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Assessment of the Cost-returns and Profitability Patterns of Tomato Production in Yamaltu-Deba Local Government Area of Gombe State, Nigeria

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ABSTRACT

The study examined profitability of tomato production in Yamaltu-Deba Local Government Area of Gombe State. A three-stage sampling technique was used to select 96 tomato producers. Data were collected using a structured questionnaire and were analysed using descriptive statistics, farm budget model, and t-test analysis. The results revealed that, the mean age of tomato producers was 38.94 years, 92.48% were males, 71.56% were married with the majority (95.44%) had family size ranging from 1 – 6 persons, and had 6.55 mean years of farming experience, having an average of 0.6 ha farm size holding. Furthermore, the result revealed that only 8.74% that have attained tertiary education. The results also revealed average variable costs constituted 88.98% and 88.84% of the average total costs of production in the dry and rainy seasons respectively. The per hectare average net income realised were found to be ₦ 154,444.20 ($ 398.05) and ₦ 39,725.14 ($ 102.38) in the dry and rainy seasons respectively. Hence, the returns per naira invested was ₦ 0.67 ($0.00173) in dry season and ₦ 0.18 ($0.00046) in rainy season ($P<0.05$). Moreover, the results revealed positive and desirable gross and operating ratios of < 1; implying the tomato farms in the study area maintained profitability levels both in the short and long run. However, inadequate capital was critical; which was attributed to lack of affordable sources of credits. Lack of storage and processing facilities were among the impediments to large scale tomato production in the study area. However, improvement in the existing patterns and as well as the provision of adequate essential factors of production will help expand the present scale of operations. Therefore, governments and other financial institutions should do more to provide soft loans to the farmers to improve efficiency.

1. Introduction

Tomato (*Lycopersicon esculentum*) is one of the most important protective food crops in the country and it is the world's largest vegetable crop because of its special nutritive value and its wide spread production [1]. It is a commercial and dietary vegetable crop which is consumed

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in diverse ways; including raw, as an ingredient in many dishes, sauces, salads, and drinks. As it is short duration crop and gives high yield, it is important from economic point of view and hence area under its cultivation is increasing day by day [2]. It is grown as food and cash crop worldwide, and also processed into industrial products such as tomato sauce and/or paste. Its nutritional value in terms of vitamins made the crop one of the most popular items on menus [3].

According to [4], vegetable production requires high level of management, labour, capital and close attention; thus, tomato production is subject to the variations that occur in weather, which may result in severe crop damage and losses. Labour requirements for production, harvesting, grading, packaging and transporting are very intense. [5] added that tomato production is labour intensive and bulk of production is mostly supported by small family farm. According to [6], tomato production is done mostly during the dry season, between October and May. The period between July to September is severe tomato scarce period because of high incidence of pests and diseases associated with growing tomato; general crop management and shifting of tomato producers to production of grain crops. These critical supply elements drive high demand for fresh tomatoes, causes inflation of fresh tomato prices; thus, opened market for unhygienic sun-dried tomato as well as clearance for imported fresh tomatoes from neighbouring states and nations [2]. Subsequently, for production to be profitable and serve as an incentive, there should be a good price and ready market for the produce. However, unlike cereal crops, the production and marketing of tomato in particular, is more complex and risky because of the special characteristics such as high perishable nature, bulkiness and seasonality in production; thus, needs special attention. This as a result, the supply of fresh tomato is subjected to various problems including wide fluctuation in prices [7].

Despite the fact that tomato production is a viable venture; in order to increase farm income and hence alleviate widespread poverty in Nigeria, considerable attention has not been given to tomato sector; because of the imbalance in distribution system and lack of organized marketing system. There is always a market glut of tomato in the main production season and always scarce in other seasons [1]. However, there is wastage of tomato annually as tomatoes harvested in the country are lost due to poor food supply chain management, price instability resulting from seasonal fluctuation in production and the supply preference of farmers and middlemen for urban markets than direct users due to low farm gate prices etc. [8]. These and other factors can reduce profit accrual to both producers and marketers. Thus, a wide gap deficit between demand and supply in the country sets in [2].

It has been a generally established fact that tomato farmers fetched fairly farm gate prices. However, on the ground of higher visible prices at market levels and without considering farm investments on production processes and intermediaries' costs on commodity transfer at various levels, the farmers claim that they are not sharing fairly on the consumers' prices. The prices available to the farmers could be genuine, considering low storability, fresh consumption-pattern and sophisticated transportation needs of tomato that render its marketing a complex business incurring higher costs and risks at marketers' level [6].

Based on such reasoning and visualizing the constraints involved in tomato production thus; [9] viewed that tomato producers were extremely exploited. Unless the associated problems are identified and abated, alleviating poverty in the farming communities as envisaged by national development goal would not be possible. Real problems in the system can only be described, when the economics of production mechanism and marketing system for tomato is evaluated. However, in order to close the gap between demand and supply of fresh tomato requirement, it has become very necessary to extend researches on the costs, returns and as well as production inefficiencies.

Therefore, it is worthwhile to study tomatoes to identify its production and marketing problems to provide information that looks into the possible ways and means of increasing producers' income. To this effect, the study is made to provide answers to the following research questions:

i) What is the socio-economic characteristic of tomato producers in the study area?

ii) What is the costs and returns of tomato production in the study area?

iii) What is the seasonal difference in farmers' income in the study area?

iv) What is the constraint to tomato production in the study area?

2. Methodology

2.1 Study Area

Yamaltu-Deba is one of the eleven Local Government Areas of Gombe State, with its headquarters situated at Deba-habe, 27 kilometers south-east of the State capital Gombe. It lies within latitude 10°50" N and longitude 11°40" E. It shares common borders with Local Government Areas of Gombe, Kwami, Akko, Kaltungo and Balanga to the West, North-West, South-West and South respectively and also with Borno State to the East [10]. It

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occupies a landmass of 1,981 km^2 with estimated human population of 255,248 with an annual growth of 3.2% [11]. The study area is presumed the home of Tera and Jara ethnic groups; with some pockets of Waja, Fulani, Hausa, Gasi, and Kanuri. The area is characterised with warmth climate having average temperature of 30°C in the dry season and 750 mm of mean annual rainfall received [12]. The soil is rich clay-loam which provides favourable conditions for agricultural activities. Both irrigated and rain fed farming are practiced in the production of wide range of vegetables, fruits and cereal crops. Also, animal husbandry and fishing are best practice in the study area [13].

2.2 Sampling Procedure

A three stage sampling technique was used to select 120 tomato producers. In stage I, Yamaltu-Deba Local Government Area will be purposively chosen being the principal area for tomato production in the State. In stage II, the study area was divided into four major tomato belts namely; *Kwadon, Dadinkowa, Baure and Dunbu* and were purposively selected for their popularity in tomato production. In stage III, a total of 120 tomato farmers were selected using simple random sampling technique disproportionate to the number of farmers in each tomato belt. This was to ensure that every member of the population had equal and independent chance of being selected [14]. The sampling frame for this study comprised of all the participants drawn from the selected tomato belts in the study area, having an estimated total of 1,203. A sample is a subset of the population on which observations were taken for obtaining information and to draw valid conclusions about the population. However, in determining the sample size appropriate for this study, the [15] model was used. According to this model, the appropriate sample size for estimated population of 1,203 vegetable farmers will be 120; representing 10%. A disproportional allocation technique was therefore employed to select 30 tomato farmers from each tomato belt.

2.3 Method of Data Collection

Data for the study were collected from primary sources using structured questionnaires in line with the objectives of the study. Also, personal interviews to observe the full production process were made simultaneously with the formal questionnaire administration. This was to enable the researchers generate qualitative information not captured in the questionnaire. The questionnaire was divided into three sections; A, B and C; containing coded questions on tomato producers' socio-economic characteristics, the production variables, and as well as constraints to tomato production respectively. Also, the questionnaire contained few open-ended questions that allowed the respondents to discuss freely particular production issues of concern to them. However, the content of the questionnaire was made to provide answers to the research questions.

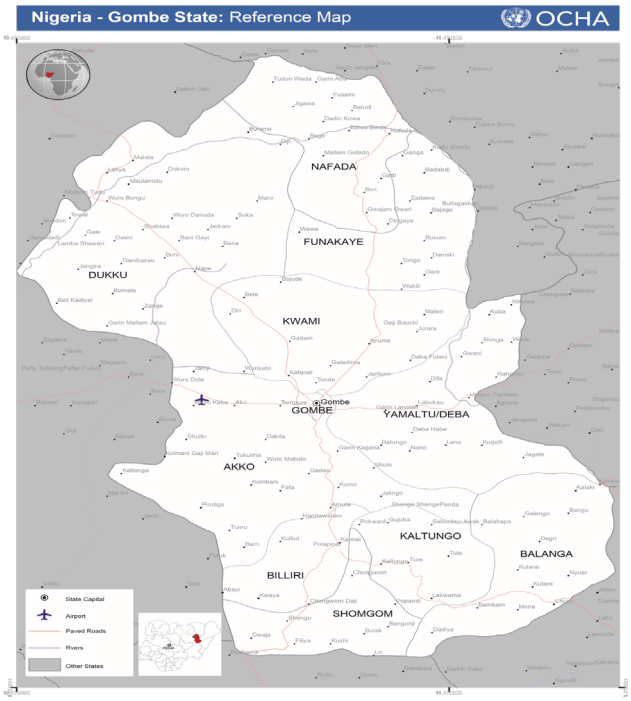

Figure 1. *Map of Gombe State Showing the Position of Yamaltu-Deba L.G.A.*

Sources: UNCS, International Organization for Migration, World Health Organization: https://www.humanitarianresponse.info/en/operations/nigeria Retrieved 28th May, 2021

2.4 Method of Data Analysis

There are many analytical tools available for use in research of this kind and the choice depends on the availability of appropriate data [14]. However, to achieve the specific objectives of the study; the descriptive and inferential statistics, and as well as the farm budget models were used for analysis.

2.4.1 Model Specification

Descriptive Statistics

The descriptive statistics such as the frequency distribution table, percentage, range, means and rankings were used to describe the observed events and as well to achieve objectives of the study. They were used to present and show the distribution of the socio-economic characteristics, cost-return and constraints variables of the respondents. The mean function used as adopted by [14] was

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expressed as:

$$\bar{x} = \frac{\sum fxi}{\sum f} \quad (1)$$

where;

$\bar{x}$ = Mean of grouped data

$\sum$fxi = Sum of products of all variables and frequencies

$\sum$f = Sum of all frequencies of variables

Farm Budgeting Model

This was used to achieve objective two of the study. The model was meant to estimate cost-returns and profitability of tomato production. According to [16,17], the Net farm income analysis is a popular model used to measure the profitability of an enterprise especially when the fixed cost components were captured and assumed significant. The model is therefore specified in the equation as:

$$NFI = TR - TC \quad (2)$$

but, the total costs (TC) is expressed as:

$$TC = TFC + TVC \quad (3)$$

where:

NFI = Net Farm Income (₦)

TR = Total revenue (₦)

TC = Total costs (₦)

T-test Analysis

The Paired t-test analysis was used to achieve objective three of the study; to assess the income variation among tomato producers due to seasonality in production. The model is assumed appropriate to compare the means of two sample groups [18]. The model is specified in a more explicit form as:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (4)$$

where;

t = t-test value

$\bar{x}_2$ = Arithmetic mean of income realised from tomato production in the rainy season

$\bar{x}_1$ = Arithmetic mean of income realised from tomato production in the dry season

$\frac{S_1^2}{n_1}$ = Variance in income realised from tomato production in the dry season

$\frac{S_2^2}{n_2}$ = Variance in income realised from tomato production in the rainy season

3. Results and Discussion

3.1 Socio-economic Characteristics of Tomato Producers in Yamaltu-Deba L.G.A. Gombe State

The socio-economic variables used for this study include; age, gender, marital status, household size, educational attainment, farming experience etc., of tomato producers in Yamaltu-Deba Local Government Area of Gombe State. However, the result showed that most (58.5%) of tomato producers in the study area were within the age range of 31-40 years, closely followed by those in the age range of 41 – 50 years accounted for 39.30%, and only 2.2% that had 21 – 30 years old of age, with the mean of 38.94 years (Table 1). Also, [19] obtained similar findings that the mean age of tomato farmers in Nigeria was approximately 40 years.

Hence, concluded that they were still in their active years and were assumed innovative, adaptive, physically and mentally upright that would make them able to withstand tedious activity in traditional patterns of farming. In the same vein, the result revealed that 92.48% of the respondents were male while 7.52% were female (Table 1). This proves the assertion that tomato farming is a male dominance activity. Such that, low women participation could be due to socio-cultural and religious barriers affecting involvement of women in outdoor economic and agricultural activities in most parts of northern Nigeria [9].

The results also revealed that, majority (70.83%) of tomato farmers in the study area were married and then 29.17% were either single or widowed. Moreover, Table 1 shows 55.33% of tomato producers had household size of 4 – 6 persons; closely followed by those having 1 – 3 persons accounted for 40.41%, and only 2.13% that have family size of 10 and above; with the mean of 4 persons per family. This entails tomato producers in the study area have the advantage of supply of average family labour especially when we look at the size of their farm holdings. The result coincides with [20] and admitted that, the farmers had manageable family sizes which may add to them of extra helping hands in their farm businesses. But in contrast with [21], who admitted that, large family size may cause negative consequences, because the family heads bear heavy burden which greatly undermined their invest-

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ment capacities resulting from higher family consumption expenditures.

Furthermore, Table 1 shows that majority (81.74%) of tomato farmers in the study had formal education, while only 18.26% that had attained non-formal education. This implies that tomato farmers may be responsive to challenges of new technologies in the study area; thus, consistent with the findings of [22]. Moreover, [23,24] both in their different studies emphasized that education assists the households to better utilize efficiently whatever available resources in their domain. Thus, the higher the level of education of individual, the stronger is the demand for his/her services in relation to production. [6] concluded that, literate farmers have been found to adopt new farming strategies faster than the illiterate ones and would find it relatively easy in their dealings with people more especially in the exchange process.

In the same vein, the results reveled years of farming experience of tomato producers as follows; 43.7% had 7 – 9 years; 37.3% had 1 – 3 years; 11.7% had 4 – 6 years; and then 7.3% had ≥ 10 years of farming experience with the mean of 6.6 years. This implies that tomato production in the study area was dominated by experienced farmers who are in their active years and thus; tomato farmers are assumed to achieve high level of productivity in the study area. However, this supports the findings of [25], who reported positive and significant relationship between farming experience and technical efficiency.

This could infer that, the more the years of experience the less the number of participants; hence the more the ability of the farmers to realize more profit. Also, [23] reported similar results and stressed that, experience in agricultural production has been identified as a key qualitative variable for farm output. Individuals with longer farming experience tend to utilize the scarce resources more efficiently than the new entrants. One may conclude that the longer a farmer stays in tomato production the more the stability and consistency of income which can in-turn determines efficiency.

Increase in hectarage outputs reflects level of income with its multiplier effect on the level of profit realized. It can be observed from Table 1; the average farm size holding of tomato producers in the study areas was 0.67 hectares. The land holding reflects the accumulated output, capital transfer and revaluation of assets. Size of farmland is considered as the biggest asset for rural households as it can be accumulated in terms of money and productive asset at the time of financial emergency [26]. The *a priori* expectation was that, farmers with large farm holdings produced additional level of the crop and vice versa.

According to [23], the finding is in agreement with the permanent income hypothesis (PIH); that, households who owned large farmlands could increase the level of their disposable income and profit by producing additional outputs. This trend is consistent with the conclusions of [27] that, large farmland ownership helps farmers to benefit from economies of scale, higher production, and profit.

Table 1. Socio-economic characteristics of tomato producers in Yamaltu-Deba L.G.A

Variable	Category	Frequency	Percentage	Mean
Age (years)	21 – 30	4	2.20	38.94
	31 – 40	55	58.50	
	41 – 50	37	39.30	
	Total	96	100	
Household size (number)	1 – 3	39	40.41	4
	4 – 6	53	55.33	
	7 – 9	2	2.13	
	10 – 12	2	2.33	
	Total	96	100	
Years of experience	1 – 3	30	37.30	6.55
	4 – 6	22	11.70	
	7 – 9	32	43.70	
	10 – 12	12	7.30	
	Total	96	100	
Farm size (hectare)	0.5	63	68.32	0.67
	1.0	33	31.68	
	Total	96	100	
Gender	Male	88	92.48	
	Female	8	7.52	
	Total	96	100	
Marital status	Married	68	70.83	
	Widowed	24	25.0	
	Single	4	4.17	
	Total	96	100	
Educational attainment	Adult/ Non-formal	19	18.26	
	Primary	30	31.80	
	Secondary	40	41.20	
	Tertiary	7	8.74	
	Total	96	100	

Source: Field survey (2019)

3.2 Cost-returns and Profitability of Tomato Production in Yamaltu-Deba L.G.A

Table 2 shows the average total costs and returns of tomato production in the study area. The results revealed the average total costs of cultivating one hectare of tomato farmland were ₦ 229,014.20 ($ 590.24) and ₦ 226,015.66 ($ 582.51) in dry and rainy seasons respectively. The results further revealed the proportions of average variable

costs (88.98% and 88.84%) of the total costs of production in the dry and rainy seasons respectively. The results agreed with [28] who conceptualized that, small-scale entrepreneurs' capital allocated to fixed inputs is low and sometimes negligible. However, [6,29] further supported the idea; that most at times, the proportion of fixed cost components in small-scale agricultural value chain constituted < 1.0% of the total costs in Bauchi State Nigeria. In terms of returns; the average gross revenues of ₦ 383,458.40 ($ 988.30) and ₦ 265,740.80 ($ 684.90) were realized from the sales of 3.8 tons and 3.3 tons of tomato in the dry and rainy seasons respectively; thus, confirmed the business was profitable when compared with the total costs of production. However, the total income might be misleading because it may not be good enough to reflect the total amount of capital involved in the production process. Furthermore, the result revealed the average net income of ₦ 154,444.20 ($ 398.05) in dry season and ₦ 39,725.14 and ₦ 39,725.14 ($ 102.38) in the rainy season. The results concurred with the findings of [30], who concluded that dry season tomato production is profitable than in the rainy season.

Table 2 further shows the positive and desirable gross and operating ratios of < 1; thus, indicated the farms maintained their profitability status [31]. The implication here is that; the total revenue realized from the business would be able to pay for the total and variable costs of production in the short run. But note that, these ratios did not guaranty debt repayment or expansion capacity of the venture. Also, the returns per naira invested were found to be ₦ 0.67 ($0.00173) and ₦ 0.18 ($0.00046) in the dry and rainy seasons of tomato production respectively.

3.3 Paired T-test Analysis of Difference in Farmers' Income Due to Seasonality in Production

Table 3 shows the result of t-test analysis of differences in net incomes of dry and rainy seasons of tomato production. The result revealed a significant difference in net income (P< 0.05) from the sales of tomato in the dry and that of rainy season. The result coincides with [32], who stated that, tomato has ceased to be main crop during rainy season in most parts of northern Nigeria. Also, [33], confirmed higher profitability and economic efficiency for most of vegetable crops produced under irrigation system relative to rain-fed system of agriculture. These results corroborate with the finding of [34], who advocated adoption and utilization of irrigation schemes as tool of poverty alleviation among rural youths in the developing

Table 2. Cost-returns and profitability of tomato production in Yamaltu-Deba LGA

Items		Dry season			Rainy Season	
Variable costs	**Quantity**	**Amount (₦)**	**% of TC**	**Quantity**	**Amount (₦)**	**% of TC**
Fertilizer	200 kg	24,023.00	10.48	200 kg	24,023.00	10.62
Seeds	25 kg	10,513.29	4.59	25 kg	10,513.29	4.65
Agrochemicals	8 litres	20,019.62	8.74	8 litters	20,019.62	8.86
Land preparations	1 ha	48,418.56	21.14	1ha	48,418.56	21.42
Family consumption	260.86 kg	26,086.00	11.39	260.40 kg	23,436.00	10.37
Gift value	240.23 kg	21,969.24	9.59	240.23 kg	21,620.70	9.57
Loading & transport	75 basket	24,250.03	10.59	75 basket	24,250.03	10.72
Empty basket	142.5 pcs	28,500.92	12.44	142.5 pcs	28,500.92	12.61
Total variable cost		203,780.66	88.98		200,782.12	88.84
Fixed cost						
Depreciation		25,233.54	11.02		25,233.54	11.16
Total fixed cost		25,233.54	11.02		25,233.54	11.16
Total costs		229,014.20	100		226,015.66	100
Returns	3.8 tons			3.3 tons		
Total Revenue		383,458.40			265,740.80	
Net Income		154,444.2			39,725.14	
Gross ratio		0.59			0.85	
Operating ratio		0.53			0.76	
Returns/ naira		0.67			0.18	

Source: Field survey (2019)

NB: ₦ 1 = $ 0.00258 (as at June, 2021)

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countries.

Table 3. T-test analysis of difference in farmers' income due to seasonality in production

Season	Mean	SE	t-statistic	P-value	N
Dry season	8.5200E3	2444.88295	1.121**	0.9462	96
Rainy season	8.1050E3	1320.21697			

Source: Field Survey data (2019); **Significant (P<0.05)

3.4 Constraints to Tomato Production in Yamaltu-Deba LGA

Table 4 shows that majority (90.63%) of tomato producers in the study area were faced with inadequate capital, closely followed by 85.42% who claimed to have problem of pests and diseases all year-round. High costs of production ranked the third problem of tomato production in the study area; which accounted for 82.29% of the respondents. The result agreed with the findings of [7], who reported inadequate capital hinders tomato farmers from expanding their business. However, [2,28] in their different studies, both attributed high tomato losses were due to pests and diseases infestation resulting from poor farm management and cultural practices. This implies that there was high level of post-harvest losses of tomato which may discourage farmers from increasing their production capacity [7].

Table 4. Constraints faced by the tomato producers

Constraints	*Frequency	Percentage	Ranking
High transportation cost	69	71.88	5th
High costs of production	79	82.29	3rd
Inadequate Capital	87	90.63	1st
Pests and diseases	82	85.42	2nd
Rainfall	62	65.58	6th
Poor storage	74	77.03	4th
Fatigue	60	62.50	7th

*Multiple response

Source: Field survey (2019)

4. Conclusions and Recommendations

Tomato production was relatively profitable venture in the study area. This was because at least 42.5% of the total investment could be generated as revenues. This is an indication that the production efficiency based on profit is good and equally viable as revealed by the gross and operating ratios. However, the profitability of the product depends largely on the least costs of production per hectare; and as well as fast and viable markets linkages to sell off the tomato due to its nature of perishability. Thus, the findings of this research attempt to contribute to the general knowledge in production economics in the study area; thereby providing basis for concerted stakeholders' action towards large scale production. However, the findings would be essential in guiding producers and traders in selecting factors that would improve their income levels, hence justifying the relevance of the study. It is also hoped that, the study contributes to the existing little stock of knowledge on tomato production which can serve as a stepping forward for further researches at local and/or national level at large. Based on the findings, it was recommended that tomato producers in the study area should form and or join Tomato Producers Unions to enable them to gain access to government interventions and loans from financial institutions. Moreover, governments and any intending investors to establish tomato processing plants in strategic locations in the study area so as to encourage large scale production; and hence will help reduce post-harvest and marketing risks of tomato in the study area.

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ARTICLE

Impact of Foreign Direct Investment on Welfare in Africa: Empirical Evidence from Guinea

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ABSTRACT

The recent economic and financial hardship has resuscitated controversies over the role of Foreign Capital in economic growth and welfare enhancement in emerging nations, particularly in Guinea. The literature that scrutinizes the causal interaction among FDI and poverty alleviation is relatively abundant, the fundamental statement shared by these empirical studies is that GDP growth is assumed to be relevant proxy of people well-being. However, Guinea and its FDI attraction policies have not been well approached by some of these paper. This empirical study examines the interaction between FDI inflows and poverty alleviation in Guinea from 1990 to 2017. The Human Development Index (HDI) and the per capita FDI net inflows are respectively employed as key welfare and FDI indicators.

The findings from the Error Correction Model (ECM) confirm that, in the long term the variables converge in the same direction. The outcomes also exhibit that per capita FDI in the long run, negatively impacts welfare but not significantly, while Inflation's coefficient remains positive and significant. With trade openness, we still found the same positive interaction but not significant.

The results from the Auto Regressive Distributed Lag Model (ARDL) exhibit that per capita FDI flows [current value and L2.] have positive but not significant impact on HDI whereas FDI [L1] has a negative interaction with welfare at 10% significance level. The trade openness variable [current value] is negatively but not significantly associated with HDI, while inflation [L1 and L2] influence on human advancement is positive and significant.

Overall, Foreign direct investment in Guinea is still resource seeking investment which impact on the domestic economy is very limited. Hence, government should introduce new policies and incentives in order to attract more market seeking or other types of FDI that may promote inclusive growth and alleviate poverty.

1. Introduction

The Sustainable Development objectives (SDOs), also known as the universal Goals, defined 17 commitments to be reached by all member states of United Nations, as a comprehensive appeal for poverty alleviation, planet protection and ensure that population everywhere enjoy peace and prosperity by 2030. The attainment of these objectives

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will significantly improve human advancement and promote social welfare around the globe.

Unfortunately, Guinea at present, as many other African nations, has gone a little off track on reaching these goals and an important amount of capital investment is needed to keep them back on track. A major provenance of this capital can be Foreign Direct Investment (FDI), since in the Guinean context, the private sector has been playing a crucial role in driving economic growth. Hence FDI's main role in the achievement of (SDGs) objectives does not need to be demonstrated. Furthermore, with the existing economic and financial hardship, the attainment of the SDOs objectives is even more compromised since most of the industrialized, capital well-endowed nations are setting fiscal and monetary rules to maintain capital home. WORLD BANK's report clearly display that remittances from 2009 to 2014 lessened by 8.3% in Sub Saharan African region. Such decline involves potential challenges for Guinea and many other African countries. In addition, with the contingencies and uncertainties which characterized the international environment, some multinational corporations are annulling or delaying investments in Africa; about 70 billion US$ of FDI towards African countries have been annulled in 2014 (representing 17% of the 393 billion US$ of total FDI stock).

To entice more foreign capital, new pro-private investment rules and procedures have been established by emerging nations that may help multinationals to open branches and subsidiaries around the world without major difficulties. In this respect, Guinean government makes great effort on attracting foreign capital to promote inclusive growth, reduce unemployment and alleviate poverty. This is grounded on the assertion that inward investment is a mean of gaining capital, know how, best managerial practices and technologies that are not accessible in the recipient country [1].

