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Dynamics of Global Agricultural Productivity and Democratic Governance Structure: Implications for Sustainable Food Supply

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Abstract

Good governance leads to economic growth although most countries of the world lack it. Little attention had been given to isolate the effect of the governance system on agricultural productivity which necessitate this research. This research is a global study on the relationship between regime type and agricultural productivity drawing data from three main sources, namely, the Economist Intelligence Unit Limited (EIU) (EIU, 2022), Economic Research Service of the US Department of Agriculture (ERS-USDA, 2023) and FAOSTAT (2022). In order to account for variability within and across continents and regime type, the data was analysed using multilevel modelling techniques. A total of 14 models and scenarios were estimated in trying to isolate the continents and or regime types that could exacerbate or enhance global Total Factor Productivity (TFP). The results indicate that full democracy is practised in about 10% of the countries. TFP is highest in most countries that practice full democracy (FD) while it was lowest in countries under authoritarian regimes. From the results of the estimation of all the models, only agriculture contribution to GDP had about .45% impact on TFP over the period of this data. However, it would appear that changes to TFP is more likely to occur in countries within continents rather than in countries practicing similar regime type. The study further reveals that changes in the random intercepts and variances can trigger some positive improvement in TFP. The interesting part of the results are that imperfect regimes tend to have low or negative TFP, although, the effects are more persistent with authoritarian types. Therefore, political reforms also contribute to food systems and supply. A upward trend in TFP is desirable in order not to over-exploit our natural resources. In terms of which regime or continent caused the greatest variability; Asia is on top of the continents while authoritarian regimes are on top of the regime type. Hence, there is link between agricultural technology, productivity and democracy and investment in both political reforms and agricultural R&D are necessary for sustainable food systems and supply. The study recommends the institution of political reforms in countries operating imperfect democratic regimes to enhance investment in agricultural R&D especially in Africa, Asia and CIS. In addition, countries in Africa and those not practicing FD should work towards improving their TFP by at least 50% of the current level and translate the free resources to other sectors; particularly, food processing and supply chains; for greater efficiency and sustainable food systems and supply.

Keywords: Multilevel modelling, Random effects, Imperfect regimes, Variances, Food sovereignty, R Software

1. Introduction

Agriculture has always been influenced by the actions of governments and governance around the world, hence, enormous resources have been invested in agricultural and food systems research and development globally in the last two decades in order to boost productivity and food security (Pratt & Fan, 2010; Zepeda, 2001). Never has this been more evident than during the first half of the 20th century, when two major wars profoundly disrupted food production. In response to the highly agitated economic climate, European countries implemented tariffs and other measures to protect local agriculture. Such initiatives had global ramifications, and by the mid-20th century various international organizations had been established to monitor and promote agricultural development and the well-being of rural societies (Thomson, 2017). However, the challenges of globalisation, green gas effects, failure of governance and policy systems as well as environmental management technologies continue to impair progress towards self-sufficiency at family, national and sub-national levels (Rao et al., 2005). There is lack of progress towards food sovereignty (Agrawal, 2014) which may be due to lack of coherent policies and effective governance structure through appropriate democratic institutions (Drury et al., 2006; Fogel, 2007; Fulginiti, 2010; Isham et al., 1997; McFadden & Stefanou, 2016; Munir et al., n.d.; Olper, 2001). According to Swinnen (2021), food and agriculture have been subjected to heavy-handed government interventions throughout much of history and across the globe, both in developing and developed countries. Political considerations are crucial to understanding these policies since almost all agricultural and food policies have redistributive effects and are therefore subject to lobbying and pressure from interest groups and used by decision-makers to influence society for both economic and political reasons. Policies, such as import tariffs or export taxes, have clear distributional objectives and reduce total welfare by introducing distortions in the economy while policies, such as food standards, land reforms, and public investments in agricultural research, may increase total welfare but at the same time also have distributional effects. These distributional effects will influence the preferences of different interest groups and thus trigger political action. In addition, achievement of food and agricultural sustainability depend on the political economy, governance and the incentives of relevant stakeholders in a local, national and global context (FAO, 2022).

Governance refers to formal and informal rules, organizations and processes through which public and private actors articulate their interests, make and implement decisions (FAO, 2013; Bojic et al., 2022). It is the process of making and implementing decisions that improve economic, political and social institutions (UNESCAP, 2014; Ronaghi et al., 2020). Good governance affects the quality of life and welfare of people. Good governance involves many actors such as companies, political parties, military, non-government organizations and even influential individuals (Pere, 2015). While all these institutions have an influence on how decisions are made within a country, government sets the rules and norms that strengthen the ability of the public and private sectors to play a meaningful role. Without good governance, economic growth creates gaps within society's social and economic sectors (Pere, 2015). Lio and Liu (2008), Pere (2015) and Ronaghi et al. (2020) also agreed that noticeable achievements are limited in a country unless they are supported by good governance which could also be the key to sustainable food security. In addition, Hayami and Ruttan (1985) opined that governance is a basic factor explaining the poor economic performance of many developing countries. However, in order to improve the agricultural performance of many developing countries, apart from physical and education investments, more emphasis should be placed on improving the governance infrastructure of such countries as better governance fosters agricultural productivity. Lio and Liu (2008) also affirmed that in a country with better governance, an agricultural worker can obtain higher agricultural productivity, given the same amounts of agricultural inputs, capital stock and land, the same education level, and the same climate condition. This implies that better governance can indirectly improve agricultural productivity by driving agricultural capital accumulation (Bayyurt and Yilaz (2012). Since political system is the most important institutional characteristic that effects policies and reforms, thus it is expected to have some effect on agricultural efficiency and productivity. The governance infrastructure may affect agricultural performance in several ways. For example, the government creates and maintains institutions that are crucial to the functioning of the market system. The protection of property rights and a judicial system administering justice and enforcing contracts strongly affect the incentives for production and investment. In addition, good governance supports a competitive and low-transaction-cost environment, which encourages agricultural innovation and stimulates the adoption of new technologies and forms of organization. The government acts as an important provider of rural infrastructure, public goods and services, and essential information on agriculture for farmers. The government also determines macroeconomic policies that affect both agricultural production and investment. In some countries, agricultural development has been seriously hindered by market-unfriendly policies that are characteristics of bad governance (Bayyurt. & Yilmaz, 2012).

The two main political systems in practice, i.e., democracy and dictatorship, have effect on macroeconomic and socioeconomic variables of a country. It has been identified that democracy, when adopted by countries, leads to higher level of economic development and growth around the world. According to Binswanger and Deininger (1997),

democracy may benefit agriculture efficiency in many ways like enhancing transparency and thus incentivize previously powerless groups to participate in agriculture. In the same view, Rodrik (1999) suggested that democracy promote stability which is translated into higher investment by all the sectors including agriculture. Lending credence to this, Aghion et al. (2007) also suggested that democracy reduces entry barriers and thus lead to introduction and adoption of technology in agriculture leading to improved productivity. Munir et al. (2018) affirmed that political interventions and agricultural policies during democracy regime and dictatorship regime have significant effects on development outcomes. They further revealed that dictatorship regime is bad for agricultural production efficiency, because dictatorship reduce the accumulation of factors of production which results in a waste in the utilization of existing resources with mean technical efficiency score (0.876) for democratic regimes which was higher than in non-democratic regime (0.733) suggesting that democracies increase returns to farmers compared to dictatorship. Government policies and involvement have significant impact on the structure and productivity of the agricultural sector. Sometimes government make such policies that directly affect the agricultural production but at the same time certain macroeconomic decisions and policies are made which have secondary effect on the agricultural sector. Agricultural policies are categorized into those that help in correcting the market inefficiencies or market failures, reduced cost, increased productivity and those that provides benefit to special interest groups at the cost of agricultural efficiency (Munir et al., 2018).

