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Managing Global Transitions (MGT) is a quarterly, scholarly journal that covers diverse aspects of transitions and welcomes research on change and innovation in increasingly digitalized and networked economic environments, from a societal, organizational, and technological perspective. MGT fosters the exchange of ideas, experience, and knowledge among developed and developing countries with different cultural, organizational, and technological traditions. MGT invites original scientific, research, and review papers advancing the field of transitions in societies, organizations, and technologies.

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Bank Development and Unemployment in Kenya: An Empirical Investigation

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This study has empirically investigated the impact of bank development on unemployment in Kenya, based on time-series data spanning from 1991 to 2019. Using the ARDL bounds testing approach, the results of the study have revealed that in Kenya, the impact of bank development on unemployment, though time-invariant, depends largely on the proxy used to measure the level of bank development. Consistent with expectations, bank development – as proxied by liquid liabilities, bank deposits, deposit money bank assets and the banking development index – has been found to have a negative impact on unemployment in Kenya. However, when bank development is proxied by the domestic credit to private sector by banks, its impact on unemployment was found to be statistically insignificant. These results were found to apply consistently in the long run and in the short run.

Key Words: unemployment, bank development, bank-based financial development, financial development, Kenya, ARDL
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Introduction and Motivation

Although alternative views exist (see Van Wijnbergen 1983; Buffie 1984; Lucas 1988; Robinson 1952), financial development has long been widely recognised as an engine for growth, from as early as the early 20th century (see, among others, Schumpeter 1911; Goldsmith 1969; Shaw 1973; Gelb 1989; Roubini and Sala-i-Martin 1992; King and Levine 1993; Odedokun 1996; Asongu 2015; Odhiambo and Nyasha 2019; Asongu, Nnanna, and

Acha-Anyi 2020). Several studies that empirically examined the impact of financial development on economic growth in Kenya confirm this notion that financial development is good for economic growth (see Kagochi 2013).

Although earlier studies recognised the importance of a well-developed financial system in solving national economic growth challenges, it is only recently that economists started focusing on examining the impact of financial development on the levels of unemployment (see, among others, Epstein and Shapiro 2018; Kanberoğlu 2014; Han 2009). Since the finance-unemployment nexus is still relatively new, a lot of African countries have not received befitting coverage, Kenya included, yet the outcome of such studies is key in driving related policies.

The choice of Kenya as a country of study is two-fold. It was motivated by the finance dynamics in this country, on the one hand, and the unemployment trends, on the other. Kenya has a growing financial sector, which has shown great improvement in the past few decades (Nyasha and Odhiambo 2016). Its financial liberation journey has resulted in a financial system that can be counted among the modest financial systems in Africa. From the labour market side, Kenya is one of the African countries with the lowest rate of unemployment. According to the World Bank (2020), the International Labour Organisation (ILO) modelled unemployment rate for Kenya was always below the 3% mark over the review period – which has been consistently lower than the global unemployment rate (International Labour Organization 2019). Given Kenya's remarkable performance in both the financial sector and the unemployment fronts, it is worth putting the finance-unemployment nexus to an empirical test in Kenya, to observe if these trends are related or coincidental.

Though Kenya's financial system consists of financial intermediaries and capital markets, which are both still at a developing stage, it is the banking sector that plays a leading role in savings mobilisation, capital allocation, and oversight of investment decisions of corporate managers, as well as the provision of risk management vehicles (Demirguc-Kunt and Levine 2001; Nyasha and Odhiambo 2016). Kenya is, therefore, generally referred to as having a bank-based financial system. For this reason, the study focuses on bank development in Kenya, rather than on the overall financial system, to allow for the examination of the maximum impact of the financial system, if any.

Against this backdrop, the objective of the study is to empirically exam-

ine the impact of bank development on unemployment in Kenya, using the autoregressive distributed lag (ARDL) bounds testing approach. To increase the rigour of the study and to check the robustness of the results, the study uses five proxies of bank development. To capture, as far as possible, the breadth and depth of the Kenyan banking system development, among the five proxies is a banking development index, constructed from the other four proxies using the method of means-removed average. This study is the first of its kind, to our knowledge, to explore in detail the finance-unemployment nexus in Kenya using five different proxies of bank development. Besides weighing in on the finance-unemployment nexus debate globally, the outcome of this study is also expected to contribute significantly to informed and intensified policy options towards improving Kenya's labour market, especially following the coronavirus-related economic shock.

The rest of the paper is organised as follows: the second section discusses the dynamics between bank development and unemployment in Kenya, while the third section reviews the literature on the impact of financial development on unemployment. The fourth section is on the methodology used, the fifth section presents the results, and the sixth section concludes the study.

Bank Development and Unemployment in Kenya

Kenya's financial sector consists of deposit-taking institutions such as commercial banks, mortgage finance companies, microfinance banks and deposit-taking Savings and Credit Co-operatives (Saccos); non-deposit-taking institutions such as insurance, pensions, capital markets, and Development Finance Institutions (DFIs); and financial market infrastructure providers (Central Bank of Kenya 2020).

In Kenya, at the apex of the banking sector is the Central Bank of Kenya (CBK), established in 1966 through an Act of Parliament, known as the Central Bank of Kenya Act of 1966. The CBK performs an oversight role in the country's financial system. Over the past decades, Kenya's banking sector has grown. The growth ranges from increased assets, deposits, and profitability to product-offerings.

Kenya is one of the countries that has taken financial liberalisation seriously since the 1970s. Various financial policy reforms were undertaken by Kenya in order to gradually liberalise, modernise and develop its banking system. These reforms aimed at controlling monetary aggregates for macro-economic stabilisation, direct development of the banking sector

in relation to asset allocation as guided by political and economic priorities, and strengthening prudential regulation and supervision (FSD Kenya 2010). In response to the financial reforms undertaken, Kenya's banking sector experienced growth in a number of facets. Foreign banks were challenged by local banks, thereby increasing the presence and influence of local banks in the country's banking sector (Central Bank of Kenya 2020). Credit extension, bank assets and liquid liabilities also increased over the period.

Despite the notable progress in its response to the financial sector reforms, Kenya's banking sector still faces some challenges. According to FSD Kenya (2010), these challenges are interrelated and include high interest rate spreads, high overhead costs and relatively high profit margins, largely driven by the non-sharing of credit information.

Regarding unemployment, Kenya is one of the African countries with the lowest rate of unemployment (International Labour Organization 2019). According to Statista (2020), the unemployment rate in Kenya was 2.64% in 2019. This represents a steady decline from the increase after the financial crisis (Statista 2020). In 2018, Kenya's unemployment rate was also at 2.64%, showing that it had descended to almost its pre-global financial crisis level (of 2.60% in 2008). Though remarkable, whereas it took only one year for the unemployment rate in Kenya to jump from 2.6% in 2008 to 2.79% in 2009, the road to recovery to the original value has been marred with oscillations and has taken a full nine years (The World Bank 2020).

Kenya has been able to maintain low levels of unemployment, arguably as a result of the technicalities associated with how unemployment is defined, where a large number of people are left out of the unemployment net because they depend on agriculture. Kenya is well known for being an agrarian economy (The World Bank 2019).

Despite this technicality, the coronavirus pandemic has created yet another shock in the global economy, Kenya included, leading to sharp rises in Kenya's unemployment levels in 2020, reaching about 10.4% in the second quarter of 2020, from 5.2% in the first quarter of 2020 (Kenya National Bureau of Statistics 2020). Figure 1 attempts to interrogate the dynamics of banking sector development and unemployment trends in Kenya over the period from 1991 to 2019. The banking sector growth in Kenya, as measured by five banking development indicators trended upwards over the review period, in the main, while unemployment trended downwards, also in the main (The World Bank 2020).

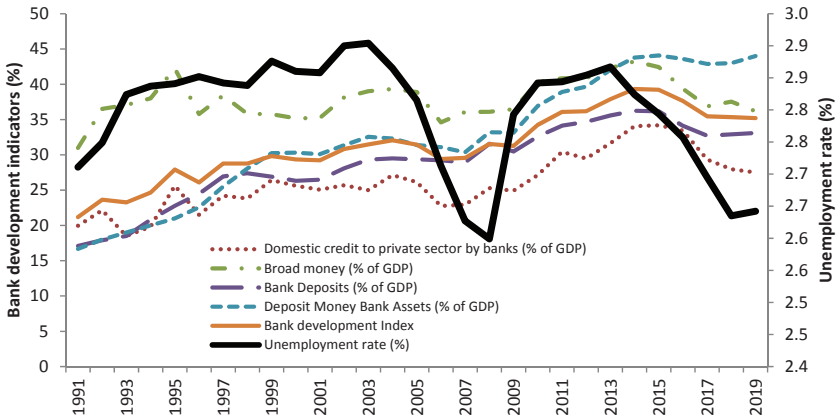

FIGURE 1 Banking Sector Development and Unemployment Trends in Kenya

Literature Review

Theoretically, the development of the banking system negatively impacts unemployment levels through various channels such as capital formation, industrial promotion, employment generation and credit extension to the government (Ernst 2019). Through this provision of direct credit, the government is able to deploy multiple development schemes, which can translate to economic growth and a decrease in unemployment (Bayar 2016; Ernst 2019).

Despite the nexus between financial development and unemployment being relatively new, the empirical trend has shown three outcomes. The first and the most common trend is where financial development has been found to have a negative impact on unemployment, implying that as the financial sector gets more and more developed, unemployment trends downwards (see, among others, Darrat, Abosedra, and Aly 2005; Gatti and Vaubourg 2009; Shabbir et al. 2012; Kanberoğlu 2014; Epstein and Shapiro 2018). The second, but less common, trend is where the development of the financial sector is found to worsen unemployment (see, among others, Gatti and Vaubourg 2009; Shabbir et al. 2012; Kanberoğlu 2014; Ogbeide, Kanwanye, and Kadiri 2015). Then, there is a third trend which confirms the neutrality effect of financial development on unemployment (see, among others, Darrat, Abosedra, and Aly 2005; Ilo 2015; Bayar 2016; Epstein and Shapiro 2018). It is quite interesting that all these trends have found empirical support.

Besides these studies, the finance-unemployment nexus terrain also has studies of the stability, rather than pure development of the financial

TABLE 1 The Impact of Financial Development on Unemployment: A Summary of Reviewed Empirical Literature

	Author(s)	Study country/region	Financial development proxy	Data type	Nature of impact
Direct negative impact	Darrat, Abosedra, and Aly (2005)	United Arab Emirates	The ratio of M2 to nominal GDP; Ratio of demand deposits to the narrow money stock; Credit issued by financial institutions to the non-financial private sector as a share of GDP	Time-series	Negative (only in the long run)
	Gatti and Vaubourg (2009)	Selected OECD member countries (1980–2004)	Stock market capitalisation credits provided by the financial sector	Panel	Negative (only for strongly regulated labour market)
	Shabbir et al. (2012)	Pakistan (1973–2007)	Diverse indicators of financial development	Time-series	Negative (both in the short run as well as in the long run when financial development is proxied by financial sector activities)
	Kanberoğlu (2014)	Turkey (1985–2010)	Major indicators of financial development	Time-series	Negative
	Epstein and Shapiro (2018)	Advanced, developing, and emerging economies	Bank credit-GDP ratio	Panel	Negative (for developing and emerging economies)

Continued on the next page

system, on labour dynamics (see Epstein and Shapiro 2018). Although most of the reviewed studies are largely based on the direct impact of financial development on unemployment, there is a pocket of empirical studies that indirectly focus on the impact of financial development on unemployment. Though indirect, these studies still help in establishing the importance of financial development on unemployment (see,

TABLE 1 *Continued from the previous page*

	Author(s)	Study country/region	Financial development proxy	Data type	Nature of impact
Direct positive impact	Gatti and Vaubourg (2009)	Selected OECD member countries (1980–2004)	Stock market capitalisation credits provided by financial sector	Panel	Positive (only in selected cases when credits provided by financial sector was used as a proxy of financial development)
	Shabbir et al. (2012)	Pakistan (1973–2007)	Diverse indicators of financial development	Time-series	Positive (when financial development is proxied by M2 minus currency in circulation as a ratio of GDP)
	Kanberoğlu (2014)	Turkey (1985–2010)	Major indicators of financial development	Time-series	Positive (when broad money supply was used as a measure of financial development)
	Ogbeide, Kanwanye, and Kadiri (2015)	Nigeria (1981–2013)	Level of banking sector development	Time-series	Positive

Continued on the next page

among others, Caggese and Cunat 2008; Han 2009; Bentolila, Jansen, and Jiménez 2017; Berton et al. 2018).

Table 1 summarises the empirical studies on the finance-unemployment nexus. Although this study is about the impact of the banking sector on unemployment, the relevant empirical studies are scant; hence, focus will also be given to studies that examine the impact of stock markets and financial development in general on unemployment. Despite these variations, the outcome is expected to shed some light on the relationship of interest (bank development and unemployment).

Based on the empirical literature reviewed, it can be concluded that each strand has evidence in its support. However, the strand that supports the negative impact of financial development on unemployment

TABLE 1 *Continued from the previous page*

	Author(s)	Study country/region	Financial development proxy	Data type	Nature of impact
Direct insignificant impact	Darrat, Abosedra, and Aly (2005)	United Arab Emirates	The ratio of M2 to nominal GDP; Ratio of demand deposits to the narrow money stock; Credit issued by financial institutions to the non-financial private sector as a share of GDP	Time-series	Insignificant (in the short run)
	Ilo (2015)	Nigeria (1986–2012)	Market capitalisation	Time-series	Insignificant
	Bayar (2016)	16 emerging market economies (2001–2014)	Domestic credit provided by the private sector as a percentage of GDP	Panel	Insignificant
	Epstein and Shapiro (2018)	Advanced, developing, and emerging economies	Bank credit-GDP ratio	Panel	Insignificant (for the advanced economies)
Indirect negative impact	Caggese and Cunat (2008)	Italy	Financing constraints	Firm-level panel	Negative
	Han (2009)	Tulsa County, USA	Financial hardship	Longitudinal	Negative
	Pagano and Pica (2012)	OECD countries	Banking crises	Panel	Negative
	Bentolila, Jansen, and Jiménez (2017)	Spain	Bank loans to non-financial firms	Firm-level	Largely negative
	Berton et al. (2018)	Italy	Financial shocks	Survey	Negative

appears to be more attractive, with more pieces of evidence than other strands, irrespective of the methodology utilised and whether the investigated impact is direct or indirect.

Estimation Method

ARDL BOUNDS TESTING APPROACH

The objective of this study is to empirically assess the impact of banking sector development on unemployment levels in Kenya. To realise this objective, the study utilises the contemporary autoregressive distributed lag (ARDL) bounds testing method (see Pesaran and Shin 1999; Pesaran, Shin, and Smith 2001; Nyasha and Odhiambo 2015). Incongruent to the best-known conventional estimation procedures such as those anchored on Johansen and Juselius (1990), Johansen (1988) and Engle and Granger (1987), among others, the ARDL approach offers a number of benefits, the most prominent one being its non-restrictive order of integration. While other methods impose a restrictive assumption that all the variables under study must be integrated of the same order, the chosen method still works even when variables are not integrated of the same order, as long as they are of order not more than one (Musakwa and Odhiambo 2019). As opposed to the conventional cointegration methods that utilise a system of equations when estimating the long-run relationships, the ARDL bounds testing procedure only employs a single reduced-form equation (see also Duasa 2007). Furthermore, the ARDL estimation method automatically addresses endogeneity issues as it usually provides unbiased estimates of the long-run model and valid *t*-statistics even when some of the regressors are endogenous (Nyasha and Odhiambo 2020). To top it all, in contrast to the other cointegration techniques that are sensitive to the sample size, the chosen methodology for this study possesses superior small sample properties, which makes it suitable even when the sample size is small (Pesaran and Shin 1999; Odhiambo and Nyasha 2020).

VARIABLE DESCRIPTION AND EMPIRICAL MODEL SPECIFICATION

Unemployment (UNE) is the dependent variable in the study. It is proxied by the national unemployment rate. The independent variable of interest is bank development (BDV). To enhance the rigour and perform robustness checks, five proxies of bank development are employed in this study. These banking development proxies have been widely used in financial development studies (see, among others, Nyasha and Odhiambo 2016; Odedokun 1996; King and Levine 1993).

To fully specify the model and minimise the variable-omission-bias, seven control variables were chosen. These are key determinants of un-

employment, based on theoretical and empirical literature (see, among others, Folawewo and Adeboje 2017), such that:

$$\text{UNE} = f(y, \text{BDV}, \text{FDI}, \text{DIN}, \text{HFC}, \text{GNE}, \text{INR}, \text{EXR}), \quad (1)$$

where each banking development proxy enters the model one at a time.

Variables are:

- UNE is unemployment, proxied by unemployment rate, total (% of total labour force) and is based on national estimates,
- y is economic growth, proxied by annual percentage growth rate of GDP at market prices based on constant 2010 US dollars,
- BDV is bank development, proxied by DCP, LLB, BDP, BAS and BDI,
- DCP is domestic credit to private sector by banks, measured by domestic credit to private sector by banks, expressed as a percentage of GDP,
- LLB is liquid liabilities, expressed as a percentage of GDP,
- BDP is bank deposits, measured by the total value of demand, time and saving deposits at domestic deposit money banks as a share of GDP,
- BAS is deposit money bank assets, calculated as total assets held by deposit money banks as a share of GDP,
- BDI is the bank development index, constructed from DCP, LLB, BDP and BAS using a mean-removed average approach following Nyasha and Odhiambo (2016),
- FDI is foreign direct investment, net inflows as a percentage of GDP,
- DIN is domestic investment, proxied by gross fixed capital formation as a percentage of GDP,
- HFC is household final consumption expenditure as a percentage of GDP,
- GNE is national expenditure proxied by gross national expenditure as a percentage of GDP,
- INR is interest rate, proxied by lending interest rate (%),
- EXR is exchange rate, proxied by real effective exchange rate index (2010 = 100).

The coefficients of all the independent variables are expected to be positive, except for interest rate and exchange rate, whose coefficients are expected to be negative.

The annual time-series data from 1991 to 2019, used in this study, were all obtained from the World Bank Economic Indicators and the World Bank Economic Indicators Archives (The World Bank 2020).

Following Pesaran, Shin, and Smith (2001), the ARDL-based empirical model specification for this study is expressed as follows:

$$\begin{aligned}\Delta \text{UNE}_t = {} & \Phi_0 + \sum_{i=1}^{n} \Phi_{1i} \Delta \text{UNE}_{t-i} + \sum_{i=0}^{n} \Phi_{2i} \Delta \text{BDV}_{t-i} + \sum_{i=0}^{n} \Phi_{3i} \Delta y_{t-i} \\ & + \sum_{i=0}^{n} \Phi_{4i} \Delta \text{FDI}_{t-i} + \sum_{i=0}^{n} \Phi_{5i} \Delta \text{DIN}_{t-i} + \sum_{i=0}^{n} \Phi_{6i} \Delta \text{HFC}_{t-i} \\ & + \sum_{i=0}^{n} \Phi_{7i} \Delta \text{GNE}_{t-i} + \sum_{i=0}^{n} \Phi_{8i} \Delta \text{INR}_{t-i} + \sum_{i=0}^{n} \Phi_{9i} \Delta \text{EXR}_{t-i} \\ & + \Phi_{10} \text{UNE}_{t-1} + \Phi_{11} \text{BDV}_{t-1} + \Phi_{12} y_{t-1} + \Phi_{13} \text{FDI}_{t-1} \\ & + \Phi_{14} \text{DIN}_{t-1} + \Phi_{15} \text{HFC}_{t-1} + \Phi_{16} \text{GNE}_{t-1} + \Phi_{17} \text{INR}_{t-1} \\ & + \Phi_{18} \text{EXR}_{t-1} + \mu_{1t}, \end{aligned} \tag{2}$$

where Φ_0 is constant, $\Phi_{1i} \ldots \Phi_{9i}$ and $\Phi_{10} \ldots \Phi_{18}$ are respective regression coefficients, Δ is the difference operator, n is the lag length, and μ_{1t} is the white noise-error term.

