Impact of Macroeconomic Factors on Foreign Direct Investment in Agro-sector: A Cointegration Analysis Based on Bangladesh

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Abstract

The role of foreign direct investment (FDI) is crucial in terms of agri-sector for fostering productivitiy, safeguarding food safety, balancing ecology, and shifting traditional to the modern systems of the environment. This study entailed macroeconomic issues such as economic growth, inflation, trade, and exchange rate onwards of FDI flows in agriculture using annual data from 1990 to 2022. Using fully modified OLS (FMOLS) and dynamic OLS (DOLS), this study observed that economic growth bolstered inflows of agriculture from the foreign side on some regression models but inflation and exchange rate reduced it. Hence, policymaking needs to be addressed to stabilize the speed of high inflation and balance exchanging rates with flexibility so that investors can raise their interest to augment their volume of currencies in agriculture. Besides, trade policy needs to be changed, omitting bureaucratic inactivities, merging gaps in export and tariff protection, and ensuring import liberalization without hurdles.

Keywords: *Foreign Direct Investment; Macroeconomic Factors; Agro-sector.*

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Introduction

FDI in terms of the agro sector is now a buzzword as it has become imperative for foreign fosters to broaden agricultural productivity, food security, and economic growth, particularly in developing countries (Dogan, 2022; Nyiwul& Koirala, 2022; Epaphra &Mwakalasya, 2017). Studies indicate that FDI contributes positively to total factor productivity (TFP) and income growth, enhancing the overall economic landscape of host countries (Epaphra &Mwakalasya, 2017). FDI is attracted to countries with huge domestic markets and mounting consumer demand. The probable of neighboring countries also plays a role, as foreign investors may use a country as a regional trade podium (Kubik & Husmann, 2019; Rashid et al., 2016). As consumer demand increases, it indicates to foreign investors that there is a feasible chance for profitability. Stockholders are more expected to arrive at markets where they antedate strong demand for their offerings, which can lead to advancedrevenues on investment. This is predominantly relevant in emerging economies, where a burgeoning middle class can drive demand for various products, including agricultural goods (Hossain, 2008).

In the context of Bangladesh, it occupies a fertile, rich land, and ecologically, the temperature, humidity, and rainfall have made farming possible (Al-Mamun, 2023). The business must solve many issues, such as insufficient money, old equipment, or the newest technology. Because of these issues, it is clear that much money needs to be spent to improve productivity and efficiency. Hence, foreign direct investment or FDI can assist in cash flow, but it faces two major hurdles: targeting the country's policies and economic stability. When it comes to the economy, things that are good for business are low inflation, stable exchange rates, and long-term spending policies. Many companies in Bangladesh have been able to get foreign investment thanks to new rules that make the economy more investor-friendly (Ablo & Boadu, 2020). Strengthening the self-sufficiency and dimensions of anti-corruption bodies like the Anti-Corruption Commission is also critical(Hossain, 2018; Miah et al., 2022). Furthermore, vigorously endorsing Bangladesh's investment chances and business-friendly policies through economic and commercial diplomacy can benefit more FDI. Hence, focusing on all these facets, this study has attempted to solve some questions.

RQ1. How do economic growth, inflation, government expenditure, exchange rate, and trade contribute to agricultural FDI inflows?

RQ2. Does any long-run equilibrium of explanatory variables exist FDI inflows on agriculture?

In the focus of these research questions, this study aims to exhibit the effect of economic growth, inflation (proxy of monetary impact), government expenditure, exchange rate (proxy of financial stability) and trade on agricultural FDI inflows using time series of 1990 to 2022.

Hypotheses Development

Influence of Economic Growth on FDI Inflows on Agriculture

Flows from foreign investors spread economic expansion, especially in developing countries, into several channels (Sultana and Sadekin, 2023; Nyiwul and Koirala, 2022; Awunyo-Vitor and Sackey, 2018).Farmers have more opportunities to upsurge their productivity and output as the economy and its several domains have increased.This expansion habit has opened the demand for food, inspiring agricultural production and investment in the sector (Awunyo-Vitor and Sackey, 2018; Epaphra &Mwakalasya, 2017).Hence, in parallel with these relevant studies, this study postulated the first couple of hypotheses:

H1. Economic growth positively and significantly influences FDI inflows to agriculturein Bangladesh.

