Analysis of World Economic Growth Using Panel Data

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Abstract

In this paper, I consider panel data analysis of world economies to identify the relationship between GDP growth and the independent variables, and the nature of effect that may exist. Annual data for 161 countries from 1990 to 2020 sourced from the World Bank and UN are used. GDP is the independent variable while the independent variables are population, gross value added, total natural resources rent, and labor force. Firstly, a poolability test is performed to test for the joint significance of the fixed effects. The null hypothesis is rejected as there exist significant individual effects. Secondly, Huesman's test is performed to test for consistency of fixed effect and random effect. The null hypothesis is rejected implying significant random effects exist. Thirdly, Bruesch-Pagan test for heteroscedasticity is performed, which shows the existence of heteroscedasticity. Finally, White's covariance matrix estimator for random effect is performed which results to consistent and efficient parameter estimate in the presence of heteroscedasticity. The random effect model is statistically significant at the 5% level, with 68 % of the variation being explained by the model. All the explanatory variables are statistically significant at a 5 % level. They all have a positive effect on GDP with the labor force and population having the highest effect. The random effect is large and significant with a variance of 2.25 ± 1.5 and 94.1 % share of the error component. Countries that have had consistent increases in either labor force or population growth or both, has over the period experienced consistent economic growth after controlling for the other variables and the random effect.

Index Terms

Economic growth, fixed effect, GDP, OLS, random effect.

I. Introduction

Economic growth is defined as the change in market value, adjusting for inflation, of goods and services produced in a financial year of an economy. In quantitative terms, it's the change in real GDP (gross domestic product). There are different ways of measuring GDP, namely; quarterly growth rate that considers a specific quarter in a financial year, year-over-year growth rate that features two successive years, and annual growth rate that shows the overall performance in a financial year. There are several economic theories that explain economic growth and development. Commonly known theories are; Adam Smith, Malthusian theory, classical growth theory, Solow [1] - Swan [2] model and Aghion *et al.* [3] endogenous theory. In these theories, the common determinants of economic growth are productivity, factor accumulation, human capital, health, political institutions, structural change, entrepreneur, and new products in the market. Cooper and John [4] explained the variation in GDP performance across countries. At different times countries experience changes in explanatory variables at different rates, which implicates a difference in the growth function. This results in different categories of countries namely; developed countries, developing or poor countries. Advanced economies are characterized by high per capita income, developed financial systems, high life expectancy and diverse industrial mix. On the other hand, developing countries are characterized by mass poverty, low living standards, high level of illiteracy, unemployment, low access to finance, and high population growth. The technical problem entails investigating the relationship and the effects between GDP performance and the explanatory variables across countries. The explanatory variables are; total natural resource rent, gross value addition, labor force, and population growth. The aim is to determine the impact of the independent variables on the growth of GDP in World economies by determining the relationship and the nature of the effects.

There are several existing literature on economic growth and development. Initially, the economic growth model had parameters that were non-economic invariant with respect to changes in other variables. The variables define how the levels of production of any economy grow and explain the variation in the growth of the societies. The key determinants of the rate of growth are savings propensities of the society which in turn influence the rate of accumulation of capital, invention, or innovation that determines the productivity growth rate and the general population. However, recent studies show interactions of these variables with respect to an increase in production rate. Kaldor [5] presented the capital economy model in a simple functional form. The model is consistent both with major shocks in the growth process and with minor growth rate fluctuations. Rostow [6] generalized the sets of stages of economic growth as: traditional society, pre-condition for take-off, take-off, drive to maturity, high mass consumption, and beyond consumption. The categories were based on dynamic preposition on demand, supply, and the pattern of production. The set of forces determining the level of output and sectoral optimum positions are;

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the level of income, population, preference, state of technology, and entrepreneurship qualities. In terms of cross economy regression Barro [7] revealed regularities in economic growth and investment. There is a negative correlation between per capita growth and the initial level of per capital holding human capital constant. Moreover, the economic growth rate is positively correlated to human capital for a given level of initial per capita. Private investment expressed as a ratio of GDP and per capita growth are negatively correlated to government expenditure expressed as a ratio to GDP. Finally, public investment has little relation to economic growth. De Long and Summers [8] showed that structural policy are dominant in raising the rates, especially in interspatial and intertemporal variation. Macroeconomic policies are less dominant in defining the productivity growth rate. Dollar [9] concluded that after controlling for development level difference, high price indicates incentives and strong protection favoring domestic market product while low price level reflect incentives and modest protection to external markets. In addition, outward orientation measures are highly correlated with the growth rate of GDP per capita in developing countries. Knight *et al.* [10] showed that human capital, trade policies that are oriented outward and public investment have a significant positive effect on economic growth across a sample of 98 countries. The gap between real per capita incomes for poor and rich countries is likely to reduce over a long time period.