Strategies and efforts to transform Guinea's economy may be analyzed through different political regimes that the country has known. From 1958-1984, major reforms have been introduced such as: achieving the country's economic independence through the creation of the national currency (Guinean Franc, which later become the Syli). Additionally, Authorities placed great emphasis on building a planned economy and collectivist society throughout the state control of commerce, consolidation of the state monopoly over all the production and distribution channels except the mining concessions which were managed by multinational corporations.

Overall, the outcomes of these reforms were not satisfactory. Apart from the 1974-1976 period corresponding to the mining boom, where growth recorded an average annual rate of nearly 6%, other periods were marked by weak rate or even negative growth. Economic growth was estimated at -2.9% in 1977, -1.1% in 1981, -5% in 1983 and -1.4% in 1984. Likewise, the outstanding debt as a percentage of GDP was estimated at 74.52% in 1984.

With the military coup in April 1984, the government advocated a new liberal economic, social development model with a great emphasis on: macroeconomic stabilization, openness to investment and liberalization of trade, followed by the state's disengagement from the productive sectors and distribution channels. New fiscal and monetary policies led by the INTERNATIONAL MONETARY FUND (IMF) and world bank were instituted such as the floating regime of the Guinean currency (Guinean franc), rationalization of tax structures, establishment of a new investment code and one-stop shop designed to FDI attraction. Following these institutional reforms, foreign investment inflows moved from 69 million (USD) in 1986 to 1,6 billion (USD) in 2016.

Even though Guinea's foreign investment inflows have considerably augmented since 1990, some remarks and comments are worth mentioning. Primary, foreign direct investment has a positive impact on the recipient country by creating employment, driving GDP growth, alleviating poverty in the long-run. However, among the total population of 12 million in 2014, the vulnerable, fragile and poor were about 7 million, representing 53%. Additionally, about the contribution of foreign direct investment to recipient nations, particularly in developing world, empirical findings propose divergent views. The principal reasons for conflicting results comprise theories such as total factor productivity model described by Solow, the beneficiary national absorptive capacity, capital flight, crowding out of domestic companies, especially with respect to market pursuing investment. While host nations expect a positive effect on their local economies, some empirical studies have found a negative interaction. As illustration, [2] noted a positive association between foreign direct investment and poverty reduction in Pakistan, the same outcome found by [3] on the impact of foreign capital on Sri Lanka's GDP growth. Inversely, [4] conducted an empirical study on the impact of FDI on welfare in seven emerging economies and the results are contrasting. Foreign investment amplified unemployment in Argentina and Turkey but in Thailand reduced it.

Additionally, Guinea's population is comprised of 70% youths. Annually, net job creation is less than 10% while more than ten thousand new graduate students leave tertiary education institutions to labor market. Among new entrant unemployment is about 90%. It has been presumed that a substantial number of jobs for youths who graduated from tertiary institutions to be generated by foreign investment

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related projects. So far, no evidence from the ministry of finance confirms that 10% of jobs generated in Guinea are driving by foreign direct investment projects. In Guinea it is usually assumed that GDP growth and welfare occur automatically from FDI related businesses.

There is rich literature that examines the underlying interaction between foreign direct investment and economic advancement, [5-10] among many others. All these mentioned studies investigate the influence of foreign capital on economic development estimated by GDP growth. Thus, the implied assumption within this research paper is the adoption of GDP growth as an appropriate estimate for social well-being and economic advancement. Recently, this hypothesis has been questioned. In fact, even if GDP growth is vital to upgrade people living standards, when this growth is not inclusive and pro-poor oriented, it can generate huge income inequalities and worsen social welfare.

Within the literature, the first constraint resides in the definition of economic advancement or welfare. Two popular indicators used to estimate social well-being and prosperity are poverty incidence and per capita GDP. The last one is very common and obtainable for any nation on the yearly basis, but covers only one facet of economic advancement. The first one appears to be a relatively appropriate estimate of inclusive welfare but countries like developing ones lack of consistent and adequate data. Decades ago, United Nation Development Program (UNDP) instituted the Human Development Index (HDI) which appears to be widely recognized as a conventional proxy for human advancement and available for each nation. Some authors have employed the HDI to examine the effect of foreign capital on poverty and these scholars mainly oriented their research on Asian, Latin American nations [11]. But, to my awareness, such kind of empirical research has not been undertaken on Guinea exclusively. Yet, investigating and analyzing all these probable implications in the Guinean context is essential.

This empirical paper examines the causal linkage between foreign capital net inflows and poverty alleviation in Guinea. Therefore, we analyze the resulting research question: (1) Does foreign direct investment improve or enhance welfare in Guinea?

To find the answer to this question, we employ main social well-being indicator, the UNDP Human Development Index to apprehend the country social advancement level. For FDI estimate, we employ as key indicator the FDI per capita net inflows.

The contribution of this empirical analysis to the literature is threefold. Primary, this empirical paper expands knowledge on the influence of foreign capital on poverty reduction in Guinea, an emerging nation. Second, the role of FDI in Guinean context has not previously been assessed econometrically. Thus, this study as pioneer induces an original quantitative record of FDI and its influence on Guinea's economy (even though this research is considering the period 1990-2017). Additionally, this paper enriches theory and knowledge by carrying two variables together into one theoretical framework: FDI (and its impact), and welfare improvement.

The remaining part of this study is structured as following. The literature review on the linkage between foreign capital and social well-being is presented in section 2 while section 3 exhibits the methodology, presents data and the variables employed. Section 4 examines the empirical findings on the causal link between social welfare and FDI in Guinea. Conclusion and policy recommendations are provided in section 5.

2. Literature Review on FDI and Welfare Nexus

Several empirical papers have examined the association between foreign capital and welfare. The key concern to be investigated is to what extent FDI has an influence on a nation's economic advancement. The implied assumption hints that FDI induces GDP growth which also leads to welfare enhancement. Recently, some scholars have challenged that role and the answers to these concerns are mixed. The contradictory outcomes may be due to the differences within methodological, conceptual and econometric frameworks, including the various descriptions of FDI and welfare variables and the absence of a broad consistent dataset.

This part presents a comprehensive review of the theoretical link and most important empirical literature relating to the poverty reduction impacts of inward FDI into Africa. It also includes a review of literature in relation with the poverty reduction effects of inward FDI into developed and developing countries in other regions.

2.1 Theoretical Arguments on the Relationship between FDI and Welfare

From World War II up to date, two major propensities have been observed in the evolution of foreign capital flows into emerging nations. From the end of World War II to the end of the Cold War (in the 1990s), both FDI flows and stocks have augmented globally, particularly in developing world. During that period, foreign capital flows have been driven mainly by ideological and political rather than economic motives. From the 1990s, foreign capital has mainly been directed to countries with favorable FDI incentive policies, such as nations providing massive tax inducements

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and other facilities. [12] reported that in 2002, within seventy nations that liberalized their economic policies and adopted FDI friendly attitude, 236 out of 248 regulatory modifications were beneficial to FDI inflow, 95 per cent were more favorable to entice FDI. With all these taxes and other inducements offered by the host nations in order to entice more foreign capital, one may question the effectiveness and the extent to which FDI improve social well-being.

The influence of foreign capital on human advancement can be assessed from at least two points of view. From the social perspective, reducing poverty and improving the whole population well-being are emerging countries key concerns. In these countries, authorities' main priority is to upgrade its population living conditions as one of its social functions. Foreign direct investments may be an important tool through which nations can attain these objectives as they generate jobs, promote indigenous skills and carry technical progress. From the economic perspective, the early standpoint is that technical progress is the ultimate locomotive of sustained economic development and societal advancement. However, the emphasis has recently switched to the human capital. The theory of endogenous growth asserts that technology and human capital are essential in development process, they are key contributors to self-sustained growth in terms of per capita GDP. Human advancement therefore becomes a crucial element that raises our primary interest in evaluating the influence of FDI on human social well-being.

Moreover, foreign capital effect on welfare can be direct or indirect. The backward and forward interactions between domestic suppliers, sourcing, customers and FDI related projects may strengthen the export potentiality of the local economy. This is known as spillover effect. Likewise, the utilization of recent and advanced technology can upgrade the overall competitiveness and generate positive spillovers that are indispensable for sustained economic growth and the reduction of extreme poverty. Another direct effect on domestic economy is employment opportunities, but this function only if the employment opportunity ratio is much higher than foreign capital-related unemployment. Therefore, foreign investment is supposed to have great influence on social well-being when it is oriented in labor-intensive industries (e.g., agriculture). These advantages depend on the type of FDI, but the mechanisms and instruments used by the government to regulate foreign investment mixed benefits are also crucial. From the macroeconomic perspective, Foreign capital are presumed to boost the country overall revenue and earning transfer; in this circumstance the linkage may be indirect subject to the inflows enticing ability of net transfer revenue.

Besides, the development stage within the host country may also affect this correlation. Resource endowments, skilled labor, efficient supply chains, social, political and cultural features of the recipient country can facilitate this interaction too. On the one hand, if foreign capital related projects are oriented in raw materials and extractive industries, then the spillovers and employment opportunities may be very limited. On the other hand, if foreign capital is market seeking type, then its influence on jobs, forward and backward interaction will be higher.

2.2 Empirical Review on FDI and Poverty Nexus

At times, predictions seem to be contradictory and complex when assessing the impact of FDI on social well-being. The FDI proponents [13] advocate that FDI and poverty nexus could be direct or indirect. FDI through labor market (human capital development and job creation) can directly impact welfare. Foreign capital and welfare indirect linkage could result from increased productivity and economic activities.

Many empirical studies on FDI and welfare association rely on the endogenous growth theory of technological dissemination to illustrate how (i) through FDI, technology can move from the secondary to tertiary sectors rather than the primary sector; and (ii) how welfare conditions of a country can be improved.

The seminal paper by [14] displays that through technological dissemination and growth in total factor productivity (TFP), a relatively backward economy may catch up faster those technologically advanced countries when the sectors have strong linkages. However, research has demonstrated that not all the sectors have the capacity to absorb these foreign technologies and improve welfare because of weak industrial linkages.

[15] posits that the aptitude of the host country to comprehend multinationals activities as well as the inherent characteristics of their investment strategies may essentially affect FDI impact on poverty (resource seeking, efficiency seeking, market seeking). Through technological diffusion, labor productivity and employment opportunities are likely to be stimulated by efficiency-seeking FDI type. Consequently, it will engender spillovers and adequate linkages (upstream and downstream) with the recipient economy. This mechanism could be beneficial to African nations that are addressing their development agenda and enhancing welfare.

[16] elucidated the mechanisms by which linkages and spillovers could be achieved. They pointed out that spillovers from foreign capital could happen through vertical, horizontal, forward and backward linkages. When a stimulation in local firm productivity is due to the presence of a foreign enterprise within the same sector or industry, hori-

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zontal spillover is said to occur. On the other hand, when an increase in home firm productivity is attributed to the presence of foreign enterprise in its suppliers, forward linkages are said to happen. When local firm productivity relies on the presence of foreign entities among its customers within the same industry, backward linkages are said to take place. Thus, the resulting rise in productivity will boost employment opportunities, upgrade skills via labor mobility, and subsequently a decline in poverty.

[17] states that "FDI has been considered as a powerful engine and a significant catalyst for attaining development, poverty reduction and global integration process. Similarly, [18] assert that FDI in social services such as water and energy is the most credible strategy to fight against poverty in developing nations. [19] assessed what impacts foreign capital may have on income inequality in 54 countries over the period 1980-2005 and found that FDI negatively affects the income of nations with limited absorptive capacity rather than those with strong absorptive capacity. However, [20] argues that contrary to conventional view, there exists little evidence that FDI inflow can cause poverty reduction.

The mechanisms through which FDI affects welfare have been identified to include stock of human capital; technology, innovation and knowledge spillover; income and productivity growth. [21] posits that since the single most significant element influencing poverty reduction is GDP growth, foreign capital is crucial in attaining that objective. [22] stated that minimum threshold stock of human capital leads to higher productivity of FDI in recipient countries. The study by [23] suggests that the instrument by which FDI can lead to welfare enhancement is through labor intensive economic growth with export oriented growth as the most principal engine. Although the study identified other mechanisms such as training programs of human capital or projects financed by government tax revenue and improving access to productive employment, but did not find any proof in support of these three other channels.

[24] analyzed how FDI may affect poverty reduction in the south east Asia region and found that at a very minimum examination, there is no evidence in support that FDI either erodes growth or reduces the incomes of the poor. However, a more rigorous estimation displays that FDI inflows are associated with higher income growth of the poor. [25], remarked that the magnitude of productivity growth increased more with corporations that have foreign partnership. However, the extent of knowledge dissemination between the domestic and foreign enterprises was not determined. Conversely, in spite of the significance of FDI towards welfare improvement, Africa is yet to take advantage of the huge opportunity offered to host countries probably due to their weak financial market, institutions and level of education.

[26] reveals that the growth enhancing and poverty alleviating impacts of FDI are greatly eroded by weak financial markets and political institutions that characterized poor nations. This finding is similar to those of [27]; [28]. While the prior study shows that FDI enhances welfare through the development of human capital, the latter argues that the financial markets development level is critical for foreign capital to drive poverty reduction. It is therefore worthy of note that strengthening the financial market and repositioning the necessary institutions through appropriate framework could be the needed catalyst for the African continent to promote social welfare and development.

[29] posit that foreign capital may affect poverty through the direct, multiplier and spillover effect. When multinational companies establish new branches and subsidiaries, construct factories, recruit and train local workers, purchase machinery from domestic suppliers, direct effect is said to occur. Via this mechanism, unemployment plunges, the stock of capital augment and as a result of increased tax revenues government spending on human capital development (education, health) rise. There is a range of factors that involve amount of wages paid, re-invested profits, number of local workers hired and the volume of initial investment on which the extent of such direct effect relies. The multiplier effect is said to happen when through forward and backward interaction within the value chain the connection between the local branch and the recipient country economic agent become important. This multiplier instrument may stimulate economic growth and employment opportunities via increased output of both distributors and suppliers. The spillover effect takes place when technology, innovation, knowledge and skills moved from the multinational local branch to the corporations in the recipient country. There could be technological spillovers, which lead to technological expansion, and these may take place in a variety of ways such as training of local workers, imitation by domestic companies, and management skills.

2.3 Summary

As conversed above, some empirical literature has analyzed the linkage among foreign capital and poverty reduction employing per capita FDI and GDP growth indicators with assorted findings. Fundamentally, the preceding empirical analysis deduces a positive association among economic advancement and social well-being thus, adopt as an appropriate proxy for welfare the GDP growth. However, this implied hypothesis has been recently questioned. Some empirical assessments reveal that poverty prevalence may still be increasing while economic growth is occurring. To transcend this constraint, very few studies recently examined how foreign capital directly interact with poverty.

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[30] is part of the rare empirical research that investigates the relationship among foreign investment and poverty adopting Human Development Index as social well-being estimate. Their findings reveal that from 1975 to 1999 foreign capital positively affected HDI in low and middle income economies. As far as we know, such analysis has not been conducted for Guinea exclusively.

3. Methodology

3.1 Data

The variables employed to assess the effect of foreign capital on poverty are essentially the FDI net inflows and social well-being indicator. The data cover the period 1990-2017 and all variables are basically from the World Development Indicators released by the WORLD BANK and the UNITED NATION DEVELOPMENT PROGRAM (UNDP). Indicators are annually times series and the choice of time period is dictated by data availability.

Foreign Direct Investment Variable

FDI indicator represents the aggregate amount of long and short term capital, equity capital, reinvestment of earnings. For FDI variable: we adopt per capita FDI ratio which is foreign capital net inflows over total population.

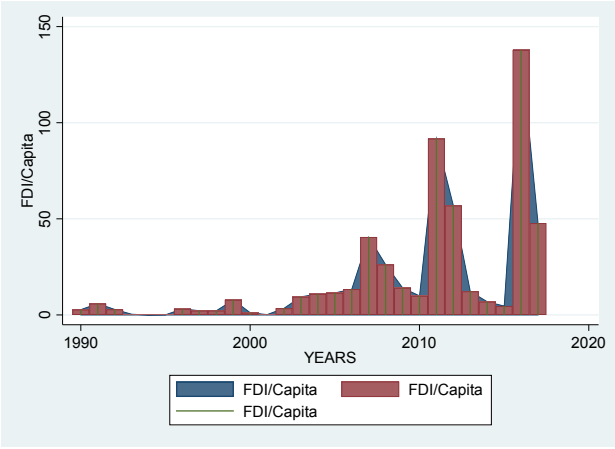

Figure 1. Foreign direct investment per capita (1990-2017)

Welfare Variable

Several poverty proxies have been suggested in the literature to examine progress achieved by nations in terms of the poverty prevalence and the per capita GDP measure. On the one hand, while the commonly employed indicator within the literature is per capita GDP, this seizes singularly one facet of social well-being: the economic aspect. However, welfare implies diverse components such as education and health care and economic advancement is a multi-dimensional concept.

On the other hand, poverty prevalence is an exhaustive indicator of welfare as it incorporates all factors of an individual basic living conditions (nutrition, education, health etc.) and compares it to the threshold needed for a reasonable living standard. Nonetheless, poverty prevalence indicator is not presented on an annual basis. This imperfection does not enable its utilization in empirical research. Therefore, Human Development Index was recently presented as suitable measure of individuals well-being.

For this empirical analysis, our key welfare estimate is Human Development Index. United Nations Development Program defines HDI as a compound indicator that estimates nation's average accomplishments in three elementary sides of human advancement: education, health and decent living standard. Health is measured by life expectancy at birth; education is measured by a combination of the adult literacy rate and the combined primary, secondary, and tertiary gross enrolment ratio; and standard of living by GDP per capita (PPP US$).

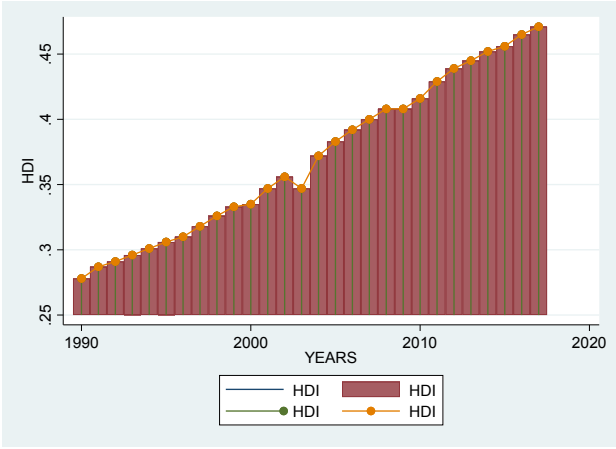

Figure 2. Human Development Index (1990-2017)

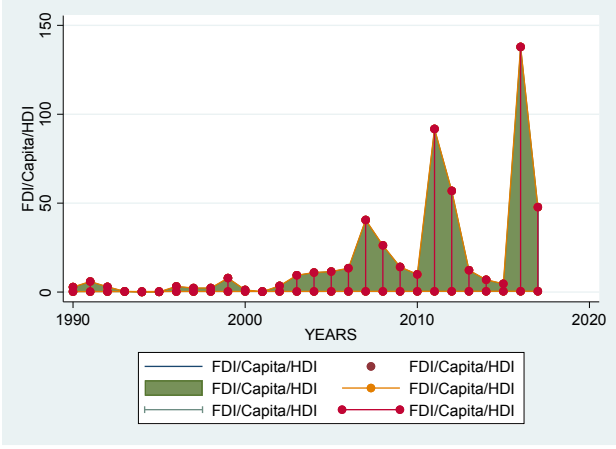

Figure 3. FDI/Capita and HDI Range Plot (1990-2017)

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Control Variables

To ensure that our results are not biased, two control variables are included, namely Inflation and Trade openness. Inflation is integrated to the model to seize macroeconomic unsteadiness, and is assumed to influence well-being negatively, as a high inflation rate may suggest more unsteady macroeconomic environment.

We also include trade openness to the framework, since in preceding empirical research, this proxy has been adopted to control foreign capital effect on economic advancement. Trade Openness is determined by the ratio of total exports plus imports over GDP.

Because HDI incorporates knowledge by definition, in order to avoid spurious regression, we do not integrate education as dependent or control variable in the regression framework.

3.2 Regression Model Specification

The study employed Bounds test technique, Auto regressive distributed lag framework and Error correction model to capture the long and short run interaction between foreign direct investment, human development index, inflation and trade openness within the Guinean context.

To assess the relationship among these time series variables, we first go through the process of optimal lag to be selected then we test stationarity level of the time series employing Bounds test framework which assert that series must be integrated in diverse orders. This is about having a combination of I (0) and I (1).

Secondly, we conduct Bounds test of co-integration with determined (n) lags. We deduce the existence of co-integration when the computed F-statistic is greater than the critical value for the upper bound, I (1), meaning that among the variables there exists a long run interaction. We ignore the null hypothesis, determine the long run interaction through the Error correction model.

We conclude that there is no co-integration when the computed F-statistic is lower than the critical value for the lower bound, I (0), meaning that no long run connection exists among the time series variables. We cannot ignore the null hypothesis and the short term association is estimated through the auto regressive distributed lag technique.

We deduce the test inconclusiveness when the computed F-statistic plunges between the lower bound, I (0) and the upper bound I (1).

Once the time series variables are integrated in different orders, we can subsequently go through the following regression model to show how foreign investment influence social welfare in Guinea:

$\Delta HDI_t = \alpha_0 + \Sigma^p_{i=1} \alpha_{1i} \Delta HDI_{t-i} + \Sigma^q_{i=1} \alpha_{2i} \Delta FDI_{t-1} + \Sigma^q_{i=1} \alpha_{3i} \Delta Openness_{t-i} + \Sigma^q_{i=1} \alpha_{4i} \Delta Inflation_{t-1} + \lambda ECT_{t-1} + e_t$

- $\lambda = (1- \Sigma^p_{i=1} \delta_i)$, Speed of adjustment parameter with a negative sign
- $ECT = (\Delta HDI_{t-i} - \Theta X_t)$, the error correction term is the extracted residuals from the regression of the long run equation
- $\Theta = \Sigma^q_{i=0} \beta_i / \alpha$, is the long run parameter
- $\alpha_{1i,} \alpha_{2i,} \alpha_{3i,} \alpha_{4i}$ are the short run dynamic coefficients of the model's adjustment long run equilibrium

4. Empirical Results

Table 1 presents some descriptive statistics on Guinea for welfare (HDI) and FDI variables. FDI flows have known a timid growth within a decade after 1985 economic liberalization. From 2003, a steady trend is observed and the peak of FDI level was reached in 2016 when Chinese multi-national corporations due to some major turmoil in the minerals market decided to invest heavily in Guinean bauxite mines. We adopt per capita FDI since it shows a broad view on how FDI is allocated among population, and this aspect is relevant when analyzing the influence of FDI on poverty reduction.

Nota Bene: All the numerical values within the tables (below) are monetary units conventionally in (USD).

Table 1. Summary statistics of variables

Variables Name	Mean	Std. Dev.	Min	Max
FDI/Capita	1.605714	37.01427	90.10	133.21
HDI	0.0068929	0.0056131	0.009	0.025
Inflation	-0.5992857	7.172406	-18.38	13.91
Openness	1.729643	9.307441	-9.97	37.61

Table 2 indicates that FDI per capita correlation with welfare variable is about 15.62 %. The 84.38 % loss of correlation appears to endorse the assertion that economic growth does not necessarily and entirely translate into welfare enhancement. Foreign investment variable is highly correlated to openness with a coefficient of 64.13 % whereas its correlation coefficient with inflation is about 0.82 %. This lower coefficient may be elucidated by the fact that the great proportion of inward investment in Guinea is concentrated in mining sector which is less sensitive to the macroeconomic environment.

Table 2. Correlation Matrix

Variables Name	FDI/Capita	HDI	Inflation	Openness
FDI/Capita	1			
HDI	0.1562	1		
Inflation	0.0082	0.1626	1	
Openness	0.6413	0.2127	0.0864	1

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4.1 Autocorrelation and Partial Autocorrelation of the Variables

This research paper adopted Autocorrelation and partial autocorrelation to display how stationary are the time series variables.

H_0= Null hypothesis, the null hypothesis is accepted when the variable is stationary at level; when the variable is nonstationary at level the null hypothesis is rejected.

H_1= Alternative hypothesis, we accept alternative hypothesis once the variable is stationary at the first differenced level and we reject it once it's nonstationary at first differenced level.

Table 3. Corrgram FDI/Capita, Prob>Q is greater than 5%

LAG	AC	PAC	Q	Prob>Q
1	0.2814	0.2916	2.4638	0.1165
2	-0.0136	-0.1315	2.4697	0.2909
3	0.0247	0.1973	2.4903	0.4770
4	0.3032	0.9359	5.7071	0.2221
5	0.4773	1.2854	14.028	0.0154
6	0.0774	-0.5089	14.257	0.0269
7	-0.0109	-1.0525	14.262	0.0467
8	0.0472	-2.3621	14.355	0.0730
9	0.1076	-0.3129	14.867	0.0947
10	-0.0251	-2.6404	14.896	0.1359
11	-0.0737	-8.4915	15.165	0.1751
12	-0.0660	0.7471	15.393	0.2206

Table 4. Corrgram HDI, Prob>Q is less than 5%

LAG	AC	PAC	Q	Prob>Q
1	0.8976	1.0049	25.067	0.0000
2	0.7987	0.3236	45.677	0.0000
3	0.7009	0.2951	62.184	0.0000
4	0.5979	0.0085	74.695	0.0000
5	0.4948	0.0993	83.636	0.0000
6	0.3919	0.3347	89.499	0.0000
7	0.2895	0.0787	92.851	0.0000
8	0.1955	-0.2526	94.456	0.0000
9	0.1078	-0.2590	94.970	0.0000
10	0.0173	0.0153	94.984	0.0000
11	-0.0733	0.1151	95.249	0.0000
12	-0.1531	0.0796	96.480	0.0000

Corrgram D. HDI (First differenced level) Prob>Q is greater than 5%.