Following the ARDL model specified in equation (2), the related ARDL-based error-correction model is specified as follows:

$$\begin{aligned}\Delta \text{UNE}_t = {} & \Phi_0 + \sum_{i=1}^{n} \phi_{1i} \Delta \text{UNE}_{t-i} + \sum_{i=1}^{n} \phi_{2i} \Delta \text{BDV}_{t-i} + \sum_{i=1}^{n} \phi_{3i} y_{t-i} \\ & + \sum_{i=1}^{n} \phi_{4i} \Delta \text{FDI}_{t-i} + \sum_{i=1}^{n} \phi_{5i} \Delta \text{DIN}_{t-i} + \sum_{i=1}^{n} \phi_{6i} \Delta \text{HFC}_{t-i} \\ & + \sum_{i=1}^{n} \phi_{7i} \Delta \text{GNE}_{t-i} + \sum_{i=1}^{n} \phi 8i \Delta \text{INR}_{t-i} + \sum_{i=1}^{n} \phi_{9i} \Delta \text{EER}_{t-i} \\ & + \varphi \text{ECM}_{t-1} + \mu_t, \end{aligned} \tag{3}$$

where ECM is the error correction term φ is the coefficient of the error correction term. All the other variables and characters remain as described under equation (2).

Results

STATIONARITY

Three unit root tests were utilised in this study – namely, the Augmented Dickey-Fuller, the Dickey-Fuller generalised least squares, and

TABLE 2 Results of Unit Root Test

Variable	Unit root test	At level		At first difference	
		(1)	(2)	(1)	(2)
UNE	ADF	−2.1966	−3.3079	−3.3730***	−4.4028***
	DF-GLS	−1.4264	−2.2058	−3.2906***	−3.8474***
	PP	−1.8235	−2.2731	−3.7457***	−4.3838***
DCP	ADF	−1.9502	−2.4730	−6.2298***	−6.1669***
	DF-GLS	−1.5563	−2.6633	−5.9702***	−6.3248***
	PP	−1.8784	−2.5175	−6.2153***	−6.1963***
LLB	ADF	−3.5024**	−4.4956***	–	–
	DF-GLS	−2.2532**	−2.7165	–	−6.0450***
	PP	−3.5917**	−3.0264	–	−6.6676***
BDP	ADF	−2.6148	−1.2401	−3.7396***	−4.2883**
	DF-GLS	−0.7888	−1.3022	−3.8085***	−4.4154***
	PP	−2.4666	−1.3800	−3.7221***	−4.2883***
BAS	ADF	−1.4172	−4.5591***	−3.7120***	–
	DF-GLS	−0.1306	−3.0116	−3.7601***	−5.0356***
	PP	−1.3406	−1.9226	−3.7513***	−3.7120***
BDI	ADF	2.1092	−1.7012	−5.2925***	−5.4178***
	DF-GLS	−0.8994	−1.8628	−4.6913***	−5.4781***
	PP	−2.1090	−2.1452	−5.2893***	−5.4127***
y	ADF	−3.0960**	−4.5386***	–	–
	DF-GLS	−2.9393***	−4.7097***	–	–
	PP	−3.0608**	−4.8235***	–	–

Continued on the next page

the Phillips-Perron unit root tests – where the latter was chosen to cater for the possibility of structural breaks in the time-series data. A summary of the results of the unit root tests conducted is displayed in table 2. The results of the stationarity tests conducted in this study reveal that most variables are conclusively stationary at first difference while a selected few, such as economic growth (y) and foreign direct investment (FDI), are conclusively stationary at levels, irrespective of the unit root testing method used. These results, therefore, validate the utilisation of the ARDL-based methodology in the empirical investigation of the impact of bank development on unemployment in Kenya.

TABLE 2 *Continued from the previous page*

Variable	Unit root test	At level		At first difference	
		(1)	(2)	(1)	(2)
FDI	ADF	−3.7493***	−4.2088**	–	–
	DF-GLS	−3.7240***	−4.3724***	–	–
	PP	−3.7467***	−4.0949**	–	–
DIN	ADF	−2.3965	−2.6034	−5.4564***	−5.4005***
	DF-GLS	−2.4342**	−2.6336	–	−5.2864***
	PP	−2.4273	−2.6188	−5.9304***	−5.9136***
HFC	ADF	−2.0926	−2.1164	−4.1685***	−4.0810***
	DF-GLS	−0.9765	−1.9222	−3.7033***	−4.0885***
	PP	−2.2708	−1.9978	−4.1297***	−3.9997**
GNE	ADF	−1.7717	−2.0132	−5.2658***	−5.3155***
	DF-GLS	−1.3077	−2.1264	−5.0858***	−5.3954***
	PP	−1.6899	−2.0132	−5.3847***	−7.3744***
INR	ADF	−1.1588	−2.4655	−5.2669***	−5.2044***
	DF-GLS	−1.2106	−4.1452***	−3.4523***	–
	PP	−1.2566	−2.6441	−5.2733***	−5.2061***
EXR	ADF	−2.2167	−3.1509	−4.9089***	−4.9856***
	DF-GLS	−0.6339	−2.6082	−4.9751***	−5.1892***
	PP	−2.2256	−3.1502	−4.9093***	−4.9812***

NOTES Column headings are as follows: (1) intercept, (2) intercept & trend. Unit root tests: ADF – Augmented Dickey-Fuller, DF-GLS – Dickey-Fuller generalised least squares, PP – Phillips-Perron. ** and *** denote stationarity at 5% and 1% significance level.

COINTEGRATION

The cointegration results are presented in Table 3. The outcome of the cointegration test reveals that the variables in the model are cointegrated across all the five functions. Thus, the presence of a stable long-run equilibrium relationship is confirmed between unemployment and the regressors regardless of the proxy of bank development considered.

LONG-RUN AND SHORT-RUN COEFFICIENT ESTIMATION

Having confirmed the long-run equilibrium relationship among the variables in the model, what follows is the estimation of coefficients – both the long-run and short-run coefficients. Table 4 displays a summary of

TABLE 3 Bounds Test *F*-test for Cointegration

Dep. variable	Function	*F*-statistic	Coint. status
BDV = DCP	*F*(UNE | DCP, *y*, FDI, DIN, HFC, GNE, INR, EXR)	4.522***	Cointegrated
BDV = LLB	*F*(UNE | LLB, *y*, FDI, DIN, HFC, GNE, INR, EXR)	6.193***	Cointegrated
BDV = BDP	*F*(UNE | BDP, *y*, FDI, DIN, HFC, GNE, INR, EXR)	3.542**	Cointegrated
BDV = BAS	*F*(UNE | BAS, *y*, FDI, DIN, HFC, GNE, INR, EXR)	6.570***	Cointegrated
BDV = BDI	*F*(UNE | BDI, *y*, FDI, DIN, HFC, GNE, INR, EXR)	6.371***	Cointegrated

Pesaran, Shin, and Smith (2001, 300), table CI(iii), case III	Asymptotic critical value					
	1%		5%		10%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	2.79	4.10	2.22	3.39	1.95	3.06

NOTES ** and *** denotes significance at 5% and 1% levels.

the coefficient results. While Panel I of the table presents long-run results, Panel II exhibits short-run results. The impact of bank development on unemployment in Kenya was found to be proxy-dependent, as the outcome varied depending on the proxy used for bank development. Consistent with expectations, bank development as proxied by liquid liabilities (LLB), bank deposits (BDP), deposit money bank assets (BAS) and the banking development index (BDI) have been found to have a negative impact on unemployment in Kenya. However, when bank development is proxied by the domestic credit to private sector by banks (DCP), its impact on unemployment was found to be statistically insignificant. Although these results were mixed depending on the proxy of bank development under consideration, they were time-invariant. These results were found to apply consistently in the long run and in the short run.

The results based on the four functions that have attested to the negative impact of bank development on unemployment are consistent with both theory and other empirical studies. The outcome was consistent with previous results obtained by Darrat, Abosedra, and Aly (2005), Gatti and Vaubourg (2009), Shabbir et al. (2012), Kanberoğlu (2014), and Epstein and Shapiro (2018), for developing and emerging economies. However, the outcome based on domestic credit to private sector by banks

TABLE 4 The Long-Run and Short-Run Results of the Selected Models

	Function	BDV = DCP	BDV = LLB	BDV = BDP	BDV = BAS	BDV = BDI
		(1)	(2)	(3)	(4)	(5)
Panel 1: Long-run coefficients; Dependent variable is UNE	DCP	−0.0017 (−0.1600)	–	–	–	–
	LLB	–	−0.0149* (−1.7759)	–	–	–
	BDP	–	–	−0.0368* (−1.8361)	–	–
	BAS	–	–	–	−0.1097** (−2.1195)	–
	BDI	–	–	–	–	−0.0128* (−1.9451)
	y	−0.0057* (−1.8524)	−0.0377* (−1.9461)	−0.0768* (−2.0403)	−0.0441* (−1.8382)	−0.0486** (−2.3986)
	FDI	0.0169 (0.7169)	0.0301 (1.4238)	0.0077 (0.2222)	0.0047 (0.1334)	0.0426 (1.5755)
	DIN	−0.0608** (−2.6949)	−0.0391** (−2.2764)	−0.0467* (−2.0249)	−0.0424* (−1.7824)	−0.0440* (−1.9478)
	HFC	−0.0807** (−2.7751)	−0.0463** (−2.1771)	−0.0690** (−2.7798)	−0.0729** (−2.8017)	−0.0612** (−2.4914)
	GNE	0.0911*** (3.0319)	0.0609** (2.8742)	0.0669** (2.7405)	0.0846*** (3.5103)	0.0727** (2.8970)
	INR	0.0183*** (3.6109)	0.0115** (2.9111)	0.0166*** (3.2926)	0.0181*** (3.3876)	0.0135** (2.9371)
	EXR	0.0031 (−0.5171)	0.0015 (0.7265)	0.0016 (0.5860)	0.0011 (0.3070)	0.0011 (0.3569)
	Constant	−0.5836 (−0.5171)	−0.4393** (−2.6061)	0.3141 (0.2860)	−0.7607* (−1.8436)	−0.3274* (−1.9298)

Continued on the next page

(DCP) as a proxy of bank development, though contrary to expectations, is not unusual (see Gatti and Vaubourg 2009; only in selected cases when credits provided by financial sector was used as a proxy of financial development). A possible explanation for it could be inefficient allocation of credit and use of credit for consumption purposes rather than on investment.

Further analysis of the results shows that despite the results being mixed depending on the proxy of bank development considered, the overall bank development, as proxied by the bank development index

TABLE 4 *Continued from the previous page*

	Function	BDV = DCP	BDV = LLB	BDV = BDP	BDV = BAS	BDV = BDI
		(1)	(2)	(3)	(4)	(5)
Panel II: Short-run coefficients; Dependent variable is ΔUNE	ΔDCP	0.9199 (0.1574)	–	–	–	–
	ΔLLB	–	−0.1177** (−2.3120)	–	–	–
	ΔBDP	–	–	−0.0149** (−2.2002)	–	–
	ΔBAS	–	–	–	−0.1045* (−1.8452)	–
	ΔBDI	–	–	–	–	−0.0256* (−1.9544)
	Δy	−0.0031* (−0.9831)	−0.0249** (−2.2887)	−0.0104* (−1.9434)	−0.0182* (−1.8176)	−0.0187* (−1.8872)
	ΔFDI	0.0091 (0.7368)	0.01560 (1.6429)	0.0035 (0.7790)	0.0056 (1.1604)	0.0040 (0.8591)
	ΔDIN	−0.0172* (−1.9360)	0.3036* (1.8955)	0.0159** (2.3161)	0.0118* (1.9962)	0.9732** (2.4076)
	ΔHFC	−0.0151 (−1.4481)	0.0016 (0.1811)	0.0044 (0.4729)	−0.0053 (−0.5386)	0.1850 (0.5700)
	ΔGNE	0.0171 (1.6600)	0.0044 (0.5322)	−0.0014 (−0.1532)	0.0096 (1.0860)	0.0050 (0.5700)
	ΔINR	0.0098*** (3.0206)	0.0060** (2.2704)	0.0067** (2.1429)	0.0084** (2.4997)	0.0059** (2.1336)
	ΔEXR	0.0017 (0.0842)	0.7573 (0.7436)	0.1070 (0.0059)	0.4922 (0.3048)	0.4690 (0.3580)
	ECM (−1)	−0.5386*** (−3.0235)	−0.5179*** (−3.7330)	−0.4043*** (−0.9714)	−0.4632*** (−3.3003)	−0.4383*** (−3.2780)

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(BDI) has shown that in general, the banking sector in Kenya is important in reducing unemployment, since the coefficient of BDI, which is built from four banking development indicators, has been found to be consistently negative and statistically significant.

The analysis of the results further reveals that as expected, economic growth (y), domestic investment (DIN) and household final consumption (HFC) have a negative and statistically significant impact on unemployment in Kenya, irrespective of the bank development proxy under consideration. While these results applied both in the long run and the short

TABLE 4 *Continued from the previous page*

Function	BDV = DCP	BDV = LLB	BDV = BDP	BDV = BAS	BDV = BDI
	(1)	(2)	(3)	(4)	(5)
R-Squared	0.7654	0.7843	0.8291	0.7724	0.7593
R-Bar-Squared	0.6177	0.6839	0.6154	0.6272	0.5968
SE of Regression	0.0497	0.0363	0.0349	0.0387	0.0383
F-Stat [prob]	4.5683 [0.003]	5.6545 [0.001]	6.4663 [0.000]	4.9005 [0.002]	4.9214 [0.002]
Res Sum of Sq.	0.0271	0.0184	0.0146	0.0194	0.0250
AIC	40.0443	48.8486	50.1072	47.0967	47.3475
SBC	31.3850	39.5232	39.4496	37.1052	38.0221
DW statistic	1.9627	1.9776	2.3180	2.1321	2.0063

NOTES Optimal ARDL model: (1) ARDL(1,0,0,0,1,1,1,0,0), (2) ARDL(1,0,1,0,1,1,1,0,0), (3) ARDL(1,0,1,1,1,1,1,0,1), (4) ARDL(1,0,1,1,1,1,1,0,0), (5) ARDL(1,0,1,0,1,1,1,0,0). *, ** and *** denote 10%, 5% and 1% significant levels, respectively; Δ = first-difference operator.

run for economic growth and domestic investment, they only applied in the long run for household final consumption.

Whereas gross national expenditure (GNE) is statistically insignificant in the short run, across all the proxies of bank development, it was found to be surprisingly positive and statistically significant in the long run across all the unemployment functions, irrespective of the bank development measure utilised. Though unexpected, it is not impossible as this outcome may be a reflection of the quality of spending – i.e. more on non-durable goods consumption – which may not be optimal or desirable for investment promotion and employment creation.

Another variable that this study has found to be worsening unemployment challenges in Kenya is the interest rate (INT), which was found to have a positive impact on unemployment irrespective of whether the estimation was in the long run or in the short run and irrespective of the measure of bank development under consideration. In the meantime, the coefficients of foreign direct investment (FDI) and exchange rate (EXR) were found to be statistically insignificant across both the time horizons and across all proxies of bank development.

The short-run results also attest to the cointegration results that confirmed the existence of a long-run stable relationship among the variables in all the unemployment functions – as evidenced by the coefficient of the error correction term [ECM (–1)] that is negative and statistically signif-

TABLE 5 Results of Diagnostic Tests

LM Test Statistic	Statistic [Probability]				
	BDV = DCP	BDV = LLB	BDV = BDP	BDV = BAS	BDV = BDI
Serial Correlation: CHSQ(1)	0.0153 [0.902]	0.0041 [0.949]	2.7244 [0.154]	0.6261 [0.429]	0.0352 [0.851]
Functional Form: CHSQ(1)	0.8374 [0.316]	2.7058 [0.100]	0.0041 [0.949]	0.0459 [0.874]	0.4484 [0.435]
Normality: CHSQ (2)	1.4098 [0.494]	0.0240 [0.988]	0.7523 [0.687]	0.3781 [0.828]	0.4342 [0.805]
Heteroscedasticity: CHSQ (1)	1.5607 [0.212]	0.2288 [0.632]	0.4881 [0.485]	0.0043 [0.947]	0.0562 [0.813]

icant at the 1% level, irrespective of the measure of bank development. The regression for the underlying ARDL model also fits well across the five functions, as confirmed by *R*-squared of at least 76%.

To check the robustness and the reliability of the results obtained in this study, diagnostic tests were performed on serial correlation, functional form, normality and heteroscedasticity. As reflected in table 5, the results of the diagnostic tests performed reveal that the model passes all the diagnostic tests, regardless of the measure of bank development used.

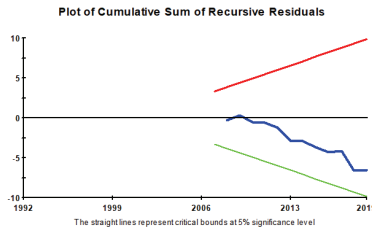
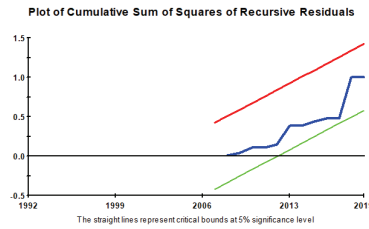
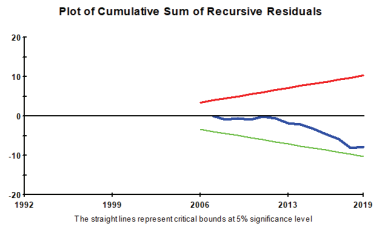
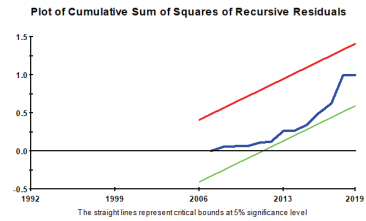
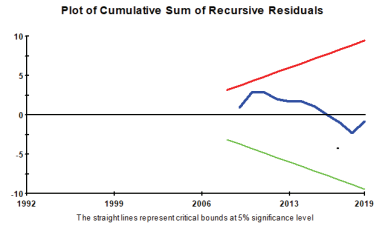
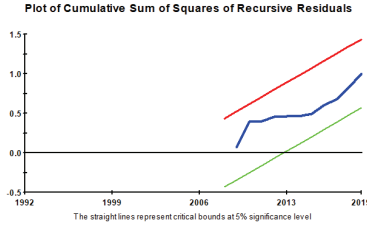
The stability of the model over the study period is also confirmed by the Cumulative Sum of Recursive Residuals (CUSUM) and the Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ) graphs of the estimated model, that are within the critical lower and the upper bounds at the 5% significance level, irrespective of the proxy of bank development used. These graphs are displayed in table 6.

Conclusion

The paper has examined the impact of bank development on unemployment in Kenya using time-series data spanning from 1991 to 2019. The study was motivated by the current insufficient coverage of the finance-unemployment nexus in general, and in Kenya in particular. Kenya makes an interesting case study as it has both a well developing financial sector on the one hand and low levels of unemployment on the other. It has become imperative to establish if both these desirable trends are empirically linked in order to guide policy in an informed manner. The study also aims to add value to the finance-unemployment literature by using a range of bank development proxies.