World Bank [11] highlights the experiences of rapid economic growth in eight Asian countries. Establishing a stable macro economy, investment in early education, agricultural focus, building a sound financial system using banks, export push, and having economic scarcities reflected by relative prices are key factors that influence positive economic growth. Leaping stages of technological development, large subsidies to borrowers, and strong negative credit interest rates impact negatively on economic growth. Benhabib and Spiegel [12] using Cobb- Douglas aggregate production model showed that human capital is insignificant in determining GDP per capita growth. Human capital has a positive role in determining the growth rate of total factor productivity. Aghion *et al.* [13] used Schumpeter's creative destruction concept to understand the effect of technology advancement on the economic system. The concept is based on a competitive process that is utilized by entrepreneurs who constantly seek new innovations to render rival innovations obsolete. They provided a way of analyzing economic growth and the interactions with growth in unemployment, education, inequality, natural resources, competition, public policy, economic cycles, and international trade. Barro [14] analysis on income inequalities and their effect on GDP per capita growth for a panel of countries provided evidence of income inequality reducing growth in poor countries while increasing growth in developed countries. Developing countries need to utilize income-equalizing policies while developed countries to trade off the benefit of greater equality and economic growth reduction. Acemoglu [15] performed a comparative analysis of world economic growth. He established a regression relationship between economic growth and independent variables namely physical capital, human capital, and technology. In addition, he explained the cause of cross-country difference in relation to the mentioned independent variables as: Multiple equilibria that leads to different paths among countries with similar market structure, opportunities, and preferences; Geographical features differences that affect the environment for human life influencing agricultural productivity, individual behavior and attitude, and natural resource occurrence; Public institution variations that affect governing laws and regulations for firm and individual functions which determines the incentives for trade, investment and accumulations; and Difference in culture that influences the beliefs, values and preference of an individual. Toma *et al.* [16] showed that human activity from an entrepreneurship perspective plays a significant role in economic development. Entrepreneurial education and tradition are determinants of the potential in entrepreneurship, which in the emergence of critical viable ventures leads to economic development. Edrees [17] using panel data for Arab world countries established high heterogeneous causal relationships in human capital, infrastructure, and economic growth. Human capital and economic growth exhibit a feedback relationship as well as infrastructure and economic growth. In non-rich countries, economic growth and infrastructure have one-way causality. Meyer and Meyer [18] provided evidence for a long-run relationship between GDP and the regressors namely; TEA (total early stage entrepreneurial activity), EI (entrepreneurial intention) and EBO (established business ownership) for BRICs countries (Brazil, Russia, India and China). TEA and EI significantly impact economic growth. Boudreaux [19] established that entrepreneurship and institutional environment positively impact on economic growth except in developing countries after examining a sample of 83 countries. Fernandez-Portillo, Almodovar-Gonzalez and Hernandez-Mogollon [20] established that use of ICT (information communication technology) and progress deployment accelerates economic growth in developed European countries. Meyer and Meyer [21] established a long-run relationship among entrepreneurial intention, early stage entrepreneurial activity, and established business ownership. Early stage entrepreneurial activities and established business ownership significantly impact economic growth.

II. Methodology

A. Data

In this empirical study, panel data from 1990 to 2020 for one hundred and sixty one countries were considered. The data set was obtained from the World bank database [22] and United Nations [23] database. The dependent variable for the study is GDP while the independent variables are total natural resource rents, gross value added, labor force, and population. Labor force is defined as the total number of persons who are 15 years and above participating in supplying labor for the production of goods and services at a particular time. Total natural resources are defined as the difference between the price of a commodity and the average production cost. It's the sum of coal rents, natural gas rents, mineral rents,forest rents, and oil rents.

