direct investment (FDI) as by Head and Ries (2008). De Sousa and Lochard (2011) extended the model to greenfield investment. In crux, the development of micro foundation of Gravity model has established that model can be applied to a range of trade as well as other bilateral flows and interactions with precision.

Hence it can be concluded that gravity model is the best approach to estimate the bilateral flows between countries. These flows estimate the elasticity of bilateral potentials between countries directly proportional to their “masses” and inversely proportional to the “distance” between them.

This study has employed the combination of gravity model and Data Envelopment Analysis (DEA) to estimate the trade potentials between Pakistan and its trade partners and to rank the countries in reference to their trade potential utilization with Pakistan. Gravity model equation is used to define the input and output variables for DEA application. DEA model is used to rank the countries based on the gravity model equation. The combination of both models apprehended the weakness of each other and a way forward for improved fall outs. The main objective of the study is to rank the trade partners of Pakistan, according to the maximum utilization (optimum) of their trade potentials, based on Gravity equation by applying the DEA model.

**METHODOLOGY**

Modeling and predicting foreign trade flows has long been an important task in international economics. One of the most fruitful ways to formalize the trade flows is gravity equation. The first key feature of trade data that mirrors the physical gravity equation is that exports rise proportionately with the economic size of the importing partner and imports rise in proportion to the size of the home country. The aggregated bilateral trade has been examined by gravity model for different data set since decades [Wang and winters (1991), Hamilton and Winter (1992), Baldwin (1994), Breuss and Egger (1999)] etc. Once the gravity equations are specified, they can be estimated using the different econometric techniques.”

The correct econometric representation of gravity model takes the form of a triple-indexed model. Matyas (1997) argued that the proper specification of gravity model takes the following representation:

 (1)

Where  andare well- known specific effects attributed to the panel data modeling approach. If only cross section data are used, and when only time series data are used then. Finally, when panel data are used, there are no restrictions. From an econometric point of view, and  specific effects can be treated as random variables. Model (1) should be viewed as the generic form of all gravity models and is a direct generalization. When cross-section data are used then T=1 and implicitly restriction is imposed on the model [(e.g.; Aitken (1973), Bergstrand (1985), Brad (1994), Oguledo and Macphee (1994), and Frankel *et al*, (1995)].”

The generalized gravity model of trade states that the volume of trade / exports / imports between pairs of countries, is a function of their incomes (GNPs or GDPs), their populations, their distance (proxy of transportation costs) and a set of dummy variables either facilitating or restricting trade between pairs of countries. That is,

 (2)

Where  indicates the GDP or GNP of the country ‘’ and ‘’, are populations of the country ‘’and ‘’,  measures the distance between the two countries’ capitals (or economic centeres.)  represents dummy variables, is the error term and’s are parameters of the model. ‘i’ is used for home country and ‘j’ for target country. Using per capita income instead of population, an alternative formulation of equation (2) can be written as”

 (3)

“Where  are per capita incomes of country ‘’ and ‘j’. As the gravity model is originally formulated in multiplicative form, we can linearize the model by taking the natural logarithm of all variables. The log form of general gravity model is as follow.

 (4)

Where



Where “ln” denotes natural logs. is the sum of (trade) dummy variables. Dummy variables take the value of one when a certain condition is satisfied and zero otherwise.”

We use the following specific variables in our study:

X= Total Exports

M= Total Imports

GDP of foreign country

=Population of foreign country

= Per capita GDP differential of Pakistan and foreign country

=Trade/ GDP Ratio of foreign country used as a proxy for trade openness

 Dis= capital distance between Pakistan and foreign country

The study presumes the gravity specification for DEA model. DEA model is used to rank the countries based on the borrowed foundation of gravity model. Partner countries are sorted on the basis of their trade relations with Pakistan. In other words, DEA ranked the countries that are utilizing its full potential of trade with Pakistan. The countries that are utilizing the relation at it maximum given its GDP, Population, per capita GDP and Distance are laid at Frontier of DEA model. Whereas, countries lay below the frontier are depicting their inefficiency in reference to trade potential utilization. In other words it indicates that potential exist to be exploited for trade relations.