LAG	AC	PAC	Q	Prob>Q
1	-0.3013	-0.3017	2.734	0.0982
2	-0.1493	-0.2627	3.432	0.1798
3	0.1630	0.0335	4.2984	0.2310
4	-0.0795	-0.0574	4.5136	0.3409
5	-0.1974	-0.2459	5.9002	0.3161
6	0.2069	0.0075	7.496	0.2774
7	0.1707	0.2674	8.6369	0.2798
8	-0.1172	0.2338	9.2029	0.3255
9	-0.0786	-0.0529	9.4715	0.3949
10	0.0292	-0.1514	9.5108	0.4844
11	-0.0895	-0.0844	9.9028	0.5392

Table 5. Corrgram Inflation, Prob>Q is less than 5%

LAG	AC	PAC	Q	Prob>Q
1	0.6274	0.6320	12.246	0.0005
2	0.3749	-0.0314	16.787	0.0002
3	0.0770	-0.2614	16.986	0.0007
4	-0.0827	-0.0810	17.226	0.0017
5	-0.0147	0.2511	17.234	0.0041
6	-0.1390	-0.3826	17.971	0.0063
7	-0.1873	-0.2301	19.374	0.0071
8	-0.3343	-0.2431	24.068	0.0022
9	-0.4459	-0.1615	32.858	0.0001
10	-0.4139	-0.7092	40.852	0.0000
11	-0.4013	-1.2012	48.809	0.0000
12	-0.2765	-1.8168	52.823	0.0000

Corrgram D. Inflation (First differenced level) Prob>Q is greater than 5%.

LAG	AC	PAC	Q	Prob>Q
1	-0.1341	-0.1341	0.54172	0.4617
2	0.1060	0.0884	0.89371	0.6396
3	-0.1375	-0.1205	1.511	0.6797
4	-0.3046	-0.3765	4.6686	0.3230
5	0.2935	0.2598	7.7342	0.1715

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LAG	AC	PAC	Q	Prob>Q
6	-0.0698	0.0223	7.9161	0.2443
7	0.1506	-0.0372	8.8045	0.2670
8	-0.1144	-0.2113	9.3434	0.3142
9	-0.1627	0.0193	10.495	0.3119
10	-0.0014	0.0911	10.495	0.3982
11	-0.1070	-0.9847	11.056	0.4386

Table 6. Corrgram Openness, Prob>Q is less than 5%

LAG	AC	PAC	Q	Prob>Q
1	0.7386	1.0037	16.97	0.0000
2	0.4921	0.0655	24.793	0.0000
3	0.4624	0.2259	31.978	0.0000
4	0.4720	0.7429	39.776	0.0000
5	0.4525	0.2449	47.254	0.0000
6	0.3257	-0.4525	51.303	0.0000
7	0.1694	-0.0788	52.451	0.0000
8	0.0454	-0.7098	52.538	0.0000
9	-0.0054	-0.2378	52.539	0.0000
10	-0.0162	-0.1048	52.552	0.0000
11	-0.0540	0.2433	52.696	0.0000
12	-0.1726	-0.4660	54.259	0.0000

Corrgram D. Openness (First differenced level) Prob>Q is greater than 5%.

LAG	AC	PAC	Q	Prob>Q
1	-0.0383	-0.0383	0.04426	0.8334
2	-0.0875	-0.1891	0.28417	0.8675
3	-0.2612	-0.6207	2.5099	0.4735
4	0.0066	-0.0367	2.5114	0.6426
5	0.2476	0.5880	4.6936	0.4544
6	0.0873	0.2184	4.9781	0.5466
7	0.0962	0.7562	5.3402	0.6185
8	-0.2328	0.2944	7.5727	0.4763
9	-0.0642	0.1994	7.7521	0.5593
10	-0.0644	-0.0392	7.9431	0.6344
11	0.3258	0.5397	13.137	0.2845

Except the per capita FDI, the other variables (HDI, Inflation and trade Openness) get to be stationary at the first differenced level, this allows us to implement the Bounds test for co-integration.

The main condition is that time series must be integrated in diverse orders, this is about having a combination of I (0) and I (1). Under the Bounds test framework, we deduce the existence of co-integration when the computed F-statistic is greater than the critical value for the upper bound I (1), meaning that among the variables there exists a long run interaction. We ignore the null hypothesis, determine the long run interaction through the Error correction model.

We conclude that there is no co-integration when the computed F-statistic is lower than the critical value for the lower bound I (0), meaning that no long run connection exists among the time series variables. We cannot ignore the null hypothesis and the short term association is estimated through the auto regressive distributed lag technique.

We deduce the test inconclusiveness when the computed F-statistic plunges between the lower bound, I (0) and the upper bound I (1).

Table 7. Lag selection-order criteria; Sample: 1990 – 2017

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-194.023	-			172.54	16.5019	16.554	16.6983*
1	-179.194	29.658	16	0.020	194.958	16.5995	16.86	17.5812
2	-163.86	30.669	16	0.015	234.469	16.655	17.1238	18.4221
3	-147.084	33.552	16	0.006	316.587	16.5903	17.2675	19.1428
4	-105.698	82.771*	16	0.000	92.5126*	14.4749*	15.3601*	17.8127

Endogenous: HDI, FDI/Capita, Inflation, Openness

e(lags) [1,4] =	HDI	FDI/Capita	Inflation	Openness
	4	2	2	1

4.2 Results of Bounds tests for Co-integration

Ho: No levels relationship
F = 10.156
t = -3.686
Critical Values (0.1 - 0.01), F-statistic

Table 8. Pesaran / Shin / Smith (2001) ARDL Bounds Test

	[I_0] [I_1] L_1 L_1	[I_0] [I_1] L_05 L_05	[I_0] [I_1] L_025 L_025	[I_0] [I_1] L_01 L_01
K_3	2.72 3.77	3.23 4.35	3.69 4.89	4.29 5.61

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Accept if F< critical value for I (0) regressors; Reject if F > critical value for I (1) regressors.

Critical Values (0.1 - 0.01), t-statistic

	[I_0] [I_1] L_1 L_1	[I_0] [I_1] L_05 L_05	[I_0] [I_1] L_025 L_025	[I_0] [I_1] L_01 L_01
K_3	-2.57 -3.46	-2.86 -3.78	-3.13 -4.05	-3.43 -4.37

Accept if t > critical value for I (0) regressors; Reject if t < critical value for I (1) regressors.

Since the calculated F-statistic get to be greater than the critical value for the upper bound, I (1) then we deduce the existence of co-integration, suggesting a long run association among the variables. We run the Error correction model (ECM) to capture this long run interaction, then the Auto regressive distributed lag model (ARDL) to seize the short term relationship.

4.3 Results of Error Correction Model

Table 9. The Error Correction Model

HDI	Coef.	Std. Err.	t	P > [t]	[95% Conf. Interval]	
ADJ					-	
HDI						
L1.	-1.90588	0.5171115	-3.69	0.004	3.044034	-0.7677251
LR						
FDI/Capita	-4.34e-06	0.0000511	-0.08	0.934	-0.0001168	0.0001081
Inflation	0.0006468	0.0002222	2.91	0.014	0.0001578	0.0011358
Openness	0.0001151	0.0001103	1.04	0.319	-0.0001276	0.0003579

R-squared = 0.9152; Adj R-squared = 0.8227; Root MSE = 0.0040

The cel. L1 (-1.90588); the speed of adjustment or error correction term towards equilibrium has a negative sign and significant for HDI, we agreed on the existence of long run association between per capita FDI, human development index, inflation and openness.

Table 9 also exhibits the regression outcomes for Guinea when the dependent variable for social well-being is Human Development Index. The results in the long run, display that per capita FDI negatively impacts welfare but not significantly. This finding contradict the classical theories about FDI which state that Foreign direct investments may be an important tool through which developing countries can create jobs, develop local skills, bring new technologies, generate backward and forward linkages with local companies, increase competition and positive spillovers and promote welfare. Another explanation of this phenomenon may be the fact that a large proportion of foreign investment in Guinea is concentrated in extractives industries (Mines) which have a very limited linkage, spillover and impact on the local economy. Those foreign multi-national corporations basically extract raw materials, commodities and export to their home countries without any transformation and value added to the Guinean economy.

When Inflation variable is incorporated, we find that inflation in the long run, influence positively and significantly the human development index. For the trade openness, the interaction still positive but not significant.

4.4 Results of Auto Regressive Distributed Lag Model (ARDL)

Table 10. The ARDL Model

HDI	Coef	Std. Err.	t	P > [t]	[95% Conf. Interval]	
HDI						
L1.	-1.00709	0.2175143	-4.63	0.001	-1.485836	-0.5283445
L2.	-0.7900258	0.2562913	-3.08	0.010	-1.354119	-0.2259326
L3.	0.2688286	0.2115319	1.27	0.230	-0.1967499	0.7344072
L4.	0.6224077	0.2081351	2.99	0.012	0.1643053	1.08051
FDI/Capita						
--	0.0000333	0.0000431	0.77	0.456	-0.0000615	0.000128
L1.	-0.0000988	0.0000469	-2.11	0.059	-0.0002019	4.33e-06
L2.	0.0000573	0.0000465	1.23	0.244	-0.0000451	0.0001597
Inflation						
--	-0.0000276	0.0001619	-0.17	0.868	-0.0003839	0.0003286
L1.	0.0006777	0.0001551	4.37	0.001	0.0003362	0.0010192
L2.	0.0005826	0.0001797	3.24	0.008	0.0001871	0.000978
Openness						
--	-0.0001924	0.0001614	-1.19	0.258	-0.0005477	0.0001629
L1.	0.0004118	0.0001656	2.49	0.030	0.0000473	0.0007764
_Cons	0.014253	0.0039136	3.64	0.004	0.0056391	0.0228668

F (12, 11) = 3.20; Prob >F = 0.0317; R-Sq = 0.7775; Adj R-Sq = 0.5347; Root MSE = 0.0040

Table 10 exhibits the short run regression outcomes for Guinea when the dependent variable for social well-being is Human Development Index. The findings display that per capita FDI [current value and L2.] have positive but not significant impact on HDI whereas FDI [L1] has a negative interaction with welfare at 10% significance level. The trade openness variable [current value] is negatively but not significantly associated with HDI, conversely the [L1 value] influence positively and significantly welfare variable.

The results also show that inflation [L1 and L2] interact positively and significantly with human advancement index whereas the [current value] is negatively but not significantly associated with welfare variable. Overall, the long and short run regression results on the interaction between inflation and welfare suggest that social well-being in Guinea goes together with relatively high inflation rate. These findings are contrary to the view of the widely recognized costs of inflation, in terms of its propensity to endanger macroeconomic stability in the short term and its possible harmful effects on economic growth in the long term.

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4.5 Robustness Tests

For robustness check, we consider several tests to assess the model stability, normality or whether there are serial auto-correlations and heteroskedasticity among the variables.

Durbin-Watson d-statistic: (13, 24) = 1.619459

The Durbin-Watson test outcome (1.619459) clearly exhibits that our model does not present any serial auto-correlation, confirming the consistency of the results.

Table 11. Breusch-Godfrey LM test

Lags (p)	Chi2	df	Prob > chi2
4	3.982	4	0.4085

Ho: no serial correlation

The Breusch-Godfrey test confirms the previous finding. Prob > chi2 = (0.4085) is greater than 5% which shows that no serial autocorrelation has been found among the variables.

White's test for Ho: Homoskedasticity

against Ha: unrestricted heteroskedasticity

chi2 (23) = 24.00

Prob > chi2 = 0.4038

For the White's test, we found Prob > chi2 = (0.4038) is higher than 5%, then we deduce that the model is not suffering from any heteroskedasticity. Hence we used a desirable framework.

Table 12. Cameron & Trivedi's decomposition of IM-test

Source	Chi2	df	p
Heteroskedasticity	24.00	23	0.4038
Skewness	10.88	12	0.5395
Kurtosis	0.08	1	0.7734
Total	34.96	36	0.5179

The skewness [Prob > Chi2 superior than 5%] and the Kurtosis [Prob > Chi2 greater than 5%] from Cameron & Trivedi's test show that residuals are normally distributed.

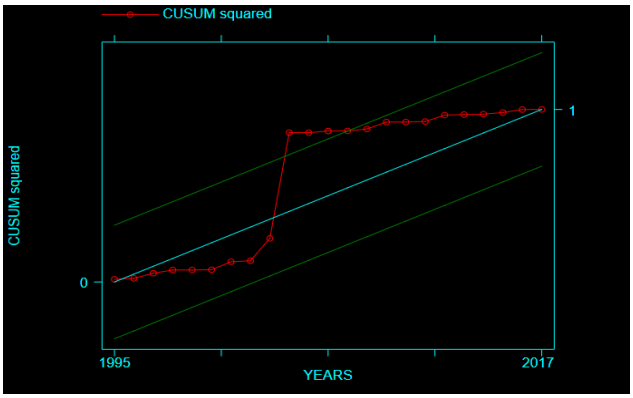

Figure 4. CUSUM Squared test

The Cusum squared graph confirms that our model is not suffering from any instability. Hence we employed the desirable framework.

5. Conclusions

This empirical study estimates the influence of Foreign Capital (FDI) on social well-being in Guinea from 1990 to 2017. We employed FDI indicator and welfare measure, respectively the per capita FDI net inflows and human development index (HDI).

By performing Error Correction Model, we noticed the existence of long run interaction among the variables. The findings also displayed that per capita FDI in the long run, negatively impacts welfare but not significantly, while with Inflation the coefficient is positive and significant. For the trade openness, we still found the same positive interaction but not significant.

This situation can be explained by the fact that a large proportion of foreign investment in Guinea is concentrated in extractives industries (Mines) which have a very limited linkage, spillover and impact on the local economy; contradicting the classical theories about FDI. Those foreign multi-national corporations basically extract raw materials, commodities and export to their home countries without any transformation and value added to the Guinean economy.

However, in the short run, the outcomes showed that per capita FDI [current value and L2.] have positive but not significant impact on HDI whereas FDI [L1] has a negative interaction with welfare at 10% significance level. The trade openness variable [current value] is negatively but not significantly associated with HDI, while inflation [L1 and L2] influence positively and significantly human advancement.

Other factors such as political stability, governance, institutions and the quality of infrastructures may have great impact on the relationship among foreign direct investment and human development in Guinea.

For policy recommendation, although Foreign capital may reduce poverty in Guinea, instruments employed to entice these inward capital should be tailored on sectors that account for Guinean economy. Instead of investing in extractive industries which have very limited linkages with domestic economy, government should diversify and encourage foreign investors to look at sectors such as agriculture, infrastructure, manufacturing and services that may have strong impact on Guinean economy in terms of inclusive growth, employment opportunities and poverty alleviation.

Limitations and Areas for Future Research

Due to lack of extensive and reliable data, some of the

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variables such as infrastructure and political stability that may count when assessing the impact of FDI on welfare are not measured in this empirical study. Those that were included were determined by data availability such as per capita FDI, human development index, inflation and trade openness where the only available data cover the period 1990-2017. Therefore, further empirical analysis should pay attention to the role of financial market within the linkage between FDI and social well-being as well as the influence foreign capital may have on economic growth within the Guinean context.

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REVIEW

History of the Human and Nature Relationship, Discovery of Greenhouse Effect and Awareness of the Environmental Problem

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Economic awareness

ABSTRACT

The evolution of man and nature relationship during human history has allowed human beings to be sheltered from the threats of their natural environments and has permitted them to exercise their powers there but has against part the breakdown of this relationship because of the excessive exploitation of natural resources, discharges and waste that cause nature pollution. This rupture caused climate change due to the evolution of the production model from the primitive model to the capitalist model. The objective of this paper is to shed light on the evolution of the relationship between human beings and their natural environment and the awareness of the climate change problem. This research allows appreciating and comparing the effectiveness of the resolutions that can help researchers understanding the climate change context, serve as a springboard for empirical studies, and represent a decision tool for policymakers. To this end, we use a knowledge synthesis methodology to make an inventory of our research problem.

1. Introduction

Climate change is one of the current scientific questions that require a study by researchers of all disciplines across the globe because of its importance and its effects on the survival of human beings. This lasting change in the climate parameters of the Earth is caused by transformations caused by human activities and intrinsic transformations. In this sense, "*Man has a story because he transforms nature. Besides, it is even the nature of man to have this ability. The idea is that, of all the forces which set man in motion and make him invent new forms of society, the most profound is his capacity to transform his relations with nature by transforming nature itself*." [3] The man and nature relationship evolved during human history. Indeed, human activities have allowed human beings to be safe from the threats of their natural environments and have allowed them to exercise their powers; but caused the rupture of this relationship following the excessive exploitation of natural resources and the emission of discharges and wastes which cause natural environments pollution.

At the international community level, awareness of climate change is reflected by the breadth of existing litera-

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ture across different disciplines. Institutionally, the debate on climate change is dominated by two interrelated issues. First, the future of the global climate objectives set by the Conference of Parties and more particularly that of the Kyoto Protocol, keeping its limitations in view. Second, a general framework conception between developed and developing countries, including a responsibility-sharing agreement considering their different economic situations. Indeed, the Kyoto Protocol is an international agreement aimed at reducing greenhouse gas emissions and which comes in addition to the United Nations Framework Convention on Climate Change. Signed on December 11, 1997, at the third conference of the parties to the convention (COP 3) in Kyoto-Japan and entered into force on February 16, 2005. The fixed objective of the protocol is to reduce during the period 2008-2012, by at least 5% of emissions of six greenhouse gases compared to their 1990 level.

To this end, countries are in the obligation to try to reduce their emissions and recourse to the mechanisms of the protocol that are international trade of emission permits, joint implementation, and clean development mechanism. As for the tradable permit mechanism, it allows companies to permits trade among themselves. This system is stimulating because it encourages companies to invest in R&D to modernize their production tools. In addition, within the framework of tradable permit markets between developed and developing countries, the latter can auction their rights to pollute to countries that have exceeded their limit. This governance should allow quotas to become more and more expensive when countries reach their limit faster. However, the risk is that the less wealthy countries tend to sell their right to pollute very quickly, thus creating a downward distortion of the price of permits.

Concerning the joint implementation mechanism, it focuses on financing industrial or forestry projects with the objective of storing carbon or reducing greenhouse gas emissions and launched by countries of central and eastern Europe. These projects generate emission credits that can be used by investors.

The third flexibility mechanism, the clean development mechanism, was created to allow Westerners to achieve their objectives by investing in projects in developing countries. It represents the response to the demands of developing countries for a financial mechanism that supports economic development by adopting more environmentally respectful production methods. It allows industrialized countries to benefit from carbon credits resulting from investments in clean technologies in GHG emission reduction projects outside their geographic area.

In addition to its unclear and disproportionate responsibility-sharing within developing and developed countries, the Kyoto treaty is contested regularly by various economic lobbies or public figures who consider that global warming is not of human origin and therefore criticize the usefulness and expenditure of the Kyoto Protocol.

At the economic level, relatively recent economic developments in the field of the environment are established and is related to two different approaches: the first concerns the orthodox approach related to the environment, which refers to the school of property rights as well as the neoclassical school also called the economics of the environment. The second relates to the heterodox approach, which includes, in addition to ecological economics, which is based on the criticism of the neoclassical school, the institutional, conventional, and regulation school linked to the environment.

This paper aims to present the history of the evolution of the relationship between human being and their environment that caused greenhouse gas emissions and consequently climate change. To shed light on the importance of the environmental problem and draw lessons from experience and overcome the gaps of the adopted solutions, we try to expose the awareness of environmental dilemma at the international level and the proposed solutions by economists.

The rest of the paper is organized as follows: Section 2 provides the history of the human and nature relationship; Section 3 sets out the history of discovery of the greenhouse effect; section 4 presents the awareness of the environmental problem; section 5 exposes the economists' vision of the environmental dilemma and section six concludes.

2. History of the Human Beings and Nature Relationship

The history of the human beings and Nature relationship has evolved considerably. Indeed, in addition to the permanent changes in environments naturally, other transformations are caused by human activities. This story began truly in East Africa there are approximately 2.5 million years ago with Homo Habilis, followed by Homo erectus, then, around 1-1.5 Million years before Jesus Christ (BC), the Homo sapiens developed in Europe (Neanderthal) around 100,000 years BC to finally arrive at Homo sapiens around 40,000 years ago.

For many millennia, human society was characterized by communism where men ate edible plants and lived in the wild. The precariousness and instability of sources of nutrition expressed the weakness men face the nature

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forces. The paleolithic man survived in living conditions quite like those of other large predators. The man was considered as one of the components of the terrestrial ecosystem. Indeed, manhunts gather and fishes. As a result, hunter-gatherers exploit natural resources through fruit harvesting and the destruction of certain species of wild animals through hunting. However, the small number of human beings at that time; makes their impact on nature modest; since the capacity of natural environments to renew themselves exceeds their exploitation by human beings.

The *first break* of the Man and Nature relationship was caused by the *discovery of fire* around 400,000 years ago. That time was marked by instrument development such as the stick and coarse uncut stones, the spear with the stone point, the bow and arrow. Indeed, the economy, at that time, was managed collectively and was known as the clan economy. Hunting, fishing, food preparation, consumption, and dwellings were in common. This way of life allowed them to provide a force to fight against nature. The *second break* in the Man and Nature relationship is the *Neolithic revolution. It* consists of an agriculture-based productive system initiation that entailed a radical change from predation to a production economy.

Global warming occurred about 10,000 to 11,000 years ago, leading to the Ice Age passage, which began about 1.8 million years ago and ended there. 11,400 years ago, (Pleistocene) in the warming era, which has lasted for almost eleven thousand years. This period coincides with the *Mesolithic* (from the Greek meso = middle and lithos = stone) then the *Neolithic* (from the Greek neo = new and lithos = stone) or "*polished stone age*". Some authors have explained the advent of agriculture in Europe by the significant changes in the climate. In this sense, [32] stated that the evolution of the way of life towards agricultural activity and riverside societies of Mediterranean Europe, from Greece to the peninsula Iberian, seems to have been regular and benefited from global warming.

According to some historians, this warming implied changes in economic and social behavior since it resulted in changes in natural environments: a shift from a hot and dry climate to a warmer and more humid one. This climate favors the development of the forests, which caused the disappearance and the flight of the herds of reindeer, bison, and horses towards the north of Europe and made hunting more complicated, leading the populations of that time to seek new sources of food and therefore to the development of the agricultural activity. According to the American economist Douglass North, this mutation has led to a new approach, called the agro-system. This latter consists in the replacement of natural balances destroyed by unstable secondary balances.

Indeed, the agro-system consists of using the natural components for other purposes than the ecosystem functioning. Therefore, the harvest impoverishes the ecosystem and imbalances it. Besides, domestication is at the origin of several consequences on the fauna. In this sense, [33] stated that individuals target plant or animal populations that best suit *their needs* and try new ways to breed plants and *animals* for *specific* desired traits. Consequently, the inability of some species to adapt to unnatural living conditions led to their scarcity and even their disappearance. On the other hand, the increase in agricultural space and the forest declines due to deforestation and grazing caused a reduction in the number of wild species.

Consequently, the development of crops and livestock has led to large-scale deforestation, which has led to the reversal of ecosystem dynamics and structure. The social forms of production have changed during human history development i.e. primitive, communism, slavery, feudalism, and capitalism.

The decomposition of primitive communism is the consequence of the development of breeding and the domestication of animals. Indeed, breeding marks the first social division of labor, allowing barter development between pastoral and other tribes, since it constitutes a permanent source of milk, meat, skins, and wool. Indeed, the agriculture development has strengthened productive sources of plant food creation stability.

Also, the invention of weaving, which made it possible to manufacture woolen fabrics and clothing, the emergence of metallurgy at the end of the Neolithic, the transformation of copper during the Chalcolithic period (Greek word khalkos: copper and lithos: stone), and gold and silver, opened new areas for human labor. The social division of labor, trade and the progress of the productive forces contributed to the transition to slavery. This production model is characterized by trade development, which contributed to city formation, and commercial development. Consequently, producing harmful effects on ecosystems because of deforestation and clearing actions to develop agricultural activity and organize human life as cities.

The liberation of slaves following their failure in achieving income for their masters allowed the development of a new category of small producers and the emergence of a new production model within the slave society, the feudal production mode. Feudalism in the West extends between the 9th and 13th centuries. The feudal production mode had an economic basis for the small production peasants that are free artisans. The production was essentially natural. The latter was devoted to meeting

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the needs of its producers and not intended for exchange. During the period 1050 to 1150, the lords recommended their peasants clear the forests to increase agricultural production. At that time, the clearing was done often using fire, which made the soil very sensitive to erosion. These large and uncontrolled clearings have caused natural disasters such as chain floods, landslides, etc. Another aspect concerns the grazing of herds in the forests.

The latter causes the stripping of small vegetation allowing water to be retained on the surface, causing damage to the soil. The impact of agricultural activities on natural environments changed with the industrial revolution at the end of the 19th century. This change is due to agricultural machinery, which began to proliferate and mineral fertilizer development and plant species improvement, and animal selection from the First World War. Thus, announcing the amplification of the impact of Man in his natural environment. Besides, the steam engine expansion in many sectors of the economy, then the diffusion of electricity, led to a considerable increase in coal withdrawals until the 20th century beginning.

Already, Marx noticed these pressures on the ecosystem. Indeed, Marx affirmed that environmental problems are not considered in an economy that is not planned. In this sense, he testified in a letter he sent to Engels that:" *Agriculture when it progresses in a primitive way and is not controlled consciously, leaves deserts behind - Persia, Mesopotamia, Greece, ...*" [22].

The rapid evolution of demography, the disappearance of small communities such as the tribe, the village, … mark the life of the human species in industrial society and the development of the capitalist mode of production.

The industrial revolution is the set of developments that have taken place in agriculture, demography, urbanization, industry, transport, technology, and commerce. These developments have kept humans away from threats to their natural environment. In fact, from the 18th century, the great famines ceased in Europe. Besides, humans began to exert pressure on their ecosystem that manifests in deforestation, fauna pressure, sea-level rise, fossil waters use, increased energy consumption, …

This human authority over nature has generated:

• The decline of forests, which seriously affects flora and fauna diversity.

• The development of artificialized environments, which modifies the environment of human beings following a change in his perception of natural elements.

• The increase in energy-intensive productive activities and consequently the increase in the withdrawal of natural resources.

• The development of new harmful physical phenomena and substances such as radioactivity.

• Air pollution and the consumption of nonrenewable energy.

Consequently, human activities generate anthropogenic gases in addition to the natural greenhouse effect that causes climate change. The 1st article of the United Nations Framework Convention on Climate Change (UNFCCC) defined climate change as: "*Changes in climate, which are attributed directly or indirectly to human activity altering the composition of the global atmosphere, and which are added to the natural variability of the climate*" [30]. However, the greenhouse emissions discovery is a phenomenon that interested researchers from different disciplines.