Influence of Inflation on FDI Inflows on Agriculture

Inflation rates in unending escalation can thrive into economic uncertainty, creating more hurdles for investors to forecast future costs and revenues. When inflation is unpredictable, it confounds financial planning and risk assessment, leading to a predilection for markets with lower inflation rates and more predictable economic circumstances (Odhiambo, 2021). Inflation also retards agriculture by upsurging the internal and external cost of agricultural inputs and their facets, such as seeds, fertilizers, insecticides, and apparatus (Uteh et al., 2022). As prices rise with time, farmers face hurdles, such as surging production costs, which can reduce their profit margins and depress investment in modern farming performance. When farming output increases, the price of the raw materials that food processing companies need decreases (Barrett et al., 2022). This lowers the cost of making food, so customers pay less. Higher agricultural output aligns with lower inflation rates, according to empirical studies and historical data from Bangladesh (Sarker, 2024). For instance, sudden tax policy, trade regulations, or funding alterations can ascend as governments respond to inflationary pressures. Such impulsiveness can deter FDI, as foreign investors prefer stable regulatory environments (Mbiakop et al., 2023). Hence, the next hypothesis is as follows:

H2. Inflation negatively and significantly influences FDI inflows to agriculture in Bangladesh.

Influence of Government Expenditure on FDI Inflows on Agriculture

According to the investment development policy (IDP) theory, government spending is quite tough to enable progress in the earlier stages of economic development. Productive expenditures on infrastructure, such as transport networks, information and communication technology, energy, education, and health, can boost the economy's productivity and competitiveness. This, in turn, attracts cross-border investments in market-seeking and asset-seeking FDI (Benin, 2019; Megbowon et al., 2022). In Bangladeshi farming, ensuring the farming sector does well is vital for Bangladesh's GDP, jobs, and rural growth. Since agriculture makes more money when output intensifies, the government can generate more money for spending without intermediaries(Santangelo, 2018). If farmers in the country can grow more food and make more money, more people will need public services like schools, hospitals, and social security. So, the next couple of hypotheses is:

H3. Government expenditure positively and significantly influences FDI inflows to agriculture in Bangladesh.

Influence of Exchange Rate on FDI Inflows on Agriculture

In the previous decades, several studies confronted that exchange rate instabilities strongly impact export competitiveness, inner side or domestic costs, profitability or productivity, and investment policies (Gopinath et al., 1998; Cheng & Orden, 2007; Uteh et al., 2022). A promising exchange rate (devalued or depreciated local currency) can open gateways to make agricultural exports low-priced and more competitive internationally. This movement can uplift the export volumes of agricultural products, snowballing revenue for farmers and agribusinesses (Iorember et al., 2024). A recent study by Hossain (2018) posited that circumstances, when the Bangladeshi Taka was feebler were reimbursed for by augmented exports of agricultural goods like rice and jute, increasing the sector's overall revenues. This strengthens the BDT by increasing the assets held in foreign currencies. Investors get excited when the farm sector's economy improves, making the currency more valuable (Dey et al., 2021). Hence, the fourth couple of hypotheses are as follows:
H4. The exchange rate negatively and significantly influences FDI inflows to agriculture in Bangladesh.

Influence of Trade on FDI Inflows on Agriculture

Contracts, strategies, and relevant meetings are now playing significant roles in encouraging openness in trade and widening the accessibility of agricultural products in the market (Nugroho et al., 2024; Jha et al., 2010). The

growth of the jute and rice industries has helped maintain a strong link between production and exports. Records of trade with other countries also show that Bangladesh's farm exports increase when the country's output increases (Islam, 2019).Trade can mitigate price volatility by consenting to the export of surplus production and import during deficiencies, promoting producers and consumers (Zimmermann &Rapsomanikis, 2023). Hence, the next hypotheses are as follows:

H5.Trade positively and significantly influences FDI inflows to agriculture in Bangladesh.

Research Methods

This study executed the power of stationarity through the traditional unit root tests- Augmented-Dickey Fuller test (1979; 1981) and Phillips-Perron's (1988) unit root test for annual data from 1990 to 2022. This study inferred upon the PP test to analyze robustness for a time series of serial correlation and heteroscedasticities, which depend on time. Afterwards, correlation along with basic statistics was stated with a proper declaration and for cointegration, the Fully Modified Ordinary Least Squares (FMOLS) estimator recognized by Phillips and Hansen (1990) and Dynamic ordinary least square (DOLS) presented by Stock and Watson (1993) were applied.