DEA model is a liner programming, non-parametric technique to calculate the relative efficiency of any unit (technically called Decision Making Unit (DMU)) against their peer group without prior information about the shape of the population distribution. It is developed by Charnes, Cooper, and Rhodes (1978). Multiple inputs and outputs can be used (Gutiérrez et al., 2007; Gutierrez & Goitisolo Lezama, 2011); moreover technique is equally beneficial for commercial and non-commercial DMUs as well as in separating technical and scale efficiency

Haq et al., 2010; Kabir Hassan & Benito Sanchez, 2009b). A significant number of researchers used non-parametric (DEA) technique to estimate the efficiency of working units based on the optimum utilization of input and output available to DMUs. Berger and Humphrey (1997) divided the papers (Out of 132 papers 62 papers used this popular approach) on the basis of methodology to investigate the performance of DMUs and found DEA is the most commonly used technique. Envisaging the importance of gravity model and DEA, this study presented a unique mixture of DEA and Gravity model.

 Import plus export of Pakistan with it major partner are considered as Output in DEA model. It represents the trade volume between Pakistan and its partner country in a specified time period. This output can be optimized if the potential of bilateral trade flows be fully exploited between trade partners. The bilateral trade potentials are dependent upon the size of economy named as mass effect and distance between partner countries. Distance is basically a proxy to estimate the cost and resistance between partner countries. The study used Population, GDP and Per capita GDP (potentials of trade) as input for DEA.

Data is taken from World Bank Trade statistics and Trade Map. Total 60 partner of Pakistan has been taken for the analysis. Trade volumes have been taken on the base of recent 8 years averages of import from and export to a specific partner of Pakistan.

**Table 1:** Input-Output Variables

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Input Variables** | **definition** | **Expected relation** | **Variables** |  |
| GDP (constant 2010 US$) | Measure the potential of bilateral trade between countries | Higher GDP more trade | Bilateral trade flowsOutput variable | Export + Import between Pakistan and its Partner country |
| Per capita GDP(constant 2010 US$) | Measures the development level between countries | Similar per capita GDP more trade | Input variable | GDP/Population |
| Population(Millions) | Measure the demand and supply for markets | More population more trade | Input variable | ……………. |
| Distance(Miles) | Measure the transport and other cost | more distance less trade | Input variable | Capital cities difference between trading partners |

**DATA ANALYSIS AND DISCUSSIONS**

The sample size of the study consists of Pakistan’s Trade partner, available with latest complete information on TradeMap database for the cross sectional data analysis. Descriptive statistics and Data Envelopment Analysis (DEA), results are reported below. Keeping into consideration the limitation of input and output variables for DEA models, this study adopted an input–output approach to estimate various DEA efficiency scores.

**Table II** Distribution of Trade Shares between Trade Partners and Pakistan

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  | Cumulative | Cumulative |
| Value | Count | Percent | Count | Percent |
| [0, 200000) | 32 | 53.33 | 32 | 53.33 |
| [200000, 400000) | 6 | 10.00 | 38 | 63.33 |
| [400000, 600000) | 9 | 15.00 | 47 | 78.33 |
| [600000, 800000) | 12 | 20.00 | 59 | 98.33 |
| [800000, 1000000) | 1 | 1.67 | 60 | 100.00 |
| Total | 60 | 100.00 | 60 | 100.00 |

Table II demonstrated the distribution of trade shares (export plus import) of Pakistan with its trade partner. Among 60 major trade partners 32 that comprises of 53.3 % are trading only up to 20 million. Whereas 12 partners that comprises of 20 % are trading up to 60 to 80 million. Other partners are between these two ranges.

Distribution of Trade Partners of Pakistan in reference to the distance is shown in Table 1.2. If we ignore the negative sign than values in the table illustrating that most of the Partners (comprises of 53.3%) have the distance from 2000 to 4000 miles from Pakistan. whereas,23.3 percent has the minimum distance that is up to 2000 miles.