For the policy purpose, the government need to focus on supply-side reforms in the agriculture sector, by encouraging private participation, reducing leakage, increasing public investment and improving marketing infrastructure for agriculture related commodities trading and developing efficient value chains. There might be need for government to focus on structural issues instead of resorting to short-term policy measures implemented during different regimes for the political reasons. Most countries face challenges of good governance such as transparency and accountability, effectiveness, regulatory quality, rule of law, and corruption. More so, despite having high agricultural potential, growth in Total Factor Productivity (TFP) and agriculture's share of GDP is lower than other sectors. Little attention had been given to isolate the effect of the governance system on agricultural productivity which necessitate this research. This has become necessary in order to support the investments in R&D with policies aimed at guiding how the governance systems can be used to leverage on productivity. Therefore, there is need to determine the dynamic relationship between agricultural productivity and the type of democratic system in practice in each country of the world. That done will enable us to outline the necessary policies and interventions necessary to enable efficient agricultural production and food supply system thereby achieving sustainable global food security in general and SDG goals 1,2,3,10 &12 in particular. Therefore, this research has proposed the following research questions:

i. What is the global trend of TFP and agriculture contribution to GDP since 1960?
ii. What are the various governance systems (democratic or regime types) and how they affect TFP?
iii. Which governance structure has optimum TFP and what are the factors promoting it?

Literature review

Agricultural productivity refers to the efficiency with which inputs such as land, labour, capital, and technology are used to produce agricultural goods. Maximizing agricultural productivity is crucial for meeting the growing global demand for food, feed, fibre, and fuel (Abouzeid, 2016; Amos et al., 2004; Fleming, 2008). Among global efforts to improve agricultural productivity in the last decades are presented in Table 1.

All the above actions involved huge expenditure using the R&D framework but they have varying levels of success. That is why share of agriculture in global GDP has diminished over the decades, but the sector remains vital for food security, rural livelihoods, and the overall economic well-being of many countries, particularly in the developing world.

In developed economies, such as the United States and many European countries, agriculture's contribution to GDP is generally lower, often less than 5%. In contrast, in several developing countries in Africa, Asia, and Latin America, agriculture can still account for a substantial portion of GDP, ranging from 10% to over 30%. However, the declining share of agriculture in GDP does not necessarily imply a decline in the absolute value of agricultural output. In fact, agricultural production has continued to increase over the years due to technological advancements, improved practices, and expansion of cultivated land in some regions (African Development Bank Group, 2014; De Abreu Paiva & Bacha, 2020; De Soyres et al., 2022).

Table 1. Global Agricultural improvement efforts

Efforts towards Agricultural productivity	Focus	Sources
Green Revolution	increased adoption of high-yielding crop varieties, improved irrigation systems, and increased use of fertilizers and pesticides	Briggs, 2009; John & Babu, 2021; Phillips, 2014; Pingali, 2012
Breeding programs	developing crop varieties with improved traits such as higher yields, disease resistance, drought tolerance, and nutritional quality using biotechnology techniques like genetic modification	Bailey-Serres *et al*., 2019
Sustainable agricultural practices	enhancing productivity while minimizing negative environmental impacts through organic farming, crop rotation, agroforestry, integrated pest management, and precision agriculture to optimize resource use, conserve biodiversity, and protect the ecosystem	Mukhopadhyay et al., 2020; Nmadu, 2016
Precision agriculture	use of advanced technologies like GPS, remote sensing, and data analytics to optimize agricultural practices at a field level enabling farmers to apply inputs (water, fertilizers, pesticides) precisely where and when they are needed, leading to more efficient resource utilization and higher yields	Davis *et al*., n.d.; Singh *et al*., 2020
Agroecology	ecology to interact within farming systems seeking to optimize productivity by enhancing biodiversity, soil fertility, and ecosystem services through organic farming, polyculture, cover cropping, and biological pest control	Hatt *et al*., 2016
Effective farm management technics like planning and decision-making regarding crop selection, input allocation, risk management, and financial management	optimal resource allocation, minimize wastage, and improve profitability	Jirgi *et al*., 2015; Nmadu & Simpa, 2014
Provision of agricultural extension services to farmers by disseminating best practices, new technologies, and research findings to farmers	make informed decisions and adopt innovative techniques which enhanced knowledge, information, and technical support and thus improved productivity and income	Antwi-Agyei & Stringer, 2021; Kadilikansimba *et al*., 2023; Maake & Antwi, 2022; Moosaei & Afshari. 2023; Ragasa et al., 2013
Economic and policy actions like improved access to credit, markets, rural infrastructure, and government policies	incentivize farmers to adopt modern technologies and practices, thereby boosting productivity	Ayinde et al., 2014; Maier, 1977

The relationship between agricultural productivity and the type of democracy in a country is complex and not deterministic but can be influenced by various factors (Isham et al., 1997; Munir et al., 2018). While the political system, including the type of democracy, can indirectly accelerate or exacerbate sustainable food supply and systems and thus agricultural productivity, there are many other factors, such as governance structures, policy environments, cultural factors, economic conditions, technological advancements, infrastructure, geographical conditions, natural resources, market dynamics, and international trade and agricultural policies that play significant roles. In addition, there can be variations across countries and regions (Agarwal, 2014; Chigara, 1994, 1994; De Schutter, 2014; Fogel, 2007; Munir et al., 2018).

There are two main governance structures globally, democracy and Authoritarianism. Democracy is characterized by political freedoms, pluralism, and accountability while Authoritarian regime is characterized by centralized power and limited political freedoms. On a long-term, sustainability, inclusivity, and accountability of agricultural policies and practices under authoritarian regimes may be compromised. The lack of political freedoms and limited participation can hinder innovation, adaptive capacity, and the ability to address long-term challenges and changes in agricultural systems (De Schutter, 2014, 2014; Fogel, 2007; Fulginiti, 2010; Greyling et al., 2015; Olper, 2001; Shiva, 2005). For example, lack of effective supply chain, low food security status and near-absence of the spirit of innovation and entrepreneurship in agriculture are factors that can be prevalent in authoritarian regimes which can impact on the type of policies they may institute.

The level of focus on agricultural R&D can vary within both democratic and authoritarian countries. Some authoritarian regimes have also made significant investments in agricultural R&D, recognizing its importance for economic development and food security. Additionally, factors such as economic capacity, historical context, and national priorities can influence the level of emphasis placed on agricultural R&D in any given country, irrespective of its political system. Overall, while democratic countries generally exhibit a greater focus on agricultural R&D due to factors such as openness, participatory decision-making, and funding, it is important to consider the specific context of each country when evaluating the level of emphasis placed on agricultural R&D (Nin-Pratt et al., 2010, 2015).

Multilevel modelling (MLM), also known as hierarchical linear modelling, offers several advantages over multiple linear regression (MLR) when analysing data with a hierarchical or nested structure. Multilevel modelling offers advantages over multiple linear regression by appropriately accounting for the hierarchical structure of data, addressing non-independence, capturing group-level variation, allowing for heterogeneity, and efficiently utilizing the available data. These features make MLM a powerful and suitable approach for analysing hierarchical data and exploring relationships at multiple levels (Bernabéu, 2022; Brown, 2021). And since we are dealing with a nested data structure (continents, democracy), the choice of this model for analysis is justified.