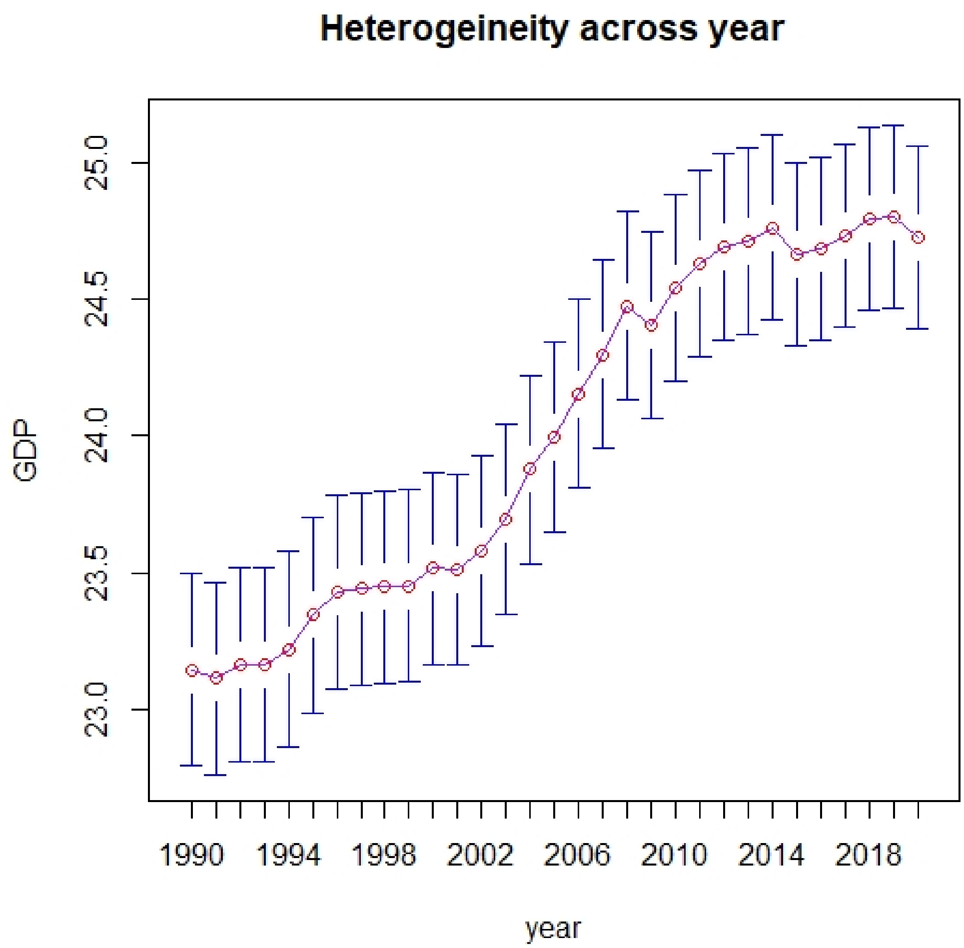

Fig. 1: Heterogeneity across year plot.

Gross value added is the value of services and goods produced by different sectors of an economy. The sectors include manufacturing, high technology products, agriculture, construction, etc. The currency unit for monetary variables is in US dollar.

TABLE I: Variable Description

Variable	Identifier	Data source
GDP	Gross domestic product in US dollars	world bank
POP	Annual population	world bank
TNR	Total natural resource rent in US dollars	world bank
lAB	Total labor force	world bank
GVA	gross value added in US dollars	UN

The data shows a decline in GDP performance between the years 1990 to 1991, 2008 to 2009, 2014 to 2015, and 2019 to 2020 as shown in Fig. 1. Tonga has had the lowest GDP while the US with the highest GDP over the years as shown in Fig. 2. Chile has experienced the highest labor force over the period while Tonga has experienced the lowest labor force. China has had a high population while Dominica has had the lowest population. In terms of total natural rent, China has the highest proportion while Malta has the lowest. United States leads in gross value added and Turkmenistan has the least value in gross value added.