**Table III** Distribution of Distance between Trade Partners and Pakistan

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  | Cumulative | Cumulative |
| Value | Count | Percent | Count | Percent |
| [-10000, -8000) | 3 | 5.00 | 3 | 5.00 |
| [-8000, -6000) | 2 | 3.33 | 5 | 8.33 |
| [-6000, -4000) | 9 | 15.00 | 14 | 23.33 |
| [-4000, -2000) | 32 | 53.33 | 46 | 76.67 |
| [-2000, 0) | 14 | 23.33 | 60 | 100.00 |
| Total | 60 | 100.00 | 60 | 100.00 |

Negative sign is taken to show the impediment of trade, depicting a negative relationship between trade flows and distance between countries. More the distance less will be the bilateral trade flows.

**Table – IV**. Distribution of GDP & Per Capita GDP of Trade Partners of Pakistan

|  |  |  |
| --- | --- | --- |
| Per Capita GDP | Count | Percent |
| [0, 20000) | 33 | 55.00 |
| [20000, 40000) | 11 | 18.33 |
| [40000, 60000) | 11 | 18.33 |
| [60000, 80000) | 4 | 6.67 |
| [80000, 100000) | 1 | 1.67 |
| Total | 60 | 100.00 |

Table-IV represents the distribution of GDP and Per Capita GDP of Partner countries. GDP distribution shows that Major trade partner of Pakistan (95%) has the GDP up to 5 trillion whereas the countries with highest GDP are only 5%. Similary per capita GDP range for 95% trade partner is 20000 to 600000 where as rest of 5 % has more than 600000.

**Table V** Distribution of Population of Trade Partners of Pakistan

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  | Cumulative | Cumulative |
| Value | Count | Percent | Count | Percent |
| [0, 200000000) | 56 | 93.33 | 56 | 93.33 |
| [200000000, 400000000) | 2 | 3.33 | 58 | 96.67 |
| [1200000000, 1400000000) | 2 | 3.33 | 60 | 100.00 |
| Total | 60 | 100.00 | 60 | 100.00 |

Table-V depicts the distribution of population that is up to 20 million for 93.33 percent of Partners. Whereas, 6.66 percent partners have more than 20 million of population.

**Table VI** Descriptive Statistics

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | IGDP | IDIS | IPC | BITR | IPOP |
|  Mean |  1.08E+12 | -3111.700 |  24051.25 |  290118.5 |  90975588 |
|  Median |  3.01E+11 | -3061.500 |  14353.04 |  162707.6 |  28559310 |
|  Maximum |  1.63E+13 | -33.00000 |  89540.25 |  979726.9 |  1.36E+09 |
|  Minimum |  9.79E+09 | -9728.000 |  413.8597 |  4783.396 |  2060317. |
|  Std. Dev. |  2.46E+12 |  2130.005 |  22825.14 |  274178.3 |  2.40E+08 |
|  Skewness |  4.660187 | -0.875665 |  0.808366 |  0.643168 |  4.721118 |
|  Kurtosis |  27.17996 |  4.233494 |  2.685917 |  2.052155 |  24.67442 |
|  Jarque-Bera |  1678.849 |  11.47167 |  6.781173 |  6.382682 |  1397.341 |
|  Probability |  0.000000 |  0.003228 |  0.033689 |  0.041117 |  0.000000 |
|  Sum |  6.45E+13 | -186702.0 |  1443075. |  17407109 |  5.46E+09 |
|  Sum Sq. Dev. |  3.56E+26 |  2.68E+08 |  3.07E+10 |  4.44E+12 |  3.39E+18 |
|  Observations |  60 |  60 |  60 |  60 |  60 |

Table-VI, represent the descriptive statistics of data. Data is almost normal in it distribution. Hence, data is suitable for auxiliary analysis. As we discussed earlier that study lend the concepts from gravity model for input and output variables of trade and apply the DEA method to corroborate the concept embedded in Gravity model foundation. The selection of input and output variables is very important in DEA application. The DEA result is sensitive towards input selections (Gutiérrez et al., 2007). Any change in inputs may turn an efficient DMU into inefficient and vice versa. Data envelopment analysis efficiency score, with the help of the selected input and output variables, has estimated under CCR (Charnes et al., 1978) input based models. It measures the Technical Efficiency (TE) of DMUs that is a comparative measure indicating DMU’s maximum potential to process inputs to achieve its outputs, represented by its possibility frontier (Barros & Mascarenhas, 2005). The Estimation of technical efficiencies helps to reveal DMUs (partner countries in our study) are capable in terms of exploiting their resources (trade potentials in our study).