Using the ARDL bounds testing approach, the results of the study have

TABLE 6 Plot of CUSUM and CUSUMQ

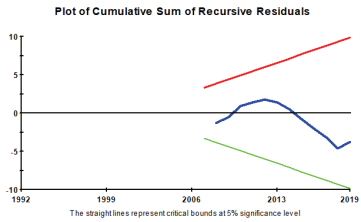
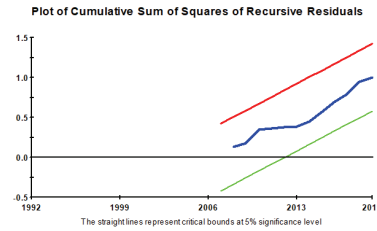
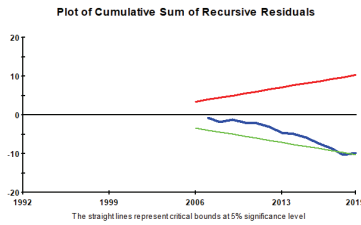
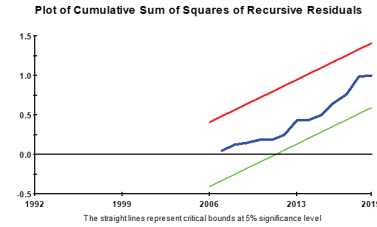
	CUSUM	CUSUMQ
BDV = DCP		
BDV = LLB		
BDV = BDP		

Continued on the next page

revealed that, in Kenya, the impact of bank development on unemployment is proxy-dependent. As expected, bank development as proxied by liquid liabilities (LLB), bank deposits (BDP), deposit money bank assets (BAS) and the banking development index (BDI) has been found to have a negative impact on unemployment in Kenya. However, when bank development is proxied by domestic credit to private sector by banks (DCP), its impact on unemployment was found to be statistically insignificant. Although these results were mixed depending on the proxy of bank development under consideration, they were time-invariant – as they were found to apply consistently in the long run and in the short run.

Despite being proxy dependent, the results have shown that, in the main, bank development is good for reducing unemployment in Kenya, regardless of the time horizon considered. The Kenyan policy makers in

TABLE 6 *Continued from the previous page*

	CUSUM	CUSUMQ
BDV = BAS		
BDV = BDI		

the macroeconomic space are, therefore, recommended to consider developing the banking sector in an effort to influence unemployment levels in the country. They may need to find strategies of increasing credit efficiency in the economy.

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The Introduction of an EU Unemployment Reinsurance System: Income Protection and Maintenance of Consumption

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The paper deals with the suitability of the introduction of unemployment reinsurance in the countries of the European Union (URS EU) in terms of maintaining the level of consumption of the unemployed and promoting economic efficiency. Based on the literature review, the analysis of the US reinsurance system and the analysis of existing unemployment insurance in the EU, a model of the reinsurance system for unemployment in the EU is developed. The model simulation, based on the data of existing EU-20 unemployment insurance systems in the period 2003–2019, is used to determine the amount of reinsurance payments to countries and the level of contributions needed, while employing various ways of defining payment triggers. We have demonstrated that the URS EU would contribute to better income protection by having a direct impact on the income of the unemployed and at the same time acting as an automatic stabilizer of the economy.

Key Words: recession, unemployment, insurance, reinsurance, European Union, model simulation, consumption, automatic stabilizer
JEL Classification: J64, E24, E63
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Introduction

In this paper, we examine the potential suitability of unemployment reinsurance in EU countries in terms of income protection and maintenance of consumption. We address the research problem in view of the needs and capabilities of establishing a reinsurance system, as well as explore possible advantages and disadvantages of introducing the unemployment reinsurance system in the EU.

We have explored the possibilities for establishing URS EU. Such a system would complement public unemployment insurance schemes and

help increase their efficiency. Public systems contribute to the protection of income and thus to the maintenance of the level of consumption of the unemployed, and they also act as automatic stabilizers at the aggregate level. In times of recession, a reinsurance system would contribute additional financial means to the state systems and consequently strengthen their effects and eliminate their shortcomings, since this is the time when they most often face deficits and thus the inability to increase unemployment benefits (Dullien 2013).

In the research, we designed and presented the basic principles of such a URS EU model and, based on a historical data model simulation (2003–2019), tried to identify the benefits that the introduction of the URS EU would bring. In the section Results and Discussion, we present the two above-mentioned aspects: (1) URS EU and protection of the income of the unemployed, and (2) URS EU as an automatic stabilizer. The final section is the conclusion, with policy implications.

The designed model is set in such a way that, at the European level, countries pay contributions during the boom period. The collected contributions are intended for countries in recession and are paid in the form of additional aid to extend the period of receiving unemployment benefits. The methodology for calculating the expenditure and benefits of the EU reinsurance system in the case of unemployment in the EU is presented in section Structure and operation of the URS EU model – methodology.

Literature Review

The EU is the culmination of a long process of economic and political integration between European countries. It started as a free trade and customs union area. Over time, it has become a supranational entity that resembles a federal state (Tupy 2016). The US represents a successful example of a federation of states, from which the EU is still very different. The main weaknesses of the latter are the following (Dickson and Eleftheriadis 2012):

1. Not all policies are effective – a good example being the common agricultural policy, which has led to oversupply and higher commodity prices.
2. The 'single currency' poses a major problem – not all member states use the euro, although the EU emphasizes its use. In addition, Kovač (2017) believes that the EU is not an optimal monetary

area, as labour mobility is insufficient, interest rates have national mark-ups, and structural reforms and policies are divergent. He further concludes that we have European money and national political sovereignty, monetary centralization and fiscal decentralization. Therefore, the euro brings benefits but does not address political risks.

3. Difficulties in regulating immigration – citizens of member states are free to move from one country to another, leading to overcrowding in larger countries, and this has led to congestion on the roads and rising real estate prices, both commercial and residential. Immigration problems have been further exacerbated by the refugee crisis.
4. Unclear external representation and visibility – when the rest of the world wants to know what the EU's views are, it is still not clear who to ask and whether the individual is actually representing the EU, or their own country.

One of the biggest challenges for the EU and the euro area is to further promote structural reforms for economic convergence. At the same time, the EU should seriously consider introducing a fiscal union. This should mean that the EU budget has to be larger than it is today. After all, the main feature of any fiscal union is the ability to spend and consequently influence economic performance. Given that business cycles are not uniform in the case of the euro area, such a move will be an important step in the right direction. It is important to note that the EU budget today is around one percent of gross domestic product (GDP) – in the US, the federal budget revolves around 37 percent of GDP (Schelkle 2017). The EU is a diverse region in terms of geography, political systems, national support and economic foundations. Northern Europe is richer in capital and technologically and administratively more advanced compared to the peripheral countries in the south. Countries in the north would want a stronger currency, while countries in the south would want a weaker currency to be more competitive abroad. This diversity of the EU impedes the efforts for political and fiscal union.

An EU reinsurance system in the case of unemployment would operate on insurance principles (such as accident and car insurance, and real estate insurance). Everyone involved in the reinsurance system (EU 27) would raise funds, which would, should need occur, be paid out to countries in difficulty. To determine a country in difficulty, the so-called trig-

gers should be identified, namely measurable values making the country eligible for aid. It should also be determined how much assistance a country is entitled to and how the money borrowed should be paid back. These parameters were determined in the simulation so that the unemployment reinsurance system should be sustainable and maintain the same share of coverage (share of the total number of short-term unemployed who actually receive unemployment benefits) during the recession (from 2009 onwards) as before the recession (until 2008).

The URS EU – as a form of assistance to the state unemployment insurance – would cover expenditure related to rising unemployment. This would leave more money in state budgets for stabilization of state economies in recession. Buti et al. (2002), Dullien (2012; 2017), Epaulard (2014), and the European Commission (Evropska komisija 2014) note that it would be appropriate to introduce an unemployment reinsurance system in the EU as well. During the period of recession, the EU members did not use fiscal policy to mitigate it (Coenen, Straub, and Trabandt 2012); the unemployment reinsurance system would achieve just that, as it acts as an automatic stabilizer. We believe that the need for an automatic stabilizer, such as unemployment reinsurance, has recently become even more apparent because of the recession. Existing unemployment insurances fail in bad times because they do not have enough stock accumulated to pay benefits. The reasons are mainly the following: (i) several recipients; (ii) lower percentage of covered unemployment period – the length of unemployment increases, but only a small part is covered; and (iii) large losses are generated.

An EU unemployment reinsurance system would act as an automatic stabilizer, as it should help to reduce the inflation gap in a time of recession. The inflation gap is the distance between the current level of real GDP and the level of GDP at full and long-term equilibrium employment. The inflation gap is so called because an increase in the consumption of the economy leads to an increase in real GDP, and this has a long-term impact on price increase (Cogley, Primiceri, and Sargent 2010; Abazi-Alili et al. 2018; Jara Tamayo and Tumino 2021). An unemployment reinsurance system would help to protect the income and thus maintain the level of consumption of the unemployed, thereby helping countries in recession, as the system would contribute to the financing of unemployment benefits during a period of sudden and deep recession. In periods of weak economic activity, the benefits of the unemployment reinsurance system decrease, as the number of employed and thus the amount of contribu-

tions paid decrease. On the other hand, expenditure increases without the need to introduce a new government measure. In contrast, in the case of increased economic activity, expenditure decreases and benefits increase (Dullien 2012; Moyen, Stähler, and Winkler 2019). As economic activity increases, the unemployment reinsurance system expenditure (e.g. the amount and number of recipients of benefits, the period of receiving the benefits) automatically decreases, while benefits increase. Such movement helps to stabilize economic activity in the future. In the US, such a system has been in place for a long time and works well in times of recession, acting as an automatic stabilizer (Chimerine, Black, and Coffey 1999; Asdrubali, Sorensen, and Yosha 1996; US Department of Labor 2012; O'Leary, Barnow, and Lenaerts 2020).

The unemployment reinsurance system in the USA can therefore serve as a model for Europe. In his study, Vroman (2010) examined the role of the unemployment reinsurance system as an automatic stabilizer during the US recession between 2008 and 2010 and concluded that the stabilizing effect in a regular unemployment insurance programme reduces inflation gaps caused by the recession by about one tenth. Extending the compensation period has contributed to stabilization; unemployment insurance contributions increased in 2009 and 2010. For the three separate components of the unemployment reinsurance system (regular programme, extension of the benefit period and contributions) between 2008 and 2010, Vroman (2010) came to the following conclusions: (i) increased regular benefits reduced the inflation gap by 10.5 percent; (ii) the extended compensation period reduced the inflation gap by 8.5 percent; and (iii) increased contributions led to an increase in the inflation gap by 0.7 percent. On average, the reinsurance programme in case of unemployment decreased the inflation gap caused by the recession by 18.3 percent, which certainly contributes to a more stable and competitive economy.

The main dilemmas of the URS EU model can be summarized in three points, namely: (i) what is the relation to the existing unemployment insurance schemes in each country; (ii) to what extent, or to no extent, should redistribution be allowed by the URS EU; and (iii) should the URS EU be led by the already existing bureaucracy of national unemployment insurance schemes. In the continuation of the research, we examined several possibilities and also addressed the aforementioned dilemmas.

The main original contribution to science in the study of the unemployment reinsurance system is the development of a model that simu-

lated the operation of the unemployment reinsurance system at the EU level in the period 2003–2019. The study is comprehensive: based on study of the literature, analysis of the current reinsurance system in the US, and analysis of existing unemployment insurance in the EU, we designed a model of the unemployment reinsurance system in the EU. We researched the unemployment rate, the number of recipients of benefits, the costs of unemployment benefits and the wage bill, and simulated the difference between the collected unemployment insurance contributions and the benefits paid. The simulation shows in which countries the unemployment insurance is set appropriately, what was the balance between the collected unemployment insurance contributions and the benefits paid in the EU-20 in individual years and what was the cumulative difference in the period under review (2003–2019). The importance of the subject of EU unemployment reinsurance is evident, as the European Commission has already published calls for proposals on common EU unemployment insurance in the past (European Commission 2020; n.d.; European Parliament 2020).

Based on the analysis of unemployment insurance systems, we determined, in an original way, the levels of triggers that determine when and to what extent a country would be entitled to funds from the unemployment reinsurance system. Through model simulation, we found that the URS EU would contribute to improving the availability and financing of unemployment reinsurance in the EU (protection of the income of the unemployed) and thus to maintaining the level of consumption of the unemployed, which would help reduce the inflation and output gap.

Conceptual Framework

At a time of recession, the labour market faces an increased unemployment rate. Typical situations in which the unemployment reinsurance system plays an important role are wars, recessions, political interventions such as the oil embargo, and the collapse or closure of large industries (US National Commission on Unemployment Compensation 1979). Unemployment reinsurance is generally considered to be useful in protecting against cyclical unemployment – cyclical unemployment is low in times of boom and high in times of recession. The US National Commission on Unemployment Compensation (1979) explains, taking the US as an example, that in reinsurance, the average unemployment is determined according to the situation in each state, regardless of other members. If the ratio between unemployment benefits and expenditure in a

given year rises above the average rate, the individual state becomes eligible for cash from the common system. The average unemployment rate of an individual state can be calculated in different ways (e.g. as the average of recent years or as the lowest rate in a given period). Financial resources from the common fund may be sufficient to cover a part or the entire excess unemployment rate.

By simulating and evaluating the operation of the model that we used for simulating the operation of the URS EU, we confirmed that the heterogeneity of EU countries, the different dynamics of economic growth and unemployment, make setting of the URS EU possible. By simulating the operation of the URS EU, we demonstrated and determined the extent to which the URS EU would contribute to better income protection and at the same time to the stabilization of the economy. However, based on a review of the literature, we found that in the US, the reinsurance system in the case of unemployment affects the development of risky industries.

Based on the collected data, we designed a model to examine in which countries equilibrium unemployment insurance is set (statutory unemployment insurance contribution rate and equilibrium unemployment insurance contribution rate are equal), what was the balance between the collected unemployment insurance contributions for the benefits paid in the EU-20 in individual years, and what was the cumulative difference in the period under review (2003–2019). Due to the specifics of the insurance system, seven countries were excluded from the model (Greece, Ireland, Lithuania, Luxembourg, Malta, Romania, and the United Kingdom). The model was simulated for the EU-20. We determined how much funds each country would allocate to the reinsurance system fund, and we also determined the levels of triggers and the eligible amount of aid. Schematic representation of the model (figure 1) shows the cash flow of the URS EU with basic elements such as triggers, contributions, and coverage period.

In the following sections, we present the importance of the basic elements and the justification for determining individual values and the method of calculation in greater detail.

Research Methodology: Model Simulation of Reinsurance in Case of Unemployment in the EU

In designing the URS EU model, we relied on research already conducted (Beblavý and Maselli 2014; Dolls et al. 2014; Dullien 2007; 2013) and the

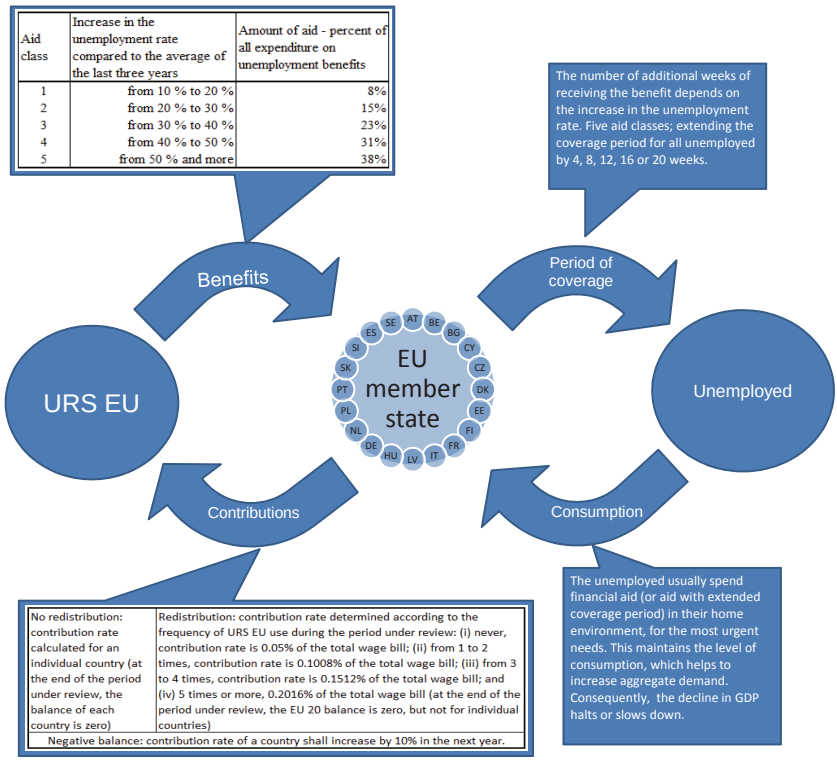

FIGURE 1 URS EU Cash Flow

US Unemployment reinsurance system. All research has a common purpose, namely, to examine the possibility of operating joint reinsurance in the case of unemployment at the EU level as an automatic stabilizer, and to increase efficiency and maintain the level of consumption of the unemployed. The idea of extending the period of receiving benefits in a period of economic recession with automatic triggers makes special sense, just as the US unemployment reinsurance system is set. Based on the research results, we determined the levels of triggers in an original way – when an individual country should be eligible for funds from the reinsurance system in the case of unemployment and to what extent. The results obtained also showed that the URS EU would contribute to improving the availability and financing of unemployment reinsurance in the EU (protection of the income of the unemployed) and thus to maintaining the level of consumption of the unemployed, which would help reduce the inflation and output gap.

The URS EU model exploits the financial and economic heterogeneity of countries and its implementation, especially in times of crisis, could contribute to maintaining consumption levels and thus to economic stabilization both in individual EU countries and in the EU as a whole. At the level of individual countries, it is very difficult to ensure balance between the payment of unemployment benefits and the collected unemployment insurance contributions during the economic crisis. The URS EU could use the heterogeneity of EU countries, reflected in different dynamics of economic growth and the unemployment rate, which would allow money to flow at the European level and thus provide help at the right time and in the right place. Namely, the state can get the right to aid at a time of recession and repay the debt at a time of boom.

The basic elements of the URS EU model are the expenditure (amount of aid to individual countries and period of receipt) and receipts (contributions of individual countries). Expenditures were determined based on the US Unemployment reinsurance system, which has been used in the US since 1935 and is proving to be an effective mechanism for maintaining stability in the US federal states. The amount of aid for each country in our URS EU model was determined to cover the total additional expenditure of an individual country in the period under review, which is a prerequisite for the sustainability of the system. The individual country begins to receive aid from the URS EU according to the level of the unemployment rate (trigger). As the unemployment rate of EU countries varies considerably, we determined five grades of the amount of aid to ensure fairness and political acceptability.

The amount and time/period of URS EU aid to an individual EU country is modelled based on the US unemployment reinsurance system, which means that the maximum aid covers the costs of an individual federal state for up to 20 additional weeks of receiving unemployment benefits for all unemployed. Based on historical data for the EU-20 in the period 2003–2019, we have calculated a potential total URS EU expenditure. We determined, in terms of the URS EU, how much money would be additionally earmarked for the unemployed (in each of the EU-20 countries and in every year during the period under review) in the event of an above-average unemployment rate increase.

Countries in which the unemployment rate has risen above average, compared to the average of the last three years, are eligible to drawing funds from the URS EU. The model we designed comprises five aid grades. The amount of aid depends on the increase in the unemployment

TABLE 1 Aid Grades

Aid grade	Increase in the unemp. rate compared to the average of the last three years	Amount of aid – percent of all expenditure on unemployment benefits
1	from 10 to 20%	8
2	from 20 to 30%	15
3	from 30 to 40%	23
4	from 40 to 50%	31
5	from 50% and more	38

rate. The calculation of the aid amount is based on the expenditure for extending the aid for up to 20 additional weeks, and consequently the amount of the aid affects the number of additional weeks of receiving the benefit. The equilibrium contribution rate for unemployment reinsurance varies from country to country. We calculated it so that in the period under review, the difference between the payment of unemployment benefits and the collected unemployment insurance contributions equals zero.

The expected long-term net receipts in the unemployment reinsurance system equal zero. By using the simulation, we determined the optimal or equilibrium contribution rate of the URS EU. With the URS EU, countries would be, under certain conditions, eligible for additional aid (table 1). We examined and determined how to cover these additional expenses. For countries that borrow money from the URS EU, we have set new (increased) contribution rates for unemployment insurance. In order to avoid permanent transfers from the system, we calculated the amount of contributions (cumulative contributions) and the amount of aid received (cumulative aid received). If the balance of these sums is negative, the contribution rate of a country shall increase by ten percent in the next year. The contribution rate shall annually increase by ten percent until the country balance is zero or positive. The current reinsurance system in the US works in a similar way (US Department of Labor 2015).