3. History of the Discovery of the Greenhouse Effect

The greenhouse effect is a natural process necessary for life. Two-thirds of the energy sent to our planet in the form of solar radiation is absorbed by plants, soil, and the atmosphere. The remaining third is returned directly to the atmosphere. In a steady-state, the Earth does not accumulate energy. Greenhouse gases (GHGs) naturally present in the atmosphere help to increase the Earth's temperature. The essential greenhouse gases are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). In addition to natural GHGs, industrial GHGs are added, including fluorinated gases such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons, tetrafluoromethane (CF_4), sulfur hexafluoride (SF_6). For their part, climatologists have tried to predict the concentrations of greenhouse gases to be able to estimate climate change in the coming years through scenario making.

The results of the work of the Intergovernmental Panel on Climate Change (IPCC) were published in 2000 in the form of a "*Special Report on Emissions Scenarios*" (SRES) following the collection of information. Concerning socio-economic modeling to be able to establish scenarios covering a wide range of possible futures. This group estimated the GHG emissions for each scenario. The IPCC announced that "*Since 1750, as a result of human activities, atmospheric concentrations of CO_2, CH_4 and N_2O have increased sharply; they are now much higher than the historical values determined by the analysis of ice cores spanning many millennia*" [17].

The history of the discovery of the greenhouse effect dates to 1780. On this date, Horace Benedict de Saussure, a Swiss naturalist, measured the thermal effects of solar radiation in the basin and at the top of a mountain. In 1774, he invented a solar collector called the Heliother-

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mometer made up of five glass cases containing thermometers nested in each other, which he exposed to daylight. He noted that the measured temperature is higher and higher as one goes towards the center. He understood that the greenhouse glazing catches solar energy and figured that the atmosphere does the same.

Jean Baptiste Joseph Fourier, French mathematician, and physicist, published in 1824 his article "*General remarks on the temperatures of the terrestrial globe and planetary spaces*" in which he interpreted the device of De Saussure and proposes an analogy with the atmosphere, throw the basics of the "*greenhouse effect*". To explain the origins of the temperature of the terrestrial globe, Fourier applied his theory of heat by assuming that it is the consequence of the combination of three sources of heat: solar radiation, the temperature of space, and internal heat. of the Earth. He first announced a greenhouse effect theory claiming that the atmosphere is more transparent to solar radiation than radiation re-emitted from Earth. In 1838, Claude Pouillet, a French physicist, assigned the natural greenhouse effect to water vapor and carbon dioxide and concluded that any variation in the amount of these components should result in climate change. It took until 1861 to discover that carbon dioxide and water vapor are the most important causes of the greenhouse effect, thanks to physicist John Tyndall. He was able to demonstrate the influence of changing components of the atmosphere on climate change. At that time, Tyndall was aware of introducing a new idea by claiming that changes in the active radio constituents of the atmosphere are associated with changes in the earth's temperature [29].

Later, in 1878, Samuel Pierpont Langley, an American experimental astrophysicist, developed the bolometer which he used to measure the spectral distribution of radiation. His work has focused on the study of the sun and its influence on the Earth's climate. Based on the work of Fournier and Tyndall, Swedish chemist Svante August Arrhenius founded the "*greenhouse theory*" in 1896. Indeed, in his work entitled: "*the evolution of worlds*" published in 1910, Arrhénius recalls the ideas of Fourier, Pouillet, and Tyndall on the atmosphere: "*Their theory bears the name of the greenhouse theory. Hot because these physicists admire that our atmosphere plays the same role as the glass of a greenhouse (...)*" [1].

Therefore, Fourier and Pouillet, admitted that "*the atmospheric belt has close properties of glass in terms of permeability for heat. The elements of the atmosphere which are the causes of this fact are water vapor and carbonic acid* [1]". Arrhenius noticed that the amount of carbon dioxide increases in geometric progression, and temperature increase almost follows arithmetic progression and has shown that a doubling the concentration of CO_2 in the atmosphere causes an increase in the average temperature of the planet by 4°C. In addition, Arrhenius was the first scientist who presented the link between industrial development, fossil fuel consumption, and the concentration of carbon dioxide in the atmosphere increase. He pointed out that: "*The consumption of coal for industrial needs is likely to significantly increase the carbonic acid content in the air* [1]".

As a result, Arrhenius made the first hypotheses suggesting that increasing carbon dioxide concentrations can lead to climate warming. French meteorologist Léon Teisserenc de Bort discovered the existence of the stratosphere in 1902 following the development of sounding balloons, which has helped to understand that ozone is a gas that absorbs solar radiation. The "*international geophysical year*", 1958, marked the beginning of the continuous measurement of the carbon dioxide concentration in the air by Charles David Keeling in Hawaii and the Antarctic, which made it possible to draw the "*Keeling Curve*" (see Figure 1).

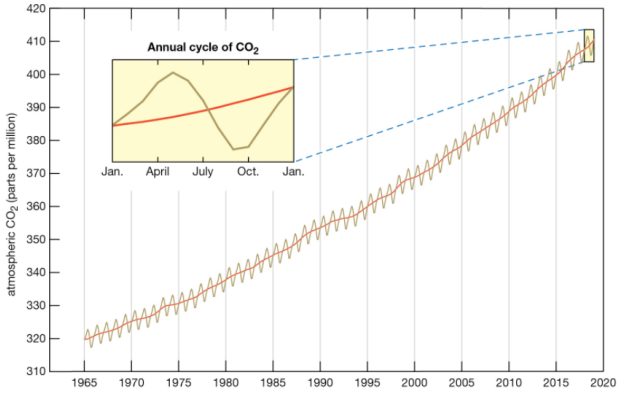

Figure 1. Keeling's curve: atmospheric concentration of carbon dioxide, measured on Mauna Loa (Hawaii), 1965-2020 (in parts per million)

Source: Encyclopedia Britannica, Inc.

This American researcher was able to underline the increase in the concentration of this substance and attributed it to fossil fuels and deforestation increase. In fact, following the industrial revolution, a sharp increase in atmospheric GHG concentrations is due to human activities. The concentration of CO_2 emissions passed from 280 ppm^2 to around 370 ppm^2 between 1750 and 2000, that of N_2O increased by 17%, and CH_4 increased by 1.5 over the same period [16].

According to the IPCC 2001 report, changes that have taken place over the past century are:

• The ground temperature has increased, on average, by about 0.6°C.

• The rise of sea level by 0.1 meters in 100 years.

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• The increase in precipitation in the mid and high latitudes of the northern hemisphere, from 0.5% to 1% per decade.

• Decrease in frequency of minimum temperatures and increase in the frequency of extremely high temperatures.

Finally, the IPCC has underlined that "*the continuation of GHG emissions at the current rate or a higher rate should accentuate warming and profoundly modify the climate system in the 21st century. These changes will probably be more important than those observed during the XXth century* [16]".

Until the end of the 1960s, the debate on climate change and the greenhouse gas effect phenomenon was dealt with by scientists (physicists, meteorologists, chemists…). However, to enrich the climate change discussions, the scientific and political sides are complementary. In fact, "*networks of scientists and environmental organizations have played a prominent role alongside some international organizations. A few scientists, sensitive to the environment protection, have contributed to the popularization and media coverage of the debate, thus making it possible to familiarize the public and the elites with this theme*" [10].

Indeed, at the international level, the awareness of climate change is revealed the first time by a world climate conference in 1979 in Geneva where a World Climate Research Program was launched, under the responsibility of the World Meteorological Organization, the United Nations Environment Program, and the International Council of Scientific Unions. In 1988, the Intergovernmental Panel on Climate Change is created to perform a regular assessment of climate change. It provides the basis for the development of the United Nations Framework Convention on Climate Change.

The Summit held in 1992 in Rio de Janeiro is a crucial step in international climate negotiations with the signing of the United Nations Framework Convention on Climate Change. It officially recognizes the existence of climate change and human responsibility for this phenomenon. Its objective is to stabilize atmospheric greenhouse gas concentrations at a level that prevents dangerous human disturbance of the climate system. The highest decision-making authority of the Convention is the Conference of the Parties that is responsible for sustaining international efforts to address climate change. On the third conference of the Parties (COP 3) in Kyoto 1997, the Kyoto Protocol was signed and entered into force in February 2005. This Protocol is an international agreement aimed at reducing greenhouse gas emissions.

However, climate change is not a priority compared to other development issues for most developing countries. They believe that developed countries must act because they are responsible for the current greenhouse gas concentrations increase. On the other hand, one of the reasons for the refusal of the United States to ratify the Protocol is that developing countries do not have a quantified commitment to reduce their emissions in the Kyoto Protocol. As for the effectiveness of Kyoto protocol ratification on emissions reduction, [2] demonstrated that protocol ratification allows emissions reduction, but the magnitude of impact is minor. As Kyoto protocol outcomes do not meet expected results, the conference of parties continues to develop other frameworks to achieve greenhouse gas mitigation targets.

As a result, Paris Agreement was approved by all 195 delegations in December 2015 and entered into force in November 2016. It is an agreement that followed the negotiations held at the 2015 Paris Conference on Climate Change (COP21) that plans to contain global warming by 2100 to well below 2 °C of pre-industrial levels and to continue efforts to limit the rise in temperatures to 1.5 °C.

4. Awareness of Environmental Problematic

Despite some existing contradictions between economic growth and preservation of the natural environment, several attempts at linking these two disciplines have started to be formulated in recent decades. In this sense, Raymond Barre's book, *Political Economy*, published in 1959 offers a definition of economic science, which links the latter to the scarcity of natural resources: "*Economic science is the science of scarce resource administration. It studies the human behavior forms taken by the management of these resources, it analyzes and explains how an individual or a society allocates limited means to the satisfaction of numerous and unlimited needs* [26]".

Moreover, economic activities and natural resources were studied in economic theory before the recent ecological awareness. The economic history of human beings demonstrated that nature has a crucial role in economic value formation. Indeed, the incorporation of environmental problems in economic thought can be attributed to pre-classics and mercantilists. In this sense, William Petty (1623-1687), indicated that "*work is the father and nature is the mother of all wealth and none of this couple can be omitted from the public record*" [23].

Besides, physical constraints represent an economic problem for the French physiocrats, and especially François Quesnay (1694 - 1774), head of the School of Physiocrats. Indeed, Quesney considered the economic activity subject to a natural order and advanced the supposedly natural character of economic laws, the guarantee of a pre-established balance, and the circular character of

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the economic process [24,25].

The Quesnay analysis center is land and natural forces. He considered natural fertility to be the origin of the product and the starting point of wealth and its circuit. On the other hand, Turgot (1727-1781) first enunciated in 1768 the "*disproportionate law, or diminishing returns*", and related the number of production factors with the quantities produced. Therefore, the physiocrats failed to distinguish between natural fertility and the productivity of human labor. As a result, they assumed the autonomy of the presumed economic sphere as a natural organism instead of integrating economics into the biosphere and its constraints on economic activity.

As for classical economists, Adam Smith (1723-1790) assumed that land division and technical progress ensure productivity increase and that nature does not impose limits. On the other hand, in his work entitled "*On Principles of Political Economy and Taxation*", Ricardo developed the idea that natural resources are unlimited and have no intrinsic economic value. He affirmed, "*by ordinary principles of supply and demand, it could not be paid rent for the land, for the same reason that one does not buy the right to enjoy the air, water, or all these other goods that exist in nature in unlimited quantities (...). But no one buys the right to enjoy these natural agents which are inexhaustible and which anyone can use*" [27].

Moreover, Ricardo compares the earth to a series of graduated machines, which exhibit imperishable and indestructible faculties. Nature was presented, by the latter, as being eternal and inexhaustible. Thus, no limit, neither ecological nor economic will affect industrial production according to the conviction of Ricardo. Although he returns to the consequences of the law of diminishing returns in agriculture by advancing that the increase in food needs following population growth will cause human beings to cultivate new lands less and less fertile leading to higher production costs.

Thus, we can deduce that the fertile land scarcity does not allow us to serve a perpetually growing population, a thesis previously defended by Malthus. In fact, [21] showed that growth is limited due to the "*population law*" following the thesis development that the misery origin comes from a gap between two laws: arithmetic progression law and geometric progression law. Indeed, [21] asserted: "*The means of subsistence, under most favorable circumstances to production, can never increase at a rate faster than that which results from arithmetic progression*". While the increase in population evolves according to a geometric progression is indisputable [21]. This imbalance can be absorbed by mortality, lower birth rates, and celibacy. Long ignored by neoclassical economic theory, natural resources were not seen as a production factor explaining economic growth. This school of thought ideas on natural resource scarcity is different from one economist to another apart from their common marginal reasoning.

In this sense, in his book "*The Coal Question*", extended these concerns to energy resources and particularly to mineral resources by his observations on the physical limits of coal deposits in England through the denunciation of the dependence of the British coal economy as a cheap and exhaustible source [19]. Furthermore, [19] in his work "*Political Economy*" discusses the relationship between the natural resources scarcity and their value and puts forward the idea that shortage alone does not create value. There are many rare metals and minerals, of which we have never had more than a few fragments, but their value remains low until the day when some uses are discovered for them.

Moreover, through his proposal for the theory of land prices, [31] anticipated the extension of private property rights to the environment and recommended studying the social side, a postulate presented in the debate on sustainable development.

Studying the relationship between economic development and its impact on natural environments became crucial. Indeed, the current development model is imposed by the capitalist production mode, by seeking capital accumulation, and profit. This production model leads to ecosystems degradation, the inequalities worsening, and the traditional lifestyles disappearance. In this sense, "*the type of development that prevails in the world is driven by the search for profit to accumulate capital, by a major degradation of ecosystems, by a considerable inequalities aggravation, by the exclusion of a majority of human beings from the possibility of satisfying their most basic needs (...), by the destruction of traditional life modes*" [18].

Past economists integrated indirectly environmental aspects in their developments. However, their ideas do not address effective solutions to this problem. Since the beginning of the twenties, solutions to environmental problems started to be developed by economists. Indeed, at the beginning of the 20th century, neoclassical no longer saw in the land a necessary input for production. Nevertheless, two economists participated in creating, what will be called around the 1970s, the economy of natural resources via the analysis of the exploitation of exhaustible resources of Hotelling and the environmental economy of Pigou through the economy of well-being and externalities analysis. The impact of human activities on natural resources begins to find its analytical bases in the 1920s with Arthur Cecil Pigou, who is the first who proposed to set up a tax to internalize negative externalities, which will make it

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possible to change the economic behavior of individuals.

In his seminal paper on *Growth Theory* published in 1928, Ramsey laid the foundations for calculating and choosing the discount rate to treat present and future generations equally [27]. Later, Hotelling introduced in 1931 the relation price - the rate of natural resource extraction in his article: "*The Economics of Exhaustible Resources*" through a balance between the safeguard of the natural heritage for future generations and the influence of monopolies [15]. The response to environmental problems is developed in the following section.

5. Economists Respond to Environmental Problem Consciousness

Economist environmental problem consideration was developed concomitantly with the awareness by the international community. Two different visions were developed, which are the orthodox and the heterodox approach. The orthodox approach is composed of the property rights school and the neoclassical school. As for the school of property rights, several writings are the basis of their analyzes, especially the article by Ronald H. Coase: "*The Problem of Social Cost*". The school of property rights, which belongs to the extreme Orthodox, sees the inadequate property rights structure related to the environment as the cause of its degradation. Indeed, the absence of private property leads to nature degradation [13]. Property rights of economists recommend environment privatization to achieve optimal pollution levels [28]. In this sense, the bargaining between producers and consumers of environmental externalities allows efficient distribution of the latter provided that the information is available, transaction costs are zero, and property rights are well defined [5].

Moreover, Coase argued that: "*the internalization can be realized without the government intervention, except the establishment of property rights, by market negotiation between the polluted and the polluters regardless the initial rights distribution between them*" [5]. Unlike Coase, Pigou puts forward the idea that externalities require government intervention since both sides of the externality will make a deal.

After forty years, the neoclassical approach imposed itself despite being severely criticized and even rejected by some pioneers during the 1970s. The contemporary neoclassical analysis notes the overexploitation of natural resources, whether concerning inputs or outputs. Indeed, they present the absence of a price system as the cause of the ecosystem overexploitation on the input side. As for yield, the increase in pollution and waste costs is due to the absence of their price.

This approach is based on the concept of weak sustainability. The origin of this approach was attributed to Hotelling and was developed by Hartwick, who established the compensation rulemaking it possible to guarantee equity between the current and future generations. Indeed, this rule stipulates that the difference between the price and the marginal cost of resources corresponds to rents which must first be withdrawn progressively with the depletion of resources, then reinvested in the production of a substitute for the depleted resources, and finally increased at the discount rate each period [14].

In this sense, the objective of sustainability is achieved only by transmitting a capacity to produce economic well-being for future generations that is at least equal to that of present generations. That is the maintenance of a constant flow of wealth over time which requires that the stock of natural capital remains intact from one generation to the next as the stocks of equipment, knowledge, and skills, the general level of education and training, and the available natural resources stock form the production capacities of an economy.

Neoclassical economists have tried to integrate the environment first into their general equilibrium models, referring to the tradition initiated by Harold Hotelling in 1931, who considers nature as a particular form of capital. Jacobs distinguished two stages of neoclassical thought. The first stage, which constitutes the radical school, consists of determining the pollution level via theoretical economic tools. The second, representing the applied school, lies in the economic instruments use in public policies.

Thus, from the point of view of radical neoclassical theorists, environmental problems are presented as particular cases of externalities. In a competitive context, the existence of negative externalities leads to a sub-optimal resource allocation. Economically, Greenhouse Gas emissions are considered as negative externalities. Since total surplus maximization with the equilibrium quantity is not achieved. The emissions presence in a market makes it inefficient.

In response to the polluter pays principle, the applied neoclassical school recommended the environmental policy instruments. Thus, the polluter pays the marginal damage costs caused by his activity to limit the external costs of pollution: this is the internalization of negative externalities.

The government can determine the optimal pollution level if it has the necessary information. Then implement regulatory or economic measures involving changing the behavior of economic agents towards a decentralized balance.

Initially, legislation was adopted widely as a tool for

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environmental protection. Regulatory instruments represent an institutional measure aimed at constraining the behavior of the polluter on the pain of sanctions; the norm is one of these instruments [9]. However, the goal of the planner is only achieved when specifying the standard correctly. If the latter is very lax, economic agents are not encouraged to reduce their emissions; consequently, the pollution level remains high. On the other hand, if it is too strict, the pollution level will be lower than its optimal level. However, from the end of the 1980s, the use of economic instruments alongside regulation was recommended by economists. Indeed, economic instruments modify prices, and market signals allow encouraging specific modes of consumption and production that respect the environment. Besides, resorting to negotiation between polluted and polluters on the emissions permit market can eliminate environmental externalities. Indeed, even in the presence of negative externalities and independently of the initial allocation of wealth, market mechanisms are sufficient to guarantee the optimum [5].

The heterodox approach related to the environment was based on the criticism of the orthodox approach. This approach includes ecological economics, industrial ecology, institutional, conventionalist, and regulations approaches.

Regarding ecological economics, it was based on a critique of the postulate of perfect substitutability between natural and technical capital proposed by environmental economics. Indeed, unlike the standard approach where the environment takes on an external dimension to economic analysis, ecological economics seeks to give it a central place within the latter. This current of thought seeks to give commencement to a new discipline allowing the integration of economy into ecology by defending the precaution principle and the stock of natural resources maintenance over time. Ecological economics is defined as "*a new field of transdisciplinary study which in a general sense addresses the relationship between ecosystems and economic systems*" [6]. Within this framework, some authors have tried to reconcile economic growth and environmental protection. In this sense, they recommended natural resources use if the capacity for renewal of natural resources is not exceeded. The concept of robust sustainability associated with this new discipline includes two schools: the London School and the American School.

The economists of the London school admit the dependence between the economy and the environment characterized by the irreducibility of *natural capital* to artificial capital and therefore adopt limited substitution because of the existence of critical natural capital for which there is no substitute and advance the idea of complementarity between the different capital forms. This school gathers several economists from the London Center for Environmental Economics, i.e. Barbier, Markandya, and Turner. According to these economists, the economy must better assess the environment by assigning fair values to the services it provides [20]. However, many services are free, which leads to overexploitation of natural resources. No market could reveal their real values because of buy and sell actions since they are common property resources. Nevertheless, according to London economists, the natural capital stock constancy is defined as an essential but not sufficient condition for sustainable development. This condition requires a nonnegative change in the natural resources stock and environmental quality.

Several measures have been adopted to define the stock of natural capital in economic terms. The London School considers three: The first consists of valuing each type of resource in monetary terms and calculating its total aggregate monetary value①. The second is to consider the unit value of the services provided by natural capital in real terms, thus making it possible to keep the prices of natural resources constant in real terms. The third is to think of the constant value of the resources flow from the natural capital stock. This latter differs from the case of constant prices because the quantity would be allowed to fall and the price to rise, keeping constant value (Pearce and Turner, 1990, cited by Lauriola, 1997, p 80)②.

Despite the monetary valuation of natural resources problems, London School economists attempted to monetize the natural capital stock, using the shadow prices determined with a total economic value of Pearce. The political weight acquired by experts and researchers at the London School in natural resource and environmental economics justified the importance given to the foundations of this school.

However, [20] has shown, by focusing on the basic assumptions and methods of calculation of the London School, that the latter is much less fundamental than it postulates. London economists use an economic evaluation that presupposes various capital types of substitutability instead of measuring them in physical terms. In addition to the methodological problems linked to the analysis, data measurement, and collection, questions concerning the effects of the economic assumptions and interpretations③. Furthermore, the concept of total economic value suggested by Pearce leads to a fundamental inconsistency. Indeed, the stock economic value can remain constant due to the failure to consider resource depletion even if the total economic value of natural resources increases with its

① Pearce and Turner, 1990, cited by Lauriola, 1997, p 80.
② Pearce and Turner, 1990, cited by Lauriola, 1997, p 80.
③ Pearce et al., 1989 cited by Lauriola, 1997, p 81.

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scarcity [20].

As for the American school, it occupies a much more radical position by assuming the non-substitutability of natural resources [7,8] and by highlighting the idea of complementarity between "natural capital" and other factors of production, in contrast to the position defended by neoclassical economists. Hence a model of "*strong sustainability*" is based on the need to maintain, over time, a stock of "*critical natural capital*" [11] whose future generations cannot happen. Maintaining a natural capital in each physical composition serves as the basis for determining environmental standards [4].

For this, three criteria allowing the preservation of natural capital [8]:

• The rate of exploitation of renewable resources must equal the regeneration rate.

• The waste emissions rate must be equal to the natural absorption capacities of ecosystems.

• The exploitation of nonrenewable natural resources must be done at a rate equals to their substitutions by renewable resources.

Besides, economists from the American school advance the idea that only the absence of quantitative growth makes it possible to ensure sustainability, the result of which is a plea for a stationary economy obtained under the pressure of interventionist measures [4]. The economic stationarity condition is that a subsystem included in a closed system cannot develop indefinitely. Thus, by opting for zero growth, the American school does not renounce development but distinguishes it from growth. For Daly, growth is quantitative on a physical scale, while development is a qualitative improvement. An economy can grow without developing or develop without growing [8].

Other schools of thought tried to offer more practical solutions to the environmental problem seeing it from resource scarcity and excess waste point of view. Industrial ecology school whose supporters have tried to develop a strategy that makes it possible to respond to four challenges, namely: waste recovery, products dematerialization using increasing the productivity of resources, energy decarbonization, and cycles closing by minimizing rejections.

Concretely, industrial ecology was defined in 1989 in an article entitled *Viable industrial strategies* by Robert Frosch and Nicolas Gallopoulos, managers of General Motors, which appeared in a special issue of the *journal Scientific America* intended for the management of the planet earth. However, this notion was only recognized and institutionalized following the Washington colloquium in May 1991, sponsored by the *National Academy of Science* and a specialized journal publication titled the *Journal of Industrial Ecology* since 1997. Industrial ecology offers solutions that must be designed at the scale of cooperating companies to reduce their environmental impacts. However, institutionalist and conventionalist approaches do not directly address the environmental problem but incorporate social institutions.

Indeed, institutionalists reject the hypothesis of methodological individualism, arguing that individuals have endogenous and changing preferences. Also, they invalidate the maximization behavior hypothesis of economic actors, arguing that human behavior is influenced by culture, social norms, and values. In this perspective, other objectives such as the definition of resources transmitted to future generations considering ethical criteria, and the analysis of institutions responsible for natural resources management was set by this school of thought. The institutionalist approach attempts to conceive integrated social management of the environment by integrating environmental values into the institutional renewal process.

Institutionalists state that public regulatory mechanisms and international institutions are incapable of solving environmental problems, given that they are confronted with the diversity of logics and actors. Among the difficulties posed the treatment of environmental problems, which have to be realized at the international level while the national agencies deal with them at a regional level. To overcome this dilemma, institutionalists proposed to renew institutions by integrating environmental constraints and challenges, especially at the international level. However, the institutionalist analysis suffers from some shortcomings, especially concerning the process of institutionalization as a variable of social transformation. Furthermore, the institutional mutations recommended by some theorists of this approach should not only reflect social values but rather the entire social dynamic of which values represent only one component. On these points, the conventionalist current can make a considerable contribution.

Concretely, the conventionalist reading of environmental problems makes it possible to consider social intervention in ecological phenomena. It overcomes the ecological economics limits by considering economic agents, and it represents a complement to the institutionalist approach by theorizing the evolution of social structures in terms of representations and values. In this sense, the conception of environmental policy is influenced by the behavior of economic agents, whose choices guide scientific development and environmental problems [12]. To deal with these problems characterized by a high level of uncertainty, Godard uses the term controversial universe and follows a different approach based on environmental conventions since convention-

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alists present conventions as a set of collective behavior rules in a radical uncertainty situation.

To conclude the conventionalist analysis linked to the environment, it should be noted that the negotiations on the greenhouse effect and the Rio conference characterized by conflicts of interest and asymmetries of power. Hence the need for a new configuration of dominant and dominated social relations. In this regard, regulations analysis makes it possible to highlight this type of relationship in the study of environmental problems.

The regulation school, inspired by the Marxist and Keynesian school, is a socio-economic school of thought found around 1975 by French economists (Billaudot, Lipietz, Boyer, Aglietta, ...) at the time of the oil shock. The regulation school tries to study the macroeconomic and mesoeconomic levels (territorial and sectoral analysis). The regulationist analysis allowed the development of several concepts, such as regulation mode. The regulation mode is a set of procedures and behaviors, individual and collective, which has the property of reproducing fundamental social relations through the conjunction of historically determined institutional forms; support and steer the current accumulation regime; ensure the dynamic compatibility of a set of decentralized decisions, without the need for the internalization by economic actors of the principles of adjustment of the entire system. Among the regulatory methods: the use of less polluting technology or the relocation of an activity by a company to comply with environmental regulations.