2. Materials and Methods

This research is a global study on the relationship between regime type and agricultural productivity. The data for this research were obtained from three main sources, namely, the Economist Intelligence Unit Limited (EIU, 2022), Economic Research Service of the United States Department of Agriculture (ERS-USDA, 2023) and FAOSTAT (2022).

The motivation to undertake the study followed the 2021 publication of the index of democracy for countries of the world by EIU. The 2021 report was tending to present quite a number of contrasts observed between full democracies and partial or no democracies. In addition to the overall Index of Democracy, EIU (EIU, 2022) provided details of the democratic and other elements used to obtain the index which elicited some knocking questions to arise. For example, what is the empirical relationship between the variables and the final index?

The 2021 Index is the average of the annual indices for the years 2006-2021 (EIU, 2022). The data is for 167 countries in eight continents. In the report, there were four types of regimes based on the index viz: Authoritarian (A, 0-5.29), Full Democracy (FD, 7.94-9.71), Flawed Democracy (FLD, 5.29-9.12) and Hybrid (H, 2.06-8.53). However, the hybrids were further classified as those tending towards authoritarian (AH, 2.06-5.29) and those tending towards democracy (HD, 5.29-8.53). As could be observed, the index was just a guide and that is why there were overlaps. The classification is based on the regime type in place and not necessarily based on the index, so the index is independent of the type of regime.

On the other hand, the data on total factor productivity [TFP] (1961-2022) of the 167 countries were obtained from ERS-USDA (2023). TFP is the index of land, labour, capital and machinery and material inputs to the total agricultural output. The average change of TFP over the entire period was used as the dependent variable. In addition, contribution of agriculture to total GDP of the 167 countries which was obtained from FAOSTAT (2022) and included in the model as one of the explanatory variables. Both ERS-USDA and FAOSTAT data covered more countries than the EIU report. Some territories and countries were not covered either because they are new or some of them do not have defined governments or democratic systems; some are even in conflict[i].

Data involving multiple trials has been analysed using repeated measures ANOVA which normally assess if means of various measures differ significantly thus accounting for the fact that observations within individuals are correlated. Other statistical techniques like multiple linear regression (fixed effects) would violate the *independence assumption*. But in this particular study, countries within a continent practicing the same regime type and with similar agricultural productivity will certainly be correlated. In the same vein, countries with similar regime types could be correlated. Since the observations are not independent, the data should be analysed with a statistical test that takes the dependencies (regime types and continent) in the data into account. Therefore, linear-mixed effects or multilevel

regression modelling, rather than repeated measures ANOVA, is more preferable in analysing the data in which observations are nested within countries in a continent and within regime types. This will enable us to simultaneously take both sources of variability (fixed and random effects) into account as wells as the magnitude or direction of the effect of each variable; so, observations within a condition must be collapsed across either regime type or continent. The empirical structure of the linear-mixed effects model is presented in eq. 1.

$$Y_{ij} = X_{ij}t\beta + U_{ij}t\gamma_i + \epsilon_{ij} \quad \text{eq. 1}$$

Where Y_{ij} = response of j-th member of cluster i, i = 1, . . . ,m, j = 1, . . . , n_i

m = number of clusters

n_i = size of cluster i

X_{ij} = covariate vector of j-th member of cluster i for fixed effects, $\in R^p$

β = fixed effects parameter, $\in R^p$

U_{ij} = covariate vector of j-th member of cluster i for random effects, $\in R^p$

γ_i = random effect parameter, $\in R^p$

$\gamma_i \sim N_q(0,D)$, $D \in R^{q\times q}$

Σ_i = covariance matrix of error vector ϵ_i in cluster i

$\epsilon_i := \begin{pmatrix} \epsilon_{i1} \\ \vdots \\ \epsilon_{in_i} \end{pmatrix} \sim N_{n_i}(0,\Sigma_i)$, $\Sigma_i \in R^{ni\times ni}$

$\gamma_1, \ldots, \gamma_m, \epsilon_1, \ldots, \epsilon_m$ independent

D = covariance matrix of random effects γ_i

In this present study, the estimation is carried out based on the nature of the data, in which the observations are nested within continents and regime type. In order to account for variability within and across continents and regime type, the data was analysed using multilevel modelling techniques which has superior advantage over multiple linear regression (Brown, 2021). The technique is able to estimate fixed and random effects simultaneously whereas, linear regression would only estimate fixed effects. A total of 14 models and scenarios were estimated in trying to isolate the continents and or regime types that could exacerbate or enhance agricultural productivity. The definition of the variables in each model and how the scenarios were created are also presented on Table 2. All the estimations were achieved with R [R version 4.2.2] (R Core Team, 2022) using two add-on packages i.e. *afex* (Singmann, Bolker, Westfall, Aust & Ben-Shachar, 2023) and *lme4* (Douglas, Maechler, Bolker & Walker, 2015). The results are presented in maps, tables and charts.

Table 2. Models estimated, variables and scenarios.

Model*	Model type	Fixed intercept	Fixed effects**	Random Intercept	Factor***	Variances***
0	Linear	✓				
1		✓	✓			
2		✓		✓	Regime type	Continent
21		✓			Continent	Regime type
3		✓		✓	Regime type	
31		✓		✓	Continent	
4		✓			Regime type	Continent
41		✓			Continent	Regime type
5	Multilevel	✓	✓	✓	Regime type	Continent
51		✓	✓	✓	Continent	Regime type
6		✓		✓	Regime type	
61		✓		✓		Continent
7		✓	✓		Regime type	
71		✓	✓		Continent	

*Total Factor Productivity, **Agricultural GDP, Overall democracy score, Electoral process and pluralism, Functioning of government, Political participation, Political culture, Civil liberties.

3. Results and Discussion

Fig. 1 shows the trend in agriculture contribution to GDP from 1961-2021, indicating that there has been reduction of agriculture contribution to GDP from the highest of 80% in 1980 to the highest of 60% in 2020 which is in line with (Oyaniran, 2020) but contrary to the finding of (Sertoğlu et al., 2017) in the case of Nigeria for 1970-1980.

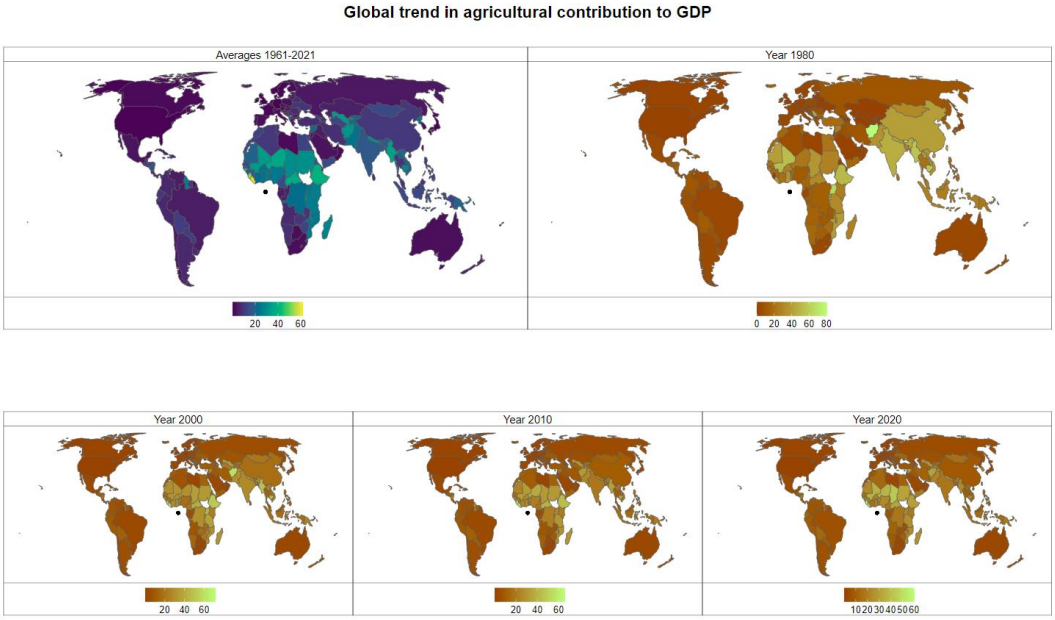

Figure 1. Global agriculture contribution to GDP, 1960-2021
Source: FAOSTAT (2022)