Data Source with Variable Description

This study covered time series data from 1990 to 2022 regarding foreign direct investment in the farm sector, trade openness (export and import percentage of GDP), government expenditure (percentage of GDP), exchange rate, and inflation. The author estimated outcome variables by adding both the agro sector and beverage or else and then linearized them into natural logarithmic transformations. All of the variables are collected from the World Development Indicator. A description of variables is given in the Appendix (A1). Also, the inflation rate is used to check robustness and exchange rate and tackle the stability of macroeconomic performance. As a scheduled sign, the table also sheds the expected relation between foreign direct investment in the farm sector and control variables.

Model Specifications

This study attempted a time series approach from 1990 to 2022 under the availability of data sources. In parallel with previous studies, this study exemplified a unique but simplistic framework for exhibiting the long-run effect of several economic variables on agricultural productivity in two regressions (Sultana &Sadekin, 2023; Adhana, 2016). The regression equations are shown below:

$$Y = f(X_1, X_2, X_3, X_4, X_5) \qquad \text{(I)}$$
$$Y = f(X_1, X_2, X_3, X_4, X_5, D_1) \quad \text{(II)}$$

Y is the outcome variable regarding the FDI inflows in the agricultural sector, respectively. For explanatory variables,X, X_2, X_3, X_4, and X_5 -these five variables are GDP per capita as a proxy of economic growth, GDP deflator as a proxy of monetary policy,expenditure from the government side, exchange rate and trade, respectively. Firstly, to explain the effect of the dummy onwards, this study extended one more model in terms of model II, where D_1 is dummy. All these variables are converted into natural logarithms for generalization in the explanation of regression to reduce heteroscedasticity (Benoit, 2011; Gujarati & Porter, 2009).

Descriptive Statistics

The central tendency, the measure of dispersion, and the normality test are shown in descriptive statistics. The average value of FDI flows on the agro side was 1.546 during this 42 years of study, while the minimum was observed as -2.222 in 1995 due to a mixture of economic liberalization processes that were still proceeding, infrastructural and institutional contests, an emphasis on more profitable sectors, and a developing, controlling environment (Hossain, 2008). Similarly, the average GDP per capita (current USD) was 6.511 units. For variability, the standard deviation (SD) was estimated, and it was observed that each variable was exhibited under closeness within the point as the value posited beneath one (except the outcome variable). Moreover, maxima, average, and minima were also clustering to each other, resulting in variables that were out of extreme values or outliers. As skewness and kurtosis were positioned behind the threshold level, there was a greater chance of following the normal distribution of each variable (Hair, 2009). For more information, the result is shown in Table 01. Moreover, a line chart was shown after logarithmic conversion. It shows some negativity in FDI investment in agriculture while economic growth is climbing, but the exchange rate and trade are parallel (See Appendix).

Table 01: Basic statistics of study variables

	Y	X1	X2	X3	X4	X5
Mean	1.546	6.511	1.596	2.374	4.104	3.438
Median	1.574	6.222	1.619	2.348	4.228	3.401
Max.	4.381	7.897	3.327	2.607	4.519	3.874
Min.	-2.222	5.647	-1.861	2.158	3.543	2.939
SD	1.436	0.722	0.786	0.125	0.298	0.257
Skewness	-0.395	0.587	-2.203	0.230	-0.444	-0.076
Kurtosis	3.593	2.003	13.133	2.109	1.807	2.349
J-B statistic	1.341	3.262	1.884	1.383	3.039	0.615
p-value	0.511	0.196	0.059	0.501	0.219	0.735
Obs.	33	33	33	33	33	33

Unit Root Test

For exhibiting linearity in time series, stationarity is significant for studying variables. Traditional unit root tests Augmented-Dickey Fuller (ADF) and Phillipes-Perron (PP) tests were estimated, and it observed that almost every variable showed stationary after the first difference (except the outcome variable (Y), GDP deflator (X2) and exchange rate (X4)). Hence, we conclude that, each variable came stationary at I(1) while most at I(0) series.

Table 02: Traditional unit root test

	ADF test				PP test			
	At level		At 1st Difference		At level		At 1st Difference	
	C	C+T	C	C+T	C	C+T	C	C+T
Y	-3.559**	-3.897**	-5.207*	-5.512*	-3.593**	-3.941**	-10.377*	-17.202*
X1	2.483	-1.448	-3.9*	-4.362*	2.483	-1.484	-3.863*	-4.366*
X2	-2.271	-4.22	-6.891*	-6.761*	-3.64**	-3.907**	-12.595*	-12.636*
X3	1.666	-1	-4.588*	-5.421*	-1.16	-3.769**	-10.275*	-10.009*
X4	-1.387	-1.034	-4.563*	-4.671*	-4.279*	-1.396	-3.947*	-4.809*
X5	-2.059	-1.652	-4.011*	-4.352*	-2.057	-1.705	-4.726*	-4.802*

*(Asterisks *, **, and *** resemble 1%, 5%, and 10% significance levels.)*

Unit Root with a Structural Break

This study also performed the Zivot& Andrews (2002) single structural break test to explain and exhibit structural break. The table shows that a structural break prevailed; thus, this study considered a single break for adopting a dummy variable (D17) for 2017 years and onward..