6. Conclusions

This article is interested in the evolution of the human and natural environment relationship. This evolution represents the transition from the primitive mode of production to the capitalist mode of production. This transformation led to perverse effects on the environment in terms of excessive exploitation of the exhaustible natural resources and waste and discharges that causing the degradation of the ecosystem's quality.

Using a knowledge synthesis methodology to make an inventory of our research problem, we tied to study the discovery history of climate change and the greenhouse gas phenomenon, which took 150 years, and the awareness of the political, social, and economic level; we sought to allow researchers and policymakers to evaluate the existing strategies and measures. Indeed, this research allows appreciating and comparing the effectiveness of the resolutions that can help researchers understanding the climate change context, serve as a springboard for empirical studies, and represent a decision tool for policymakers.

As for the economic level, the orthodox and heterodox approaches were developed by economists to understand and bring solutions to environmental issues. The peculiarities, advantages, and limitations of the schools that make up these two doctrines presented to provide support for future researchers to overcome their limitations through the development of new solutions that are applicable in the field and that allow more satisfactory results in terms of improving the environmental impact of human activities since developed economic solutions do not all contain practical and measurable tools to ameliorate economic incidence on the natural environment.

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ARTICLE

Inflation and Unemployment Trade-off: Is Phillips Curve True for African Developing Countries? Evidence from Sudan

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ABSTRACT

The relationship between wage inflation and unemployment (Phillips Curve) is controversial in economic thought, and the controversy is centered around whether there is always a trade-off or not. If this relationship is negative it is called The short-run Fillips Curve. However, in the long run, this relationship may probable not exist. The matter of how inflation and unemployment influence economic growth, is debatably among macroeconomic policymakers. This study examines the behavior of the Phillips Curve in Sudan and its effect on economic growth.

1. Introduction

The relationship between inflation and unemployment (The Phillips Curve) is considered a vital instrument of macroeconomic analysis. The study of the Phillips Curve gives signals for policymakers in assessing the overall performance of the economy. The history of economics thought witnessed a controversy about the relationship between inflation and unemployment. In the short run, an increase in wage inflation may reduce unemployment (a trade-off between inflation and unemployment). While in the long run, it is probably to be unrelated. Another issue that needs more investigation is to what extend the components of this curve affect economic growth. This study aims to examine the relationship between inflation and unemployment and recognize how it influences economic growth in Sudan.

2. Literature Review

The term Inflation measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly [1]. ILO defines the unemployment rate as a rate which gives us "the number of unemployed persons as a percentage of the labor force (the total number of people employed plus unemployed)". Also, unemployed workers are those who are currently not working but are willing and able to work for pay, currently available to work, and have actively searched for work [2]. The gross domestic product (GDP) is defined in the literature as the gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products [3].

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Historically, British economist A.W. Phillips considered the first economist who investigated the relationship between the unemployment rate and the rate of money wage changes. His study found that inflation and unemployment have a stable and inverse relationship. Nevertheless, it is expected that economic growth would generate inflation and more work opportunities, which decreases unemployment [4].

In 1958 Phillips examined the relationship between wage inflation and unemployment by an equation taking the following form [5]:

$$w = f(U) \quad (1)$$

In the short run, the relationship between wage inflation rate and unemployment is predictable to be negative.

$$w = f(U) = -a + bU^{-c} \quad (2)$$

Where:

w: wage inflation rates

U: Actual unemployment rates.

Introducing natural rate of unemployment to equation (1) we get

$$P_t = P_{t-1}[1 - b(U_t - U^*)] \quad (3)$$

Where:

U_t and U^* are the actual and natural levels of unemployment;

b is a coefficient indicating the response of wage's fluctuation or changes to the labor market situation;

P_t and P_{t-1} are respectively the prices or wage inflation rates in the current and past periods. Fitting equation (3) to the scatter of annual observations on wage inflation rates(w) and unemployment rates (U) for the UK economy for the period 1948-1957. Philips's study found that observations lay close to his fitted curve, showing its apparent long-term empirical stability.

The Key idea of the Phillips Curve (1958) implies that wage inflation (w) is a function of the excess demand for labor as measured by the unemployment rate (U).When unemployment falls below its natural rate it may lead to a more rapid increase in wages and vice versa[6].

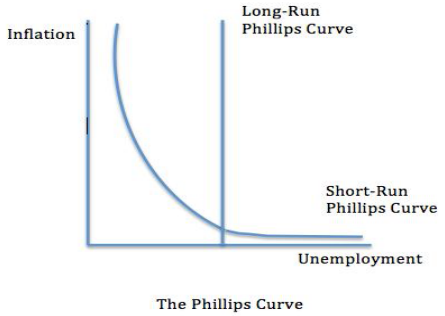

Figure 1. Short/Long-term Phillips Curve [7]

The Phillips curve in Figure 1 displays that if the government in the short term selects the monetary policy to targeting inflation or unemployment, it has to decide whether to choose higher inflation or higher unemployment. The reason is that high unemployment may lead to a reduction in production size, incomes, and purchasing power, which in turn leads to worsening the standards of living because of the increasing pricing of goods and services.

In addition to Phillips curve, many empirical studies were conducted on the relationship between inflation and unem-ployment. Some of the results of these studies found a negative relationship between inflation and unemployment. However, other studies disagree with the results of the Phillips study. After a decade of analysis by Phillips, the idea of a relatively stable long-run trade-off between price inflation and unemployment was firmly built into policy analysis in the United States and other countries. Such a long-run trade-off was at the core of most prominent macro-econometric models as of 1969 [8].

Canadian Phillips Curve for 1957-1990 exhibited a sharp structural shift towards a high degree of unemployment hysteresis after 1972, implying that macro-policy, which aims at lower and more stable inflation, is then shown to make unemployment higher[9]. The Phillips Curve from the American Perspective resulted in a positive correlation between inflation and unemployment in the 1970s. This result conflicts with the original theory of the Phillips Curve [10].The reason is that the American economists had a solid tendency to enforce the linearity assumption on the data. Therefore, their study provides some empirical estimates of Phillips curve for the United States and uses some illustrative simulations to contrast the policy suggestions of the two models (linearity and non-linearity Phillips curves) [11].

In the late twentieth century, some economists and researchers tried to explain why the estimated results of the Phillips curve/equation differ from one period to another or from one region to another. The different versions of the Phillips curve involved a lack of classical dichotomy, effective Keynesian policies, and neoclassical synthesis. Moreover, the neutrality of money and price flexibility had come full circle from the classical era until the new classical school [12]. The theory of the Phillips curve focused on the difference between the "formation" of inflation expectations and the "incorporation" of inflation expectations. Empirical studies of the Phillips curve have shown that the inclusion of inflation expectations provides a welfare economics rationale for Keynesian policies that decrease unemployment at the time of higher cost of inflation [13]. The difficulty

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of estimating the natural rate of unemployment during the slow recovery is still a matter for economists and macroeconomic policymakers [14].

The greatest failure in the history of the Phillips curve occurred in the mid-1970s when the predicted negative relation between wage inflation rate and unemployment may turn out out to be wrong. A study on Greece economy for the data covering the period 1980-2010 indicated a causal relationship between inflation and unemployment [15]. Another study conducted in the Russian Federation from 1999 through to 2015 concludes that Phillips Curve is not applicable for the Russian situation [16]. The Philippines' Philip's Curve for the period 1950-2017 exhibited a strong positive correlation between unemployment and inflation. The Philippian Government needs to implement policy tools in such a way that GDP and annual wage rate positively influence the unemployment rate and inflation rate [17].

The difference in the methodologies and models used to formulate the relationship between inflation and unemployment considers one of the most vital factors leading to differences in the output of the models [18]. In the year 2008, the economist called Gordon reviewed the views of Friedman on the Phillips curve based on a half century's perspective. Gordon used the methodology of the triangle model to explain the positive correlation of unemployment and inflation throughout the 1970s. The parameters of the model continued relatively unchanged during the 1980s and 1990s [19]. Many new models contributed to the literature by introducing the concept of a cumulated wage gap. The gap between inflation and unemployment indicates arising cumulative gap between the current wage and maximum wage value in the past [20]. Therefore, the core issue is about how to strike a balance between wage inflation and unemployment [21].

It is difficult to formulate appropriate economic policies in African countries, so the relationship between the target inflation rate and the unemployment rate could be positive or negative. Godwin and Johnson (2017) assessed the validity of Philip's Curve hypothesis in the Sub-Saharan African region during 1991-2015. The result shows that Philip's Curve (that is, unemployment-inflation trade-off) does not apply to the Sub-Saharan African countries [22]. Besides, data of the Nigerian economy from 1970-2011 displayed a positive relationship between inflation and unemployment in Nigeria- this is called Lon-Run Philip's Curve [23]. This situation raises the question of why inflation follows a seemingly exogenous process, unconnected to the output gap, leading economists or policymakers in African developing countries to argue that the Phillips curve is ineffective. The reason is simply that the matter regards the monetary policy itself [24].

Discussion of the literature review showed a debuted and variation in the conclusions and results related to the relationship between inflation and unemployment and their effects on economic growth. The differences might be attributed to the difference in the application of methodologies and models used to examines the inflation and unemployment trade-off. However, analysis of the Phillips Curve exhibits a different direction in its relation to macro-policies. This study wishes to inspect the Fillips Curve and its implications for economic growth in Sudan.

3. Background of Sudan Economy

Sudan has a different economic and demographic situation compared to some African developing countries.

3.1 Basic Economic Indicators of Sudan

Table 1 displays the key economic indicators of Sudan (1989-2019) indicating inflation rate, unemployment rate and GDP growth rate. Table 2 presents a comparison between Sudan, Egypt, Eritrea, Kenya, Uganda, Chad, and Angola in terms of the average value of the economic indicators for the period 1989-2019.

Table 1. Key Indicators of Sudan Economy (1989-2019)

Year	Inflation Rate (InfR)	Unemployment Rate (UnR)	GDP Growth Rate (GDPR)
1989	65.3	17.2	1.4
1990	-0.90	16.6	0.8
1991	123.6	16	7.0
1992	117.6	15.4	5.5
1993	101.3	15.8	2.8
1994	115.5	15.2	3.5
1995	69	14.6	8.9
1996	86.8	14	5.5
1997	47.2	13.5	6.1
1998	24.6	13	8.2
1999	17.2	12.5	4.2
2000	7.10	15.2	8.4
2001	4.9	15	10.9
2002	22.2	15.9	5.9
2003	6.5	15.8	6.3
2004	9.4	16.2	5.1
2005	8.5	17	5.6
2006	7.2	17.5	6.5
2007	14.8	16.8	5.7
2008	14.3	16	3.8
2009	11.2	14.9	-2.8
2010	13.1	13.7	3.9
2011	18.1	12	-3.2
2012	35.6	14.8	-17
2013	37.1	15.2	2.0
2014	36.9	19.8	4.7
2015	16.9	21.6	1.9
2016	17.8	20.6	3.5
2017	32.4	19.6	0.7
2018	63.3	19.5	-2.3
2019	51	22.1	-2.5

Source [25]: ILO and CBOS Annual Reports

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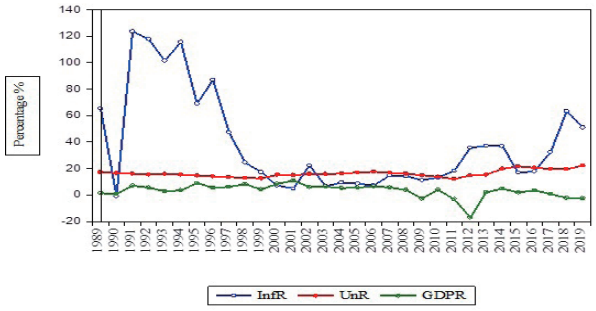

Figure 2. Key Indicators of Sudan Economy (1989-2019)
Source: Made by author using Eviews.10- based on data on Table 1

Table 1 and Figure 2 show that the inflation rate of Sudan during the period (1989-2019) ranges between (%-0.9 - %123). Additionally, the unemployment rate ranges between (%12-%22.1) during this period. The GDP growth rate ranges between (% -2.3 to %10.9). As a result, Sudan's economy was affected by hyperinflation and high unemployment.

Table 2. Key Indicators of Sudan Economy Compared to some African Countries

Country	Inflation Rate (InfR)	Unemployment Rate (UnR)	GDP Growth Rate
Sudan	38.5	16.2	3.2
Egypt	13	11	4
Eritrea	3.7	6.71	5.1
Kenya	4.56	2.56	5.14
Uganda	6.5	2.45	5.17
Chad	2.3	1.82	3.12
Angola	32.1	7.2	1.9

Average Value (1989-2019)
Source[26]: ILO and CBOS Annual Reports

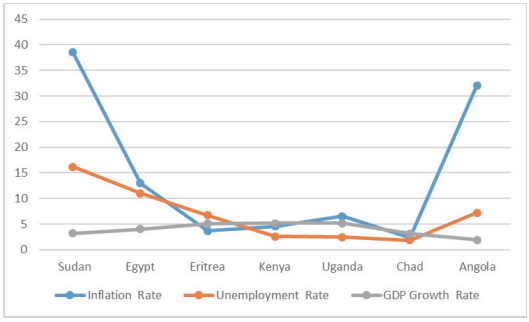

Figure 3. Key Economic Indicators of Selected African Countries
Average Value (1989-2019)
Source: Made by author based on data on Table 2

Table 2 and Figure 3 show that Sudan achieved the highest rates of inflation and unemployment of %38.5 and %16.2 respectively during the period 1989-2019 compared to Egypt, Eritrea, Kenya, Uganda, Chad, and Angola. As for the economic growth, Angola achieved the lowest rate of %1.9 compared to the other African country in the group.

3.2 Basic Demographic Indicators of Sudan

Table 3 presents some social indicators of Sudan including population growth rate, human development index (HDI), birth rate, and death rate. Table 4 presents comparisons between Sudan, Egypt, Eritrea, Kenya, Uganda, Chad, and Angola in terms of average values of the social indicators throughout 1989-2019.

Table 3. Key Demographic Indicators of Sudan (1989-2019)

Year	Population Growth Rate	HDI	Birth Rate	Death Rate
1989	3.2	0.31	41.9	12.2
1990	3.4	0.33	41.8	12
1991	3.6	0.34	41.7	11.9
1992	3.8	0.34	41.6	11.8
1993	3.8	0.35	41.4	11.7
1994	3.5	0.36	41.2	11.5
1995	3.2	0.37	41	11.3
1996	2.8	0.37	40.7	11.1
1997	2.5	0.38	40.4	10.9
1998	2.3	0.39	40.1	10.7
1999	2.3	0.40	39.8	10.5
2000	2.4	0.40	39.5	10.3
2001	2.5	0.41	39.2	10
2002	2.6	0.42	38.9	9.3
2003	2.6	0.42	38.5	9.6
2004	2.5	0.43	38.1	9.4
2005	2.4	0.44	37.7	9.2
2006	2.3	0.44	37.3	9.0
2007	2.2	0.45	36.8	8.7
2008	2.1	0.46	36.4	8.5
2009	2.2	0.46	35.9	8.3
2010	2.2	0.47	35.5	8.1
2011	2.3	0.48	35	7.9
2012	2.4	0.49	34.6	7.8
2013	2.4	0.48	34.2	7.6
2014	2.4	0.50	33.7	7.5
2015	2.4	0.50	33.3	7.4
2016	2.4	0.50	32.9	7.3
2017	2.4	0.51	32.5	7.3
2018	2.4	0.51	32.2	7.2
2019	2.4	0.51	31.8	7.1

Source [27]: Konema and CBOS Annual Reports

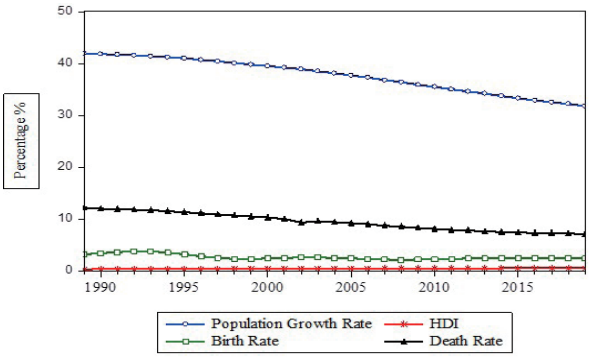

Figure 4. Key Social Indicators of Sudan (1989-2019)
Source: Made by author using Eviews.10- based on data on Table 3

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Table 3 and Figure 4 show that the population growth rate of Sudan ranged between (%2.1-%3.8) during (1989-2019) while HDI ranges between 0.31 and 0.51 during this period. HDI indicates that progress has been severely slowed by the eruption of violent conflict (political instability) between Sudan and South Sudan and the resulting impacts on institutional stability and social capital [28]. In 2019, the birth rate for Sudan was 31.8 per 1,000 people. The birth rate fell gradually from 41.9 per 1,000 people in 1989 to 31.8 per 1,000 people in 2019. The death rate of Sudan declined from 12.2 per 1,000 people in 1989 to 7.1 per 1,000 people in 2019. The signature of the Comprehensive Peace Agreement (CPA) between North and South Sudan in 2005 in Kenya after more that two decades of protracted war may have contributed to the improvement of this indicator [29].

Table 4. Key Demographic Indicators of Sudan Compared to some African Countries

Country	Population Growth Rate	HDI	Birth Rate	Death Rate
Sudan	2.6	0.42	37.6	9.4
Egypt	2	0.68	27.2	5.01
Eritrea	3.02	0.45	30.3	6.5
Kenya	2.5	0.57	28.9	6.2
Uganda	3.4	0.51	41	7.8
Chad	3.2	0.38	44	13.1
Angola	3.5	0.55	42.9	9.6

Average Value (1989-2019)

Source [30]: World and Regional Statistic

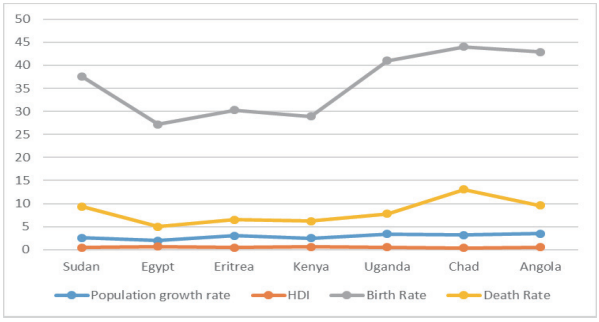

Figure 5. Key Social Indicators of Sudan Compared to some African Countries

Average Value (1989-2019)

Source: Made by author using Eviews.10- based on data on Table 4

Table 4 and Figure 5 show that although Angola achieved a high death rate on average of 9.6 per 1,000 people during 1989-2019, it also achieved the highest population growth rate on average of %3.5 compared to Sudan and the rest of the African countries in the study. Egypt achieved the highest HDI of 0.55 compared the other countries. Sudan has attained HDI on average of 0.42 throughout this period.

4. Methodology and Data

4.1 Models Specifications

The objectives of the study will be achieved by applying two models. The first model (Model-1) aims to examine the relationship between inflation and unemployment (Phillips Curve) in Sudan for the period (1989-2019). The second model (Model-2) measures the effect of inflation and unemployment on the Sudan economy.

The following equation is used to examine the relationship between inflation and unemployment.

$$\text{Inflation} = f(\text{Unemployment}) \quad (4)$$

Equation (4) in the econometric format becomes as shows

$$\text{InfR} = \alpha_0 + \alpha_1 \text{UnR} + \varepsilon \quad (5)$$

Where:

InfR: Inflation rate measured by consumer price index.

UnR: Unemployment rate measured by the number of unemployed persons as a percentage of the labor force.

α_0: The constant term.

α_1: The coefficients of the independent variable (UnR).

ε = Error term.

Equation (6) was used to examine the effect of inflation and unemployment on the economic growth of Sudan for the duration of 1989-2019.

$$\text{Economic Growth of Sudan} = f(\text{Inflation, Unemployment}) \quad (6)$$

Equation (6) in the econometric format becomes as follows:

$$\text{GDPR} = \beta_0 + \beta_1 \text{InfR} + \beta_2 \text{UnR} + \epsilon \quad (7)$$

Where:

GDPR: Gross Domestic Product Rate.

InfR: Already defined in equation (5).

UnR: Already defined in equation (5).

β_0: The constant term.

$\beta_1 and\ \beta_2$: The coefficients of the independent variables (InfR and UnR).

ϵ = Error term.

4.2 Descriptive Statistics

Table 5 displays a summary of the descriptive statistics of inflation (InfR), unemployment (UnR), and GDP growth rate (GDPR) for 31 observations covering the period 1989-2019.

As seen in Table 5, inflation rates (InfR) in Sudan on average were %22.2 and the minimum rate of % -0.9 while the maximum rate was %123. As for unemployment rate (UnR), the average rate was %15.8 and the minimum

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rate was %12 whereas the maximum rate of %22.1. Alternatively, the average growth rate of Sudan(GDPR) during 1989-2019 was %4.2 and the minimum growth rate of % -17 whereas the maximum rate of %10.9.

Table 5. Model-1: Descriptive Statistics

Item	InfR	UnR	GDPR
Mean	38.56452	16.22581	3.258065
Median	22.20000	15.80000	4.200000
Maximum	123.6000	22.10000	10.90000
Minimum	-0.900000	12.00000	-17.00000
Std. Dev.	36.71030	2.544925	5.135223
Skewness	1.117799	0.700928	-2.029672
Kurtosis	3.031143	2.926029	8.916411
Jarque-Bera	6.456868	2.545450	66.49783
Probability	0.039619	0.280067	0.000000
Sum	1195.500	503.0000	101.0000
Sum Sq. Dev.	40429.39	194.2994	791.1155
Observations	31	31	31

Source: Own Calculation, based on data on Table 1

4.3 Augmented Dickey-Fuller Test

The Augmented Dickey-Fuller (ADF) test was applied to examine whether the variables (InfR, UnR, and GDPR) are stationary or not. (Table 6) presents the results of Unit Root Test.

Table 6 shows that the set of variable which includes inflation(InfR), unemployment (UnR), and gross domestic product (GDPR) are stationary at 1st difference, 2nd difference, and on the level, respectively, at 5% MacKinnon Critical Value.

5. Results

5.1 Results of Model-1

The results of the estimated parameters of the relationship between inflation and unemployment in Sudan (model-1) are showed in Table 7 below.

5.2 Results of Model-2

Table 8 presents the estimated parameters of the relationship between inflation, unemployment, and Sudan's GDP growth during the period 1989-2019.

6. Discussion

The OLS results shown in Table 7 indicate that the model of Phillips Curve-Sudan is relatively fitted through the negative relation between inflation and unemployment but its set of variables (InfR and UnR) is statistically insignificant. The coefficient of the constant variable achieved is 4.05which indicates a positive relationship between the constant parameter and the InfR. The constant parameter has no significant influence on the model other than reflecting the value of InfR when other independent variables are held constant.

The coefficient of unemployment rate (UnR) exerts insignificant negative effect on the dependent variable InR, which means 1% rise in UnR, might bring %2.6 decrease in InfR. The overall coefficient of determination (R^2) shows that the fitted equation is under evaluation because it has a negative small value of -0.032257. As a final point, the finding revealed that the value of F-statistic is very little with probability >0.05 (about 0.6958390)meaning that model is insignificant. This result agrees with the graphical presentation showed in Figure 3 indicating that inflation and unemployment are randomly correlated. It's a key conclusion which should be understood by policymakers.

Table 6. Stationary Results (ADF Test)

Variables	Level	1st or 2nd diff.	5% cri. Value	P-value at Level	P-value at 1st or 2nd	Status	Variable Form
InfR	-3.679322	-2.998064	-2.568305	0.0627	0.0206	I(2)	D(InfR(-1),2)
UnR	-0.677393	-4.095876	-2.967767	0.8376	0.0036	I(1)	D(UnR)
GDPR	-3.252500	Not Required	-2.963972	0.0266	Not Required	Level	GDPR

Source: Own Calculation, based on data on Table 1

Table 7. OLS Results (Model-1)

Dependent Variable: D(InfR(-1),2): Method: Ordinary Least Squares(OLS)

Date: 05/14/21 Time: 23:25: Sample (adjusted): 1992 2019

Included observations: 28 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.050515	9.853281	0.411083	0.684
D(UnR)	-2.674493	6.765552	-0.395310	0.6958
R-squared	0.005974	Mean dependent var		3.467857
Adjusted R-squared	-0.032257	S.D. dependent var		50.74015
S.E. of regression	51.55203	Akaike info criterion		10.79181
Sum squared resid	69097.90	Schwarz criterion		10.88697
Log likelihood	-149.0853	Hannan-Quinn criter.		10.82090
F-statistic	0.156270	Durbin-Watson stat		2.482565
Prob(F-statistic)	0.695839			

Source: Own Calculation, based on data on Table 1

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Table 8. OLS Results (Model-2)

Dependent Variable: GDPR-Method: Ordinary Least Squares(OLS)				
Date: 05/15/21 Time: 01:23-Sample (adjusted): 1992-2019				
Included observations: 28 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.431561	1.040487	3.298035	0.0029
D(InfR(-1),2)	0.001729	0.020642	0.083747	0.9339
D(UnR)	-0.729763	0.714255	-1.021713	0.3167
R-squared	0.041063	Mean dependent var		3.278571
Adjusted R-squared	-0.035652	S.D. dependent var		5.331969
S.E. of regression	5.426184	Akaike info criterion		6.321306
Sum squared resid	736.0869	Schwarz criterion		6.464043
Log likelihood	-85.49829	Hannan-Quinn criter.		6.364942
F-statistic	0.535267	Durbin-Watson stat		1.033135
Prob(F-statistic)	0.592074			

Source: Own Calculation, based on data on Table 1

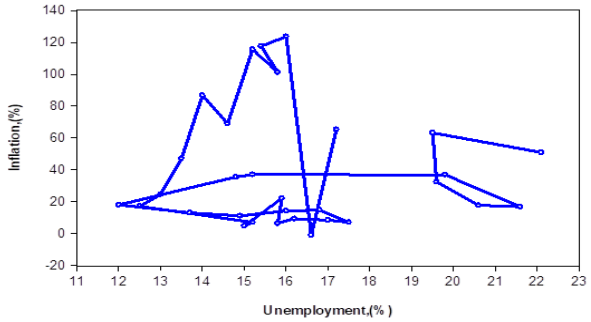

Figure 6. Chart of Fillips Curve-Sudan (1989-2019)
Source: Made by author using Eviews.10- based on data on Table 1

Figure 6 shows that the chart of the Phillips Curve for Sudan during the period 1989-2019 exhibits a random interrelationship between inflation and unemployment (overlap between short/long-term) where there is difficulty in differentiating between the two runs (short and long). Therefore, policymakers need to evaluate and reform macroeconomic policy in Sudan. The results of Ordinary Least Squares (OLS) of the model-2 are presented in Table 8.