It would also be observed that more of the reductions occurred in CIS following the breakup of the Soviet Union into the confederation units which has encouraged freedom of speech, creativity and industry. No any appreciable changes have taken place in Africa, most especially, SSA. Land extensification (Nkamleu, 2011) and over-application of manual labour (Steenwyk et al., 2022; Sui et al., 2022) are most likely the drivers behind static or increasing contribution to GDP of some of the countries because of low funds available for R&D leading fading productivity and low technology improvement (John & Babu, 2021). Land extensification has led to deforestation thereby exposing it to precursors of climate change (Sallawu et al., 2020).

On the other hand, Fig. 2 shows that there are three major phases of changes to TFP. The first phase is the improvement of TFP from below -150% to -100% which occurred in the period 1961-2000, while the second period, 2000-2010, there was improvement of TFP from -100% to -75%. The last phase, 2010-present, saw the TFP steadying at -75% on the minimum side. On the maximum side, over the entire period, the TFP has dropped from 50% growth to 25%. It took a period of 40 years for the negative growth in TFP to improve to a third but took a period of twenty years for another third improvement in the negative growth. This is an indication that TFP increased faster after the turn of the millennium. This might have occurred as a result of the campaign for the achievement of the SDG goals as well as increased concern over climate change. However, while some countries have achieved tremendous improvement in TFP; notably, Namibia, Botswana, Morocco, Libya, others have remained relatively stable. Although it appears that the gain by Libya seems to be on reverse, perhaps owing to the conflict currently ravaging the country. So, while addition to GDP might be on the rise, TFP is on decline. That situation supports the earlier argument that land extensification probably contributed to the GDP.

Table 3 and Figure 3 shows the distribution of the countries based on the type of regime indicating that full democracy is practised in about 10% of the countries while around 30% are authoritarian. The balance is a mixed of the two. Quite unexpectedly, the US is classified as a country practicing flawed democracy in spite of being the yard stick on democratic governance around the globe. This might be due to the practice of the college vote for the final winner of the presidential elections which has received some criticisms over time (Norris, 2017).

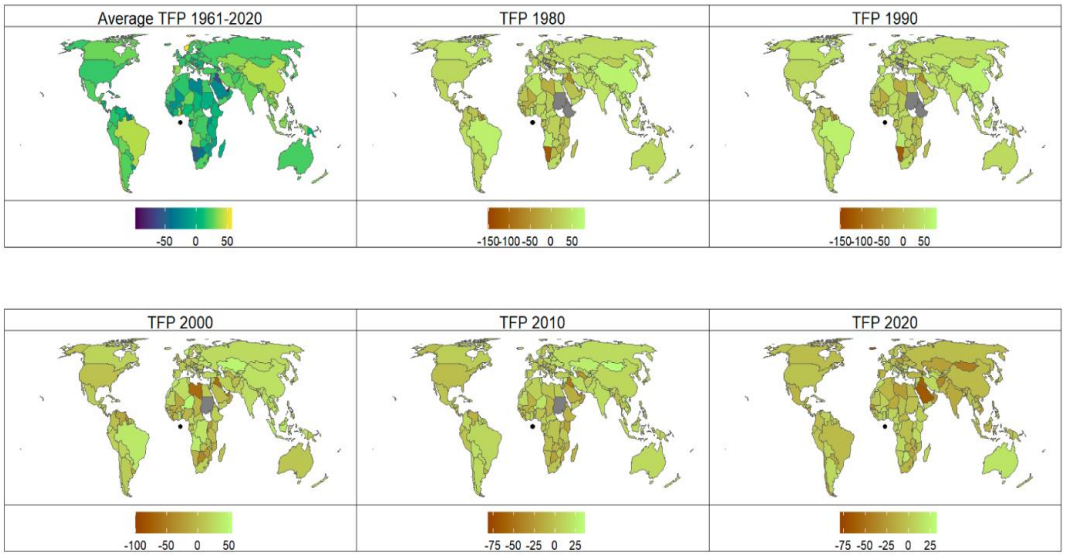

Figure 2. Global TFP changes, 1960-2021, Source: ERS-USDA (2023)

Table 3. Distribution of countries based on the type of regime in place as at 2021

Continent	A	AH	HD	FLD	FD
Africa	27	8	8	6	1
Asia	7	3	2	9	3
CIS	8	2	1	1	0
Europe	0	1		23	12
Middle East	13	0	1	1	0
North America	0	0	0	1	1
Oceania	0	1	0	1	2
South America	4	5	2	11	2
Total	59	20	14	53	21

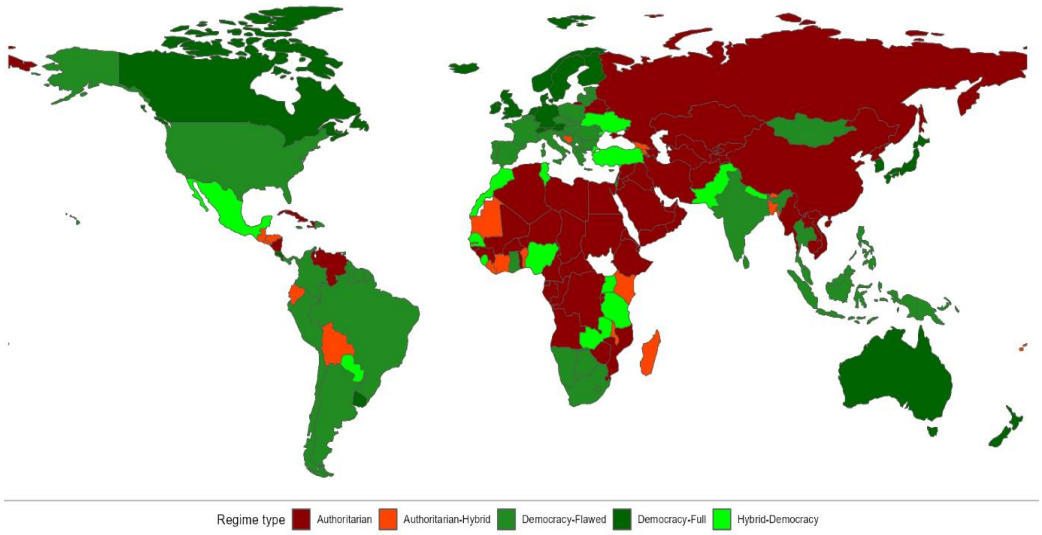

Figure 3. Spatial distribution of countries based on regime type. Source: EIU (2021)

The results on Table 4 and Fig. 4 shows the distribution of the countries based on the level of agriculture contribution to GDP. The results indicate that agriculture contribution to GDP is smallest in all the countries with FD while it was highest in all the countries under various forms of authoritarian regimes, except in the case of the countries in the Middle East where there is absence of full democracy yet their agriculture contribution to GDP is very low. Meanwhile, the results in Table 5 and Fig. 5 tend to suggests that the highest change to TFP is from Asian Authoritarian regimes while the worst improvement in TFP is from Authoritarian regimes from Oceania. In terms of continent improvement, Africa seems to be the worst as the TFP for all the regimes hover around zero. In fact, countries practicing democracy in Africa seems to be having retrogressive TFP. Asia and North America have highest TFP on average. On the basis of the regime type, it could be observed that countries under full or varied democracy out-perform those under authoritarianism.