MEASUREMENT OF IMPACTS OF THE MODEL

If redistribution between countries were allowed, the effect of stabilization could be greater. In the simulations, we focused on the alternative with no redistribution, as it ensures greater political acceptability of the URS EU model. The calculated equilibrium contribution rates assume that the balance of an individual country is zero during the period un-

der review. In one of the models, we also simulated the operation of the URS EU, in which countries have three different contribution rates depending on the frequency of use of the system, according to the principle that in countries that use the system more often, the contribution rate is higher. If during the period under review they were eligible for aid up to (i) twice, the contribution rate is 0.1008 percent of the total wage bill; (ii) three to four times, the contribution rate is 0.1512 percent of the total wage bill; and (iii) five times or more, 0.2016 percent of the total wage bill. In order to avoid a permanently negative monetary position in the post-recession system, a single contribution rate has been set in order to balance the fund at the level of the EU-20 (e.g. for the last five years or for the entire period under review, the balance is zero). In setting up such a system, we would probably encounter resistance from more prosperous and stable countries, which would use the URS EU less frequently, so in simulations we focused on the URS EU model where we do not allow redistribution. Redistribution would be interesting and acceptable if we could prove its positive effects for net contributor countries, but we did not include this issue in the research.

We calculated the stabilizing power for each country separately, namely how aid received from the unemployment reinsurance system affects the GDP. The method of calculating the stabilizing power of the model was summarized according to the Dullien (2013) method, which defines stabilizing power as the ratio between the change in reinsurance contributions or payments in the EU in case of unemployment (as a percentage of GDP) and the change in the output gap. In addition, the stabilizing power was calculated according to the method of Beblavý and Maselli (2014) – see also Mitmana and Rabinovich (2015), according to which stabilization is calculated as the change in the balance as a percentage of GDP multiplied by a multiplier. The URS EU assumes that the additional aid received by the unemployed is used mainly for the most urgent needs and thus immediately returns to the economy, thereby increasing consumption, which has the effect of increasing GDP and reducing the output gap.

STRUCTURE AND OPERATION OF THE URS EU MODEL: METHODOLOGY

In the model designed, we simulated the operation of URS EU (with redistribution and with no redistribution), by taking into account the version of the equilibrium contribution rates of individual countries. We also calculated a uniform equilibrium contribution rate at the URS EU level

and an equilibrium contribution rate at the level of an individual country, but only for comparison with the actual (statutory) contribution rate in individual countries. Thus, we determined which countries should increase the legally determined rate in the case of a uniform equilibrium rate, and which could lower it.

With the designed model, we simulated several possible variants with different variables. In all cases, we studied the period between 2003 and 2019 in 20 European countries (Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Italy, Latvia, Hungary, Germany, The Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, and Sweden).

Prior to the implementation of the simulation, we determined the amount of assistance from the URS EU to each country, so that the maximum aid should cover the average state costs of 20 weeks of receiving unemployment benefits for the period 2003–2019. In the following, a comprehensive simulation of the most efficient version of the URS EU, which does not allow for redistribution, is presented, and consequently the URS EU contributions are set in a way that the balance of each country at the end of the period under review should be zero. Also in the simulation which does not allow redistribution, due to the solidarity of countries (in our case it is Germany) which do not benefit from the URS EU in the period under review (2003–2019), a contribution rate amounts to 0.002 percent, which is approximately half of the lowest calculated contribution rate; we can say that 'minimal' redistribution is enabled. Based on the country data, we calculated the average unemployment rate of the last three years (thus avoiding a sudden increase or decrease):

$$\mathrm{AUR}_t = \frac{\mathrm{UR}_{t-1} + \mathrm{UR}_{t-2} + \mathrm{UR}_{t-3}}{3}, \tag{1}$$

where AUR is the average unemployment rate of the last three years, UR the unemployment rate, and t the year.

The average unemployment rate thus obtained was compared to the unemployment rate in the current year, as a difference in percentages (trigger). Given the amount of difference between the average unemployment rate and the unemployment rate in the current year, we determined the amount of benefit that the state receives for the payment of unemployment benefits (URS EU expenditure). Thus, we calculated in which year a specific country should receive aid. On the other hand, there are contributions (URS EU funds) where the equilibrium contribution rate is

set so that the balance is zero during the period under review. When the difference between the sum of contributions (cumulative contributions) and the sum of aid received (cumulative aid received) in a given year is negative, the state contribution rate is increased by ten percent in the following year. The contribution rate is increased by ten percent annually until the country balance is zero or positive. Therefore, the contribution rate of each country is determined as follows:

$$\sum_{2003}^{2019}(\text{URS EU funds}_i - \text{URS EU expenditure}_i) = 0. \tag{2}$$

Country balance i in year t is greater than or equal to zero:

$$\text{Contribution rate}_{i,t} = \frac{\text{URS EU expenditure}_{i,t}}{\text{total wage bill}_{i,t}}. \tag{3}$$

Country balance i in year t is negative:

$$\text{Contribution rate}_{i,t} = \frac{\text{URS EU expenditure}_{i,t}}{\text{total wage bill}_{i,t}} \times 1,1. \tag{4}$$

The calculated contribution rate varies greatly from country to country, as certain countries would be less likely to use URS EU aid during the period under review and have a lower contribution rate as well (table 2). The lowest calculated contribution rate is in Poland and the highest in Spain.

Results and Discussion

According to the model presented, we have performed a simulation of the operation of the reinsurance system in the case of unemployment in the EU-20. We used MS Excel and secondary data from the databases of the European Commission, i.e. Mutual Information System on Social Protection (MISSOC n.d.), and Eurostat (n.d.), the International Labour Organization (n.d.) and OECD (2015a; 2015b).

The model simulation is based on the described URS EU model with no redistribution (the balance of each country is zero at the end of the period under review, and the contribution rates vary from country to country). The simulation was performed for various extensions of the benefit period: for 4, 8, 12, 16 or 20 weeks (the maximum duration of additional aid is 20 weeks). In the following, we present the results of the research and model simulation. The results of the research are presented from two aspects: protection of the income of the unemployed and automatic stabilizer.

TABLE 2 Equilibrium Contribution Rates Used in the URS EU Model (in Percent)

County	Contribution rate	County	Contribution rate
Austria	0.031	Latvia	0.054
Belgium	0.011	Hungary	0.038
Bulgaria	0.040	Germany	0.002
Cyprus	0.156	Netherlands	0.075
Czech Republic	0.010	Poland	0.004
Denmark	0.070	Portugal	0.099
Estonia	0.073	Slovakia	0.006
Finland	0.042	Slovenia	0.041
France	0.029	Spain	0.303
Italy	0.102	Sweden	0.017

NOTES In percent. Germany did not receive any URS EU aid during the period under review, so the calculated contribution rate is zero; for the sake of solidarity, we have determined that countries that do not use the URS EU have a contribution rate of 0.002 percent, which is approximately half of the lowest calculated contribution rate. In addition to solidarity and strengthening of the EU as a federation, the potential effects for net contributor countries (Germany) may be, for example: maintaining exports in times of crisis and maintaining investors.

URS EU AND PROTECTION OF THE INCOME OF THE UNEMPLOYED

An EU unemployment reinsurance system would contribute to better income protection by directly affecting the income of the unemployed. The aid granted as a possible extension of the benefit was calculated on the basis of the difference between the aid received and the contributions paid by each country (table 3; bold indicates the years and countries when the assistance of the URS EU is higher than the contributions). Most countries received the most assistance from the URS EU between 2009 and 2010, with the exception of Germany, which never received URS EU assistance during the period under review, which can be attributed to the persistently low unemployment rate.

The URS EU model is set up in such a way that countries use the aid received to extend the period of receiving unemployment benefits. Prolonging the receipt of benefits has an impact on better income protection, as it directly affects the income of the unemployed. The amount of the aid may extend the period for receiving the benefit by 4, 8, 12, 16 or 20 weeks, depending on the increase in the unemployment rate. According to the URS EU model, the maximum aid is set to cover the extension of the un-

TABLE 3 Difference between Transfers and Contributions Paid to the URS EU (in EUR million)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	−65.8	−65.7	−70.1	−74.0	−77.9	−82.3	**192.9**	−85.4	−88.0	−91.3	**214.8**	**236.7**	−108.6	−123.0	−137.0	−110.0	−113.7
Belgium	−29.8	−31.1	−32.3	−33.6	−35.4	−37.2	−37.2	**380.2**	−43.8	−49.2	−54.4	−59.6	−64.2	−69.7	−75.8	−83.5	−49.2
Bulgaria	−5.2	−5.8	−6.4	−7.5	−9.3	−12.2	−13.2	**24.2**	**24.0**	**13.8**	−2.5	−18.3	−18.0	−18.9	−20.7	−24.8	−25.3
Cyprus	−15.6	−16.3	−17.5	−19.0	−20.8	−22.3	−5.3	**3.7**	**14.1**	**38.1**	**53.5**	**0.1**	−26.0	−28.2	−31.6	−36.2	−41.0
Czech Rep.	−8.8	−9.5	−10.0	−10.7	−11.6	−12.3	**34.1**	**71.8**	−14.0	−15.6	−17.1	−18.8	−20.9	−23.4	−26.6	−17.6	−18.7
Denmark	−149.2	−156.7	−162.1	−171.9	−176.7	−183.8	**697.5**	**583.3**	**284.5**	−229.5	−251.4	−278.0	−308.5	−340.6	−369.5	−400.7	−436.2
Estonia	−5.7	−6.5	−7.3	−8.8	−11.2	−12.2	**62.8**	**36.3**	−13.6	−15.8	−18.1	−20.6	−23.3	−26.2	−17.2	−19.2	−21.1
Finland	−42.4	−43.6	−45.3	−47.6	−50.1	−53.0	**142.9**	**150.0**	−61.7	−58.0	−58.2	−58.5	**252.9**	−65.6	−72.5	−81.2	−90.5
France	−304.1	−315.2	−330.1	−343.5	−357.8	−371.7	**2419.1**	**2540.9**	−470.1	−518.9	−567.4	−622.8	−676.6	−730.4	−791.7	−857.3	−921.4
Italy	−1090.9	−1156.3	−1196.0	−1254.2	−1289.1	−1339.6	**175.5**	**272.1**	−1362.8	**2344.5**	**2390.7**	**543.1**	−1381.6	−1410.5	−1430.3	−1458.3	−1483.9
Latvia	−5.4	−6.3	−8.1	−10.4	−14.6	−17.0	**60.4**	**26.9**	−13.0	−15.3	−17.6	−14.8	−16.1	−17.2	−18.4	−20.0	−21.8
Hungary	−15.4	−17.2	−18.7	**4.4**	−20.8	−22.0	**75.9**	**85.4**	**25.6**	−28.7	−31.9	−35.8	−40.0	−44.6	−51.8	−60.4	−38.5
Germany	−53.1	−52.9	−55.0	−56.9	−59.0	−61.3	−61.2	−63.2	−65.6	−67.9	−70.1	−72.4	−75.0	−78.6	−81.3	−84.0	−87.1
Netherlands	−839.7	−860.0	−877.0	−914.7	−969.2	−1009.9	−1034.3	−322.0	−357.7	−248.8	**883.7**	−53.6	−1086.7	−1111.2	−1138.7	−1175.7	−1221.3
Poland	−7.8	−8.0	−8.4	−8.9	−9.8	−11.1	−11.5	**50.8**	**44.3**	−14.0	−15.5	−17.3	−19.1	−21.3	−15.5	−17.0	−18.4
Portugal	−138.7	−141.6	−145.3	−14.4	−154.2	−159.0	−2.1	**183.3**	**170.8**	**256.6**	**67.8**	−158.2	−175.4	−193.3	−157.4	−164.7	−168.7
Slovakia	−2.2	−2.3	−2.6	−3.0	−3.3	−3.6	−3.6	**20.7**	**9.2**	−4.3	−4.8	−5.4	−6.1	−4.7	−5.0	−5.3	−5.7
Slovenia	−10.8	−12.3	−13.1	−14.0	−15.2	−16.6	**1.2**	**40.9**	**34.7**	**7.3**	**5.2**	−19.7	−21.9	−24.3	−27.7	−31.4	−35.2
Spain	−2231.1	−2358.2	−2606.6	−2787.9	−3008.1	−158.0	**6321.4**	**4397.4**	**1610.4**	**2009.6**	−823.0	−3478.5	−3902.3	−4310.7	−4735.2	−5199.3	−3423.8
Sweden	−38.2	−39.3	−41.0	−43.2	−46.4	−49.1	**362.2**	**159.3**	−63.2	−70.6	−78.1	−86.2	−95.1	−105.0	−115.8	−127.5	−139.6

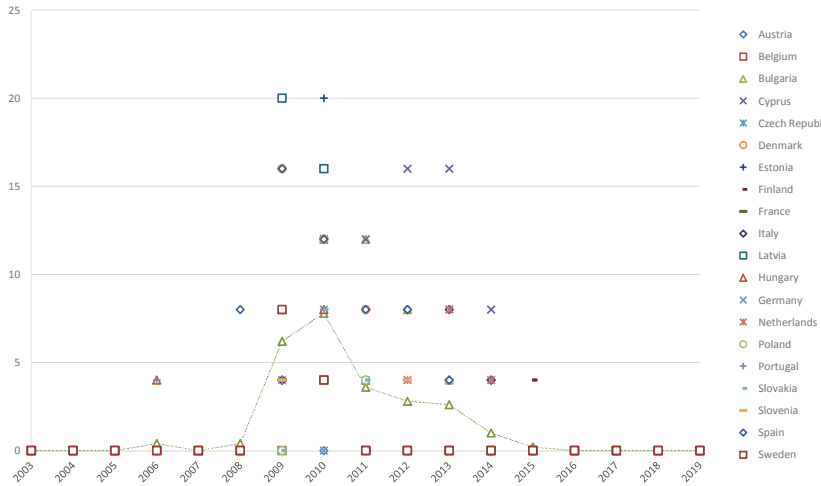

FIGURE 2 Aid Granted as a Possible Extension of Benefits (in weeks)

employment benefit of all unemployed persons in the current year for a maximum of 20 weeks (table 4 and figure 2). Due to the economic boom in all EU-20 countries, the URS EU was not activated in 2003–2005 and 2007, so the values in the table are zero in those years.

In times of recession, unemployment rises and GDP falls. Unemployment benefits (or extending coverage/benefit period), which the unemployed usually spend in the home environment, for basic needs, maintains the level of consumption, which contributes to an increase in unemployment benefits and thus to an increase in aggregate demand, which leads to a halt or a slow-down of further redundancies and GDP reduction. Using the URS EU model, we had calculated how extending the compensation period would affect GDP, which is presented below.

URS EU AS AN AUTOMATIC STABILIZER

The role of macroeconomic and structural policies is important in the recovery of the labour market. The unemployment rate in the OECD has approached pre-crisis levels (2008–2009), but the unemployment costs of the great recession have nevertheless been very high and long-lasting in many countries. In addition, as the recovery in production has been weak relative to the recovery in employment, labour productivity and wage growth remain low. Labour market resilience depends on macroeconomic policy and labour market settings. Macroeconomic policy is effective in limiting employment decline in times of slower economic

TABLE 4 Aid Granted, Expressed as an Extension of the Benefit (in weeks)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria							4				4	4					
Belgium								4									
Bulgaria								12	12	8	4						
Cyprus							8	12	12	16	16	8					
Czech Rep.							4	8									
Denmark							16	12	8								
Estonia							20	20									
Finland							4	4					4				
France							4	4									
Italy							4	4		8	8	4					
Latvia							20	16									
Hungary				4			8	8	4								
Germany																	
Netherlands								4	4	4	8	4					
Poland								4	4								
Portugal				4			4	8	8	8	4						
Slovakia								8	4								
Slovenia							4	12	8	4	4						
Spain						8	16	12	8	8	4						
Sweden							8	4									
Average	0	0	0	0.4	0	0.4	6.2	7.8	3.6	2.8	2.6	1	0.2	0	0	0	0

growth and preventing the cyclical rise in unemployment from becoming structural (Senekovič, Kavkler, and Bekő 2019). Spending on active labour market policies needs to respond strongly to the cyclical rise in unemployment to encourage a rapid return to work in the recovery. Excessively strict employment protection for regular workers reduces flexibility and encourages the use of temporary contracts and slows down job creation in recovery (OECD 2017).

The research focuses on the URS EU model simulation with no redistribution. The contribution rate of each country is set so that the balance by country at the end of the study period is zero; we performed:

1. Calculations according to the Dullien (2013) method for the case of the URS EU with no redistribution and for the case of the URS EU with redistribution, which otherwise means greater stabilizing power and greater solidarity, but at the same time lesser political acceptability. Stabilizing power is calculated as the ratio between the change in EU unemployment reinsurance contributions/payouts (as a percentage of GDP) and the change in the output gap. In addition, we have shown an increase in consumption as aid received as a percentage of GDP.
2. Calculations according to the method of Beblavý and Maselli (2014) only for the case of the URS EU without redistribution. Stabilizing power is calculated as the change in the balance as a percentage of GDP multiplied by the multiplier.

The calculated stabilizing power in most EU-20 countries shows a slowdown in economic overheating by 2008 and an impact/assistance to get out of the crisis faster from 2009 onwards.

An unemployment reinsurance system would contribute to the stability and efficiency of the EU member states and thus of the EU as a whole, as it would emphasize the role of automatic stabilizer inherent in unemployment insurance. URS EU would complement public unemployment insurance schemes and help increase their efficiency. Public systems contribute to the protection of income and thus to the maintenance of the consumption level of the unemployed, and they also act as automatic stabilizers at the aggregate level. In times of recession, a reinsurance system would contribute additional financial means to state systems and consequently strengthen their effects and eliminate their shortcomings, since this is the time when they most often face deficits and thus the inability to increase unemployment benefits.

Authors of various studies (Beblavý and Maselli 2014; Chimerine, Black, and Coffey 1999; Dolls et al. 2014; Dullien 2007; 2013; Vroman 2010) found that unemployment insurance can be introduced without causing large permanent transfers between countries and in such a way that possible stabilization would be beneficial for all countries. Beblavý and Maselli (2014), Dolls et al. (2014), and Dullien (2007; 2013) note that the unemployment insurance system in the euro area could be implemented with a relatively small budget and, on the other hand, with a relatively high stabilizing power (2 to 16 percent reduction in the output gap).

In the research, despite the lower stabilizing power, we assume that the URS EU model, in which we do not allow redistribution, is more politically acceptable. The contribution rate of each country is set so that the balance by country at the end of the study period is zero. However, in the version where redistribution is not allowed, the stabilizing power of the URS EU is slightly less than in the version that allows redistribution. Germany is not eligible for aid due to low unemployment. In the version where redistribution is enabled, Poland is also included in the system. This is a country that receives aid but pays more in contributions than it receives in aid each year (table 5). The URS EU would not provide greater stabilization for Germany in the great recession of 2008 and 2009, but it has to do with the fact that the German labour market did not deteriorate too much in this recession and the initial reduction in the output gap quickly returned to previous levels.

In the presented model, we measure the stabilizing power by changing the balance as a percentage change in the production gap, and the increase in consumption as the received aid as a percentage of GDP.

With certain assumptions, the URS EU influences reducing the output gap and increasing consumption. In the simulation, we assumed that the additional assistance obtained by the unemployed is used for the most urgent needs and thus immediately returns to the economy, as consumption increases, which in turn has an impact on GDP growth (table 5 and figure 3). We calculated the stabilizing power for each country separately. How the aid received affects GDP, is determined as follows:

- We determine the period under review: the initial year is when the balance is highest, and the period under review lasts as long as the balance decreases (falls); the last year is when the balance is lowest.
- We calculate the change in the balance over the period under review.