Table 03: Zivot-Andrews structural break test

	At level				At 1st difference			
	Trend	Date	Both	Date	Trend	Date	Both	Date
Y	-5.002***	1996	-5.341**	1995	-7.387***	1996	-11.089***	1996
X1	-3.284	2007	-3.418	2001	-4.709*	2017	-5.067*	2016
X2	-4.199*	2012	-5.118	2003	-6.681***	2017	-7.305***	2016
X3	-4.442*	2007	-4.772	1996	-6.206***	1998	-7.087***	2007
X4	-4.44*	2007	-4.332	2005	-5.093***	2000	-5.182**	2002
X5	-3.54	2012	-3.684	2011	-5.016***	2017	-5.795***	2016

(*Asterisks *, ** and *** resemble 1%, 5%, and 10% significance levels. The tabulated values for the Zivot-Andrews test were for trend 1%: -4.93; 5%: -4.42; 10%; -4.11 and for both trend and constant were 1%: -5.57; 5%: -5.08; 10%: -4.82 respectively.)*

Correlation Matrix

In the correlation matrix, the degree of association was examined among variables. In this study, the response of FDI in agro side (Y) with response variables was moderately associated with economic growth (X1), government expenditure (X3), and exchange rate (X4) on a 1% level of significance.

Table 04: Correlation matrix among study variables

	Y	X1	X2	X3	X4	X5
Y	1					
X1	0.306*	1				
X2	-0.33*	0.278	1			
X3	0.181	0.916***	0.217	1		
X4	0.132***	0.893***	0.33***	0.8438	1	
X5	-0.229	0.444**	0.385**	0.493*	0.733*	1

(Asterisks *, ** and *** resemble 1%, 5% and 10% significance levels.)

Cointegration Test

As both had rejected the null hypothesis of no cointegration in two available trace statistic and maximum-eigenvalue, we concluded a long-run association exists between the variables. This conclusion was ensured in four models.

Table 05: Johansen cointegration with trace statistic and maximum eigenvalues of four parsimonious models

	Model I		Model II	
Hypothesized No. of CE(s)	**Trace Statistic**	**Critical Value**	**Trace Statistic**	**Critical Value**
None	98.57**	95.754	98.57**	95.754
At most 1	55.378	69.819	55.378	69.819
At most 2	32.487	47.856	32.487	47.856
Hypothesized No. of CE(s)	**Max-Eigen Statistic**	**Critical Value**	**Max-Eigen Statistic**	**Critical Value**
None	43.192**	40.078	43.192**	40.078
At most 1	22.891	33.877	22.891	33.877

(Asterisks *, ** and *** resemble 1%, 5% and 10% significance levels.)

Model Estimates

This study assessed Fully-Modified Least Square (FMOLS) (Phillips and Moon, 1990) and Dynamic Least Square (DOLS) (Saikkonen, 1992; Stock& Watson, 1993) for explaining long-run equilibrium. Both toolkits were implementedby picking Akaike's Information Criterion (AIC). In DOLS, optimal lag and lead were partaken as two on FMOLS but one on DOLS, whileNewey-West fixed bandwidth was considered for approximating cointegration for long-run variance. In the first stage, both models were executed under fully modified OLS, and economic growth (X1) influenced imperatively FDI flows on a 1% significance level. Another explanatory variable, inflation (X2), curtailed the outcome variable on a similar significance level. The rest of the variables, including the dummy effect on model II, do not show statistical significance except the exchange rate in model II. Linear trend effect specified model I more correctly indicating that FDI will be decreased after a certain trending drift. For model diagnostics, the R-square and adjusted R-square were shown. Under DOLS, inflation and trade showed statistical significance, while inflation (X2) was in the reverse direction in both models. However, Under model diagnostics, R-square and adjusted R-square exhibited that the explanation of outcome variable was explained mostly correctly as the values exceeded almost 0.8 on both models.