Table 4. Mean agriculture contribution to GDP based on continents and regime types

Continent	A	AH	HD	FLD	FD	Mean
Africa	20.84	29.87	21.71	8.47	3.95	16.97
Asia	24.38	11.46	27.20	11.74	1.76	15.31
CIS	14.29	14.48	9.41	12.41		12.65
Europe		7.03		4.38	1.57	4.33
Middle East	5.47		7.71	1.37		4.85
North America				1.83	0.99	
Oceania		10.88		19.85	4.08	11.60
South America	11.26	10.03	7.22	7.64	7.04	8.64
Mean	15.25	13.96	14.65	8.36	3.37	

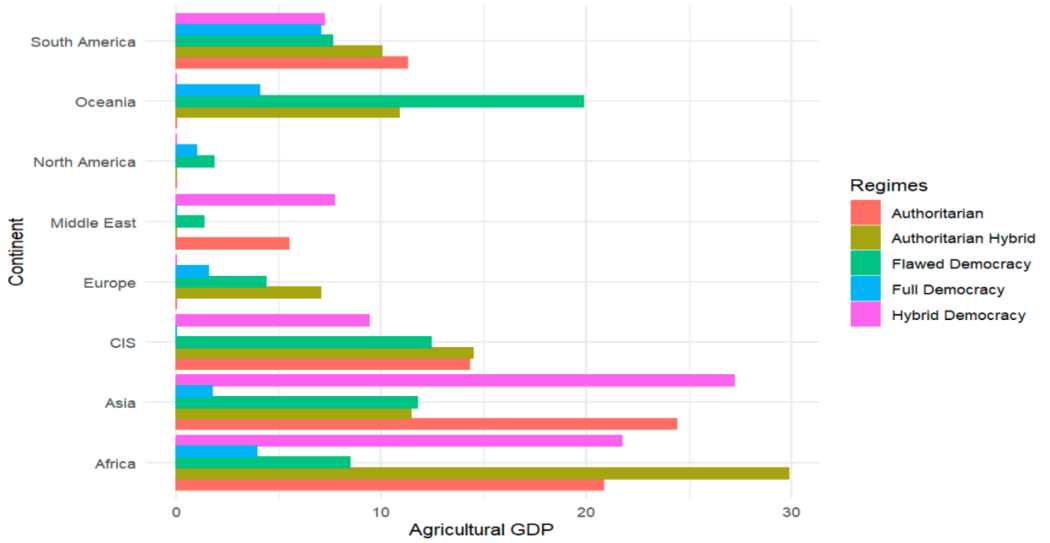

Figure 4. Continental mean of agricultural GDP of the various regime types

Table 5. Mean TFP based on continents and regime types

Continent	A	AH	HD	FLD	FD	Mean
Africa	-3.39	5.47	9.3	-6.05	-15.23	-1.98
Asia	35.08	14.54	25.43	18.57	21.89	23.10
CIS	22.81	11.29	22.3	21.52		19.48
Europe		0.02		14.05	19.83	11.3
Middle East	-4.29		22.69	25.12		14.51
North America				18.21	29	23.61
Oceania		-46.71		4.56	28.03	-4.71
South America	7.22	19.59	20.84	5.45	4.7	11.56
Mean	11.49	0.7	20.11	12.68	14.70	

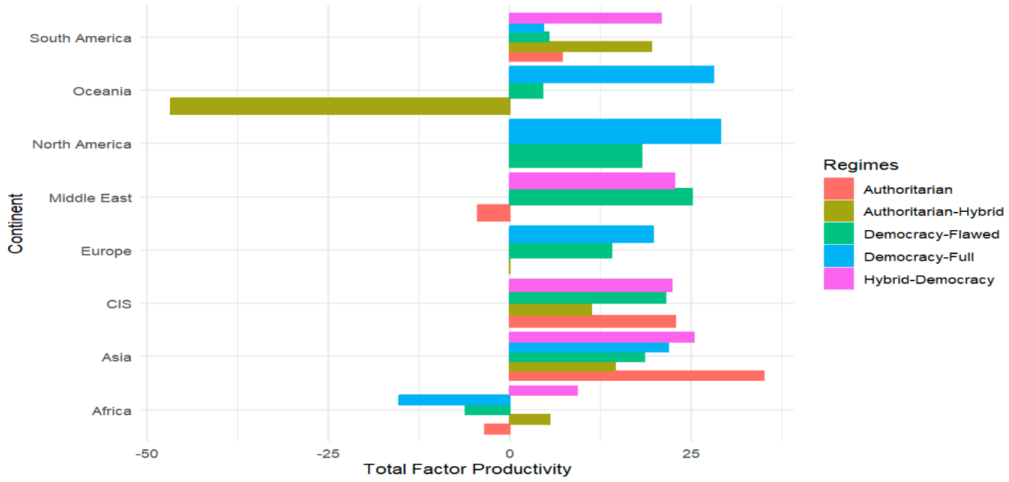

Figure 5. Continental mean of TFP of the various regime types

The results of the estimation of all the models are presented on Table 5 and Fig. 6-Fig. 12. From the results on Table 5, only agriculture GDP gave an indication of changing TFP by between 0.37% and .45% among all the factors that had been used to determine fixed factors impacting global TFP. However, it would appear that changes to TPP is more likely in terms of random intercepts and slopes especially of countries/continents rather than regime type. For example, while only AH showed a reduction of TFP by 27.44%, there is a change of TFP caused by countries in Asia (21.40%-25.06%), CIS (17.68%-25.03%), Europe (18.11%-21.24%) and South America (13.21%) all in the positive direction. Furthermore, Africa, Middle East, North America and Oceania did not show any change the level of TFP over all the models quite contrary to what ought to be, especially in North America and Oceania. Based on these results, hybrid authoritarianism has impacted the most on TFP changes for the period 1961-2021.

The results in Figure 7 are all in support of these percentage changes to TFP, particularly indicating mixed results but efforts should be geared towards improvement at the continental levels especially those practicing authoritarianism. The best model providing policy path for regimes to ensure sustainable food systems and supply is Model 6 which have postulated a mean that for sustainability, authoritarian regimes should work at achieving TFP of around 25% as presented in Fig. 8. On the other hand, all the models show encouraging outcome in modelling the continental effects on TFP. However, Model 71 seems to provide a policy path for Africa to catch up with the level of TFP in Asia since Asia gave the best impact from the various models. The interesting part of the results are that the downward trends only affect imperfect regimes, i.e., authoritarianism.