TABLE 5 Stabilizing Power of URS EU

Country	With no redistribution			With redistribution		
	(1)	(2)	(3)	(1)	(2)	(3)
Austria	2008–2014	0.638	0.029	2012–2014	1.948	0.041
Belgium	2008–2009	−3.520	0.056	2009–2010	−2.908	0.046
Bulgaria	2009–2013	1.169	0.047	2009–2013	0.945	0.038
Cyprus	2008–2014	0.825	0.124	2008–2014	0.963	0.145
Czech Rep.	2008–2010	0.319	0.026	2008–2010	0.207	0.017
Denmark	2008–2011	5.305	0.192	2008–2011	5.246	0.190
Estonia	2008–2010	2.013	0.247	2008–2010	2.064	0.254
Finland	2008–2015	0.285	0.025	2008–2010	0.815	0.048
France	2008–2010	3.473	0.088	2008–2010	4.452	0.061
Italy	2008–2014	1.273	0.075	2008–2014	1.284	0.076
Latvia	2008–2010	1.091	0.169	2008–2010	1.097	0.170
Hungary	2008–2011	1.088	0.055	2008–2011	0.936	0.047
Germany						
Netherlands	2009–2014	7.405	0.097	2009–2014	6.494	0.085
Poland	2009–2011	−0.446	0.010			
Portugal	2008–2013	1.308	0.098	2008–2013	1.302	0.097
Slovakia	2009–2011	−1.387	0.017	2009–2011	−0.488	0.006
Slovenia	2008–2013	0.422	0.059	2009–2013	0.924	0.042
Spain	2008–2013	2.540	0.317	2007–2013	2.746	0.379
Sweden	2008–2010	1.998	0.056	2008–2011	2.518	0.027

NOTES Column headings are as follows: (1) period, (2) balance change as a percentage of output gap change, (3) increase in consumption as a percentage of GDP.

- We calculate the change in the balance as a percentage of GDP over the period under review.
- We calculate the change in the output gap as a percentage of GDP over the period under review.
- We calculate the change in the balance as a percentage change in the output gap; the result obtained indicates by how much the output gap would be reduced in the event of the operation of the URS EU.

With the financial aid for the unemployed, the level of consumption is maintained. With the increase in unemployment benefits or the extension of the coverage period, the aggregate demand increases. Using the URS

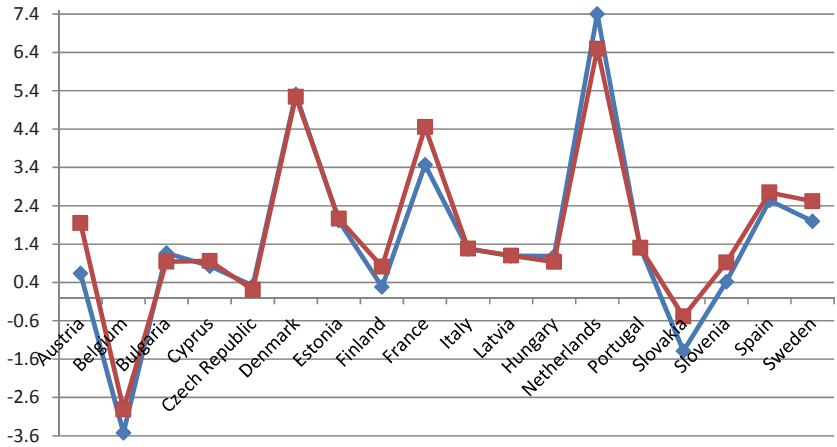

FIGURE 3 Change in Balance as a Percentage Change in the Output Gap (blue – no redistribution, red – distribution)

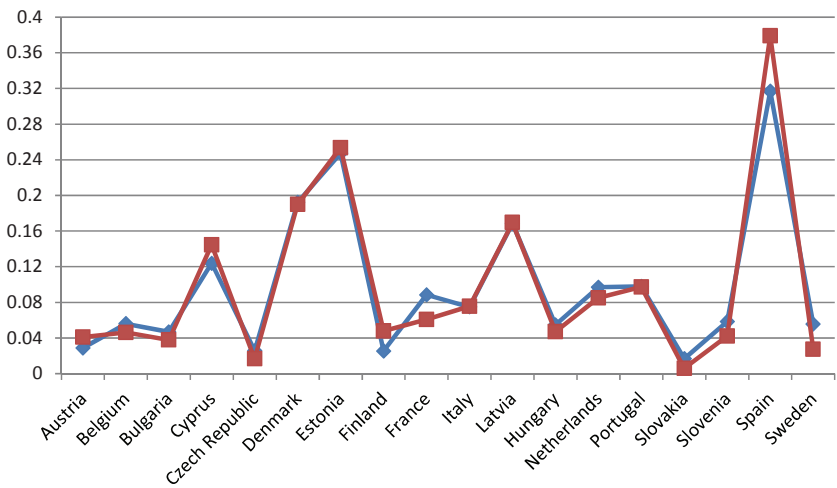

FIGURE 4 Increase in Consumption as a Percentage of GDP (blue – no redistribution, red – distribution)

EU model, we calculated how extending the compensation period would affect GDP (figure 4), namely:

$$\text{increase in consumption}_{t,i} = 100 \times \frac{\text{change in balance}_{t,i}}{\text{GDP}_{t,i}}. \tag{5}$$

The additional euros spent on unemployment benefits has an impact on GDP. The potential effects of the unemployment insurance system

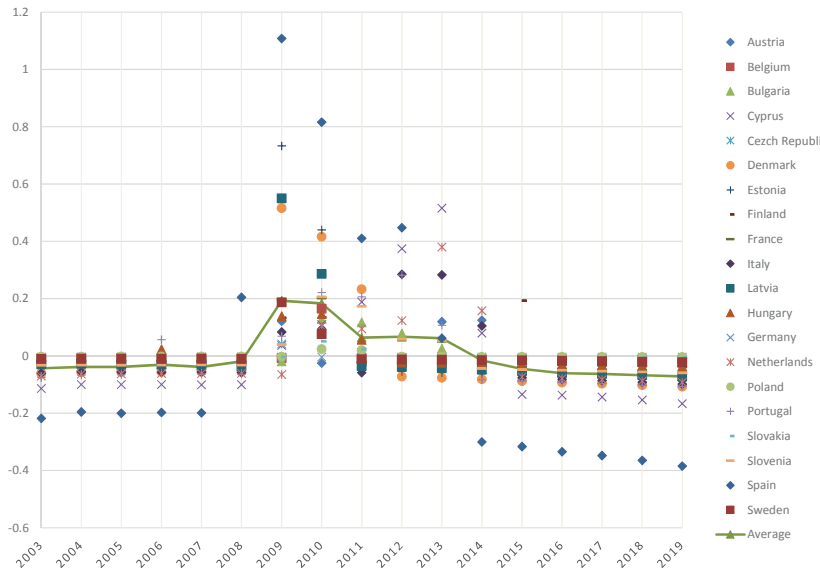

FIGURE 5 Stabilization as a Percentage of GDP

were also calculated according to the method of Beblavý and Maselli (2014) and the Congressional Budget Office (2012), thus taking on a series of estimates of how the additional euros spent on unemployment benefits affects GDP. This fiscal multiplier is assumed to be in the range between 0.5 and 1.5, which is also consistent with the evidence from the Ramey (2011) research.

The stabilizing power was also calculated according to the Beblavý and Maselli (2014) method, according to which stabilization is calculated as a change in the balance as a percentage of GDP multiplied by a multiplier (table 6, the years and countries when the URS EU aid promotes economic growth are indicated in bold):

$$\text{stabilization}_t = 1,5 \times \sum_{i}^{j} \text{URS EU balance (in GDP \%)}, \tag{6}$$

where t is the country, i the initial year when the balance is highest, and j the last year when the balance is lowest.

The calculated stabilization as a percentage of GDP, according to the Beblavý and Maselli (2014) method, shows a slowdown in economic overheating by 2008 and an impact/aid for a faster exit from the crisis from 2009 onwards (figure 5).

TABLE 6 Stabilization As a Percentage of GDP

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	**0.12**	−0.03	−0.02	−0.02	**0.12**	**0.12**	−0.03	−0.03	−0.03	−0.03	−0.04
Belgium	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	**0.16**	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Bulgaria	−0.02	−0.01	−0.01	−0.01	−0.02	−0.02	−0.02	**0.13**	**0.12**	**0.08**	**0.03**	−0.03	−0.03	−0.03	−0.04	−0.04	−0.04
Cyprus	−0.11	−0.10	−0.10	−0.10	−0.10	−0.10	**0.04**	**0.11**	**0.19**	**0.37**	**0.52**	**0.08**	−0.13	−0.14	−0.14	−0.15	−0.17
Czech Rep.	−0.01	−0.01	−0.01	−0.01	−0.01	0.00	**0.04**	**0.08**	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Denmark	−0.06	−0.06	−0.06	−0.06	−0.06	−0.06	**0.52**	**0.42**	**0.23**	−0.07	−0.08	−0.08	−0.09	−0.09	−0.10	−0.10	−0.11
Estonia	−0.04	−0.04	−0.04	−0.04	−0.04	−0.05	**0.73**	**0.44**	−0.05	−0.05	−0.06	−0.06	−0.07	−0.07	−0.08	−0.08	−0.09
Finland	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	**0.13**	**0.13**	−0.03	−0.04	−0.04	−0.04	**0.19**	−0.03	−0.03	−0.04	−0.04
France	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	**0.20**	**0.20**	−0.02	−0.02	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.04
Italy	−0.06	−0.06	−0.06	−0.06	−0.06	−0.06	**0.08**	**0.09**	−0.06	**0.28**	**0.28**	**0.10**	−0.08	−0.08	−0.09	−0.09	−0.10
Latvia	−0.03	−0.03	−0.03	−0.03	−0.03	−0.04	**0.55**	**0.29**	−0.04	−0.04	−0.04	−0.05	−0.05	−0.06	−0.06	−0.07	−0.07
Hungary	−0.02	−0.02	−0.02	**0.02**	−0.01	−0.01	**0.14**	**0.15**	**0.06**	−0.02	−0.02	−0.03	−0.03	−0.03	−0.03	−0.03	−0.04
Germany	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	−0.07	−0.06	−0.06	−0.06	−0.06	−0.06	−0.07	**0.10**	**0.09**	**0.12**	**0.38**	**0.16**	−0.07	−0.08	−0.08	−0.09	−0.09
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**	**0.02**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	−0.08	−0.07	−0.07	**0.06**	−0.06	−0.06	**0.07**	**0.22**	**0.21**	**0.28**	**0.11**	−0.08	−0.09	−0.09	−0.10	−0.10	−0.11
Slovakia	−0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.05**	**0.02**	0.00	0.00	0.00	−0.01	−0.01	−0.01	−0.01	−0.01
Slovenia	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	**0.04**	**0.21**	**0.17**	**0.06**	**0.05**	−0.04	−0.05	−0.05	−0.05	−0.06	−0.06
Spain	−0.22	−0.20	−0.20	−0.20	−0.20	**0.20**	**1.11**	**0.82**	**0.41**	**0.45**	**0.06**	−0.30	−0.32	−0.33	−0.35	−0.36	−0.38
Sweden	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	**0.19**	**0.08**	−0.01	−0.01	−0.01	−0.01	−0.02	−0.02	−0.02	−0.02	−0.02

Conclusion and Policy Implications

Unemployment reinsurance contributes to protection of income and thus to maintenance of the level of consumption of the unemployed. In periods of weak economic activity, the benefits of the unemployment reinsurance system decrease, as the number of employed and thus the contributions paid decrease. On the other hand, expenditure increases without the need to introduce new government measures. The system, in contrast, also works in the case of increased economic activity, when expenditure decreases, and benefits increase (Dullien 2012; see also Boeri and Jimeno 2016). As economic activity increases, the reinsurance system expenditure in the case of unemployment (e.g. the amount and number of recipients of benefits, the period of receiving the benefits) automatically decreases, and benefits increase. Financial assistance to the unemployed (by extending the coverage of the period of receiving the benefit) maintains the level of consumption, as the unemployed spend financial assistance in the domestic environment, for the most urgent needs. Aid to the unemployed in the long run contributes to an increase in aggregate demand, which leads to a halt (slowdown) in further redundancies and a reduction in GDP.

By simulating and evaluating the URS EU model, we achieved the purpose of the research: we were able to confirm the basic thesis that the reinsurance system in the case of unemployment in the EU would improve the basic function of insurance – it would contribute to maintaining the level of consumption and affect the economic stability of the EU. We confirmed that the heterogeneity of EU countries (different dynamics of economic growth and unemployment) allows for the establishment of the URS EU. With a model simulation, we proved that the URS EU would contribute to better income protection by directly influencing the income of the unemployed.

The URS EU model exploits the financial and economic heterogeneity of countries. Its implementation, especially in times of crisis, would contribute to maintaining consumption levels and thus to economic stabilization in both individual EU countries and in the EU as a whole. At the level of individual countries, it is very difficult to ensure a balance between the payment of unemployment benefits and the collected unemployment insurance contributions during (their) economic crisis. Unemployment insurance at the EU level can be introduced without causing large and permanent transfers between countries and in such a way that

possible stabilization would benefit all countries. In three cases studied in more detail, the authors Dolls et al. (2014) and Dullien (2007; 2013) note that the reinsurance system in the case of unemployment in the euro area could be implemented with a relatively small budget but a relatively large stabilizing power (from 2 to 16 percent reduction of the output gap).

The basic elements of the URS EU model are expenditure and receipts. Expenditure was determined on the basis of the US unemployment reinsurance system, as it is proving to be an effective mechanism for maintaining stability in the US federal states. Receipts in the presented URS EU model were determined so as to cover the total additional expenditure of an individual country in the period under review, which is a condition for the sustainability of the system. An individual country begins to receive assistance from the URS EU according to the level of the unemployment rate (trigger).

The amount of URS EU aid to an individual EU country is determined on the model of the US unemployment reinsurance system, which means that the maximum aid covers the costs of an individual federal state for up to 20 additional weeks of receiving unemployment benefits for all unemployed. On the basis of historical data for the EU-20 in the period 2003–2019, we have calculated total URS EU expenditure. With the calculated URS EU expenditure, we determined how much money would be additionally allocated to the unemployed (in each of the EU-20 countries and in every year during the period under review).

EU-wide unemployment reinsurance would be integrated into existing national unemployment insurance schemes and would be politically acceptable to all countries. Labour market reforms have generally been implemented without learning from the heterogeneity of labour market responses to euro area shocks and without taking into account the findings that fiscal measures and labour market reforms that are effective in normal economic conditions can be very ineffective in times of major recessions. The realization from the recession period is that fiscal constraints can be used as a tool to induce institutional reforms. The release of fiscal constraints during the recession was considered to pose moral hazard problems in monetary union (Schmid 2020). A typical (and current) concern that arises when discussing the implementation of labour market reforms is that countries are less prepared for labour market reforms without strong fiscal constraints. Assuming that, given the need for institutional reforms in the euro area, as monetary union reduces the level of macroeconomic stabilization policies in the EU, policy-makers

should be in favour of establishing a reinsurance system in the case of unemployment.

Based on the research and models studied, we find that the EU countries have not applied fiscal policy effectively in order to stabilize the economic cycle; therefore, unemployment reinsurance would act as an automatic stabilizer and thus contribute to a faster exit from the recession. The fiscal policy of most EU countries was mainly cyclical rather than counter-cyclical, which further accelerated the fall in GDP. Leiner-Killinger and Nerlich (2019) note that the recent shift towards balanced budget rules in the euro area is an important achievement in this direction and has contributed to better average underlying budgetary positions. Still, the fiscal rule framework needs to be rendered more effective in reducing high levels of government debt and their dispersion across the euro area. Reducing the heterogeneity of government debt positions is also an important prerequisite for setting up a well-governed common macroeconomic stabilization function at the centre of EMU in case of deep economic crises.

It would be useful to introduce an unemployment reinsurance system in the EU. The URS EU as an aid to the national insurance in the case of unemployment would cover expenditure related to increase in unemployment, while on the other hand, there would be more money left in state budgets to stabilize state economies in recession. Authors of already conducted research (Buti et al. 2002; Dullien 2012; Epaulard 2014; Evropska komisija 2014; Davoine and Molnar 2020) find that the unemployment reinsurance system has a direct impact on the level of consumption, as it increases the income of the unemployed and also mitigates the fall in production during the crisis. Institutional reforms are needed in the euro area, as the monetary union reduces macroeconomic stabilization policies at the national level. EU members have not used fiscal policy to alleviate the recession, and the unemployment reinsurance system, acting as an automatic stabilizer, would achieve just that. We believe that the recession is increasing the need for an automatic stabilizer.

The EU (especially in times of recession) needs mechanisms that act as automatic stabilizers. Given the many agreements and treaties within the EU that emphasize solidarity and social and economic cohesion, the URS EU could be a good solution for both reducing asymmetric financial and economic shocks, and for economic integration between members. After 2008, differences in the unemployment rate have been increasing, between EU countries and also by age groups. Boeri and Jimeno (2016)

argue that the reason for these differences is related to labour market institutions, especially given their interactions with the scale and nature of the shocks of the great recession and the euro area debt crisis. The authors also argue that the introduction of such a reinsurance system in the case of unemployment would give the EU its first common institution. They argue that the EU cannot be a federation of states without common institutions, setting the USA as an example.

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Using Nighttime Luminosity as a Proxy for Economic Growth in Africa: Is It a Bright Idea?

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In this paper, we question whether night light luminosity data can be used as an alternative measure of GDP in 49 African countries. For this to be proven true, evidence of significant relationships between night light data and GDP time series variables needs to be confirmed through empirical analysis. In differing from previous studies, we employ pooled mean group (PMG) cross sectional cointegration estimators and wavelet coherence tools to examine the cointegration relationships and time-frequency synchronizations between GDP and DMSP-OLS night light intensity for annual data collected between 1992 and 2012. All in all, we find little evidence of significant relationships between nighttime data and GDP for individual African countries and therefore caution policymakers in strictly using DMSP-OLS data to create synthetic measures of economic growth. Possible avenues for future research are further recommended at the end of the study.

Key Words: DMSP-OLS night light, economic growth, complex wavelet analysis, Morlet wavelets, Africa
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Introduction

Over the last couple of decades, there has been much debate on the reliability of gross domestic product (GDP) as a standard measure of economic activity (Deaton 2005; Johnson et al. 2013; Dynan and Sheiner 2018) and economists have contemplated adopting alternative, 'out-of-this-world' remote sensing measures of human activity in the form of night light intensity data obtained from satellite sensors in outer space. Following Croft's (1978) demonstration on how a series of images obtained from

the US Air Force Meteorological Satellite sensors can capture and distinguish between city-level activity (city lights) in advanced European countries, gas flares in the Middle East and Northern Africa (MENA) region, a fleet of well-lit fishing boats along the coast of Japan, agriculture fires in Mexico, and natural fires along the Australian coast as well as the pattern of population distribution across the US states, many researchers have used similar night light intensity data to track economic activity at the national level (Elvidge et al. 1997; Doll, Muller, and Elvidge 2000; Sutton and Costanza 2002; Henderson, Storeygard, and Weil 2011; 2012; Chen and Nordhaus 2011, Nordhaus and Chen 2012; 2015; Pinkovskiy and Sala-i-Martin 2016; Guerrero and Mendoza 2019; Galimberti 2020), state level (Doll, Muller, and Morley 2006; Ghosh et al. 2010; Hu and Yao 2019; Chanda and Kabiraj 2020), regional level (Sutton¸ Elvidge, and Ghosh 2007; Ghosh et al. 2009; Omar and Ismal 2019), provincial level (Zhao, Currit, and Samson 2011; Propastin and Kappas 2012; Nonso 2015; Coetzee and Kleyhans 2021a; 2021b), district level (Bhandari and Roychowdhury 2011; Forbes 2011; 2013; Wang et al. 2019), and city-level (Ma et al. 2014; Roberts 2021; Perez-Sindin, Chen, and Prishchepov 2021) as well as across different economic sectors such as primary, secondary and tertiary levels (Keola, Anderson, and Hall 2015; Chen et al. 2021).