In summary, out of four models, inflation curtailed on response variable in each model, while economic growth was boosted in two models. Only government expenditure did not exhibit statistical attention in any model, whereas the exchange rate boost in model I under FMOLS was curtailed on DOLS.

Table 06: Long-run estimates under FMOLS and DOLS of estimated parsimonious models

	FMOLS			
	Model I		Model II	
	Coefficient (S.E.)	t-Statistic	Coefficient (S.E.)	t-Statistic
C	-10.233** (3.868)	2.646	4.727 (4.851)	0.974
X1	9.092* (2.616)	3.476	2.732* (0.853)	3.202
X2	-0.741* (0.25)	-2.969	-0.859* (0.211)	-4.078
X3	-5.371 (3.628)	-1.481	-5.23*** (3.065)	-1.706
X4	18.786** (7.006)	2.681	0.035 (1.95)	0.018
X5	-0.313 (1.445)	-0.217	-2.086 (1.429)	-1.46
D17			-1.14 (0.935)	-1.218
Trend	-1.093* (0.384)	-2.844		

Model diagnostics				
R2	0.558		0.522	
Adj-R2	0.452		0.407	
S.E.	1.010		1.051	
L.R. Var,	0.922		0.608	
DOLS				
	Model I		Model II	
	Coefficient (S.E.)	t-Statistic	Coefficient (S.E.)	t-Statistic
C	-1.587 (7.434)	0.833	-9.098 (8.161)	-1.115
X1	1.756 (1.074)	1.635	-2.242 (1.687)	-1.329
X2	-2.518* (0.456)	-5.511	-3.829* (1.021)	-3.752
X3	-3.753 (4.965)	-0.756	1.245 (5.17)	0.241
X4	-0.728 (1.854)	-0.393	-3.249*** (1.63)	-1.993
X5	2.709 (1.338)	1.554	10.886* (3.91)	3.522
D17			5.734** (1.824)	3.144
Model diagnostics				
R2	0.809		0.891	
Adj-R2	0.619		0.604	
S.E.	0.825		0.857	
L.R. Var,	0.391		0.210	

*(Asterisks *, ** and *** resemble 1%, 5% and 10% significance levels.)*

Discussion

The role of macroeconomic variables in terms of FDI concentration on agriculture in Bangladesh has been analyzed in the shortest form. Dealing with this, this study perceived annual dataset of 1990 to 2022 for addressing long-run equilibrium by using mostly two applicable tools: Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) for scrutinizing the impact of trade, monetary policy, government spending, and exchange rates. Firstly, the study observed positive attention to economic growth on FDI flows on the agro side. This finding was similar to previous studies (Sultana and Sadekin, 2023; Awunyo-Vitor and Sackey, 2018). Economic growth is strikingly imposing in the service or industry sector, but the agro sector was unnerved. Still, the laborforce of the agricultural sector is large, like in Tanzania, where agriculture services over 70% of the labor force but contributes only about 30% of GDP (Epaphra &Mwakalasya, 2017).

As the economy grows, other parts of Bangladesh are getting more attention and resources than farmland (Miah et al., 2020). When foreign direct investment (FDI) comes in, it adds more than just money, which makes agriculture more productive. It also brings new ideas, technology, and better business operations. The reversenexus of exchange rates and FDI flows shows that flexibility in exchange rates needs to be ensured with thinking about foreign issues (Awunyo-Vitor & Sackey, 2018). It is safer to do business across borders when the exchange rate is steady but in a supple position, so foreign investors will want to put their money in that country. The study also observed there is no statistically significant link between government spending and farm output or FDI. The farming business is not making good use of its government funds now that this has been found. It is clear from this study that the government needs to make some changes and put more money into this area. Some of these are improving infrastructure, giving people access to new technology, and ensuring farms have better ways to get help. Efficiency of government spending in enticing FDI is contingent on factors like the composition, efficiency and type of spending, as well as the relative importance of other bases of FDI. Unnecessary spending can also be counterproductive. Policymakers must prudently design and mark government expenditure to maximize its impact on FDI inflows (Othman et al., 2018).