**Table-VII:** Efficiency Scores

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Turkey** | **1** | **Mexico** | **0.99** | **Sweden** | **0.894726** | **Philippine** | **0.54754** | **Norway** | **0.276069** |
| **Switzerland** | **1** | **Canada** | **0.99** | **Portugal** | **0.878742** | **Iran, Islamic Rep.** | **0.537415** | **Iraq** | **0.221657** |
| **Senegal** | **1** | **Poland** | **0.989511** | **Bangladesh** | **0.871612** | **Romania** | **0.527154** | **Qatar** | **0.190784** |
| **New Zealand** | **1** | **Finland** | **0.984892** | **South Africa** | **0.785571** | **France** | **0.503459** | **Spain** | **0.173202** |
| **Mozambique** | **1** | **Ghana** | **0.98** | **Ireland** | **0.770137** | **Hong Kong SAR, China** | **0.49664** | **Jordan** | **0.15648** |
| **Madagascar** | **1** | **Saudi Arabia** | **0.976973** | **Hungary** | **0.737964** | **Afghanistan** | **0.49** | **Chile** | **0.137873** |
| **Japan** | **1** | **Lithuania** | **0.97** | **Greece** | **0.722199** | **Malaysia** | **0.442357** | **United States** | **0.133** |
| **Indonesia** | **1** | **Thailand** | **0.963363** | **Uganda** | **0.65** | **United Kingdom** | **0.44068** | **Kuwait** | **0.073842** |
| **India** | **1** | **Russian Federation** | **0.957222** | **Argentina** | **0.636898** | **Sri Lanka** | **0.437993** | **Kazakhstan** | **0.06671** |
| **China** | **1** | **Italy** | **0.908306** | **Netherlands** | **0.624832** | **Egypt, Arab Rep.** | **0.42009** | **Oman** | **0.057899** |
| **Australia** | **1** | **Kenya** | **0.905403** | **Tanzania** | **0.579986** | **Belgium** | **0.294206** | **United Arab Emirates** | **0.034083** |
| **Nigeria** | **0.99** | **Singapore** | **0.8967** | **Denmark** | **0.56123** | **Germany** | **0.278451** | **Slovenia** | **0.017178** |

Table VII; provides the information about the ranking of partner countries with respect to inputs and outputs efficiency in terms of usage of trade potentials. Turkey, Switzerland, Senegal, New Zealand, Mozambique, Madagascar, Japan, Indonesia, India, China, and Australia (18.33%) are exploiting their trade potentials fully with Pakistan. These are the countries with which Pakistan has 100 percent utilization of trade possibilities. These countries are utilizing their trade shares with Pakistan optimally with reference to the inputs that are GDP, per capita GDP, population and distance for the output of bilateral trade volume. Therefore, these 18% countries are reclined on the frontier of DEA. Whereas, all the other 82% countries that are trade partner of Pakistan are positioned below the frontier. Among the remaining 82% trading countries Nigeria, Mexico, Canada, Poland, Finland, Ghana, Saudi Arabia, Lithuania, Thailand, and Russian Federation (16.66%) are the countries that positioned near the frontier. These are the countries with which Pakistan can utilize more fruitful trade relations. Total 35% countries are utilizing more efficient relations with Pakistan. Among these trade partners all the other 65% are below the frontier and not exploiting full potentials of trade with Pakistan. The countries that are near in proximity e.g Bangladesh, Afghanistan and Iran comprise of TE score much below the frontier. It indicates towards many interesting results. It is contradictory to gravity model assumption that less the distance more will be the trade, similarly another assumption of Gravity model that culture and religion similarities enhances the trade volumes. These three countries are not only having the same religion as of Pakistan but also in neighborhood. It can be inferred that trade is not affected by distance and culture; it is dependent on the demand of the consumers. Either it can be fulfilled from a neighboring country at a lower transaction cost or from a faraway country at a higher transaction cost. Except China and India all the other trade partners of Pakistan are distant from it. Another interesting implication from the analysis can be drawn, Pakistan should look at it trade opportunities with the neighbor countries. Because according to DEA model TE score ranking, there is huge trade potential left to be explored between trade partners of Pakistan. Similarly visualizing the DEA score of TE for Partner countries, Policies of trade can be modified according to the potential left.