Based on the results obtained after all the estimations, the natural question is 'Which is likely to give greater outcome and enhance sustainable food systems and supply: investment in political reforms or investment in agricultural R&D?' The answer would be both. For example, the results in Fig. 6 shows the variability of TFP based on random effects of intercepts, continents and regime types. They indicate that the range of change in variance of the estimates based on continents is a very wide gap from -694 to 1559 while it is just between -135 to 561for regime types. However, the actual quantity of change in the estimates depends on the current level. What can be said is that the higher variance occurs in countries of Asia, CIS, Oceania, North America and Europe in which the governance systems are authoritarian or are in transition to FD. The variances in North America and Oceania are contrasts because the estimated coefficients are not significant. The results in Fig. 7-Fig. 12 are actually the indication of the inherent speed of change in TFP and regime types by countries included in this study. But only an upward trend in TFP is desirable in order not to over-exploit our natural resources and exacerbate precursors of climate change and environmental degradation. Hence, it is imperative to institute political reforms in countries operating imperfect democratic regimes and enhance investment in agricultural R&D in Africa, Asia and CIS to tigger upward trend. Therefore, investment in both political reforms and agricultural R&D are necessary for sustainable food systems and supply. The results also show clearly that the widest variability was caused by Model 2 series while models 3 and 6 shows the smallest though it was only random intercepts.

It could be inferred that those countries where TFP is low are still operating under labour-extensive and land area extensification agriculture (Blanco and Raurich, 2022) in contrast to capital-intensive and land area intensification agriculture in countries operating full democratic institutions. Therefore, it is clear that there is link between agricultural technology and hence productivity, and democracy. Freedom entails creativity and industry which are

often lacking in authoritarian regimes. It is then concluded that in future development goals targeting, efforts are to be made to assist authoritarian regimes to embrace democracy so as to promote prosperity, enhanced income and food sovereignty.

Table 5. Coefficients of multilevel models of global TFP based on regime type and continents

Variables	(1)	(2)	(21)	(3)	(31)	(4)	(41)	(5)	(51)	(6)	(61)	(7)	(71)
(Intercept)	30.69	11.14***	11.43***	10.34***	11.22**	11.02***	11.43***	-8.33	22.47	30.69	30.69	1.79	22.69
	(114.77)	(1.94)	(3.03)	(2.36)	(3.82)	(1.94)	(3.03)	(117.14)	(116.90)	(114.77)	(116.01)	(113.64)	(114.48)
Agric GDP	0.45+							0.37	0.42+	0.45+	0.45+	0.37	0.42+
	(0.23)							(0.22)	(0.23)	(0.23)	(0.23)	(0.22)	(0.23)
Overall dem. score	-4.56							14.83	-0.31	-4.56	-4.56	14.81	-0.30
	(21.41)							(22.58)	(22.36)	(21.41)	(21.41)	(22.58)	(22.36)
Rank	-0.23							-0.01	-0.19	-0.23	-0.23	-0.01	-0.19
	(0.60)							(0.60)	(0.60)	(0.60)	(0.60)	(0.60)	(0.60)
Electoral process & pluralism	-0.68							-3.15	-1.23	-0.68	-0.68	-3.15	-1.24
	(4.64)							(4.65)	(4.71)	(4.64)	(4.64)	(4.65)	(4.71)
Functioning of govt	3.11							-0.35	2.32	3.11	3.11	-0.35	2.32
	(4.43)							(4.55)	(4.59)	(4.43)	(4.43)	(4.55)	(4.59)
Pol. participation	1.96							-1.59	1.17	1.96	1.96	-1.58	1.17
	(4.36)							(4.48)	(4.54)	(4.36)	(4.36)	(4.48)	(4.54)
Pol. culture	-2.26							-5.37	-2.87	-2.26	-2.26	-5.37	-2.87
	(4.26)							(4.41)	(4.46)	(4.26)	(4.26)	(4.41)	(4.46)
Civil liberties	0.24							-2.09	-0.37	0.24	0.24	-2.08	-0.37
	(4.06)							(4.07)	(4.23)	(4.06)	(4.06)	(4.07)	(4.23)
Democracy-Authoritarian-Hybrid	-7.75							-5.76	-12.26	-7.75	-7.75	-27.44+	-12.26
	(11.42)							(36.48)	(12.92)	(11.42)	(11.42)	(15.67)	(12.92)
Democracy-Democracy-Flawed	-12.11							-13.92	-13.18	-12.11	-12.11	-23.85	-13.18
	(15.61)							(37.98)	(15.63)	(15.61)	(15.61)	(18.02)	(15.63)
Democracy-Democracy-Full	-7.50							-16.44	-9.30	-7.50	-7.50	-20.44	-9.31
	(20.43)							(40.31)	(20.49)	(20.43)	(20.43)	(22.04)	(20.49)
Democracy-Hybrid-Democracy	3.12							3.34	1.19	3.12	3.12	-11.57	1.19
	(13.99)							(37.28)	(14.11)	(13.99)	(13.99)	(18.01)	(14.11)
Continent-Asia	23.28**							21.40*	25.33	23.28**	23.28	21.40*	25.06**
	(7.25)							(8.96)	(34.34)	(7.25)	(25.01)	(8.96)	(7.57)
Continent-CIS	23.44**							17.68+	25.34	23.44**	23.44	17.68+	25.03**
	(8.12)							(9.71)	(34.52)	(8.12)	(25.28)	(9.71)	(8.35)
Continent-Europe	20.37**							18.11+	21.50	20.37**	20.37	18.11+	21.24**
	(7.50)							(10.06)	(34.33)	(7.50)	(25.09)	(10.05)	(7.59)
Continent-Middle East	3.28							15.74	4.00	3.28	3.28	15.73	3.84
	(8.38)							(12.50)	(34.51)	(8.38)	(25.36)	(12.49)	(8.39)
Continent-North America	24.99							22.27	26.22	24.99	24.99	22.28	25.99
	(18.14)							(19.50)	(38.06)	(18.14)	(30.04)	(19.49)	(18.13)
Continent-Oceania	5.77							5.14	9.29	5.77	5.77	5.14	8.74
	(13.41)							(23.51)	(36.16)	(13.41)	(27.44)	(23.52)	(13.60)
Continent-South America	13.21+							9.45	12.61	13.21+	13.21	9.45	12.62
	(7.67)							(7.84)	(34.41)	(7.67)	(25.14)	(7.84)	(7.91)
Num. Obs.	167	167	167	167	167	167	167	167	167	167	167	167	167
R^2	0.203												
R^2 Adj.	0.100												
R^2 Marg.		0.000	0.000	0.000	0.000	0.000	0.000	0.152	0.199	0.184	0.130	0.174	0.197
R^2 Cond.		0.143		0.012	0.117						0.423		
AIC	1552.4	1599.8	1563.1	1550.8	1539.6	1599.8	1563.1	1533.2	1494.9	1467.3	1467.3	1533.2	1494.9
BIC	1617.8	1718.3	1616.1	1560.1	1549.0	1718.3	1616.1	1710.9	1607.1	1535.9	1535.9	1710.9	1607.1
ICC		0.1		0.0	0.1						0.3		
Log. Lik.	-755.183												
F	1.967												
RMSE	22.27	22.23	22.82	24.74	23.22	22.23	22.82	21.43	21.94	22.27	22.27	21.43	21.94