Foreign investors do not put their fototsteps like investing money into long-term projects like farming when inflation is high because it makes the economy unclear. This result shows how important it is to have good monetary policies that keep inflation in check to stabilize the economy and invite FDI.The findings are similar to what other research has found about how foreign FDI can help economies grow, especially in LDC countries (Salma, 2021; Abdfallah, 2021). FDI could make a big difference in the food grown. However, the success of these kinds of investments relies on many things, like a stable economy, enough infrastructure, and government policies that encourage growth. It was found that Bangladesh needs to fix its infrastructure, ensure its economy is stable, and set up rules to draw and keep investors to get the most out of foreign direct investment (FDI) in agriculture. Trade mostly shows statistically insignificant due to several facets (except the last one). Trade policies need to focus on the substitution theory of importing goods and products for accumulating large currencies instead of concentrating on neighboring countries, and small or infant industries need to survive after the epidemic havoc to encourage capitalization in the market. Moreover, the preferential trade agreement (PFTA) will be revised to attract other foreign flows apart from the Caribbean or US markets.

Future Implications

The study shows that investors who put money into Bangladesh's agriculture should think about how safe the country's economy is. Foreign investors will be more interested in farming if the exchange rate stays steady and inflation is low (Trukhachev et al., 1992). Also, investors should contemplate how their money can help fill in technological, infrastructure, or market access gaps. They should also look for ways their money can add to government programs already in place. Besides that, the study makes it possible to do much new research. We could study how different kinds of FDI that pay for training, technology transfer, or building up facilitiescan affect the amount of food grown. If money comes from outside the country, like FDI, it might be interesting to look into how FDI affects growth in agriculture.

Conclusion

The study revealed that FDI is a key way for Bangladesh to increase farm production. Since more people working in the economy means less food for farms, the agriculture sector needs more attention to ensure it keeps helping the economy. It will be important for the economy to see how the results of this study turn out. This study applied two common econometric tools for explaining long-run equilibrium among variables with a single dummy. A country like Bangladesh needs to ensure that investors are safe and welcome if it wants to get FDI in agriculture. Some of these steps are meant to stabilize the currency, bring down inflation, boost infrastructure, and help the farming industry even more. High inflation is playing a reverse effect while the exchange rate is in the dubious direction. The study shows that the money the government spends on farming might not be having the impact that was hoped for. Bangladesh needs to fix these issues so that its farming industry can stay competitive and continue to grow with the help of foreign funding (Othman et al., 2018). Policymakers in countries like Bangladesh should aim to uphold steady and favorable exchange rates to make best use of the benefits of FDI in the agricultural sector while taking the risks associated with volatility (Alba, 2023). On the organizational policy front, the Government has continued to track, among other things, trade liberalization, financial sector reform, and privatization while upholding legislative terms one of the most generous FDI regimes in South Asia (WTO, 2024).

Acknowledgement

Appendix

Table A1. Variable label, label description, and Data source of study variables

Variable (acronym)	Description	Data source	Expected sign
Outcome variable			
Foreign investment in agriculture (Y)	FDI (inflows) to the agricultural sector (Agriculture, Forestry, Food, Beverages, Tobacco, and Fishing) (annual %) (Author estimated)	FAO	
Independent variables			
Economic growth (X1)	GDP per capita (current US ($)	WDI	+
Macroeconomic performance as inflation (X2)	Inflation, GDP deflator (annual %)	WDI	-
Government expenditure (X3)	Government expenditure (% of GDP)	WDI	+
Financial Performance (monetary policy) (X4)	Official exchange rate (LCU per US$, period average)	WDI	+ or -
Competitiveness or trade (X5)	Export & import percentage of GDP	WDI	+

Figure A1. Linechart of study variables
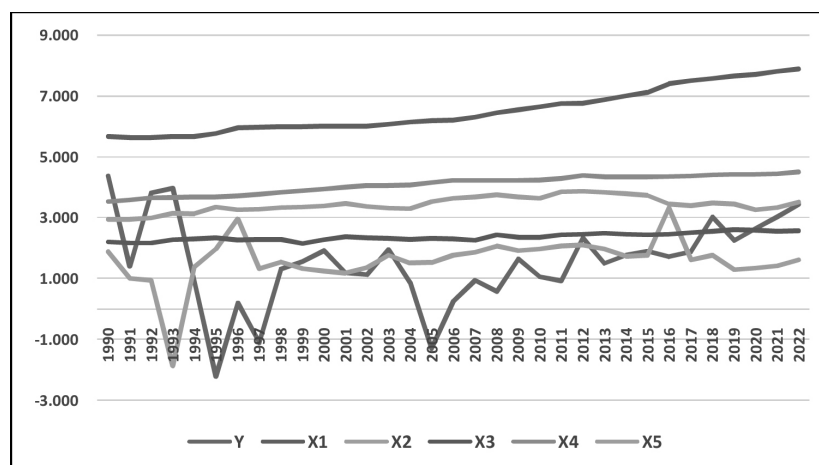
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