In the context of African countries, the use of night light intensity as a proxy for economic growth is of more appeal considering that the continent suffers from problems of reliable economic data mainly due to low levels of resources available to national statistics offices (Devarajan 2013; Jerven 2013). Data derived from satellite imagery holds several advantages over traditional survey-based data in the sense that it is easily and widely available, relatively cheap to obtain, and is not subjected to any statistical inference in the way that it is created (Bluhm and Krause 2018). Notably, there already exists a handful of papers which have made use of night light data as proxies for African economic statistics such as urbanization (Abay and Amare 2018), municipal and electoral district level activity in South Africa during the 2010 World Cup (Pfeifer, Wahl, and Marczak 2016), human development in Africa (Bruederie and Hodler 2018), regional inequality trends in Africa (Mveyange 2015), district-level economic growth (Coetzee and Kleynhans 2021a; 2021b), and detection of rural electrification (Min et al. 2013).

Despite the widespread use of nighttime lights as a proxy for economic activity, it is interesting to note that such proxies are built on the theoretical assumption of some form of correlation existing between luminos-

ity and measured economic growth (Chen and Nordhaus 2011; Henderson, Storeygard, and Weil 2011; 2012; Pinkovskiy and Sala-i-Martin 2016). Only if a relationship exists between the two variables at the national level, can night light data be used as a predictor of economic growth at various sub-national levels where nighttime data is available and there is insufficient GDP data. Whilst many previous studies have relied on cross-section estimates, time series and/or panel data modelling to validate the relationship between night lights obtained from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS) night lights and GDP (see the second section for detailed discussion of the literature), our study challenges the reliability of these previous results based on three criticisms. Firstly, the cross-section estimates used in most previous literature failed to account for heterogeneity effects amongst a host of countries with different developmental characteristics. Secondly, with the sole exception of Coetzee and Kleyhans (2021a; 2021b), previous studies have ignored possible cointegration effects, hence failing to distinguish between short-run and long-run co-movements along the steady state. Thirdly, previous studies do not adequately account for possible time-varying and asymmetric effects of night light activity on economic growth. Whilst some studies attempt to test for nonlinear effects by including a 'squared interactive term' in the estimated regression, they all fail to observe a significant coefficient on the interactive term (Zhao, Currit, and Samson 2011; Henderson, Storeygard, and Weil 2012; Hu and Yao 2019; Chanda and Kabiraj 2020; Otchia and Asongu 2020).

To deal with the empirical shortcomings identified from previous studies, we re-examine the relationship between DMSP-OLS night lights and GDP for 49 African countries between 1992 and 2018 using the pooled mean group (PMG) cointegration estimators of Pesaran, Shin, and Smith (1999) as well as continuous complex wavelet coherence tools discussed in Aguiar-Conraria and Soares (2014). On the one hand, the PMG estimators are used to capture the panel cointegration effects between night lights and GDP whilst providing short-run cross-sectional estimates for individual countries. On the other hand, we make use of complex wavelet coherence techniques which allows us to decompose the time series along a time-frequency space and thereafter yield localized time-frequency information on the series. Since wavelets can localize a time series in both time and frequency via dilation and translation operators, they ultimately allow us to capture various forms of asymmetries existing in the time series which reflect structural changes in the economy and the chang-

ing lengths of business cycles. This differs from the PMG estimators and other traditional estimators used in the literature, which are strictly localized in time and therefore provide little to no information on possible time-varying or frequency-varying relationships between the variables.

The main contribution of our study is that it is the first to examine the relationship between night light and GDP for individual African countries, whereas previous African-related studies have relied on panel-based estimations (Nonso 2015; Otchia and Asongu 2020). Consequently, by taking a country-specific approach using more advanced empirical techniques, our study distinguishes between those African countries which display significant correlations between night light intensity and GDP and those which do not. This, in turn, has important policy implications as it allows us to determine which African economies can use regression analysis to create synthetic time series measures of GDP data at the subnational level based on luminosity data.

The rest of the study is organized as follows. The following section presents the literature review of the study. The third section outlines the empirical methods used in the study. The fourth section presents the data and empirical analysis. The fifth section concludes the study in the form of policy recommendations and avenues for possible future research.

Literature Review

Whilst acknowledging the extensive empirical applications of high spatial resolution satellite imagery following the release of the DMSP-OLS archive in mid-1992 (see Donaldson and Storeygard 2016; Gibson, Olivia, and Boe-Gibson 2020; and Levin et al. 2020 for reviews of the different academic uses of nighttime light data), our study is specifically related to literature which has examined the empirical relationship between luminosity and GDP and has used the predicted values from the regressions to either (i) map out GDP-night light activity across different countries, or (ii) provide estimates of GDP in regions where there exists night light data but insufficient GDP statistics.

In reviewing the literature, we focus on the empirical estimates obtained in previous studies which have used a regression of the form $\text{GDP} = a + \beta\text{NTL} + e_t$, (where NTL is nighttime intensity) to validate the existence of a significant GDP night light relationship for various samples. To facilitate a discussion of the previous studies, we find it most convenient to segregate the literature into two broad strands of empirical works, the first of which provides cross-sectional estimates of the baseline regression, and

the second of which uses time-series and/or panel methods for regression analysis. The coefficient estimates (β) and the coefficient of determination (R^2) of the estimated regressions, which are the two most common measures of the strength of a linear relationship obtained in previous studies are summarized (together with other details of the literature) in tables 1 and 2, respectively.

Table 1 summarizes the empirical findings from the strand of studies which have examined the cross-sectional relationship between luminosity and GDP across a single time period. Notably, these cross-sectional studies have either used country-level data to produce a singular estimate for all countries (Elvidge et al. 1997; Doll, Muller, and Elvidge 2000; Sutton and Costanza 2002; Zhao, Currit, and Samson 2011; Nonso 2015), or have used regional or sector-level data of singular countries to produce national level estimates (Doll, Muller, and Morley 2006; Sutton, Elvidge, and Ghosh 2007; Ghosh et al. 2009; Bhandari and Roychowdhury 2011; Ma et al. 2014) and as can be observed, most reviewed studies produce positive and statistically significant β coefficient estimates with relatively high R^2 values. An exception is observed for the study conducted by Nonso (2015) for 48 African countries which reports a low R^2 value of 0.418.

Table 2 summarizes the empirical findings from the strand of studies which either use time series and/or panel analysis to examine the GDP luminosity relationship and produce more variability in empirical findings. Chen and Nordhaus (2011), Henderson, Storeygard, and Weil (2011; 2012) and Pinkovskiy and Sala-i-Martin (2016) were amongst the first to use panel analysis over a large sample of countries to validate the existence of a GDP night light relationship but do very little to account for heterogeneity effects. Nordhaus and Chen (2012; 2015) segregate a large sample of countries according to the 'grade' of their national statistics and apply both time series and panel estimators to find significant relationships (i.e. higher β and R^2 values) for countries with the lowest data grade qualities. For a sample of 24 countries, Keola, Anderson, and Hall (2015) segregate the data according to the countries' share of GDP in the agriculture sector and apply panel estimation techniques to find insignificant β estimates for countries with higher shares of GDP in agriculture. Bickenbach et al. (2016) use panel regressions to estimate both national and regional relationships between luminosity and GDP for Western European countries and the US and find that the β coefficient at the regional level is either negative or insignificant. Omar and Ismal (2019) estimate

TABLE 1 Summary of Cross-Sectional Literature

Authors	Sample	Period	Coefficient estimate and R^2
Elvidge et al. (1997)	19 non-African emerging countries and the US	1994	$\beta = 1.159$ ($R^2 = 0.97$)
Doll, Muller, and Elvidge (2000)	46 countries	October 1994 and March 1995	$\beta = 0.9735$ ($R^2 = 0.85$)
Sutton and Costanza (2002)	122 countries	1995–1996	$\beta = 1.05$ ($R^2 = 0.86$)
Doll, Muller, and Morley (2006)	Subnational level for 11 European countries and US	1996–1997	Coefficient range from 0.0499 (USA) to 0.2103 (Germany); R^2 from 0.75 (France) to 0.99 (Portugal)
Sutton, Elvidge, and Ghosh (2007)	Subnational level for China, India, Turkey, US	1992–1993 and 2000	China: $R^2 = 0.94(0.96)$ India: $R^2 = 0.70(0.84)$ Turkey: $R^2 = 0.58(0.95)$ US: $R^2 = 0.70(0.72)$
Ghosh et al. (2009)	Subnational level for China, India, Mexico, US	2006	China: $\beta = 10.16$ ($R^2 = 0.97$) India: $\beta = 2.16$ ($R^2 = 0.99$) Mexico: $\beta = 1.10$ ($R^2 = 0.99$) US: $\beta = 0.57$ ($R^2 = 0.99$)
Bhandari and Roychowdhury (2011)	India, district level (35 states, 593 districts)	2008	Multivariate GDP: $\beta = 0.36$ ($R^2 = 0.79$) GDP.pri: $\beta = 0.30$ ($R^2 = 0.73$) GDP.sec: $\beta = 0.50$ ($R^2 = 0.73$) GDP.ter: $\beta = 0.30$ ($R^2 = 0.87$)
Zhao, Currit, and Samson (2011)	For subset of 31 Chinese provinces	1996 and 2000	Estimate OLS regression with squared terms for nonlinearity GDP.1996: $\beta = 0.6029$ ($R^2 = 0.66$) GDP.2000: $\beta = 0.7507$ ($R^2 = 0.69$)
Forbes (2013)	US states/ metropolitan levels	2006 and 2010	MSA: $\beta = 0.244$ to 0.691 (R^2 0.976 to 0.845) State: $\beta = 0.482$ to 0.696 (R^2 0.976 to 0.878)

a panel regression of night light intensity and gross governorate product (GGP) for 27 Egyptian governorates and obtain positive β coefficient estimates and high R^2 at both the national and subnational level. Guerrero and Mendoza (2019) estimate country-specific time series regressions for

TABLE 2 Summary of Time-Series Literature

Authors	Sample	Period	Coefficient estimate and R^2
Ma et al. (2014)	Chinese cities	2012	GDP ($R^2 = 0.91$)
Nonso (2015)	48 African count.	1999 and 2012	$\beta = 1.384$ ($R^2 = 0.418$)
Chen and Nordhaus (2011)	170 countries	1992–2008	Time series and cross-sectional estimates/ Correlation coefficient between 0.797 and 0.842
Henderson, Storeygard, and Weil (2011)	118 countries	1992–2006	FE: $\beta = 0.308$ ($R^2 = 0.78$) Country time trend: $\beta = 0.270$ ($R^2 = 0.903$) Long difference: $\beta = 0.329$ ($R^2 = 0.301$)
Henderson, Storeygard, and Weil (2012)	188 countries	1992–2008	$\beta = 0.22$ ($R^2 = 0.769$) Squared negative and insignificant (–0.00058)
Nordhaus and Chen (2012)	170 countries (5 quality grade levels from A to E)	1992–2008	Cross sectional A: $\beta = 0.777$ B: $\beta = 0.742$ C: $\beta = 0.990$ D: $\beta = 0.952$ E: $\beta = 1.318$ Time series A: $\beta = 0.161$ B: $\beta = 0.251$ C: $\beta = 0.424$ D: $\beta = 0.882$ E: $\beta = 0.011$
Propastin and Kappas (2012)	Kazakhstan/17 provinces	1994–1999 and 2004–2009	Province: $\beta = 0.6903$ ($R^2 = 0.76$) Total: $\beta = 0.0048$ ($R^2 = 0.94$)

Continued on the next page

Mexico, China and Chile, and also find positive β estimates and high R^2 values.

It is also interesting to note that there exist some literatures which have put forward arguments in favour of a possible nonlinear relationship between GDP and night lights. For instance, Hu and Yao (2019) argue that the relationship between nighttime lights and true GDP per capita is most likely nonlinear as it varies with geographic location. Chen et al. (2021) argue for a nonlinear relationship on the basis of diverse indus-

TABLE 2 *Continued from the previous page*

Authors	Sample	Period	Coefficient estimate and R^2
Nordhaus and Chen (2015)	167 countries (5 quality grade levels from A to E)	1992–2010	Cross sectional A: $\beta = 0.779$ B: $\beta = 0.773$ C: $\beta = 0.980$ D: $\beta = 0.953$ E: $\beta = 1.318$ All: $\beta = 0.953$ Time series A: $\beta = 0.424$ B: $\beta = -0.486$ C: $\beta = 0.014$ D: $\beta = 1.253$ E: $\beta = 0.001$ All: $\beta = 0.322$
Keola, Anderson, and Hall (2015)	24 African, emerging and industrialized countries	1992–2009	GDP by agriculture share: >10%: $\beta = 0.67453$ 10–20%: $\beta = 0.39278$ 20–30%: $\beta = -0.408595$ 30–40%: $\beta = -0.50387$ 40–50%: $\beta = 0.0235$ (insign.) <50%: $\beta = 0.03823$ (insign.) Estimate for agriculture at national level: $\beta = 0.028$ (insign.)
Bickenbach et al. (2016)	Brazil, India, Western Europe and US	1995–2010	India: $\beta = 0.10$ ($R^2 = 0.060$) Brazil: $\beta = 0.148$ ($R^2 = 0.045$) US: $\beta = 0.164$ ($R^2 = 0.048$) Western Europe: $\beta = 0.113$ ($R^2 = 0.024$) Coefficient on NTL at regional level is either -ve or insignificant

Continued on the next page

trial structures, socioeconomic patterns, and development levels which exist in studies which use a large number of countries. Galimberti (2020) attributes nonlinear effects to differences in the sectoral composition of a country's GDP, where some industries may generate more lights than others and also to satellite sensor noise which causes production activities to be reflected by nighttime lights in a nonmonotonic manner. Notably, there are a few empirical studies which have tested for a possible non-

TABLE 2 *Continued from the previous page*

Authors	Sample	Period	Coefficient estimate and R^2
Pinkovskiy and Sala-i-Martin (2016)	123 countries	1992–2010	National accounts: $\beta = 1.160$ ($R^2 = 0.72$) Surveyed income: $\beta = 1.286$ ($R^2 = 0.63$)
Omar and Ismal (2019)	Egypt, 27 governorates	2008–2013	$\beta = 0.69$ ($R^2 = 0.80$)
Guerrero and Mendoza (2019)	Mexico, China, Chile	1992–2008	Mexico: $\beta = 0.808$ China: $\beta = 1.204$ Chile: $\beta = 1.139$
Hu and Yao (2019)	162 countries/BRICS countries and 4 low-income African countries (Congo, Ethiopia, Kenya, Sierra Leone)	1992–2013	NTL = a + GDP $\beta = 0.5351$ to 0.662 ($R^2 = 0.0109$ to 0.439) Squared terms are insignificant
Chanda and Kabiraj (2020)	520 Indian districts: also distinct between rural and urban places	1992–2013	State level regression: $\beta = 0.591$ ($R^2 = 0.396$) Squared term insignificant
Otchia and Asongu (2020)	46 African countries	1992–2013	Total: $\beta = 0.259$ ($R^2 = 0.837$) Agric.: $\beta = 0.236$ ($R^2 = 0.576$) Manu.: $\beta = 0.257$ ($R^2 = 0.536$) Ind.: $\beta = 0.513$ ($R^2 = 0.683$) Service: $\beta = 0.268$ ($R^2 = 0.780$) (Insignificant squared terms)

linear relationship between GDP and night lights by adding a quadratic term to the baseline regression. However, these studies fail to find a significant estimate on the squared term coefficient at both the national (Zhao, Currit, and Samson 2011; Henderson, Storeygard, and Weil 2012; Hu and Yao 2019; Chanda and Kabiraj 2020) and sectoral level (Otchia and Asongu 2020).

Our study draws and improves on three aspects of the current literature. Firstly, we expand on the literature for African economies of which the works of Nonso (2015) and Otchia and Asongu (2020) are currently the only studies available in the literature which provide regression estimates between GDP and night light intensity. Secondly, we differ from

Nonso (2015) and Otchia and Asongu (2020) by taking a country-specific, time series approach to estimating the night light GDP relationship as in the studies of Guerrero and Mendoza (2019) for Mexico, China and Chile. Thirdly, since previous studies have investigated possible cointegration effects between night light intensity and GDP, our study employs PMG estimators to investigate cross-sectional relationships of the individual African countries across the steady-state equilibrium. Lastly, in differing from previous studies which use quadratic terms as a measure turning points in the data as a means of capturing nonlinearity, this study employs wavelet coherence which examines the asymmetric co-movement between the variables across five dimensions, namely (i) strength variation, (ii) time variation, (iii) frequency variation, (iv) direction of relationship (negative or positive), and (v) phase dynamics (causality between the time series). The PMG estimators and wavelet coherence tools used in this paper are outlined in the following section.

Methods

PMG ESTIMATORS

The pooled mean group (PMG) estimator of Pesaran, Shin, and Smith (1999) can be obtained from the following panel autoregressive distributive lag (P-ARDL $(p, q, q, \ldots, q)$ model:

$$\text{GDP}_{it} = \sum_{j=1}^{p} \lambda_{ij} \text{GDP}_{i,t-j} + \sum_{j=0}^{q} \delta_{ij} \text{NTL}_{i,t-j} + \alpha_i + \varepsilon_{it}, \tag{1}$$

where $t = 1, 2, \ldots, T$, $i = 1, 2, \ldots, N$, α_i is the fixed effect, and λ_{ij} and δ_{ij} are vectors of parameters. The error correction representation of equation (1) is:

$$\Delta \text{GDP} = \phi_i \text{GDP}_{i,t-1} + NTL_{it}\beta_i + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta \text{GDP}_{i,t-1} + \sum_{j=0}^{q-1} \Delta \text{NTL}_{i,t-j} \delta_{ij}^{*} + \mu_i + \varepsilon_{it}, \tag{2}$$

where ε_{it} are serially not correlated across i and t, have zero means, variance $\sigma_i^2 > 0$, and finite fourth-order moment conditions, and:

$$\phi_i = \frac{-1}{1 - \sum_{j=1}^{p} \lambda_{ij}} \quad \text{and} \quad \beta_i = \sum_{j=0}^{q} \delta_{ij}. \tag{3}$$

The long-run relationship can compactly be denoted as:

$$\text{GDP}_{it} = \theta_i \text{NTL}_{it} + \eta_{it}, \tag{4}$$

where: $\theta_i = -\frac{\beta_i^{'}}{\phi_i}$ are the long run-run coefficients and η_{it} is a stationary process. The long-run coefficients defined by θ_i are constrained to be the same for all cross-sectional units and can be expressed as:

$$\Delta\text{GDP}_i = \phi_i \xi_i(\theta) + W_i k_i + \varepsilon_i, \qquad i = 1, 2, \ldots, N \tag{5}$$

with

$$W_i = \Delta\text{GDP}_{i,-1}, \ldots, \Delta\text{GDP}_{i,-P+1}, \Delta\text{NTL}_i, \text{NTL}\Delta_{i,-1}, \ldots, \Delta\text{XNTL}_{i,-q+1,\iota} \tag{6}$$

$$k_i = (\lambda_{i1}^{*}, \ldots, \lambda_{i,p-i}^{*}, \delta_{i0}^{*'}, \delta_{i1}^{*'}, \ldots, \delta_{i,-q-1}^{*'}, \mu_i)^{'} \tag{7}$$

and the error correction term is computed as:

$$\xi_i(qtheta) = \text{GDP}_{i,-1} - \text{NTL}_i\theta \qquad i = 1, 2, \ldots N. \tag{8}$$

And this measures the speed of 'correction' back to steady-state equilibrium following a shock to the system of time series variables.