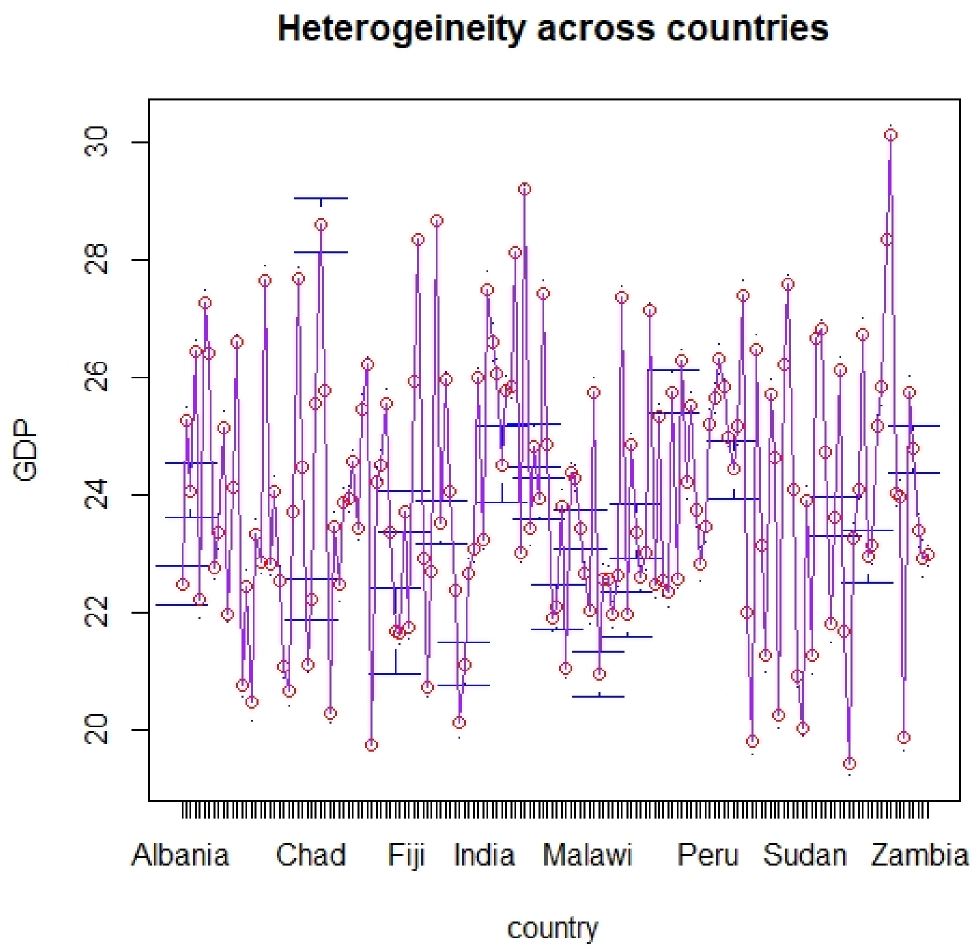

Fig. 2: Heterogeneity across countries plot.

The functional model is stated as:

$$GDP_{it} = f(POP_{it}, TNR_{it}, LAB_{it}, GVA_{it}) \tag{1}$$

where i= 1, 2, 3,..., n observation and t= 1,2,3, ... , T time period.
All the variables were translated by a constant value of 10 so as to enable a log transformation of the values including zero in the total natural resource variable. A log data transformation helps to remove the outlier effect and dampen the variance.

B. Model

1. Model estimation

The basic model for panel data analysis with the assumption of homogeneous unit in Baltagi *et al.* [24] article is:

$$y_{it} = \alpha + {X_{it}}'\beta + \gamma_{it} \tag{2}$$

For i= 1,2,3,...,n is the individual index; t=1,2,3,4,...,T is the time index, α is the individual effect and X is vector of the explanatory variables. For one way error component, then:

$$\gamma_{it} = \gamma_i + \epsilon_{it} \tag{3}$$

where γ_i is the unobserved individual specific effect and ϵ_{it} is the idiosyncratic error term. The idiosyncratic error component is assumed to be independent of both the individual component and the regressors. However, the individual component may either be correlated or independent of the regressors. This results in various estimation methods, namely:

1) Fixed effect estimator

2) random effect estimator
3) pooled estimator
4) Time fixed effect estimator
5) First difference estimator