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Models' definition

Model 1: Full Fixed Effects

Model 2: Random effects on Regime types

Model 21: Random effects on Continents

Model 3: Random effects on regime types without variance/co-variance

Model 31: Random effects on continent without variance/co-variance

Model 4: Random effects without random intercept on regime types
Model 41: Random effects without random intercept on continents
Model 5: Full model - effects and random intercept with regime type
Model 51: Full model - effects and random intercept with continent
Model 6: Random intercept with regime type only without fixed effects and variances
Model 61: Random intercept with continent only without fixed effects and variances
Model 7: Fixed effects without random intercept and variances with regime type
Model 71: Fixed effects without random intercept and variances with continent

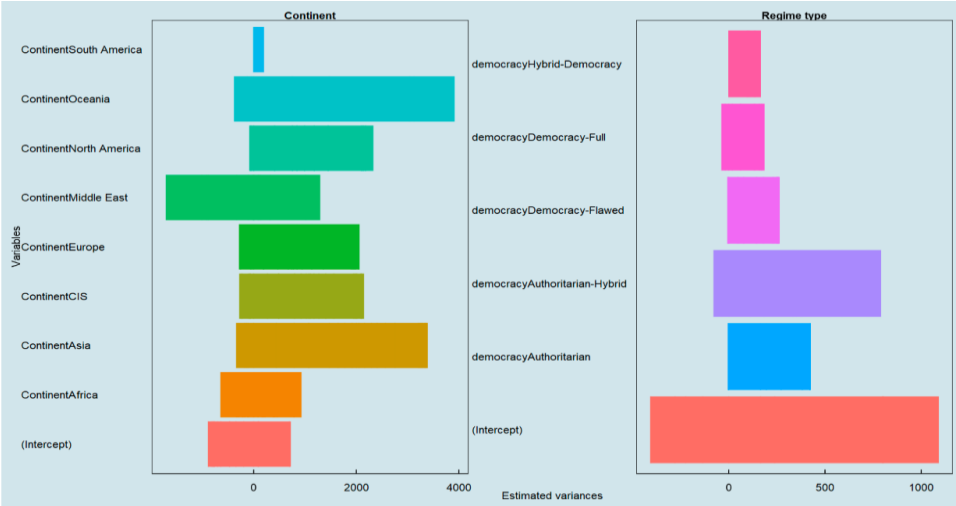

Figure 6. Estimated variances of TFP of various continents and regime types

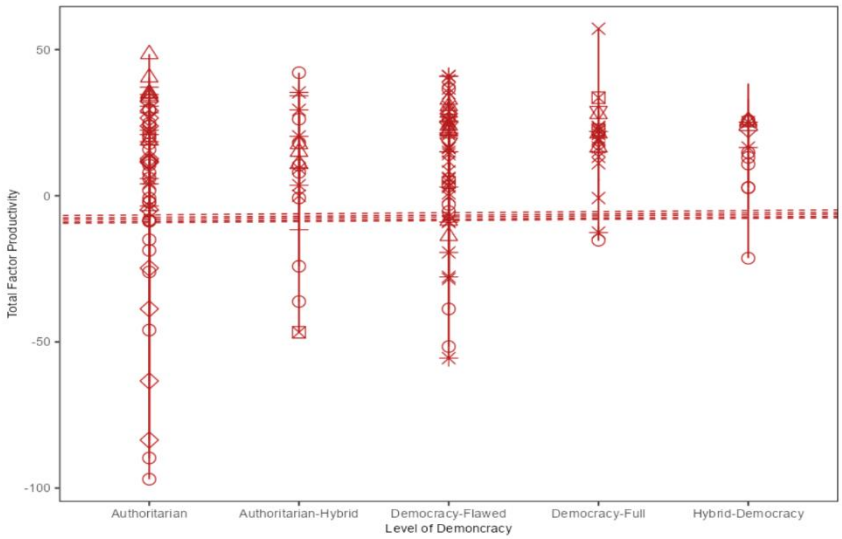

Figure 7. Estimates of fixed effects and random intercept with regime type

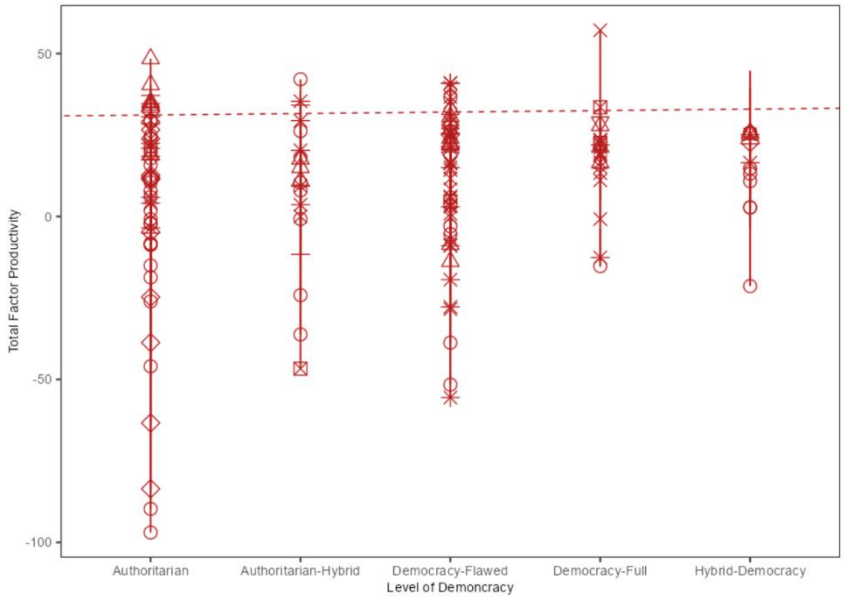

Figure 8. Estimates of random intercept with regime type only

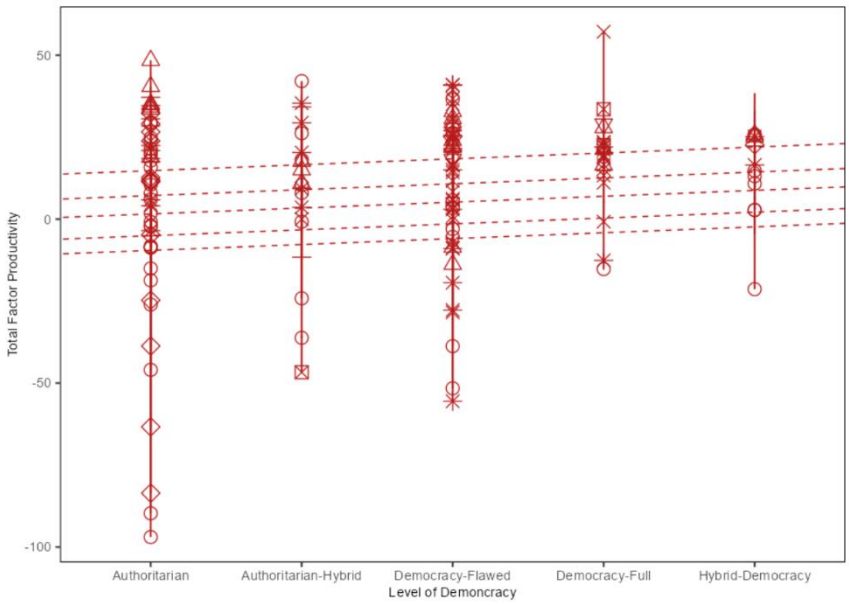

Figure 9. Estimates of fixed effects and variances with regime type

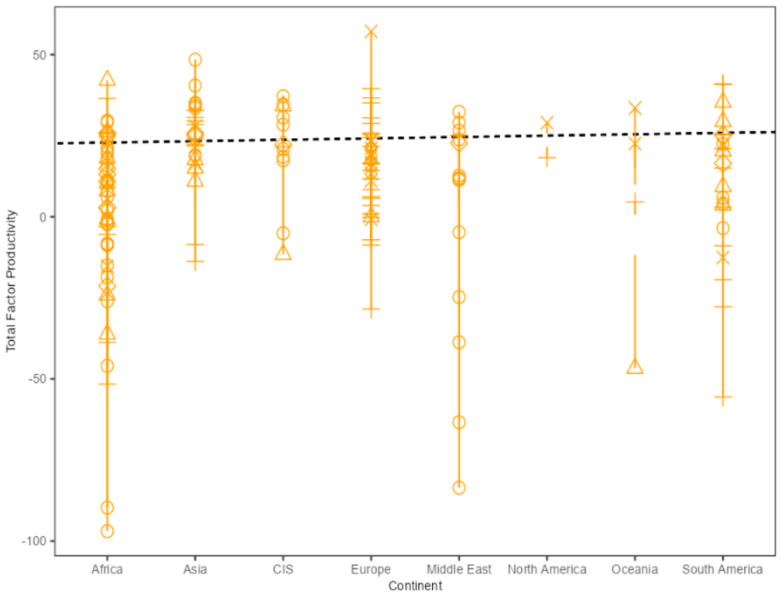

Figure 10. Estimates of effects and random intercept with continent

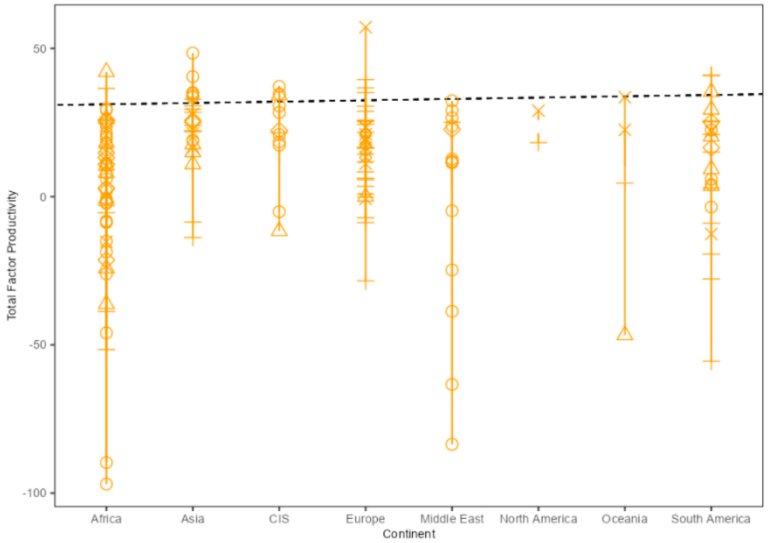

Figure 11. Estimates of random intercept with continent only

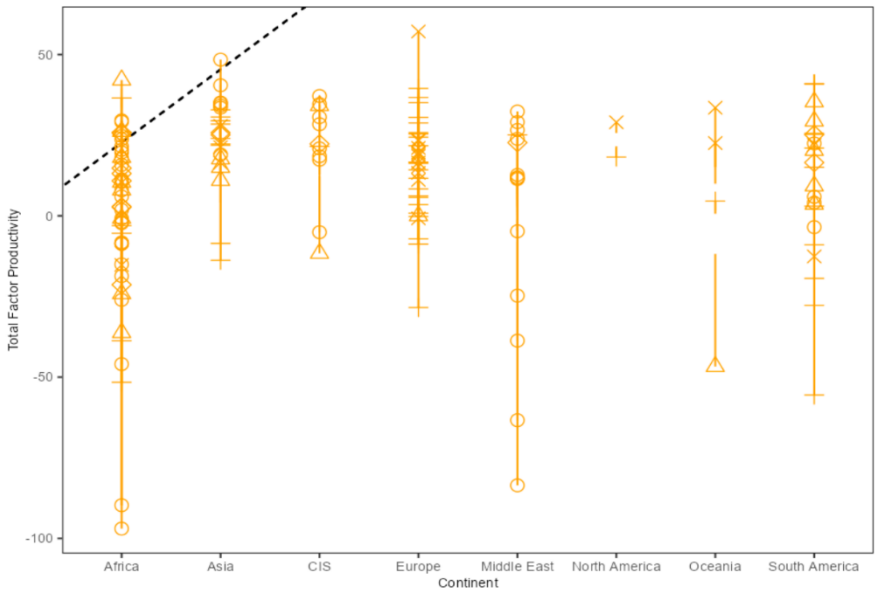

Figure 12. Estimates of fixed effects and variances with continent

4. Conclusion and Recommendation

The world is faced with ever-increasing population but the resources to maintain efficient and sufficient food systems and supply, like land and capital, are continuously constrained. Therefore, every factor that could lead to enhanced efficiency and ensure food sustainability have to be critically examined and analysed. That is why this research focussed on the relationship between TFP and regime type of 167 countries classified into five regime types, viz, FD, FLD, HD, A and AH. The relationship was estimated using multilevel modelling techniques which consists of fixed and random effects. The random effects were estimated for the intercept, the regime type and the continent each country belongs.