WAVELET COHERENCE ANALYSIS

Wavelets are small waves that stretch and compress in a limited time-period and are used to decompose a signal or time series across a time-frequency plane; these transforms can either be discrete (returns data vector of the same length as the input signal) or continuous (returns an output vector which is one dimension higher than the input). In our study, we focus on continuous wavelet transforms (CWT) of the GDP and NTL data:

$$W_{\text{GDP}}(s, \tau) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{s}} \psi^{\star}\left(\frac{t-\tau}{s}\right) dt \tag{9}$$

$$W_{\text{NTL}}(s, \tau) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{s}} \psi^{\star}\left(\frac{t-\tau}{s}\right) dt, \tag{10}$$

where τ and s are time and scale parameters responsible for dilation and translation of the wavelet in time frequency space. To explore the instantaneous phase information in the time-scale plane, a complex mother wavelet is required; in this study we use complex Morlet wavelets which are complex sinusoids modulated by a Gaussian envelope:

$$\psi(t) = \pi^{-\frac{1}{4}} \exp(i\omega_c t) \exp\left(-\frac{1}{2} t^2\right), \tag{11}$$

where $\omega_c = 2\pi f_c$ is the central frequency of the wavelet and determines the number of oscillations of the complex sinusoid inside the Gaussian. To ensure equation (11) is admissible as a wavelet, with a zero-mean function, we set $\omega_c = 6$. The term $\pi^{-\frac{1}{4}}$ ensures the wavelet has unit energy. Since the wavelet function is complex, the wavelet transform is also complex and can be divided into a real and imaginary part. The wavelet power spectrum (WPS) for a discrete series measures the variance of the GDP and NTL series across a time-scale dimension, i.e.

$$\text{WPS}_{\text{GDP}}(\tau, s) = |W_{\text{GDP}}(\tau, s)|^2 \tag{12}$$

$$\text{WPS}_{\text{NTL}}(\tau, s) = |W_{\text{NTL}}(\tau, s)|^2 \tag{13}$$

and using (12) and (13) we can compute the Cross-Wavelet Power Spectrum (CWPS) between GDP and NTL which is analogous to the covariance between the variables in time-frequency domain.

$$(\text{CWPS})_{\text{GDP,NTL}} = W_{\text{GDP,NTL}} = W_{\text{GDP,NTL}}. \tag{14}$$

The wavelet coherency is referred to as the ratio of the cross spectrum to the product of each series spectrum and can be thought of as the local correlation between the pair of time series in time-frequency space, i.e.

$$R_n(s) = \frac{|S(W_{\text{GDP,NTL}})|}{[(S|W_{\text{NTL}}|^2)(S|W^2_{\text{GDP}})]^{\frac{1}{2}}}, \tag{15}$$

where $0 \leq R_n(s) \leq 1$ and S is a smoothing operator in both time and scale. To further distinguish between negative and positive correlation between a pair of time series as well as identifying lead-lag causal relationships between the variables, we explore phase difference dynamics through a complex number which is parametrized in radians:

$$\phi_{\text{NTL,GDP}} = \tan^{-1}\left(\frac{\mathcal{I}\{W_{\text{NTL}}\}}{\mathcal{R}\{W_{\text{NTL}}\}}\right)), \tag{16}$$

where $\phi_{\text{NTL,GDP}}$ is bound between π and $-\pi$ which encompasses all possible lead-lag synchronizations between the time series in a time-frequency plane.

Data and Empirical Findings

DATA DESCRIPTION

This study uses two sets of time series variables, GDP and night light intensity, collected for 39 Sub-Saharan African (SSA) countries, on annual frequency between 1992 and 2012. Firstly, GDP data is sourced from

the World Bank Development (WBD) indicators. Secondly, the DMSP-OLS night light time series dataset is retrieved from the US Air Force sub-division Earth Observation Group's (EOG-NOAA) online website (https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html). The DMSP-OLS oscillating scanning devices observe all locations around the planet with the intention to capture some indoor and outdoor utility of lights using high resolution technology. Under the DMSP-OLS program there are approximately 5 sensors namely, F10 (for years 1992–1994), F12 (for years 1994–1999), F14 (for years 1997 to 2000), F15 (for years 2000 to 2008), F16 (for years 2004 to 2008) and F18 (for years 2009–2013). The images are 30 arc second grids which span –1800 to 1800 longitude and –650 to 750 latitude. The raw dataset values range between 0 (no light activity) and 63 (strongest light intensity activity), with the exception of the value 255 representing areas with zero cloud-free observations and the ephemeral events such as fires and background noise have been eliminated and replaced with 0. We focus on the mean lights and compute annual growth rates at the second administrative regions (ADM2) level for our sample data.

Table 3 presents the descriptive statistics, unit root properties and correlation indices for GDP and nighttime lights (NTL), whilst figure 1 presents time series plots of the variables for the individual African countries. Note that both the panel correlation coefficient reported in table 3 and visual appreciation of the time series data in figure 1 present preliminary evidence of a positive co-movement between the variables. However, this preliminary analysis does not take into consideration important econometric issues such as cointegration effects and nonlinear dynamics amongst the data. Considering that both series are integrated of order I(1), the data can be considered for cointegration analysis.

COINTEGRATION ANALYSIS

In this section we present the results obtained from the cointegration analysis and table 4 presents the results for the long-run estimates. Note that along with the PMG estimator we also present the estimates from the panel ordinary least squares (POLS) models, fixed effects POLS (FE-POLS), random effects POLS (RE-POLS), fully modified POLS (FM-POLS) and dynamic POLS (D-POLS) estimators. The obtained long-run coefficients produce estimates which range from as high as 2.38 (FE-POLS) to as low as 0.20 (PMG) and it is important to note that these are statistically significant at all critical levels. Overall, these estimates fall in

TABLE 3 Descriptive Statistics

Item	GDP	NTL
Mean	41.95347	79.87134
Median	15.61398	25.57545
Maximum	833.2920	1685.208
Minimum	0.427544	0.190523
Std. Dev.	98.46180	234.4203
Skewness	4.822411	5.412865
Kurtosis	28.72450	32.43515
Jarque-Bera	26417.04	34426.85
Probability	0.00	0.00
Sum	35240.92	67091.93
Sum Sq. Dev.	8133875	46105471
LLC (levels)	−1.78	5.79
LLC (1st differences)	−4.09***	−3.73***
IPS (levels)	5.49	6.04
IPS (1st differences)	−4.57***	−8.45***
Correlation with GDP	1	0.8
Observations	840	840

NOTES *** Rejection of H0 at 10% significance level.

TABLE 4 Long Run-Estimates

Estimator	Coefficient estimate	*t*-stat	*p*-value
POLS	0.33	36.94	0.00***
FE-POLS	1.01	19.56	0.00***
RE-POLS	0.53	18.75	0.00***
FM-POLS	2.58	12.09	0.00***
D-POLS	0.35	39.26	0.00***
PMG	0.20	5.09	0.00***

NOTES *** Rejection of H0 at 10% significance level.

the range of those obtained in previous literature (Nonso 2015; Otchia and Asongu 2020).

Table 5 presents the short-run and error correction cross-sectional results obtained from PMG estimators for the individual African countries. Note that in order for there to be a significant GDP night light cointegra-

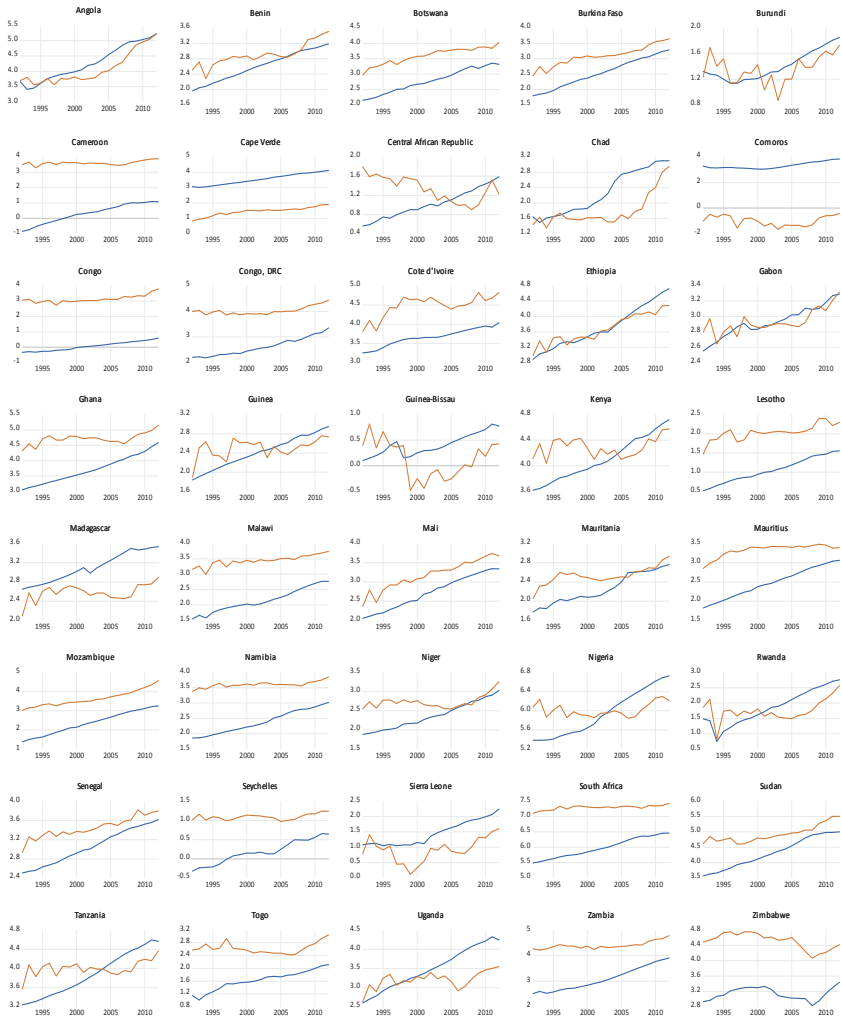

FIGURE 1 Individual Country Plots per Variable, 1992–2012 (blue – LGDP, red – Lnighttimelights)

tion relationship there must exist a negative and significant coefficient estimated on the error correction term (ECT) and a positive and significant estimate on the NTL coefficient. For the sake of convenience, in table 5 we highlight in bold the countries which satisfy these two conditions and find that only 16 countries out of the 49 countries satisfy the criteria (Angola, Benin, Burkina Faso, Burundi, Comoros, Côte d'Ivoire, Gabon, Guinea, Mauritania, Nigeria, Rwanda, Senegal, Sierra

TABLE 5 PMG Short-Run Cross-Sectional Estimates

Country	ECT			ΔNTL		
	(1)	(2)	(3)	(1)	(2)	(3)
Angola	−0.02	−36.92	0.00***	0.07	6.10	0.01**
Benin	−0.01	−153.81	0.00***	0.02	47.68	0.00***
Botswana	−0.03	−71.93	0.00***	−0.34	−23.35	0.00***
Burkina Faso	−0.01	−45.46	0.00***	0.07	23.53	0.00***
Burundi	−0.01	3.82	0.03**	0.07	80.15	0.00***
Cameroon	−0.06	−148.95	0.00***	−0.03	−6.00	0.01**
Cape Verde	−0.01	−147.09	0.00***	−0.06	−50.77	0.00***
Central African Rep.	0.04	40.55	0.00***	0.05	22.61	0.00***
Chad	0.00	−1.86	0.16	−0.17	−13.91	0.00***
Comoros	−0.02	−16.33	0.00***	0.03	61.40	0.00***
Congo	0.04	70.01	0.00***	0.03	13.62	0.00***
Congo, DRC	0.05	36.75	0.00***	0.30	19.83	0.00***
Côte d'Ivoire	−0.04	−38.24	0.00***	0.09	57.29	0.00***
Ethiopia	0.03	69.48	0.00***	0.03	5.04	0.02*
Gabon	−0.03	−12.62	0.00***	0.04	5.81	0.01**
Ghana	0.05	240.11	0.00***	0.02	14.36	0.00***
Guinea	−0.01	−63.70	0.00***	0.02	27.14	0.00***
Guinea-Bissau	0.08	−7.12	0.01**	0.01	1.34	0.27
Kenya	0.02	55.22	0.00***	−0.01	−9.98	0.00***
Lesotho	−0.01	−56.19	0.00***	−0.06	−43.03	0.00***
Madagascar	−0.02	−12.38	0.00***	−0.01	−3.27	0.22
Malawi	0.01	9.60	0.00***	0.26	40.23	0.00***
Mali	−0.01	−57.94	0.00***	0.00	1.23	0.31
Mauritania	−0.01	−7.48	0.01**	0.15	3.89	0.03*
Mauritius	−0.03	−196.27	0.00***	−0.16	−22.17	0.00***
Mozambique	0.00	24.00	0.00***	−0.28	−26.20	0.00***

Continued on the next page

Leone, Togo, Uganda, Zimbabwe). In further disseminating these results, we note that, in similarity to the findings by Keola, Anderson, and Hall (2015), a majority of the countries which find significant cointegration relationships between GDP and nigh tlight are those with higher shares of agriculture, forestry, and fishing in their GDP such as Benin

TABLE 5 *Continued from the previous page*

Country	ECT			ΔNTL		
	(1)	(2)	(3)	(1)	(2)	(3)
Namibia	0.02	57.94	0.00***	−0.13	−14.02	0.00***
Niger	0.05	87.03	0.00***	0.00	0.62	0.58
Nigeria	−0.01	−42.80	0.00***	0.09	46.82	0.00***
Rwanda	−0.07	−79.85	0.00***	0.49	252.82	0.00***
Senegal	−0.01	−14.75	0.00***	0.02	6.02	0.01**
Seychelles	−0.02	−8.27	0.00***	−0.12	−2.83	0.07*
Sierra Leone	−0.04	−26.30	0.00***	0.14	39.78	0.00***
South Africa	−0.02	−71.71	0.00***	−0.16	−21.87	0.00***
Sudan	−0.01	−44.68	0.00***	−0.05	−7.07	0.01**
Tanzania	−0.02	−36.54	0.00***	−0.05	−20.50	0.00***
Togo	−0.11	−228.45	0.00***	0.28	100.52	0.00***
Uganda	−0.03	−78.69	0.00***	0.02	5.52	0.01**
Zambia	0.06	102.58	0.00***	−0.11	−7.20	0.01**
Zimbabwe	−0.20	−17.76	0.00***	0.45	17.56	0.00***

NOTES Column headings are as follows: (1) coefficient estimate, *t*-stat, *p*-value. *, **, and *** denote 1%, 5% and 10% significance levels, respectively.

(27.11%), Burkina Faso (18.40%), Burundi (28.45%), Comorros (36.70%), Cote d'Ivoire (21.39%), Guinea (23.67%), Mauritania (20.19%), Nigeria (24.14%), Rwanda (26.25%), Senegal (17.03%), Sierra Leone (54.49%) Togo (18.78%), Uganda (23.93%) all which are above the SSA average of 18.51%. Interestingly, most of these identified countries heavily rely on fishing activities for livelihood and Li et al. (2021) recent showed that fishing activities can be easily captured from outer space using nightlight data. Furthermore, we observe that oil-rich countries, particularly, Angola, Gabon, Guinea, and Nigeria, tend to have more significant GDP night-light relationships and this finding is not surprising since, as recently noted by Maldonado (2022), oil-rich regions tend to exert more luminosity compared to non-oil producing regions.

Moreover, our findings resonate with those Nordhaus and Chen (2012; 2015), who find that countries with worse (better) of data quality tend to have stronger (weaker) GDP-night light relationships. Based on the data quality grading system presented in Nordhaus and Chen (2012; 2015) as adopted from Summers and Heston (1988), there are 9 African countries

with higher quality data (i.e. Botswana, Cameroon, Cote d'Ivoire, Kenya, Morocco, Senegal, South Africa, Tanzania, Tunisia and Zimbabwe) and out of these countries only Cote d'Ivoire and Zimbabwe reported significant cointegration relationships. The remaining 14 countries which find significant relationships (i.e. Angola, Benin, Burkina Faso, Burundi, Comoros, Gabon, Guinea, Mauritania, Nigeria, Rwanda, Senegal, Sierra Leone, Togo, Uganda, Zimbabwe) have poor data quality.

WAVELET COHERENCE ANALYSIS

In this section of the paper, the findings from the wavelet coherence analysis for the individual African countries are reported in the form of wavelet coherence plots which are essentially 'heat-maps' depicting the time-frequency correlation between GDP and night light intensity. The time domain on the wavelet coherence plots is measured along the horizontal axis whilst the frequency components are measured along the left-hand side of the horizontal axis with cycles ranging from 0 to 32 years. Note that the colour contours within each heat map measure the strength of the co-movement between the series, ranging from cooler colours (weaker correlations) to warmer colours (stronger correlations). The colour scales corresponding to the correlation strength are provided on the right side of each wavelet plot. The 5% significance level is represented by the faint white lines surrounding the colour contours whilst the inverted cone shape is the 'cone of influence' which accounts for edge effects.

Further note that the arrows contained within the colour contours describe the phase dynamics between the series which provides information on the direction of correlation (positive or negative) and the direction of causality. On the one hand, the series are considered in-phase or positively correlated with GDP leading (lagging) night light intensity if the arrow orientations are ↑, ↗, and → (↘), whilst on the other hand, the series are considered anti-phase or negatively correlated with GDP leading (lagging) night light intensity if the arrow orientations are ↓, ↙, and ← (↖).

From the wavelet coherence plots reported in the appendix, we group the findings from the individual countries into three categories. Firstly, there are 11 countries which produce in-phase correlations (positive) throughout the entire sample periods (Burundi, Central African Republic, Côte D'Ivoire, Democratic Republic of Congo, Ethiopia, Ghana, Mauritius, Nigeria, Sierra Leone, Togo, Zimbabwe). Secondly there are

10 countries which find in-phase through some or a majority of the time period (Cape Verde, Congo, Gabon, Guinea, Guinea-Bissau, Lesotho, Mali, Malawi, Rwanda, Zambia) Thirdly, there are 17 countries which either find predominantly anti-phase (negative) or insignificant correlations between the time series (Angola, Benin, Botswana, Burkina Faso, Cameroon, Comoros, Chad, Kenya, Madagascar, Mozambique, Namibia, Niger, Seychelles, South Africa, Sudan, Tanzania, Uganda).

It is also interesting to note that most African countries which have found significant time-frequency co-movements between GDP and nightlight data are countries which have faced civil wars during the period of observations (i.e. Burundi civil war (1993–2005), CAR bush war (2004–2007), Ivorian civil war (2002–2007; 2010–2011), DRC war (1996–2003), Ethiopia (various), Nigeria (Boko Haram conflicts since 2009), Sierra Leone civil war (1991–2002)) and these periods of conflict are dominated by high frequency oscillations in the wavelet plots. As observed by Witmer and O'Loughlin (2011) nightlights can be used to trace wars and conflicts, particularly where there are large fires that burn for weeks and large refugee movements. Moreover, Li and Li (2014) note that nighttime light and lit areas tend to decline (recover) during periods of conflict (peace) which correspond to declining (recovering) economic performance.

In further comparing the findings from the wavelet coherence analysis with those obtained from the PMG estimators, we find that only 6 countries commonly establish a significant relationship between night light intensity and GDP (Burundi, Côte D'Ivoire, Nigeria, Sierra Leone, Togo, Zimbabwe). In further comparing the results found in our study with previous literature, we conclude that our findings are not as optimistic as those obtained in previous African and international literature and only a few African countries find significant relationships between the variables from a cointegration and time-frequency perspective.

Conclusions

So, is it a bright idea to use country-specific night light luminosity as a proxy for economic growth in African countries? To answer this question, our study employs PMG estimators and wavelet coherence analysis applied to GDP and DMSP-OLS night light intensity data for 49 African countries to examine the cross-sectional cointegration relationship and time-frequency co-movements between the variables. On the one hand, the PMG estimators identify 16 out of the 49 countries which find sig-

nificant positive cross-sectional cointegration effects between the night light and GDP, whilst on the other hand, the wavelet coherence identifies 11 out of the 49 countries which show positive synchronization between the variables across a time-frequency domain. And if these results are further narrowed down, we find that only 6 countries mutually establish significant relationships between PMG estimators and wavelet coherence analysis.

Altogether our study concludes that only very few African countries are at liberty to use regression analysis to create reliable synthetic GDP time series using DMSP-OLS night light intensity. Although our findings show little evidence of country-specific relationships between night light intensity and GDP for African countries, we do not refute the use of nighttime data as a proxy.