The models are chosen based on statistical tests and assumptions. The assumptions for panel data analysis are: a). linearity, b). homoskedasticity and non-autocorrelation c). exogenity, d). non-stochastic independent variables and e). no multicolinearity. In case of assumption (b) or (c) or both are violated, then more efficient model are either random effect or fixed random.
Pooled estimation is used when the statistical assumptions are not met as it turns out to be BLUE (best linear unbiased estimator). Pooled OLS (ordinary least square) tends to ignore individual characteristics and time, putting more weight on dependencies between the individuals. OLS estimation is used where the coefficients of estimations are the same for all units i.e no individual difference. The model for pooled estimator is given as:

$$y_{it} = \alpha + {X_{it}}'\beta + \gamma_{it} \tag{4}$$

A fixed or within model accounts for individual effects. The fixed effect model treats the individual component as a set of n parameters to be estimated, where in general $\alpha_{it} = \alpha_i$ for all t. The model uses transformed data, giving a consistent estimate of the β using OLS estimation. The fixed effect model is given as:

$$y_{it} = \alpha_i + {X_{it}}'\beta + \gamma_{it} \tag{5}$$

where $\alpha_i = \alpha + \nu_i$ capture the individual effect. A timed fixed effect model is used where there is a time effect, in which the average value of y_{it} changes over time but not across individuals. The time fixed effect model is given as:

$$y_{it} = \alpha + {X_{it}}'\beta + \lambda_t + \gamma_{it} \tag{6}$$

Random effect model assumes the individual specific effect is independent of the regressors. The model uses GLS (generalized least squares) estimation as the error component inducing correlation across the composite error term making OLS estimators inconsistent. The random effect model is given as:

$$y_{it} = \alpha + {X_{it}}'\beta + \gamma_{it} \tag{7}$$

The error component consists of individual specific random component and idiosyncratic disturbance:

$$\gamma_{it} = \gamma_i + \epsilon_{it}$$

The first difference model estimates unobserved effects by eliminating the time-invariant individual component by obtaining the first difference. Differencing is taking a one step lag in time, subtracting the intercept and individual error component which are time-invariant. The first difference model is given as:

$$\Delta y_{it} = \sum_{k=1}^{k} \beta_k \Delta X_{kit} + \Delta\gamma_{it} \tag{8}$$

2. Analysis framework

Panel data analysis framework involves steps followed to ascertain the appropriate model to be used among the random effect model, fixed effect model, and pooled OLS. The steps are:

1) perform probability test for fixed effect model and pooled OLS. The test is used to test the joint significance of individual specific intercepts i.e., fixed effects are different among units.

   The test statistics are:

$$F = \frac{(SSE_r - SSE_u)/N - 1}{SSE_u/NT - K} \quad \sim F(N-1, NT-K) \tag{9}$$

   The hypothesis is given as:

$$H_0 : \alpha_i = \alpha_1 = \alpha_2 = ... = \alpha_N$$

   If the null the null hypothesis is rejected, proceed to step 2. Choose a pooled OLS model if you fail to reject the null hypothesis. The poolability test statistics is 504.24 with 161 and 4842 degrees of freedom respectively and p-value less than 0.001. The null hypothesis is rejected implying that a fixed model is preferred.

2) perform Heusman's test for fixed effect model and a random effect model. The null hypothesis is that both the fixed effect and random model are consistent versus an alternative of inconsistent. A fixed model is assumed to be consistent under both null and alternative. The test statistics are given as:

$$H = [\beta^{FE} - \beta^{RE}]^1[Var\beta^{FE} - Var\beta^{RE}][\beta^{FE} - \beta^{RE}] \sim \chi^2(k) \quad (10)$$

Rejecting the null hypothesis implies that the random effect model is the most efficient to use, otherwise proceed to step 3. The Heusman's test statistical is 722.15 following a chi-square distribution with 4 degrees of freedom and a p-value less than 0.0001.

3) perform F test for individual and time effects. The null hypothesis states that there are no significant time or individual effects versus significant effects.

From the analysis framework, a random effect model is significant for the analysis of the data.