**CONCLUSION**

The study has used the combination of models to analyze the trade relations of Pakistan with major trade Partners. Gravity model of trade is used to select the input and output variable for the estimation of DEA model. DEA methodology is applied to sort the trade partners of Pakistan in reference to the utilization of trade potentials. The study categorized the trade partners utilizing 100% trade potentials positioned at optimum frontier and others that are below the 100% optimum frontier.

The novel combination of models to analyze the trade potentials of partner countries can helps the policy makers to modify the trade policies in favor of the countries where opportunity for trade expansion exist. The study opens door of research in the contemporary trail to exercise the combinations of models that apprehend the weakness of each other and provide more reliable and productive results.

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**APPENDIX**

**Partner -Countries- Trade-Data**

|  |  |  |  |
| --- | --- | --- | --- |
| **Country** | **Log of Trade flows** | **country** | **Log of trade flows** |
| United States | 15.15116930311558 | Madagascar | 11.55801354678615 |
| AFG | 14.11408360783141 | Malaysia | 11.96719978468547 |
| Argentina | 10.71774555884513 | Mexico | 11.53734486951097 |
| Australia | 12.41457757310084 | Mozambique | 11.04164101582477 |
| Bangladesh | 13.57194106013081 | Netherlands | 13.75661157138255 |
| Belgium | 13.40968738575881 | New Zealand | 10.50925055935364 |
| Canada | 12.51142271563536 | Nigeria | 10.77398562323661 |
| Chile | 11.153718747367 | Norway | 10.94174809881949 |
| China | 14.41328550679471 | Oman | 11.83684061896831 |
| Denmark | 12.06143985983448 | PHL | 11.6254770627086 |
| Egypt, Arab Rep. | 11.32263625052697 | Poland | 12.36661712708786 |
| Finland | 10.22803178972048 | Portugal | 12.16515168777989 |
| France | 13.00993796402438 | Qatar | 11.53477501549676 |
| Germany | 14.08587656905081 | Romania | 10.19481297990271 |
| Ghana | 10.56869811440305 | Russian Federation | 11.96457416849399 |
| Greece | 11.31563239224613 | Saudi Arabia | 12.66451596109563 |
| Hong Kong SAR, China | 11.58883039305969 | Senegal | 10.69543880215465 |
| Hungary | 9.360999248261295 | Singapore | 11.58245152761884 |
| India | 12.85591036538946 | Slovenia | 11.04445665728306 |
| Indonesia | 12.62115469559027 | South Africa | 12.09040923687645 |
| Iran, Islamic Rep. | 10.03337481337055 | Spain | 13.7352739981693 |
| Iraq | 10.07382087001802 | Sri Lanka | 12.77855953008729 |
| Ireland | 11.04184926072152 | Sweden | 11.83150282481005 |
| Italy | 13.5562124879145 | Switzerland | 9.747184558140728 |
| Japan | 12.28307072301748 | Tanzania | 11.64355013717313 |
| Jordan | 10.38964131349647 | Thailand | 12.32606213406697 |
| Kazakhstan | 11.37250180370741 | Turkey | 12.62068247955092 |
| Kenya | 12.53208681527924 | Uganda | 7.294377299288821 |
| Kuwait | 11.48758714395503 | United Arab Emirates | 13.79894917216505 |
| Lithuania | 10.61633931637041 | United Kingdom | 14.36284379467648 |