The OLS results shown in Table 8 indicate that the coefficient of the constant term appeared with a significant positive sign recording 3.43 and probability<0.05 which indicates a positive relationship between the constant parameter and the GDPR. The constant parameter has a significant influence on the GDPR when other independent variables are held unchanged.

The parameter of inflation rate (InfR) exerts an insignificant positive effect on the dependent variable (annual economic growth rate) or (GDPR) indicating that %1 increase in InfR will lead to an increase of GDPR by %0.001729. However, inflation has an influence on economic growth but with a weak correlation.

The parameter of the unemployment rate (UnR) exerts an insignificant negative effect on GDPR showing that a one percent increase in UnR might bring %0.729 decreases in GDPR. The overall coefficient of determination (R^2)shows that the fitted equation is under evaluation because it has a negative value of -0.035652. Moreover, the value of the F-statistic is very low with probability >0.05 approximately 0.592074 showing that model-2 is insignificant in its relation to inflation and unemployment. Similarly, to model-1, it's the second important signal for policymakers.

7. Conclusions

Based on the discussion of the results, the study found an insignificant negative relationship between inflation and unemployment in Sudan.

There is an insignificant positive relationship between inflation and economic growth in Sudan. Thus, accelerating economic growth in developing countries like Sudan may require the government to spend more on purchasing machinery, and equipment.

There is an insignificant negative relationship between unemployment and economic growth indicating that the macroeconomic policy is a going way, but the degree of its effectiveness still needs more effort by policymakers.

Sudan's economy exhibits a low growth rate of GDP (negative rate for the years 2018-2019) demonstrating that if the government is targeting a low level of unemployment, it needs to spend more for new jobs. If there are insufficient funds, this may force the government to print more money to finance the deficit of the public budget which causes more inflation but unemployment will be reduced.

Regarding the insignificant negative relationship between inflation and unemployment, policymakers in Sudan need to reform and reassess the monetary policy instruments used to target inflation.

The procedures of accelerating economic growth in Sudan during (1989-2001) result in high inflation. This

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situation is normal for developing countries like Sudan. Since borrowing from the public leads to reducing the inflationary effects through issuing government securities. One of the vital sources available for the government is to borrow money from inside monetary stock.

Concerning unemployment, policymakers have the option to invite the private sector to contribute to reducing unemployment by creating new jobs.

It's very difficult for developing countries in the short run to reduce inflation and unemployment simultaneously, so the problem of targeting inflation or unemployment requires good knowledge of the real economic situation, which needs high consideration.

Conflict of Interest

The author undertakes and declared that there will be no conflict to publish the paper. Moreover, it prepared ethically.

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ARTICLE

Domestic Savings, Investment, and Economic Growth: an Empirical Evidence from Nepal using VEC Model

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ABSTRACT

This study examines the relationship between domestic savings, investment, and economic growth in Nepal by using time series data covering from the period 1975 to 2019. The vector error correction model (VECM) has been used to investigate the long-run and short-run causal relationship between the variables. The Johansen cointegration test results confirmed that there is a long-run relationship between savings, investment, and economic growth. Therefore, further analysis has to be set for the VEC model to analyze both long-run and short-run causality. The VECM equation result is -0.1363 which is the adjustment speed of disequilibrium towards the equilibrium in long run. The coefficient of savings and investments are positive with economic growth which also indicates that both variables have a positive impact on economic growth in the short run. The results of the Jarque-Bera test show the residual distribution is normally distributed. For the model stability test, the study performed recursive estimation applying CUSUM and CUSUM of square, and both tests move within the 5 percent level of upper and lesser bound significance indicating that the model is stable over the observation period. Overall, the study suggests that in Nepal, domestic savings and investment growth have a positive contribution to economic growth. The central bank, planning commission, and ministry of finance should focus on stimulating the capital formation and productive sector investment for sustainable economic growth in Nepal.

1. Introduction

Economic growth is defined as the increment in the inflation-adjusted market value of the goods and services produced by an economy in a particular time period. Economic growth represents the country's socioeconomic wellbeing and quality of life in terms of financial value. This is an indicator to show how the nation economically developed and stable [65]. Generally, economic development or growth is measured as the percentage increase in the real gross domestic products (GDP). Economic deeds are interconnected with almost all the activities that human

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being performed and the economic theory is the central theory of development, politics, policy practicing, productions, distributions, consumptions, and many more theories existing and was practiced in the past as well.

The current globalized market has focused on physical facilities to be benefited from the globalized and borderless market using a high level of advanced technologies and quality products as possible. All the countries across the world have been prioritizing how to improve people's living standards and mobilized resources equitably across the country. As the prime objective to achieve economic prosperity goals of the nation, the governments have to launch different programs and policies to improve living standards and economic growth. Especially to continue economic growth, financial regulatory institutions and stakeholders launches economic packages such as domestic saving stimulation, increase in consumptions, income level, and many more which contributes to the aggregate economic growth and income level of the county [25].

The neoclassical growth models of [59,36,54] have believed there is the central role of saving on economic growth. These models emphasized on capital accumulation as the major sources of investment to improve productivity and production growth. The economists [24,54] also believes the domestic capital accumulation is the central player and leads all the activities that have been taken place in the market. The monetarism school of thought also states that the money supply is the most important driver of economic growth which is directly connected to the capital formation and input factor of productions. There are many factors which impact economic growth such as inflation rate, cost of production, factors of productivity, government policy, economic size, growth in capital formation and saving, trade openness, natural resources, available infrastructure, and many. This paper will be focusing on only saving and investment factors which directly influence the capital formation and economic growth.

Long-term economic growth depends on capital formation and capital formation depends on the saving behavior of people in the economy. There are many studies have done to understand the economic growth and savings in different countries in different ways and they have concluded a high rate of saving leads to rapid economic growth [43,41,39]. To increase the production of goods and services, the country needs a huge amount of financial resources to invest from domestic and external sources. External sources help to fulfill immediate financial gaps but for industrial stability and sustainable growth domestic source is vital.

In general, increasing aggregate savings push to higher investment and lead to higher GDP growth in the short run. It means that a higher saving rate leads to a higher amount of capital formation and a higher amount of capital formation result in a large amount of capital investment. A large amount of investment injects into the economy that increases the production, employment, and income level of the people. The empirical study of [3] suggests that when the economy grows, the economy contributes to a growth in the household disposable income. The marginal propensity to saving theory also supports that increase in personal disposable income results in a high amount of saving [66].

Financial system development and stability helps to promote capital formation and economic growth sustainability [22]. The study also says the savings is positively associated with productivity growth in poor countries but it has a negative impact on rich countries [1]. Domestic savings matters for innovation, entrepreneurship, and technology transfers in least developed and developing countries. In contrary, domestic entrepreneurs are already familiar with advance technology and do not need to attract external investment on innovation and technology. Thus, domestic savings does not matter for growth. But for the least developed and developing countries, a low range of savings can be a constraint for domestic capital formation and investment which ultimately gives a low economic growth and income.

National saving comes from the domestic, firms, and government saving. Therefore, private firms' savings play a crucial role in capital formation. The question comes why do private firms retained cash? This question had already been answered [63] by comparing marginal benefits against marginal costs. As with personal saving, firms also considered the estimated future uncertainty and future opportunities. [28] Suggested that managerial ownership reduces the incentives for value-destroying actions and has a negative influence on cash reserves with different objectives which also supported by [30].

The major objective of this paper is to examine the relationship between domestic saving, investment, and economic growth in Nepal. For the rest of the paper, section 2 will be discussing the economic overview of Nepal followed by literature review, data & methodologies, empirical analysis result, and summary and conclusion in sections 3, 4, 5, and 6 respectively.

2. Economic Overview of Nepal

Nepal is geo-strategically located on the Southern lap of the Himalayas between India and China. These two countries are the world's largest economic market with 1.37 billion and 1.40 billion of pupations. If you look at Nepal only, there is 30 million of populations with about

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$31 billion of GDP. To understand Nepal's economy and its nature, it is very much important to add current major economic information and historical knowledge.

2.1 Economic Growth

Economic growth of the country indicates the economic prosperity and welfare of the people and nation. GDP per capita growth represents the distributions of average economic valued output of the nations among the people. Thus, it is calculated diving total monetary value of gross domestic product by total population at current price in the particular time point i.e. every year. GDP per capita growth best represents the economic growth proxy among the various macroeconomic indicators.

The given figure shows the historical trend of annual GDP per capita growth of Nepal. This trend line also shows three years moving average and five year moving average from the year 1961 to 2019. Overall moving trend is upward moving however continuous fluctuation during the time observed time period.

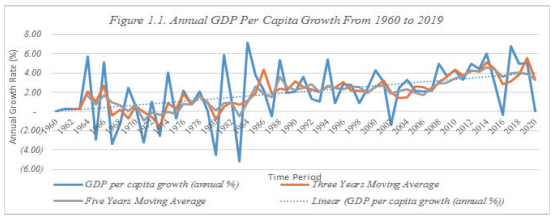

Figure 1. Annual GDP per capita growth of Nepal from 1960 to 2019

Source: Author's own calculation based on World Bank database using Microsoft excel 2013.

2.2 Sectorial Composition of GDP

Nepal's economic records found only after the 1960s. Prior to the year 1960s, there are very few informal data records found but the validation of the data is not sure. For the economic policy and program evaluation, research, policy purpose and concerned stakeholders use the data archive from the 1960s onwards. Therefore, here is also mentioned major composition of gross domestic product (GDP) in terms of percentage in this study. The major economic drivers of the Nepalese economy have given in Figure 2. In a broad category. The contribution of the major economic sectors to the gross domestic product (GDP) and its trend from history to now has given in the figure.

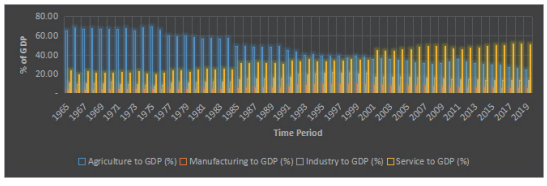

Figure 2. Major economic drivers of Nepal

Source: Author's own calculation based on World Bank database using Microsoft excel 2013.

Figure 2 shows that shows the historical economic composition trend line of Nepal. Figure 2 shows that the major contributor to the gross domestic product was the agriculture sector which was 64.58 percent in the year 1965. After 10 years later in the 1965, agriculture, forestry and fishing's contribution to the economy rose to 69.1 percent which was the all-time highest contribution of the economy during the observation period. With the introduction of new economic areas and globalization in the service and manufacturing sector, the agricultural sector's contribution to the economy has been falling down gradually and stuck at only 24.26 percent only in 2019 which is the lowest value addition in the GDP from this sector. The service sector contribution to the GDP has been growing the same as opposition to the agriculture, forestry, and fishing's contribution. Only 23.17 percent of contribution in the year 1965 reached 50.61 percent in the year 2019. The average growth rate in service sector contribution is 4.13 percent over the period of 55 years from 1965 to 2019. From the Figure 2, Nepalese economy has shifted to service oriented economy from the agronomy.

The manufacturing and industrial sector are still at the very initial stage of the advanced economy. These two sector's contribution to the economy has not changed much as it would be with modern technological advancement and globalization. In sum, the major contribution of the GDP of the nation is the service sector which accounted for more than 50 percent followed by agriculture, industry, manufacturing, and other sectors. This also concludes that the Nepalese economy is service-oriented which used to be an agriculture-based economy.

2.3 Structure of Output

The structure of output indicates the entire economic structure of the country. There are many macroeconomic indicators to show the economic system, size, characteristics, and movement on a particular trend. Nepalese economy can be categorized in three sector economy in term of output in broad i.e. Agriculture, industry and service industry.

Figure 3 shows the overall output structure of the Nepalese economy from the year 2000 to 2019. The data illustrated in the figure have taken from the year 2000 to 2019 because of the data consistency and representation of the current dynamics economy.

Figure 3 shows how the output structure of Nepal has

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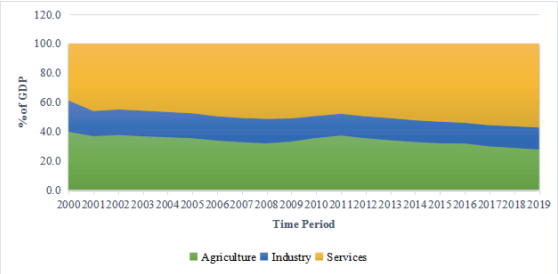

Figure 3. Structure of output of Nepal

Source: Author's own calculation based on Asian Develo-pment Bank database using Microsoft excel 2013.

been changing over the period of years 2000 to 2020. The contribution to the total output from agriculture sector which is 39.6 percent followed by service with 38.9 percent and industry with 21.5 percent in the year 2000. Indeed, the agriculture and industry sector's contribution to the output structure is declining to 27.9 and 15.1 percent in the year 2019 respectively. However, service sector contribution has been expanded and reached 57.4 percent in the year 2019.

2.4 Balance of Payment

After the successful People's Movement of 1990 and dismantle of Party-less monarchical autocracy Nepal entered the global trending liberalization and start force to promote an open market. As a result of liberalization and globalization, Nepal started to gain global advantages. In another word, the global market became one of the pillars of the Nepalese economy. Especially, remittance inflow, foreign direct investment, and foreign aids have increased significantly [40]. The worker's remittance is the most important factor of the economy which accounted for 25.1 percent of the economy as of monetary survey 2017/18. However, the worker's remittance has declined in the fiscal year 2019/20 and contributes only 19 percent of the economy because of the worldwide spreading of deathly virus COVID-19 in the year 2020. The overall, balance of payment status of Nepal from the year 2000 to 2019 has been given in Figure 4.

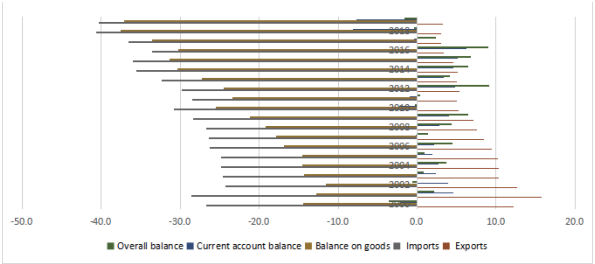

Figure 4. The balance of payment's status in Nepal from the year 2000 to 2019

Source: Author's own calculation based on Asian Develo-pment Bank database using Microsoft excel 2013.

Figure 4 shows the overall external trade of Nepal from the year 2000 to 2019 including an overall balance of payments, current account balance, balance on goods, imports, and exports. The overall balance of payments indicates the overall economic transaction of the economy with the rest of the world. Nepal's balance of payment rises by 2.8 percent on average during observation i.e. 2000 to 2019. The highest growth of BOP was in the year 2012 accounted for 9.2 percent and the lowest growth was in 2000 which was the adverse rate of 3.5 percent.

The highest growth in exports was in the year 2001 with 15.8 percent and the lowest growth was in the year 2017 and 2018 which was just 3.1 percent. Growth in exports indicates the expansion of domestic products in foreign markets. The overall growth in imports trade is negative by an average of 30.2 percent. The data and figure indicate that imports of goods and services to the economy have been declining over the observation period. This is a good signal of strengthening of Nepalese market to meet the domestic demand by itself. The figure balance on goods shows the net foreign trade status of the economy which is influenced directly by the imports and exports. Thus, there is no required to illustrate more about it. Similarly, the national current accounts report the aggregate foreign trade. The current account has grown by 1.3 percent over the period from 2000 to 2019.

2.5 Bank and Financial Institutions

Bank and financial institutions have a very crucial role in saving mobilization and domestic capital formation [49]. Nepalese financial sector has been gradually developing with the application of BASEL-III and the adoption of advanced financial technologies to provide security and quick financial services to the customers. Although Nepal has no long history of the modern financial services industry, it has done a quick progress in comparison to other similar aged industries. Modern banking technologies such as banking software, Automated Teller Machine (ATM), E-banking, debit, and credit cards, connect IPS, and QR code are available in Nepal as well.

Nepal Bank Limited is the first financial institution in the country which was established in 1037 A.D. Even there was no central bank prior to the year 1956. To regulate and maintain stability in the financial and money market, the government of Nepal founded the country's central bank in 1956 as per the Nepal Rastra Bank Act 1955. From the incorporation of the central bank, it started to work as a regulatory institution of the financial sector and overall financial and economic advisory body for the government of Nepal. Another commercial bank named Rashtriya Banijya Bank was established in 1965

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after 9 years of NRB foundation. However, the private banking institution had come into operation in 1984 after structural changes in financial sector policies, regulations, and institutions development in 1980. In the early 2000s, the Nepalese banking and financial sector had changed drastically with the economic globalization and liberalization policy of Nepal. The current banking and financial institutions incorporate under the central bank regulations and Bank and Financial Institution Act-2017 have been presented in Figure 5.

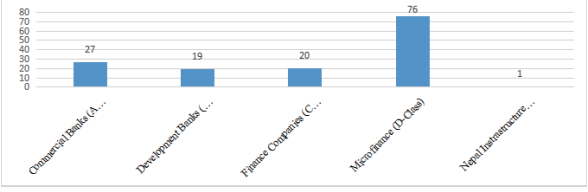

Figure 5. Number of Bank and Financial Institutions of Nepal as per Classification
Source: Nepal Rastra Bank as per the January 2021.

Figure 5 shows the number of banking institutions operating in Nepal as per the classification of Nepal Rastra Bank regulations as of January 2021. The government of Nepal has focused on financial sector stability and to make them strong. NRB has been pressurizing banks to maintain a high level of paid-up capital either way. Therefore, banks have been going through both force and voluntary mergers with each other in the same and different category banks. The number of commercial banks is only 27 which was 32 in 2014. The major changes happened in the development banks due to merger and acquisition policy. Other C and D class financial institutions also decreased due to this policy and there is still under the process of merger and acquisition between and among the all classes banking and financial institutions. In the economy, there is another special category bank named Nepal Infrastructure Development Bank has been operating with the objective of financing the big national pride projects and infrastructure development across the country.

3. Literature Review

This section gives a brief review of existing researches related to domestic saving, investments, and economic growth across the academic world. The study of [60] examined causality between financial development and economic growth for 10 Sothern African Development Community countries for the period 1994 to 2013. The study employed the vector autoregression (VAR) approached to conduct Granger causality tests to determine the direction of causality relationship between financial development and economic growth. The study used broad money and direct credit as measures of financial development and the study also concludes there is a causal link between financial development and economic growth. [44] used time series methods to investigate the long and short-run dynamics and interrelationship between savings and current account balance in the USA for the period 1947Q1 to 2017Q3.The study controls the impact of the non-linear dynamics of GDP growth over the business cycle. Similar study has been done by [11,61] in different countries.

Study of [8] founds the financial system development has a negative impact on local economic growth in China over 1990-1999 because the banking sector was mainly supporting the loss making state owned enterprises in the 1990s by using provincial level data over 1986-2002. [33] suggested a positive correlation between financial system development and economic growth by using 80 countries over 1960-1989. The study of [55] has supported the financial access help to promote saving channelize and growth using panel dataset covering 74 countries. [67] Study investigates the impact of financial development on economic growth at city level in China by using 286 Chinese cities over the period 2007-2014. The result of cross sectional regression suggested the negative impact on growth. Similarly, GMM estimators for dynamic panel data also suggested there is no significant effect on economic growth. The study also investigates the relationship between domestic saving and economic growth and convergence hypothesis in Thailand. The study analyzed causality of saving on economic growth by using time series annual data from 1960 to 2010. The results of Granger causality suggest the economic growth rate does not matter on domestic saving. The results of OLS also suggest that there is no significant impact of domestic saving on economic growth in Thailand. [38] examined the relationship between the growth of domestic savings and economic growth in China by using cointegration and causality on the data of four provinces from the period of 1955-2004. The study concludes a long-run relationship with between household savings and enterprise savings. Likewise the study also shows the bilateral causality exists between the domestic savings growth and economic growth.

To conduct a descriptive analysis of long and short-run correlations among saving, investment and economic growth for the 123 countries from the period of 1961-1994. [3] estimate a flexible dynamic model. The study found there is a positive impact of lagged saving on economic growth. The study also concluded the inverse granger causality between investment and economic growth. The pattern of domestic saving in Asian

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economies is analyzed by [25]. Their study has pointed out that the three major determinants of household saving including age structure of population, level of income and financial system development in the country.

The study of [16] had found the close relationship between domestic saving and investment by using time series data. In between the period of 1960s and 1970s observation shows substantial effect of domestic saving on the investment and capital formation within a country [17]. The study also found that there is no spurious impact of an omitted economic growth on saving and investment. However, the budget deficit has an inverse impact on private investment and saving. The study had employed data of 23 OECD countries for the year 1981 through 1986. The data are also categorized into two sub-period: 1961-1973 and 1974-1986 for the comparison of periodic results.

The optimal accumulation of capital and the welfare effects of government debt in neoclassical growth models have invested by [4]. They have expanded the Solow growth model and [14] overlapping generations model by adding firms with market power in the original model. The expended Solow model calibration suggests that the US economy is dynamically efficient and the real interest rate earned by savers is below the net marginal product of capital. Likewise expanded Diamond model with market power also indicates the government Ponzi schemes can have a distinct impact on welfare than they do under completion. The study linked between market power and real interest rate that provide a new lens to view fiscal policy and optimal national saving and investment which connects to the economic growth suffers by crowding out capital due to the low-interest rate. The crowding out issues in the economy because of low real interest rate has also observed by [6,18] through a large randomized control trial on US households. [57] explained that household saving constitutes a large proportion of gross domestic saving by applying autoregressive distributed lag (ARDL) model. The study applied Bayesian Vector Autoregressive (BVAR) with a quarterly data to examine the determinants of household saving in South Africa. As per the [54] inverse elasticity rule, tax on goods should be inversely related to the demand elasticity. The study of [29] investigate the determinants of household saving by employing ordinary least square (OLS) methods on primary survey data of 490 households in between 1958-1959. The survey was focused on income age, education, and interest rate. The study result concludes that income and age had a significant impact on household saving while education had no significant contribution. [2] used household budget survey data from 2003 to 2008 to estimates the structural components of household savings. The cross-sectional data analysis results found that increased female labor force participation, higher would be the employment rate, income level, and savings. However, the study results on inverse relationship of age, inflation rate, and interest rate on household saving. The study of [53] used descriptive statistics to analyses household saving patterns in Australia between 2003 and 2009. The study found that income had a positive impact while wealth had a negative effect on domestic savings.

Likewise, [31] analyzed the factor affecting personal saving in USA for the period of 1950 to 2007 by using OLS estimation and Arellano-Bond difference GMM estimation technique. The study found that the coefficient of lagged private saving, tax, and real estate loans were negative with personal saving. [31] also found there was negative growth on economics. This implies that the personal saving would be higher during the economic dynamics and low personal saving when economy is in good conditions. The study had been used lag saving, tax, young dependency, credit outstanding, employment, real estate loan, GDP, interest rate, social security, current account as the explanatory variables and saving as the explained variable in the basic model. The similar results of findings by [50,13] in Nepalese cases as well. The study of [13] use primary survey data from province five of Nepal and analysis data using OLS methods to investigate the financial literacy and personal financial planning. The study concluded that well financial awareness and financial services access helps to make proper allocation of income including savings, investment and consumption.

The inter linkages between domestic saving and real economic activities growth have examined in India by [37] with employing Autoregressive Distributed Lags (ARDL) model. The study result confirmed to have important policy implication role to boost domestic savings in India and consequently sustaining high economic growth. [57] also used life cycle hypothesis of saving (LCH) to set analytical framework for the household saving and economic growths which was first time introduced by [45]. The study assessed the stationarity by using Augmented Dickey-Fuller (ADF) unit root rest. The lag order was chosen using Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC). The study of [48] accesses the relationship between savings and total and non-oil economic growth of Iran and found a positive and significant impact on both total and non-oil economic growth. The study analyzed the long-run causality among the selected variables such as savings, total economic growth, and non-oil economic growth of Iran with the annual data for the period 1972-2010 and they have

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used Autoregressive Distributed Lag Model (ARDL) for empirical results. The ARDL results also show a long-run counter causal relationship between savings and economic growth.

[62] conducted a study to examine the relationship between domestic saving and economic growth in North Africa using a Vector Error Correction Model (VECM) with the data of 1946 to 1992. The study concluded that private savings has bi-directional causality on economic growth. The study of [46] took 13 countries having different levels of income during the period of 1960-2001 to investigate the causality relationship between savings and economic growth. The study had divided selected countries into four groups according to the income levels: low income, less than the average, more than the average, and high-income level countries. The study used a Granger Causality Test and found the causality relations and directional variations among different groups of countries. Similarly, another study by [23] investigated the relationship between protective savings and economic growth by using the Autoregressive Conditional Heteroskedstic (ARCH) model with annual data from the year 1955-1990. The study concluded that increasing saving boost domestic capital formation which provides investment funds and growth on industrial productions.

Similarly, [58] research the relationship between savings and economic growth in Indian cases, and the study results concluded the significant impact on GDP. He checks the long-run effects of savings on GDP through the Engel-Granger Co-Integrated test. Another Indian study of [58] analyzed the short-run relation between saving and economic growth variable using an ARDL model for the period 1950 to 2002. The results found that there is a bi-directional relationship between savings and economic growth. The results also indicate that higher the propensity to savings increase capital accumulations and higher domestic capital accumulations will lead to higher income level and economic growth as a whole. A similar study of [42] from Mexico also supports Indian study results by using Vector Autoregressive (VAR) method for the annual data for 1960 to 1996. The domestic savings contribution on capital formation is most contributing factors during the stud period. The time series analysis results also suggested bi-directional causality between the private savings and economic growth. Empirical analysis of [52] suggests that the economic impact of unstable oil supply has a significant impact on economic growth. The positive shocks on oil price increases domestic saving through the wealth increments and also income level.

From the above existing reviews, the study concluded there is both evidence of positive and adverse relationship between savings, investment, and economic growth across the world but no clear evidence to justify that how Nepal's case moves towards. Therefore, this study is important to conduct how Nepal's domestic savings, investment, and economic growth impact each other. Based on the existing study's conclusions, the study has developed the following directional framework.