3. Random effect model

3.1. Test for heteroscedasticity

This is a test that is used to test whether the error variance is dependent on the regressor's value. Breusch and Pagan [25] developed a test for heteroscedasticity with asymptotic properties computed by two least square regression that helps in avoiding iterative calculations for maximum likelihood parameters estimates. Breusch and Pagan [26] constructed a LM (Lagrange multiplier)test considering a number of particular specifics where they showed that LM statistics is computed by a regression using fitted model residual by OLS estimation. The test statistics are given as:

$$\chi^2 = NH^2 \sim \chi^2(k)$$

where H is either a positive exponential or linear variance function. Test hypothesis

$$H_0 : Homoscedasticity$$

$$H_1 : Heteroscedasticity$$

The Bruesch - Pagan test statistics is 6885.7 with 164 degrees of freedom and p-value less than 0.0001. There is heteroscedasticity in variables, and a robust co-variance matrix is used to account for it. Heteroscedasticity always leads to consistent but inefficient parameter estimates and inconsistent estimates of the co-variance matrix. Covariance matrix estimator by White [27] reults to consistent in parameter estimation in the presence of heteroscedasticity. The estimates for the parameter are the same as for homoscedasticity, only that the standard error margin reduces under covariance matrix estimation. The results for robust variance random effect model are shown in table II.

TABLE II: Random Effect Model Results after Adjusting for Heteroscedasticity

a		Effects	
	variance	std.dev	share
idiosyncratic error	0.1424	0.3773	5.9 %
individual specific component	2.2518	1.5006	94.1 %
b		Estimations	
Variable	Estimate	Std. Error	P-value
Intercept	-10.5190	1.7924	< 0.0001
POP	0.8316	0.2387	0.0005
GVA	0.1130	0.0210	< 0.0001
TNR	0.2145	0.0470	< 0.0001
LAB	0.9700	0.1981	< 0.0001
c		Overall Statistics	
	Total Sum of Squares: 2524 Residual Sum of Squares: 773 R-Squared: 0.69374 Adj. R-Squared: 0.69349 Chisq: 807.713 on 4 DF p-value < 0.0001		

The random effect model is statistically significant at 5% level, with 68 % of the variation being explained by the model. The variance of the random effect is large and significant. All the explanatory variables are statistically significant at a 5% level. They all have a positive effect on GDP with labor force and population having the highest effect. An induced 1 % increase in labor force, increases the GDP by 0.97 %. Gross value addition has the least effect on GDP growth, resulting in a 0.113 % increase in GDP for a 1 % increase in gross value addition.

III. Conclusion

The study sought to establish the existence of a significant relationship between the GDP performance and the independent variables which are; gross value added, population, total labor force, and total natural resource rents. It also identifies the nature of the effect that exists therein. The poolablity test for joint individual effect provides evidence of significant individual effects. Similarly, Heusman's test for consistency of random effect and fixed effect, shows that random effects are inconsistent as per the alternative hypothesis. The Bruesch-Pagan test for heteroscedasticity shows the presence of heterogeneity in the data. White's covariance matrix estimator for random effect results in consistent and efficient parameter estimates by reducing the margin error of the estimates. The random effect model is statistically significant at a 5% level. The study provides evidence that all variables are statistically significant and have a positive influence on economic growth. Total labor force and population have the highest impact with parameter estimates of 0.970 and 0.832 respectively. The random effect is large and significant with a variance of 2.25 ± 1.5 and 94.1 % share of the error component.

From the study, there exist the presence of unobserved time invariant factors across countries that are independent of the population, gross value added, total natural resource rents, and labor force that influence economic growth across countries in the world. Human capital and population related parameters are key determinants of economic growth. Countries that have had a consistent increase in either labor force or population growth or both, has over the period experienced consistent economic growth after controlling for the other variables and the random effect. Policy makers at the national level should develop and advocate for national population growth policies and human capital development policies.

Appendix

The following countries were considered in the analysis:

Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Cuba, Cyprus, Czech Republic, Denmark, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eswatini, Ethiopia, Fiji, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hong Kong SAR China, Iceland, India, Indonesia, Iran, Iraq, Ireland, Isreal, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea Rep., Kuwait, Kyrgyz Republic, Lao PDR, Lebanon, Lesotho, Libya, Luxembourg, Macao SAR China, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Myanmar, Namibia, Nepal, Netherlands, New Caledonia, New Zealand, Nicaragua, Niger, Nigeria, North Macedonia, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico, Qatar, Romania, Russian Federation, Rwanda, Samoa, Saudi Arabia, Senegal, Sierra Leone, Singapore, Slovak Republic, Solomon Islands, South Africa, Spain, Sri Lanka, St. Vincent and the Grenadines, Sudan, Suriname, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Vanuatu, Venezuela RB, Vietnam, Yemen Rep., Zambia, Zimbabwe.

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