From the results has been obtained, there has been an improvement of TFP which has risen from below -150 in the 1960s to the highest of 25% in 2021. Furthermore, FD is practised in about 10% of the countries while around 30% are A. In addition, countries which practice FD have lower TFP. Also, countries with low TFP practice imperfect democracy and they are in Africa, Asia, CIS, Oceania and South America. Mixed effect variances are wider between continents than between regime types suggesting that country-level policies are likely to have more impact on changes in TFP than regime type could have. Finally, mixed effect factors suggest path for imperfect regime and continents not operating at optimal TFP to follow in order to reach a level of sustainable food systems and supply and ensure food and income security for a world threatened with constrained natural resources to support ever expanding populations. Therefore, it is recommended that there should be *political reforms in countries operating imperfect democratic regimes to enhance investment in agricultural R&D especially in Africa, Asia and CIS. In addition, countries* in Africa and those not practicing FD should work towards improving TFP by at least 50% of their 2021 levels through investing in higher productivity technology thereby reducing land and labour-intensive resources for promoting green economy. The free resources can be utilised in other sectors; particularly, food processing and supply chains; for greater efficiency to achieve sustainable food systems and supply.

In view of the short-coming of data availability that limited this research to only 167 countries, there is need to expand this study to include all countries and independent territories so as to outline a global action strategy on governance and sustainable agricultural and food systems. In addition, there is need to examined more factors that could either impact or confound agricultural productivity as well as technology for food systems thereby ensuring that whatever population the world has, receives adequate food and nutrition.

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[i] List of countries and territories not included in the research due to incomplete data: Puerto Rico; Saint Barthélemy; Saint Helena, Ascension and Tristan da Cunha; Saint Kitts and Nevis; Saint Lucia; Saint Pierre and Miquelon; Saint Vincent and the Grenadines; Saint-Martin (French part); Samoa; San Marino; Sao Tome and Principe; Seychelles; Sint Maarten (Dutch part); Solomon Islands; Somalia; South Georgia and the South Sandwich Islands; South Sudan; Vanuatu; Tokelau; Tonga; Turks and Caicos Islands; Tuvalu.