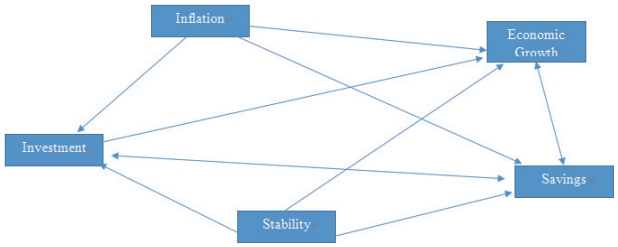

Figure 6. Directional framework

Source: Author's own development based on existing literature reviews.

4. Data and Methodology

This section presents the data sources and methodologies used in this paper. The research design, data nature, sources, study period, data analysis model, and tools to analyze the data are major factors associated with research work.

4.1 Data and Data Sources

This paper has employed time series data covering from the period 1975 to 2019. Annual time series data for the gross domestic savings, fixed capital formation, real gross domestic product per capita income, and inflation are extracted from the World Bank's World Development Indicators (WDI)-2020. Figure 7 shows the time series plot of the major variables.

An Empirical Framework

This study investigates the relationship between savings, investment, and economic growth in Nepal by applying time series econometric analysis method using the general form of the model specified below:

$$GDP_t = \alpha_0 + \alpha_1 DS_t + \alpha_2 FCF_t + \emptyset X_{it} + \varepsilon_t \quad (4.1)$$

$$DS_t = \alpha_0 + \alpha_1 GDP_t + \alpha_2 FCF_t + \emptyset X_{it} + \varepsilon_t \quad (4.2)$$

$$FCF_t = \alpha_0 + \alpha_1 DS_t + \alpha_2 GDP_t + \emptyset X_{it} + \varepsilon_t \quad (4.3)$$

Where, GDP denotes the gross domestic product per capital in current price and also a proxy of economic growth in this model. DS and FCF are the major endogenous variables as the percentage of domestic savings to GDP and fixed capital formation to GDP in current price. The calculation methods of the GDP, DS, and FCF are given in the equations 4.4, 4.5, and 4.6. X is the vector of exogenous variables which has an intuitively

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significant impact on economic growth, savings, and investment variables. Here in this model has employed inflation and economic stability as exogenous or control variables. Alpha a_0 is the intercept on each model and a_1 and a_2 represents the coefficient parameters of savings and investments respectively. ϕ is the notation of coefficient parameter of exogenous control shocks in the model and is denotes error terms in the model.

4.2 Definition and Measurement of Variables

Economic Growth (GDP)

Real gross domestic product per capita (GDP) is the measure of economic growth in this research study. The World Bank defines real GPD per capita as gross domestic product divided by the mid-year population, adjusted for inflation as measured by the GDP deflator. The data are in current US dollars. This indicator gives how the economy grows in connection to the population thus it is a conventional measure of economic growth. An increase in a country's GDP related to populations suggests an improvement in the economic living standard of people in the country. On the other hand, high per capita GDP is the high level of income and higher propensity to savings and investment in the country. In this thesis, growth of GDP per capita has used as the proxy of economic growth as many existing researches have been used [34,32,35]. Equation 4.4 has been used to calculate the proxy indicator of economic growth (GDP), particularly for this study.

$$GDP_t = \frac{GDP_t - GDP_{(t-1)}}{GDP_{(t-1)}} \quad (4.4)$$

Where, t denotes the particular time point of the series and (t-1) is the previous years' time point. This is the simple mathematical calculation of GDP per capita growth for the conventional proposed. As the basic time series data consists of non-stationary in nature. Thus, the application of this helps to remove stationary problems as well.

Domestic Saving (DS)

Gross domestic savings defined as gross domestic product less consumption by private sectors and government [65]. A high gross domestic saving rate usually indicates a country's high potential to invest and economic growth [19]. According to [36] arguments, a higher propensity to savings accelerate economic growth. In line with existing Horica and Hagiwara (2012) and many other economic researchers, this study has been employing the percentage of domestic savings to gross domestic savings as the proxy of saving. This study has assumed that there is a causal connection between economic growth and savings growth rate. The calculations of the domestic savings proxy (DS) for the study has employed the following equation.

$$DS_t = \frac{\left\{\left(\frac{GDS}{GDP}\right)_t - \left(\left[\!\left[\frac{GDS}{GDP}\right]\!\right]_{t-1}\right\}}{\left(\left[\!\left[\frac{GDS}{GDP}\right]\!\right]_{t-1}\right)} \quad (4.5)$$

Where, DS_t denotes growth in percentage of domestic savings to GDP in time t from the time period (t-1). The remaining are defined as in previous equations.

Fixed Capital Formation (FCF)

From the Keynesian perspective, capital formation is the key driver of economic activities and sustainable growth. Therefore, this research also used gross fixed capital formations as a proxy of investment. In financial and economic research many studies have been employed fixed capital formation as a proxy of investment in their study [39,10,26]. In line with the existing literature and intuitive analysis, this study has also employed the percentage of fixed capital formation to GDP growth as an investment proxy which is calculated by using the following equation.

$$FCF_t = \frac{\left\{\left(\frac{FCF}{GDP}\right)_t - \left(\left[\!\left[\frac{FCF}{GDP}\right]\!\right]_{t-1}\right\}}{\left(\left[\!\left[\frac{FCF}{GDP}\right]\!\right]_{t-1}\right)} \quad (4.6)$$

Where, FCF_t denotes the growth in percentage of fixed capital formation to GDP in a particular time t from the time period (t-1). The rest of the indicators are defined in previous equations.

Inflation Rate

Inflation is a continued increase in the general price level of goods and services in an economy over a period. Inflation has been measured by the consumer price index (CPI) and used as exogenous variables in the model. Previous studies of [7,47] have used CPI as a proxy of inflation and found that the theoretical and empirical evidence of market uncertainty and negative growth in economic activities due to high inflation rate. This statement also supported by [5] and also highlighted that inflation reduced propensity to savings and capital accumulation for the industrial investment. Therefore, this study has been expecting a negative relationship between inflation and economic growth in the economy.

Economic Stability

Economic stability is a very crucial condition for the sustainable economic growth and prosperity of the country. Economic activities and market are fluctuating

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due to many economic and non-economic agents and shocks. Economics shocks can be occurred because of political instability, natural calamities, border disputes and policy shifts in the economy. Economy can grow and sustain only when the economy is in normal condition and can perform freely interacting between demand and supply sides of economic agents. Therefore, this study has used a binary or dummy variable to incorporate economic stability in Nepal. In this study dummy variable has been defined as value (1) for economic turbulences or economic shocks due to negative impact on economic and other wise value (0) for normal economic operational year. The major political and socio-economics shocks happened during the observation period in Nepal. Similarly, summary descriptive statistics of the major variables are presented in the Figure 7 presents the time series plot of the major variable including GDP, DS, FCF, and CPI used in this study. All the values in the time series plot are in fractional form. The data series are covered from the year 1975 to 2019.

Figure 7. Time series plot of GDP, DS, FCF and CPI from the year 1975 to 2019 in Nepal.

Source: Author's own calculations using Gretl software based on WDI data from the World Bank.

Figure 7 shows there is a common and positive trend between GDP, DS and FCF. If you observed in GDP, DS, and FCF plots, we can see parallel fluctuation with different ranges. But FPIC fluctuation trend is quite opposite during the observation period.

Time Series Model Specification

In this sub-section, the time series empirical analysis method applied in this thesis is examined in more detail. The basic time series model for the impact of savings and investment on economic growth is given by equation 4.1, the impact of economic growth and investment on savings by equation 4.2, and the impact of savings and economic growth on investment by equation 4.3. However, the research model should be more specific according to the data nature and objective of the study. Therefore before move to the time series model specification, it is necessary to test some basic requirements.

Structural Stability Test

The time series analysis will begin with a stability test by using multiple regression and the CUSUM test at a 5 percent level of significance. The multiple regression analysis helps the researcher to control the different components that simultaneously impact the target variable. As suggested by [64], addition of more factors that affect the dependent variables in the model better explained the dependent variable. Therefore, multiple regression analysis is helpful for setting a good model to explain the variation in the target variable.

The CUSUM test and CUSUM of squares test at 5 percent level of significant results shows that both the estimate lies in between the upper bound and lower bound. From the CUMUM and CUSUMS test results, the model does not require to go through the structural breaks during the observation period. Thus, this the model will not use structural break in the time series analysis.

Testing for the Stationary

In traditional empirical analysis methods in econometrics are standing on the assumption that the time series variables are stationary. With the development of emerging econometric techniques, those stationary assumptions became invalid for economic growth studies using time series data and the research also found that most of the time-series data are non-stationary. According to [15,27] argument, non-stationary variables can cause spurious regression results and increase the confidence intervals for the estimated coefficient parameters. Therefore, this thesis study has been used Augmented Dickey-Fuller (ADF) test equations for the stationary check on each variable. The ADF test hypothesis will be rejected if the probability value (P-value) is greater than five i.e. P>5 %. The null hypothesis H0: the series has the presence of unit root. The rejection of H0 indicates the data series is stationary at level. If the data series do not reject H0 at level based on Akaike Information Criterion (AIC) maximum lag difference, the test assumption can be included at level with intercept and time trend and also can apply the first difference at the given significance level.

H0: a = 0, there is existence of unit root

H1: a < 0, There is no unit root

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Test for the Cointegration

Another test will be done to examine the cointegration between and among the variables. This econometric technique is used to find whether the variable has long-run time relations or not. The null hypothesis of H0: there is no cointegration (No long-run relationship between variables) is rejected indicates the variables have cointegration. If the p-value > 5, reject the H0. For the test of cointegration, there two popular methods: the Engle-Granger estimation and Johansen estimation test. In this study, the Johansen Cointegration test applied for the test. If the cointegration test fails to reject H0, the analysis process can apply a simple VAR model for short-run dynamics. But if it is rejected, the process should estimate both the long-run and short-run model which is called Vector Error Correction Model or VECM Model.

H0: a = 0, there no cointegration between variables

H1: a < 0, There is cointegration between variables

After the time series model design investigation, this study has set the following time series data analysis research model to meet the research objective set in this study.

Vector Error Correction (VEC) Model

As per the Johansen cointegration test results, if the null hypothesis (H0) is rejected, the suitable time series analysis model is the vector error correction model (VECM) which defined both long-run and short-run association between the series. Therefore, this study has been employing the multivariate regression model to test the long-run and short-run causal impact between endogenous variables. This study has set the following expanded model of equation 4.1 to 4.3 basic regression models.

$$\Delta GDP_t = \alpha + \sum_{i=1}^{p} \beta_{1i} \Delta GDP_{t-i} + \sum_{i=0}^{q} \beta_{2j} \Delta DS_{t-j} + \sum_{k=0}^{r} \beta_{3k} \Delta FCF_{t-k} + \delta_1 GDP_{t-1} + \emptyset X_{it} + \delta_2 DS_{t-1} + \delta_3 FCF_{t-1} + \varepsilon_t \quad (4.7)$$

$$\Delta DS_t = \alpha + \sum_{i=1}^{p} \beta_{1i} \Delta DS_{t-i} + \sum_{j=0}^{q} \beta_{2j} \Delta GDP_{t-j} + \sum_{k=0}^{r} \beta_{3k} \Delta FCF_{t-k} + \emptyset X_{it} + \delta_1 DS_{t-1} + \delta_2 GDP_{t-1} + \delta_3 FCF_{t-1} + \varepsilon_t \quad (4.8)$$

$$\Delta FCF_t = \alpha + \sum_{i=1}^{p} \beta_{1i} \Delta FCF_{t-i} + \sum_{j=0}^{q} \beta_{2j} \Delta DS_{t-j} + \sum_{k=0}^{r} \beta_{3k} \Delta GDP_{t-k} + \delta_1 FCF_{t-1} + \emptyset X_{it} + \delta_2 DS_{t-1} + \delta_3 GDP_{t-1} + \varepsilon_t \quad (4.9)$$

Where, α represent the intercept of the model and β and δ represents the coefficient parameter in short-run dynamics and long-run coefficient in the model. Likewise, Δ indicates the lag difference operator to adjust short-run dynamics in the models, and ϕ represents the coefficient parameter of exogenous variables (Xit) used in the model. The exogenous variables such as inflations and economic stability are manually converted as a stationary series applying the first difference technique before running the model.

The following Vector Error Correction Model (VECM) has been set for the analysis of long-run and short-run causality and speed of adjustment for the equilibrium. The values (p, q, r) are the selected number of lags for the cointegrating equations based on AIC. As suggested by Engle and Granger (1987), the short-run dynamic model can be rewritten as an error correction model (ECM) of the following equations:

$$\Delta GDP_t = \alpha + \sum_{i=1}^{p} \beta_{1i} \Delta GDP_{t-i} + \sum_{j=0}^{q} \beta_{2j} \Delta DS_{t-j} + \sum_{k=0}^{r} \beta_{3k} \Delta FCF_{t-k} + \emptyset X_{it} + \gamma_1 ECT_{t-1} + \varepsilon_t \quad (4.10)$$

$$\Delta DS_t = \alpha + \sum_{i=1}^{p} \beta_{1i} \Delta DS_{t-i} + \sum_{j=0}^{q} \beta_{2j} \Delta GDP_{t-j} + \sum_{k=0}^{r} \beta_{3k} \Delta FCF_{t-k} + \emptyset X_{it} + \gamma_1 ECT_{t-1} + \varepsilon_t \quad (4.11)$$

$$\Delta FCF_t = \alpha + \sum_{i=1}^{p} \beta_{1i} \Delta FCF_{t-i} + \sum_{j=0}^{q} \beta_{2j} \Delta DS_{t-j} \sum_{k=0}^{r} \beta_{3k} \Delta GDP_{t-k} + \emptyset X_{it} + \gamma_1 ECT_{t-1} + \varepsilon_t \quad (4.12)$$

ECT is the error correction term produced from the OLS residuals through the following long-run cointegrating regression estimates. The rest of the parameters included in the estimate equations defines as in previous equations.

$$\Delta GDP_t = \alpha + \delta_1 \Delta GDP_{t-1} + \delta_2 \Delta DS_{t-1} + \delta_3 \Delta FCF_{t-1} + \varepsilon_t \quad (4.13)$$

$$\Delta DS_t = \alpha + \delta_1 \Delta DS_{t-1} + \delta_2 \Delta GDP_{t-1} + \delta_3 \Delta FCF_{t-1} + \varepsilon_t \quad (4.14)$$

$$\Delta FCF_t = \alpha + \delta_1 \Delta FCF_{t-1} + \delta_2 \Delta DS_{t-1} + \delta_3 \Delta GDP_{t-1} + \varepsilon_t \quad (4.15)$$

The error correction term (ECT) is defined as:

$$ECT_{t-1} = \Delta GDP_{t-1} - \alpha - \delta_2 \Delta DS_{t-1} - \delta_3 \Delta FCF_{t-1} \quad (4.16)$$

$$ECT_{t-1} = \Delta DS_{t-1} - \alpha - \delta_2 \Delta GDP_{t-1} - \delta_3 \Delta FCF_{t-1} \quad (4.17)$$

$$ECT_{t-1} = \Delta FCF_{t-1} - \alpha - \delta_2 \Delta DS_{t-1} - \delta_3 \Delta GDP_{t-1} \quad (4.18)$$

To find the causal relationship between saving, investment, and economic growth in Nepal's case, the study will try to prove the relationship from various tests based on VECM estimated results. The additional test for residual serial correlations LM test, residual normality test, Heteroskedasticity test, impulse response test, variance decomposition test, and finally CUSUM test for the model stability over the study period. The CUSUM test was also performed based on initial OLS for the structural break existence in the procedure. But base on VECM estimation will give overall model stability and also helps to justify regression results produced by the estimated research design and model.

5. Empirical Analysis Results and Discussion

This section presents the times series data analysis results and interpretations.

Test for the stationary

In time series regression analysis, a critical assumption is that the time series under concern is stationary in data.

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A time series is to be stationary if its mean and variance are constant over the time period and the value of the covariance between two-time points depends only on the distance between the two time periods [20,21]. As suggested by [21], the study has been tested stationary in the variables. The stationary has not test for dummy variable as it is already a binary variable.

The presence or absence of unit root is tested by using the Augmented Dickey-Fuller (ADF) Test Equations. The results of ADF unit root rest has done at level and first difference to confirm the presence of unit root in the data series which is reported in Table 1.

The Augmented Dickey-Fuller test results at level shows there is no presence of unit root for the series GDP, DS, and FCF as the null hypothesis has rejected at 5 percent level in both assumption with intercept and intercept with trend. The hull hypothesis is H0: there is presence of unit root in the series. The null hypothesis has failed to reject CPI in the given assumptions. On the other hand, at first difference results shows there is no unit root presence in the data series with both intercept only and with intercept and time trend assumptions. Therefore, the ADF unit root rest concluded that the data has mixed of stationary and non-stationary.

Johansen Cointegration Test

Using the Akaike information criterion for the optimal lag selection, a suitable lag length of 1 is selected and set the multivariate cointegration equations. The multivariate Johansen cointegration results have been reported in Table 2.

The hypothesized equations have been rejected null hypothesis i.e. H0: There is no cointegration or there is no long-run relationship between and the variables. It means there is a long-run relationship among the series and the time series analysis model should be estimated both long-run and short-run through the Vector Error Correction (VEC) models which is also supported by the Johansen normalization results as given in Appendix 4.3. The results show that in the long-run, DS and CPI have a negative impact on GDP while FCF has a positive impact on an average, ceteris paribus. The normalized coefficients of DS and FCF are statistically significant at the 1 % level. The conclusion of the result is that the null hypothesis of no cointegration is rejected against the alternative of a cointegrating relationship in the model.

Vector Error Correction Model Results

As suggested from the Johansen cointegration test results, the null hypothesis of no cointegration between the variables have been rejected. The Johansen cointegration results show there exists of long-run relationship between the series. Therefore, the study has employed the Vector Error Correction Model (VECM) for the investigation of long-run and short-run causal relationship between the endogenous variables. The results for the long-run cointegration between gross domestic product per capita growth as dependent variable and growth in domestic savings and fixed capital formation is

Table 1. ADF Unit Root Test Results for the GDP, DS, FCF, and CPI.

Variables	Level		Remarks	First difference		Remarks
	Intercept	Intercept and Trend		Intercept	Intercept and Trend	
GDP	0.000	0.000	Stationary	0.000	0.000	Stationary
DS	0.038	0.028	Stationary	0.002	0.006	Stationary
FCF	0.000	0.000	Stationary	0.000	0.000	Stationary
CPI	0.081	0.244	Non-Stationary	0.000	0.000	Stationary
Null hypothesis H0: The series has the presence of unit root and the P-values reported at level and first difference are Mackinnon (1996) one-sided p-values.						

Source: The results reported are the author's own calculation by using E-views software.

Table 2. Johansen Multivariate Cointegration Test Results

Hypothesized no of CEs	Eigenvalue	Trace Statistic	0.05 Critical Value	P-Value	Remarks
None*	0.48919	86.95098	47.85613	0.00000	Cointegration
At most 1*	0.44259	58.06539	29.79707	0.00000	Cointegration
At most 2*	0.33714	32.93371	15.49471	0.00010	Cointegration
At most 3*	0.29883	15.25279	3.84147	0.00010	Cointegration

*Note: Gross domestic product per capita growth, gross domestic savings, gross fixed capital formation, and inflation are included in the cointegration equation. The trace test indicates 4 cointegrating equations based on linear deterministic trend assumption at 0.05 level. The model assumptions have taken from Akaike Information Criteria. * denotes rejection of the hypothesis at the 0.05 level. The probability value is based on Mackinnon-Haug-Michelis (1999). The null hypothesis is H0: There is no cointegration (No long-run relationship between variables). The data results are calculated by using E-views software.*

Source: The results reported are the author's own calculation by using E-views software.

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presented in Table 3.

Table 3. Results of Vector Error Correction Estimates with the observation from 1977 to 2019 after adjustment

Cointegrating equation:	Cointegrating Equations Estimates		
GDP (t-1)	1.000000		
DS (t-1)	0.134233 (4.19070)		
FCF (t-1)	-0.890713 (-9.50219)		
Constant	0.028347		
Error Correction:			
Cointegrating Equation	-0.136269 (-0.35251)	3.493654 (1.29771)	2.125429 (2.50459)
(t-1)	-0.612861 (-2.71920)	-1.800696 (-1.14720)	-1.185852 (-2.39674)
(t-1)	0.002960 (0.06925)	-0.710366 (-2.38648)	-0.098803 (-1.05302)
(t-1)	0.115774 (0.57309)	1.549513 (1.10135)	0.459692 (1.03654)
CPI(t-1)	-0.004105 (-0.29081)	-0.092347 (-0.94028)	-0.011881 (-0.38342)
Stability	0.001801 (0.05710)	0.259399 (1.18066)	0.027318 (0.39445)
Constants	0.003514 (0.19060)	-0.081825 (-0.63722)	-0.004644 (-0.11472)
R-squared	0.289285	0.322039	0.396306
F-statistics	2.442208	2.850068	3.938817

Source: The results reported are the author's own calculation by using E-views software.

The results of the cointegration equation in Table 3 show the clear cointegration as the endogenous variables are significant at a 5 percent level of significance. It indicates that there is both long-run and short-run causal relationship between the endogenous variables. The second part of Table 3 presented error correction estimates and short-run model output. The major concern in this table is estimated VECM with the target variables. The coefficient of the cointegration equation is negative i.e. -0.136269. The error correction coefficient gives the speed of adjustments within which the model will restore its equilibrium following any disturbances but the adjustment coefficient at first difference of GDP is not significant. The EC coefficient -0.136269 means that the speed of disequilibrium is 13.63 percent. In another word, the previous year deviation for the long-run equilibrium is corrected at the speed of 13.63 percent.

However, the coefficient of adjustment for the DS and FCF are positive and only FCF is significant at a 5 percent level of significance. The positive coefficient of adjustment indicates the lack of adjustments towards long-run equilibrium in any disequilibrium situation. The coefficient of DS is 0.00296 which means the percentage change in growth in domestic savings rate is associated with a 0.296 percent increase in GDP per capita growth on average ceteris paribus in the short-run. Likewise, coefficient of FCF is 0.115774 which indicates that the percentage growth in FCF is associated with an 11.57 percent increase in GDP per capita growth on average ceteris paribus in the short-run.

Further, for the long-run and short-run causality, we need to perform VAR model estimation based upon the error correction model. Therefore, the vector error correction model estimates' output is presented in Table 4.

Table 4. Results of VECM estimates

	Coefficients	Std. Error	t-Statistic	Probability
Dependent variable: GDP Per Capita Growth				
C(1)	-0.136269	0.386564	-0.352513	0,7265
C(2)	-0.612861	0.225383	-2.719195	0.01
C(3)	0.00296	0.042741	0.06925	0.9452
C(4)	0.115774	0.202018	0.573085	0.5701
C(5)	0.003514	0.018438	0.190601	0.8499
C(6)	-0.004105	0.914116	-0.290805	0.7729
C(7)	0.001801	0.031547	0.057098	0.9548
R-squared	0.289285			
Adj. R-squared	0.170833			
F-statistics	2.442208			
Pro (F-statistic)	0.043917			

Source: The results reported are the author's own calculation by using E-views software.

Table 4 presents the least Squares (Gausss-Newton/ Marquardt steps) output based on VEC model estimates. Here in the model, C (1) represents the long-run coefficient which is negative but not significant. It indicates that there is no long-run causality between GDP per capita growth and growth in domestic savings and investment. The coefficient should have a negative sign showing the ability to bounce back to the equilibrium. On the other hand, the positive sign indicates the movement away from the equilibrium in the long-run.

For the short-run, the coefficient of C (2) is negative 0.6129 which indicates that a one percent increase in itself will lead to a decline in GDP per capita growth by 0.6129 percent which is also significant at the five percent level of significance. Similarly, C (3) is the coefficient of savings which is 0.00296. It shows that one percentage increase in DS will lead to increase in GDP by 0.00296 and vice-versa. The coefficient of investment in short-run is C (4) which is 0.11577. The results shows that one

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percentage increase in investment will lead to increase in GDP by 0.11577 percent and vice-versa. The coefficients of C (6) and C (7) are exogenous variable representing inflation and economic stability. The coefficient of C (6) is negative with -0.0041 which indicates that one percentage increase in inflation rate will lead to decline in GDP by 0.0041 percentage in short-run. Likewise, economic stability is coefficient of C (7) is positive which is 0.0018 but not significant. The results show that economic stability has a positive impact on GDP in comparison to unstable economic environment. This means the stable economic environment is positively associated with the economic growth in Nepal.

The coefficient of C (5) is intercept term which is the value of dependent variable when all the included variable in the model is zero. Another interest in the table is R-square which shows the explanation power of the model. The value of R-squared is 0.2893 indicates that this model can explain the objective by 28.93 percent on average ceteris paribus.

Results of Cholesky Variance Decomposition Factors

These estimates give the general idea about the long-run and short-run causality between the dependent and independent variable but more investigation is needed to justify the idea generated from the VECM estimated results in a given condition. Therefore, the study also performs the variance decomposition test to support ratify the conclusion from the VECM estimate result and the results are presented in a graphical form in Figure 8.

This study has been employed the Cholesky Decomposition model and the results are presented in the multiple-Graphs format and table for the convenience of the readers. This test gives the descriptive eye view of the influencing power to each variable in the long-run and short-run. The time period has taken 10 years due to which is generally accepted as most of the countries are taking 10 years of time period for the census survey. Here, this might not be applicable but 10 years period can be normal to feel the long-run socio-economic shocks in the country.

Figure 8 shows there is very low influencing power to GPD per capita growth by DS and FCF in short-run. In year 1 both DS and FCF have zero influencing power to the GDP which means GDP can influence by GDP itself. But in year two, the influencing power increases 0.789 and 2.886 of DS and FCF respectively. As the observation period increases, the influencing power of both variable are declining. It means that both variables are strongly exogenous in year one. However, if you see the second row's figure, the 25.88 percent of DS influence by GDP and 74.12 percent of DS influence DS itself in year zero where FCF is strongly exogenous with zero influence to DS. But in long-run the influencing power of FCF rose up to 5.097 percent in 10th years of observation. Finally, the explanatory power to FCF in year 1 are 69.91 percent and 14.62 percent of GDP and DS respectively. The variance composition results of FCF shows there is direct impact of GDS and DS influencing power to FCF with time and inverse impact of itself with time period.

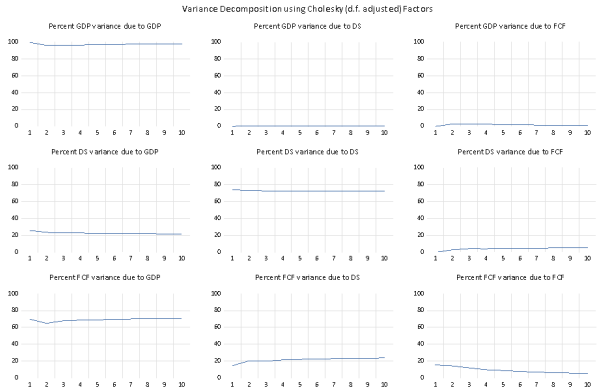

Figure 8. The Results of Cholesky Variance Decomposition Factors

Source: The results reported are the author's own calculation and plots by using E-views software.

Results of Normality Test

For the VECM estimate residual test, the following Figure 9 has been presented below.

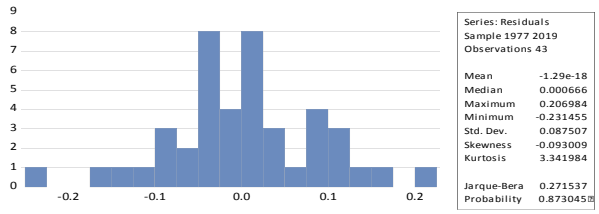

Figure 9. Results of normality test from the VECM estimates

Source: The results reported are the author's own calculation and plots by using E-views software.

For the diagnostic test of residual distribution, normal histogram normality test methods have employed with necessary information. The interest is in the value of the Jarque-Bera probability value in the figure. As a rule of thumb, if the p-value of JB is greater than five percent, we reject the hull hypothesis and accept the alternative hypothesis. In this case, the probability value is 0.8730 which is greater than 0.05. The result indicates that the residual distributions are normally distributed.

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Results of Serial Correlation Test

To test the presence of serial correlation test, the study performed the Breusch-Godfrey Serial Correlation LM Test and the result found there is no serial correlation in the model. As the null hypothesis H0: no serial correlation at up to 1 lag is accepted which means the model has no serial correlation. These results also support by the Durbin-Watson statistic as the value of DW=1.957 which is closed to 2.0. Therefore, the study concluded that there is no serial correlations presence.

Another residual test has been done for the Heteroskedasticity test. The result of Heteroskedasticity fails to reject the null hypothesis of no Heteroskedasticity. The keen interest in analysis the heteroskedasticity also in Durbin-Watson statistic value. The DW value is 2.037 which is also closed to 2.0. Therefore, the analysis results concluded that there is no presence of any Heteroskedasticity in the data. On the other hand, if the probability of Chi-Square distribution is greater than 5 percent then we can say that there is no Heteroskedsticity in the data. In this way, with the help of this test, the study result can be concluded that the regression results of the model are not spurious.

Results of Model Stability Test

The results will be valid and applicable only if the model is stable over the observation time period. Thus, for the model stability diagnostic purposed, the study used performed recursive estimation applying the CUSUM Test and CUSUM of Squares test method. The results of CUSUM and CUSUM of squares are presented in Figure 10 and 11 below.

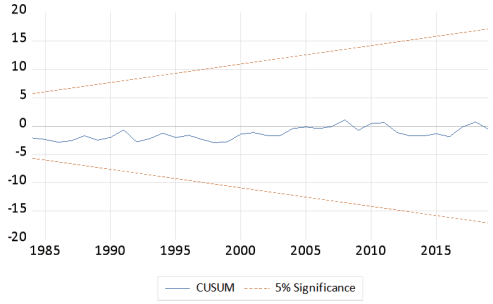

Figure 10. The result of squares tests

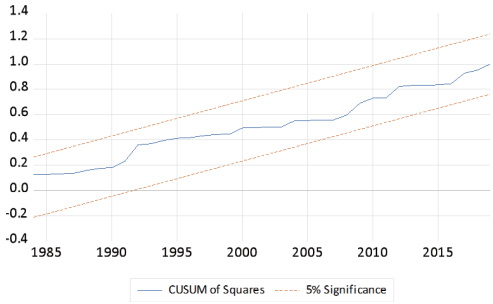

Figure 11. The result of CUSUM of squares tests

Source: The results reported are the author's own calculation and plots by using E-views software.

The CUSUM test gives the fluctuation detection over the time period. In this study case, time series fluctuation lies within the upper bound and lower bound of critical value at a 5 percent level of significance. Both figure shows the CUSUM and CUSUM of squares are within the critical value which indicates the model is stable over the observation period.

6. Conclusions

This study examines the relationship between domestic savings, investment, and economic growth in Nepal by using time series data covering from the period 1975 to 2019. The vector error correction model (VECM) has been used to investigate the long-run and short-run causal relationship between the variables.

The Johansen cointegration test results confirmed that there is a long-run relationship between savings, investment, and economic growth therefore, further analysis has to be set for the VEC model to analyze both long-run and short-run causality. The VECM equation result is -0.1363 which indicates that the adjustment speed of disequilibrium is 13.63 percent on average towards the equilibrium position in the long-run but the results are not significant at a 5 percent level of significance. The coefficients of savings and investments are positive with economic growth which also indicates that both variables have a positive impact on economic growth in the short-run. The results of the Jarque-Bera test show the residual distribution is normally distributed. For the model stability test, the study performed recursive estimation applying CUSUM and CUSUM of square, and both tests move within the 5 percent level of upper and lower bound significance indicating that the model is stable over the observation period.

This study suggests that in Nepal, there is a positive role of domestic savings and investment growth for the economic growth. The central bank, planning commission, and ministry of finance should focus on promoting domestic capital formation via domestic savings and properly investing those funds in the productive sector to stimulate sustainable economic growth in Nepal. Further, the study can be extended to provide better empirical evidence in the future with the coverage of a wide range of economic sectors and by applying an advance econometric models.

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ARTICLE

Quasi Maximum Likelihood for MESS Varying Coefficient Panel Data Models with Fixed Effects

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ABSTRACT

The study of spatial econometrics has developed rapidly and has found wide applications in many different scientific fields, such as demography, epidemiology, regional economics, and psychology. With the deepening of research, some scholars find that there are some model specifications in spatial econometrics, such as spatial autoregressive (SAR) model and matrix exponential spatial specification (MESS), which cannot be nested within each other. Compared with the common SAR models, the MESS models have computational advantages because it eliminates the need for logarithmic determinant calculation in maximum likelihood estimation and Bayesian estimation. Meanwhile, MESS models have theoretical advantages. However, the theoretical research and application of MESS models have not been promoted vigorously. Therefore, the study of MESS model theory has practical significance. This paper studies the quasi maximum likelihood estimation for matrix exponential spatial specification (MESS) varying coefficient panel data models with fixed effects. It is shown that the estimators of model parameters and function coefficients satisfy the consistency and asymptotic normality to make a further supplement for the theoretical study of MESS model.

1. Introduction

The matrix exponential space specification (MESS), originally proposed by Lesage and Pace [1], has been used as an alternative to the spatial autoregressive (SAR) specification due to its significant advantages. There are few studies on MESS models. At present, Debarsy et al. [2] is the most representative one to study MESS cross-section data model. Relevant studies extending MESS to panel data include Figueiredo and Silva [3] and Zhang et al. [4].

Recently, the combination of spatial models and non-parametric or semi-parametric models have gradually become a research trend. Su and Jin [5] propose the profile quasi maximum likelihood (QML) estimation of partially linear spatial autoregressive models. On the basis of [5], Su [6] proposes a semi-parametric spatial autoregressive model with heteroscedasticity and spatial correlation of error terms, and obtains the semi-parametric GMM estimation through the two-step estimation method. For more literature, see Zhang [7], Sun [8], Koroglu and Sun [9], etc.

Variable coefficient model, as a special semi-parametric model, has been proposed by Hastie and Tibshirani [10]. Fan and Zhang [11] further propose a more general variable

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coefficient model. For more literature, please refer to Cai et al. [12] and Xia et al. [13]. By introducing variable coefficients to describe the nonlinear effects of the explanatory variables on the explained variables, not only can the problem of dimension curse in non-parameters be overcome, but also can avoid the risk of model error. Therefore, it is inevitable to introduce the variable coefficient model into the spatial econometric model. In terms of the cross-section data model, Sun [8] studied the variable coefficient spatial autoregressor model with non-parametric spatial weight matrix. With the increase of the availability of panel data, studies on variable coefficient panel data model include Cai and Li [14], Chen et al. [15], etc.

MESS can also be extended to the variable coefficient panel data model. Based on the existing studies, this paper studies the quasi-maximum likelihood estimation of the variable coefficient panel data model with fixed effects, and derives the large-sample properties of the resulting estimator. The rest of the paper is arranged as follows: Section 2 introduces the model and estimation method. Section 3 presents some assumptions and main results. Section 4 gives some related lemmas and proofs.

2. Model and Estimation

We consider the following MESS varying coefficient panel data model with fixed effects:

$$e^{\alpha W_n} y_{it} = \mathrm{x}_{it}^{\tau}\beta(u_{it}) + \gamma_i + v_{it}, i = 1,\cdots,N, t = 1,\cdots,T, \quad (1)$$

where y_{it} is the dependent variable, $\mathrm{x}_{it} = (x_{it1},\cdots,x_{itp})^{\tau}$ is a p-dimensional independent variable, α is a scalar spatial dependence parameter, W_n is a known $N \times N$ spatial weight matrix with diagonal elements are zero, $\beta(u_{it}) = (\beta_1(u_{it}),\cdots,\beta_p(u_{it}))^{\tau}$ is a p-dimensional vector of unknown functions, and γ_i is the unobserved individual fixed effects. For convenience, we assume that u is a one-dimensional random variable, then $\beta_i(u)$ is an unknown function of one variable. We also assume that model holds with the restriction $\sum_{i=1}^{N}\gamma_i = 0$, and v_{it}'s are independent identically distributed (i.i.d.) of sequence of random errors with mean zero and variance σ^2.

Denoting

$$Y = (y_{11},\cdots,y_{1T},\cdots,y_{N1},\cdots,y_{NT})^{\tau},$$
$$X = (\mathrm{x}_{11}^{\tau},\cdots,\mathrm{x}_{1T}^{\tau},\cdots,\mathrm{x}_{N1}^{\tau},\cdots,\mathrm{x}_{NT}^{\tau})^{\tau},$$
$$v = (v_{11},\cdots,v_{1T},\cdots,v_{N1},\cdots,v_{NT}),$$
$$\beta(u) = (\beta(u_{11}),\cdots,\beta(u_{1T}),\cdots,\beta(u_{N1}),\cdots,\beta(u_{NT}))^{\tau},$$

then model (1) can be rewritten in a matrix format yields

$$S(\alpha)Y = X\beta(u) + U_0\gamma_0 + v, \quad (1)$$

where $S(\alpha) = (I_T \otimes e^{\gamma W_n})$, $\gamma_0 = (\gamma_1,\cdots,\gamma_N)^{\tau}$, $U_0 = I_N \otimes i_T$. I_N denotes the $N \times N$ identity matrix, i_T denotes the $T \times 1$ column vector of ones, and $\otimes$ is the Kronecker product.

Let $\theta = (\alpha,\sigma^2)^{\tau}$, Let $\gamma = (\gamma_2,\cdots,\gamma_N)^{\tau}$, then model (2) can be converted to

$$S(\alpha)Y = X\beta(u) + U\gamma + v, \quad (3)$$

where $U = (-i_{N-1}, I_{N-1})^{\tau} \otimes i_T$ is $NT \times (N-1)$ matrix.

According to Chiu et al. [16], for any square matrix A, $|e^{\alpha A}| = e^{\mathrm{tr}(\alpha A)} = e^{\alpha \mathrm{tr}(A)}$. At this moment, suppose that $v_{it} \sim i.i.d(0,\sigma^2)$, then $E(vv^{\tau}) = \sigma^2 I_{NT}$, and as W_n has zero diagonal, the log-likelihood function of the model (3) based on the response vector Y is as follows:

$$\ln L(\theta,\gamma) = -\frac{NT}{2}\ln(2\pi) - \frac{NT}{2}\ln(\sigma^2) - \frac{1}{2\sigma^2}[S(\alpha)Y - X\beta(u) - U\gamma]^{\tau}[S(\alpha)Y - X\beta(u) - U\gamma]. \quad (4)$$

Take the partial derivative of (4) with respect to γ, and make it be 0, then the maximum likelihood estimate of γ is

$$\hat{\gamma}_L = (U^{\tau}U)^{-1}U^{\tau}[S(\alpha)Y - X\beta(u)].$$

Further, by substituting $\hat{\gamma}_L$ into (4), we obtain the log-likelihood function of θ

$$\ln L(\theta) = -\frac{NT}{2}\ln(2\pi) - \frac{NT}{2}\ln(\sigma^2) - \frac{1}{2\sigma^2}[S(\alpha)Y - X\beta(u)]^{\tau}H[S(\alpha)Y - X\beta(u)], \quad (5)$$

where $H = I_{NT} - U(U^{\tau}U)^{-1}U^{\tau}$. Take the partial derivative of (5) with respect to σ^2, and make it be 0, then the maximum likelihood estimate of σ^2 is

$$\hat{\sigma}_L^2 = (NT)^{-1}[S(\alpha)Y - X\beta(u)]^{\tau}H[S(\alpha)Y - X\beta(u)].$$

Substituting $\hat{\sigma}_L^2$ into (5), one can show that the following concentrated log-likelihood function respect to γ:

$$\ln L(\alpha) = -\frac{NT}{2}[\ln(2\pi) + 1] - \frac{NT}{2}\ln(\hat{\sigma}_L^2). \quad (6)$$

Due to the varying coefficient functions $\beta(u_{it})$ is unknown, the estimate of α cannot be obtained directly by maximizing (6). Hence, we need to apply a local linear regression technique to estimate the varying coefficient functions $\{\beta_j(u_{it}), j = 1,\cdots,p\}$.

Firstly, for given θ, replace γ with $\hat{\gamma}_L$, then the weighted least-squares estimation method is used to obtain the feasible initial estimation $\hat{\beta}_{IN}(u)$ of $\beta(u)$. For u in a small neighborhood of u_0, one can approximate $\beta_j(u)$ locally by a linear function

$$\beta_j(u) \approx \beta_j(u_0) + \beta_j'(u_0)(u - u_0) \equiv a_{1j} + a_{2j}(u - u_0),\ j = 1,\cdots,p,$$

where $\beta_j'(u)$ is the derivative of $\beta_j(u)$ at u. This leads to the following weighted local least-squares problem: find $\{(a_{1j}, a_{2j}), j = 1,\cdots,p\}$ to minimize

$$\sum_{i=1}^{N}\sum_{t=1}^{T}[e^{\alpha W_n} y_{it} - \hat{\gamma}_{L,i} - \sum_{j=1}^{p}(a_{1j} + a_{2j}(u_{it} - u_0))x_{itj}]^2 K_h(u_{it} - u_0), \quad (7)$$

Where K is a kernel function, h is a bandwidth and $K_h(u_{it} - u_0) = h^{-1}K((u_{it} - u_0)/h)$..

Denote $NT \times NT$ diagonal matrix $W_u = diag(K_h(u_{11}$

$-u),\cdots,K_h(u_{NT}-u)\big)$, $\delta=\big(\beta_1(u),\cdots,\beta_p(u),h\beta_1'(u),\cdots,h\beta_p'(u)\big)^\tau$, and

$$D_u=\begin{pmatrix} x_{11}^\tau & \frac{u_{11}-u}{h}x_{11}^\tau \\ \vdots & \vdots \\ x_{1T}^\tau & \frac{u_{1T}-u}{h}x_{1T}^\tau \\ \vdots & \vdots \\ x_{NT}^\tau & \frac{u_{NT}-u}{h}x_{NT}^\tau \end{pmatrix},$$

then the matrix form of (7) is

$$\underset{\delta}{\operatorname{argmin}}[S(\alpha)Y-D_u\delta]^\tau HW_uH[S(\alpha)Y-D_u\delta].$$

The solution to (7) is given by

$$\hat{\delta}=[D_u^\tau HW_uHD_u]^{-1}D_u^\tau HW_uHS(\alpha)Y.$$

Then the feasible initial estimation of $\beta(u)$ is

$$\widehat{\beta}_{IN}(u)=(\beta_1(u),\cdots,\beta_p(u))^\tau=(I_p,0_p)^\tau\hat{\delta}=(I_p,0_p)^\tau A_u^{-1}Q_u, \quad (8)$$

where $A_u=(NT)^{-1}D_u^\tau HW_uHD_u$, $Q_u=(NT)^{-1}D_u^\tau HW_uHS(\alpha)Y$. Thus, the estimator for $X\beta(u)$ is

$$X\widehat{\beta}_{IN}(u)=\begin{pmatrix} (x_{11}^\tau \quad 0)(D_{u_{11}}^\tau HW_{u_{11}}HD_{u_{11}})^{-1}D_{u_{11}}^\tau HW_{u_{11}}H \\ \vdots \\ (x_{NT}^\tau \quad 0)(D_{u_{NT}}^\tau HW_{u_{NT}}HD_{u_{NT}})^{-1}D_{u_{NT}}^\tau HW_{u_{NT}}H \end{pmatrix}S(\alpha)Y=MS(\alpha)Y,$$

where the matrix M is a smoothing matrix and depends only on the observations $\{(u_{it},x_{it}^\tau),i=1,\cdots,N,t=1,\cdots,T\}$.

Secondly, taking $X\widehat{\beta}_{IN}(u)$ in to (5), we get the approximation of $\ln(\theta)$:

$$\ln\tilde{L}(\theta)=-\frac{NT}{2}\ln(2\pi)-\frac{NT}{2}\ln(\sigma^2)-\frac{1}{2\sigma^2}[S(\alpha)Y-X\widehat{\beta}_{IN}(u)]^\tau H[S(\alpha)Y-\widehat{\beta}_{IN}(u)]. \quad (9)$$

Maximizing $\ln\tilde{L}(\theta)$ with respect to θ, we have the estimate of θ, i.e.,

$$\hat{\theta}=\underset{\theta}{\operatorname{argmax}}\ln\tilde{L}(\theta).$$

In solving maximum (9) with respect to σ^2, we obtain the following initial estimate:

$$\hat{\sigma}_{IN}^2=(NT)^{-1}[S(\alpha)Y-X\widehat{\beta}_{IN}(u)]^\tau H[S(\alpha)Y-X\widehat{\beta}_{IN}(u)]. \quad (10)$$

Replace σ^2 in the (9) with $\hat{\sigma}_{IN}^2$, then the concentrated log-likelihood function respect to α is:

$$\ln\tilde{L}(\alpha)=-\frac{NT}{2}[\ln(2\pi)+1]-\frac{NT}{2}\ln(\hat{\sigma}_{IN}^2). \quad (11)$$

Further, α is estimated to be

$$\hat{\alpha}=\underset{\alpha}{\operatorname{argmax}}\ln\tilde{L}(\alpha)$$

The above nonlinear optimization problems can be solved by iterative method.

Next, according to (8) and (9) and $\hat{\alpha}$, we obtain the final estimates of β_u and σ^2, respectively:

$$\tilde{\beta}(u)=(I_p,0_p)^\tau[D_u^\tau HW_uHD_u]^{-1}D_u^\tau HW_uHS(\hat{\alpha})Y,$$
$$\tilde{\sigma}^2=(NT)^{-1}[S(\hat{\alpha})Y-X\tilde{\beta}(u)]^\tau H[S(\hat{\alpha})Y-X\tilde{\beta}(u)].$$

Finally, γ is estimated to be

$$\hat{\gamma}=(U^\tau U)^{-1}U^\tau[S(\hat{\alpha})Y-X\tilde{\beta}(u)].$$

3. Assumptions and Main Results

Denote $\rho_j=\int u^jK(u)du,\varphi_j=\int u^jK^2(u)du$. Let $\theta_0=(\alpha_0,\sigma_0^2)^\tau$ be the true valve of the parameter θ. To obtain the consistency and asymptotic normality of the resulted estimators of θ and function coefficient $\beta(u)$, we need following assumptions:

A1 $\{x_{it},y_{it},u_{it},v_{it},i=1,\cdots,N;t=1,\cdots,T\}$ are i.i.d. random sequences. They satisfy the following conditions: (i) The random variable u has a bound support $\mathcal{U}$, and the edge density function $f_t(u)$ is continuous differentiable and bound away from 0 on its support. (ii) The matrix $\Omega(u)=E(x_{it_1}x_{it_2}^\tau|u_{it_1}=u,u_{it_2}=u)$ is non-singular and every element is second-order continuous differentiable. The matrix $E(x_{it}x_{it}^\tau)$ is a non-singular constant that satisfies $E(x_{it}v_{it}|u_{it})=0$ and $E(x_{it}b_i|u_{it})=0$. (iii) There exists $r=\max 4,s$ such that $E(\|x_{it}\|^r<\infty)$, $E(\|b_i\|^r<\infty),E(\|v_{it}\|^r<\infty)$ and for some $\epsilon<2-s^{-1}$such that $(NT)^{2\epsilon-1}h<\infty$.

A2 $\{\beta_i(u),i=1,\cdots,p\}$ have continuous second derivative in $u\in\Omega$ and for any u, $|\beta_i(u)|\le c$ is a positive constant.

A3 The kernel $K(\cdot)$ is a symmetric density function with a continuous derivative on its compact support [-1,1].

A4 (i) The row and column sums of W_n and S^{-1} are uniformly bounded in absolute value. (ii) $S^{-1}(\alpha)$ are uniformly in α in a compact convex parameter space Θ. The true α_0 is an interior point in Θ.

A5 $NTh\to 0$ as $N\to\infty,T\to\infty$ and $h\to 0$.

A6 There is a unique θ that makes model (2) true.

A7 Either (i) $\lim_{NT\to\infty}(NT\sigma_0^2)^{-1}[X\beta(u)+U\gamma]^\tau\Lambda_0^\tau H\Lambda_0[X\beta(u)+U\gamma]$ exists and is non-singular, where $\Lambda_0=W_nS^{-1}(\alpha_0)$; or (ii) $\lim_{NT\to\infty}\{(NT)^{-1}\mathrm{tr}(\Lambda_0^2)+(NT)^{-1}\mathrm{tr}(\Lambda_0^\tau H\Lambda_0)-2(NT)^{-2}\mathrm{tr}^2(\Lambda_0^\tau H)\}>0$..

Remark 1. A1 to A3 and are the basic assumptions for nonparametric models, which can be used in Fan and Huang [17]. A4 concerns the essential features of spatial weights matrix, which can be found in the Assumptions 4, 5 and 7 in Lee [18]. A5 is easily satisfied. A6 is the unique identification condition of the parameter. A7 guarantees the asymptotic normality of parameter estimation (see e.g., Chen et al.[15]).

Denote $\Theta_0=\{\alpha|\alpha\in\Theta,\|\alpha-\alpha_0\|\le\eta_1(NT)^{-1/2}\}$, where η_1 is a given positive constant. We now sate the main results.

Theorem 1. *Suppose that Assumptions A1-A6 are satisfied.* $\forall u\in\mathcal{U},\forall\alpha\in\Theta_0$, *then (i)* $\hat{\theta}-\theta_0=o_p(1)$, *and (ii)* $\tilde{\beta}(u)-\beta(u)=o_p(1)$.

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Theorem 2. *Suppose that Assumptions A1-A7(i) or A1-A6 and A7(ii) are satisfied. Then* $\sqrt{NT}(\hat{\theta}-\theta_0) \xrightarrow{d} N(0,\Sigma^{-1})$,

where $\Sigma = -\lim_{NT\to\infty} E\left[\frac{1}{NT}\frac{\partial^2 \ln L(\theta)}{\partial\theta\partial\theta^\tau}|_{\theta=\theta_0}\right]$.

Theorem 3. *Suppose Assumptions A1-A6 hold, for any* $u \in \mathcal{U}, \alpha \in \Theta_0$,

$$\sqrt{NTh}(\hat{\beta}(u)-\beta(u)-\phi(u)) \xrightarrow{d} N\left(0,\sigma_\beta^2(u)\right),$$

where $\phi(u) = h^2\rho_2\beta''(u)/2$, $\sigma_\beta^2(u) = \varphi_0\sigma_0^2[F(u)\boldsymbol{\Omega}]^{-1}$, $\beta''(u)$ *is the second derivative of* $\beta(u)$, $F(u) = \lim F(u) = \lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T} f_t(u)$ *and* $\boldsymbol{\Omega} = E\left(x_{i_1t_1}x_{i_2t_2}^\tau\right)$.

Further, as $NTh^5 \to 0$, *then* $\sqrt{NTh}(\hat{\beta}(u)-\beta(u)) \xrightarrow{d} N\left(0,\sigma_\beta^2(u)\right)$.

4. Lemmas and Proofs

Lemma 1. *Suppose that Assumptions A1-A5 hold true, then*

$$A_u = F_u\begin{pmatrix}\boldsymbol{\Omega} & 0\\ 0 & \mu_2\boldsymbol{\Omega}\end{pmatrix}\{1+O_p(c)\}, Q_u = F_u\begin{pmatrix}\boldsymbol{\Omega}\beta(u)\\ 0\end{pmatrix}\{1+O_p(c)\},$$

where $F(u) = \lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T} f_t(u), \boldsymbol{\Omega} = E\left(x_{i_1t_1}x_{i_2t_2}^\tau\right), i_1, i_2 = 1,\cdots,N, t_1, t_2 = 1,\cdots,T.$

Proof. See Lemma 1 in Chen et al. (2019).

Lemma 2. *Suppose that Assumptions A1 - A5 hold true, then* $\hat{\beta}_{IN}(u) - \beta_u = o_p(1)$.

Proof. Note that

$$\hat{\beta}_{IN}(u) = \left(I_p, 0_p\right)^\tau A_u^{-1}Q_u,$$

and from Lemma 1, one can show that $\hat{\beta}_{IN}(u) \xrightarrow{p} \beta_u$. Then the Lemma 2 is proved.

Proof of Theorem 1 to 3. Using Lemma 1, Lemma 2 and following the proof of Theorem 1 to 5 in Chen et al. [15], one can easily show that Theorem 1 to 3 hold true.

5. Conclusions

This paper combines the advantages of MESS models and the characteristics of fixed effects and variable coefficient models to change the spatial correlation from geometric decay to exponential decay, which makes the theoretical modeling simpler. We study matrix exponential spatial specification varying coefficient panel data models with fixed effects. Firstly, the dummy variable method is used to deal with the fixed effect, then the weighted least square estimation method is used to estimate the variable coefficient function, and the quasi-maximum likelihood estimation method is used to estimate the model parameters. Finally, the consistency and asymptotic normality of model parameter estimation and function coefficient estimation are deduced.

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