Instead, we propose two avenues for future research to reconcile the differences in empirical findings. Firstly, future studies could consider creating hybrid measures of economic growth using both night light intensity and other satellite imagery data such those capturing biodiversity, land cover and vegetation change which is more relevant for African countries whose economic output is highly dependent on fishing, farming and agriculture production. Secondly, future studies can focus on other sources of night light intensity data such as the Visible Infrared Imaging Radiometer Suite (VIIRS) day-night band (DNB) database which has luminosity time series in quarterly frequency and spans longer than the DMSP-OLS data.

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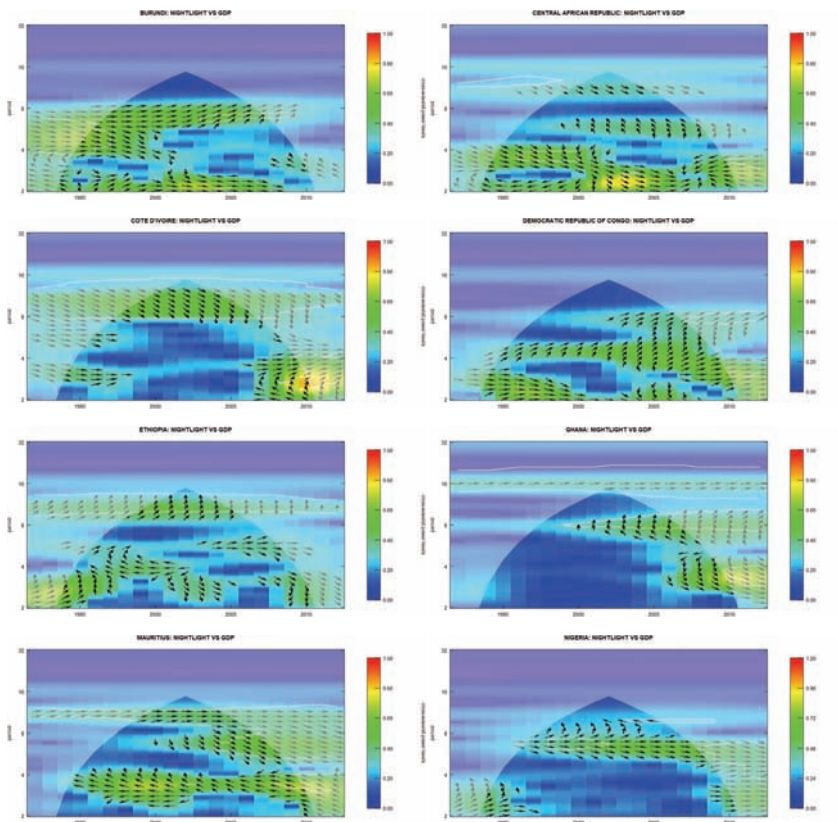
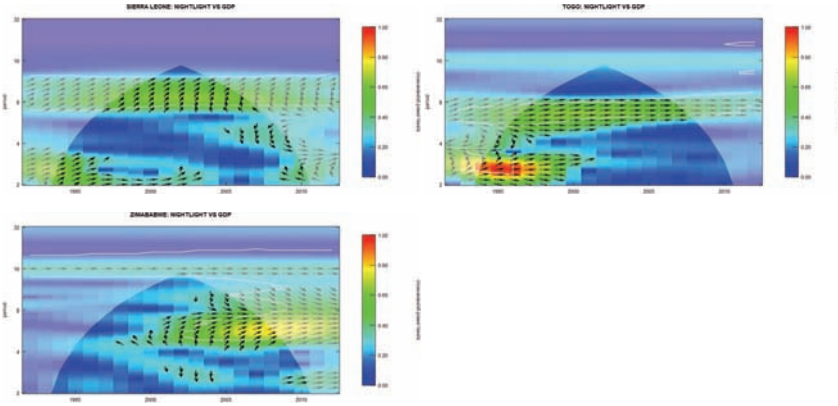
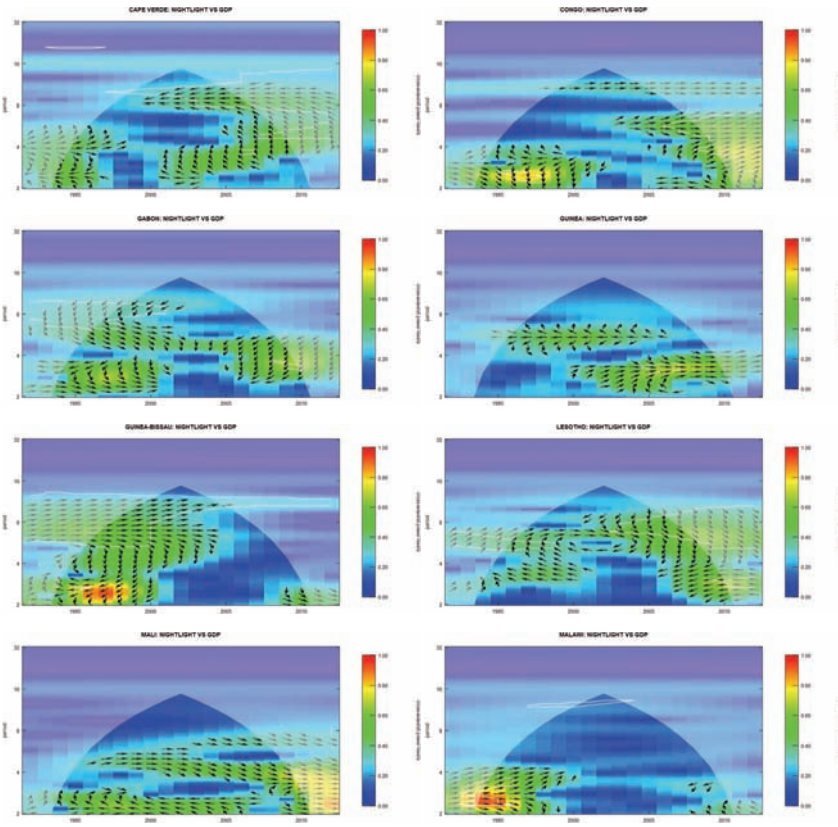
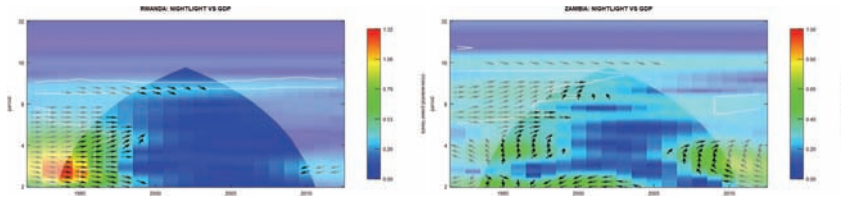
Appendix A



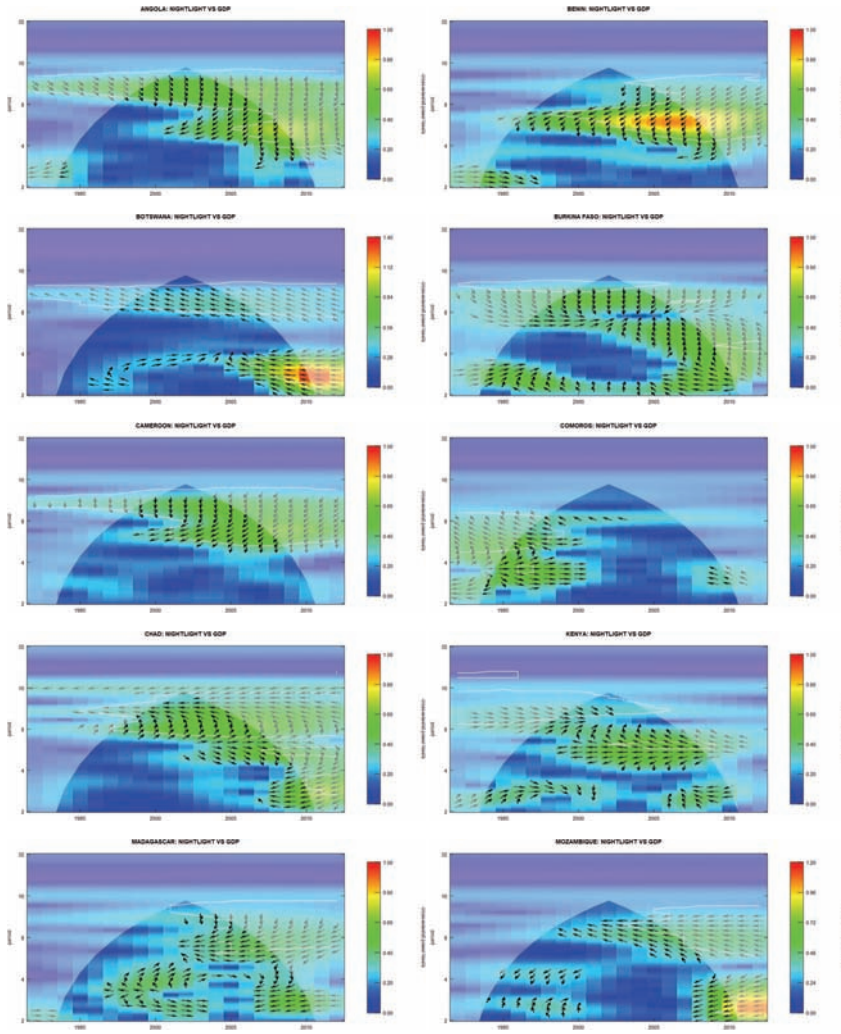

SIERRA LEONE: NIGHTLIGHT VS GDP
TOGO: NIGHTLIGHT VS GDP
ZIMABABWE: NIGHTLIGHT VS GDP

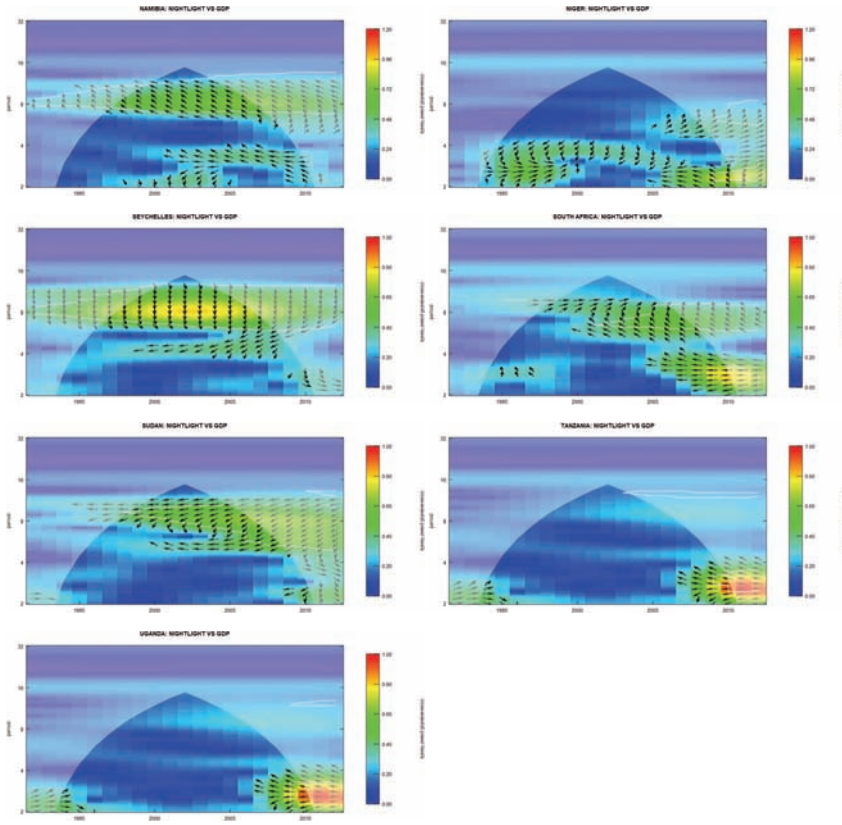
Appendix B


CAPE VERDE: NIGHTLIGHT VS GDP
CONGO: NIGHTLIGHT VS GDP
GABON: NIGHTLIGHT VS GDP
GUINEA: NIGHTLIGHT VS GDP
GUINEA-BISSAU: NIGHTLIGHT VS GDP
LESOTHO: NIGHTLIGHT VS GDP
MALI: NIGHTLIGHT VS GDP
MALAWI: NIGHTLIGHT VS GDP


RWANDA: NIGHTLIGHT VS GDP
ZAMBIA: NIGHTLIGHT VS GDP

Appendix C


ANGOLA: NIGHTLIGHT VS GDP
BENIN: NIGHTLIGHT VS GDP
BOTSWANA: NIGHTLIGHT VS GDP
BURKINA FASO: NIGHTLIGHT VS GDP
CAMEROON: NIGHTLIGHT VS GDP
COMOROS: NIGHTLIGHT VS GDP
CHAD: NIGHTLIGHT VS GDP
KENYA: NIGHTLIGHT VS GDP
MADAGASCAR: NIGHTLIGHT VS GDP
MOZAMBIQUE: NIGHTLIGHT VS GDP


NAMIBIA: NIGHTLIGHT VS GDP
NIGER: NIGHTLIGHT VS GDP
SEYCHELLES: NIGHTLIGHT VS GDP
SOUTH AFRICA: NIGHTLIGHT VS GDP
SUDAN: NIGHTLIGHT VS GDP
TANZANIA: NIGHTLIGHT VS GDP
UGANDA: NIGHTLIGHT VS GDP

Climate Change and Macro Prices in Nigeria: A Nonlinear Analysis

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The study analyses the impacts of climate change on macro prices (food prices, interest rate, and exchange rate). Secondary data from 1960–2019 are used, and the nonlinear autoregressive distributed lag method is employed accordingly. The results reveal that there is a long-run relationship among the variables employed. In addition, asymmetry only exists between food prices and exchange rate in the short run while it only subsists for all macro prices, except interest rate as a dependent variable, in the long run. Also, the relative effects of climate change on macro prices grade food prices with the highest effect. In fact, the continual need for climate policies in both financial and real sectors to douse the effect of climate change on macro prices cannot be overemphasised. Therefore, this study recommends that the Nigerian government and policymakers should ratify and pursue policy initiatives and strategies based on both negative and positive changes in macro prices.

Key Words: asymmetry, climate change, macro prices, nonlinear ARDL
JEL Classification: E31, E43, F31, Q54
 https://doi.org/10.26493/1854-6935.20.167-203

Introduction

Literature is replete with the impact of climate change on food prices, owing to its implication for agricultural and manufacturing-sector productivity growth (Food and Agriculture Organisation of the United Nations 2016; 2019b; 2021; Foye and Benjamin 2021; Hendrix and Haggard 2015; Kreidenweis et al. 2016; Ogbuabor et al. 2020; Zhang et al. 2018). However, there is a paucity of literature on the relationship that exists between climate change and macro prices (food prices, and also isolated exchange and interest rates generally). This is because a general increase in food prices (food inflation) is one of the major channels to exchange rate volatility in an open economy, and interest rate has become topical in climate economics, as policymakers seek to stabilise the general price level by targeting inflation. In addition, studies on climate change and international trade have been able to establish that the former is critical

in achieving the macroeconomic objective of exchange rate stabilisation (Lee et al. 2021; Mckibbin et al. 2017; Tol 2006). To sum up, the relationship between climate change and macro prices is intertwined with not only a dearth of studies on the exchange and interest rates aspects but also the fact that little or no attention has been given to it, and likewise the relative effects of climate change on the different macro prices in a study. This has inhibited policymakers in formulating and proffering adequate policy strategies and recommendations to reverse the consequences of climate change for macro prices. Therefore, this study seeks to analyse the extent to which climate change affects macro prices and also to determine the relative effects of climate change on macro prices in Nigeria. This is with the view to attending to the peculiarity of Nigeria, as one of the countries most vulnerable to climate change, and also for adequate policy initiatives, recommendations, and implementations.

Climate change (global warming) is a long-term change in weather patterns reflected as a sustained increase in the mean temperature of the earth over decades (Foye and Benjamin 2021; IPCC n.d.; NASA: Global Climate Change; Vital Signs of the Planet n.d.). This change could be anthropogenic (human induced) or biogeographical. However, research has unequivocally established that climate change is human induced (Foye 2018; IPCC n.d.; NASA: Global Climate Change; Vital Signs of the Planet n.d.). Examples of such human activities are the burning of fossil fuels like coal, oil and natural gas (through industrialisation, gas flaring, and urbanisation, among others) which results in the dominance and persistence of carbon dioxide (CO_2) among other greenhouse gases (GHGS, such as methane, nitrous oxide, and fluorinated gases) in the atmosphere (see United States Environmental Protection Agency n.d.a; n.d.c; Foye 2018). These gases remain in the atmosphere for decades to thousands of years, and long enough for the gases to become well mixed. This means that the amount that is in the atmosphere is approximately the same all over the world, regardless of the source/country of the emissions (United States Environmental Protection Agency n.d.c). This is why climate change is referred to as a global phenomenon which impairs lives and livelihoods. Therefore, at the last 26th Conference of Parties (COP), efforts were made to deliver on and keep to the Paris Agreement of a 1.5° Celsius global temperature limit, as global temperature is already 1.1° Celsius above pre-industrial level, and this determines local mean temperature. For instance, statistics show that Nigeria's mean temperature rose from about 26.98° Celsius three decades ago to approximately 27.27

and 27.45° Celsius in the last two decades, respectively (The World Bank n.d.). This signifies that much still has to be done to avoid dangerous and irreversible consequences of climate change pushing about 132 million of the world's population into poverty (IPCC n.d.; The World Bank n.d.).

Over the years (2010–2020), the agricultural, industrial and services sectors have contributed about 22 percent, 25 percent and 53 percent to gross national product in Nigeria and employed 35, 12, and 53 percent of the labour force, respectively (The World Bank n.d.). The relationship between climate change and these sectors is well documented, with the argument that climate change impacts negatively on the sectors (Tanure et al. 2020; Foye 2018; Foye and Benjamin 2021; Graff Zivin, Hsiang, and Neidell 2018). This suggests that the consequences of climate change could result in a very devastating decline in income and saving which are consequent to the movement of macro prices (see Bofinger and Ries 2017) and the welfare of every population. Unfortunately, the climate change mitigation policies (National environmental policy, National drought and desertification policy, National forest policy, National erosion and flood control policy) designed to curb climate change (most importantly the reduction of fossil fuel consumption) have substantial economic impacts on income, consumption and saving, as these sectors are mostly reliant on fossil fuels for existence in Nigeria (Foye and Benjamin 2021). In précis, the impact of climate change on macro prices is worrisome in Nigeria, given that Nigeria lacks the capacity to cope with the consequences of climate change because of its reliance on the environment for livelihoods, high rate of poverty incidence, poor energy and road infrastructures, accelerated degradation of resources, conflicts, weak governance and, lately, high insecurity for lives and properties. For instance, this is manifested in the current escalation in prices; particularly, food prices have tripled over the past decade in Nigeria, as the consumer price index which was 110.84 in 2011 became 324.99 in 2020. In the same vein, the exchange rate of naira to American dollar has more than doubled over the same period from ₦153.86 to ₦358.81 per dollar, and this has had a tremendous effect on the interest rate which increased from 6.25 percent in 2010, to 12 percent in 2011 and was 13.5 percent in 2020 after hovering between 12–14 percent in 2012–2018 (CBN 2020). The implications of rising macro prices are of great concern. An increase in food prices alone could move millions of Nigerians into poverty characterised by uncertainty, welfare, and investment losses, through lower real wages, higher input prices, and reduced international competitiveness. On the other hand, an exchange

rate hike weakens foreign earnings which reduces availability of funds to priority sectors, thereby reducing economic activities, employment, per capita income and, again, the welfare of the citizens. In the same manner, a higher interest rate means lower investment and economic activities, an increase in unemployment and a reduction in income and welfare of the population (Adedeji and Foye 2019). Therefore, reversing this status quo is non-negotiable for Nigeria.

Furthermore, the importance of dealing with these different macro prices in a study cannot be overemphasised, as they are interrelated. Studies have shown that trying to mitigate the consequences of climate change on food-price hikes by employing inflation targeting measures (through interest rates), reduces investment and income. On the other hand, increasing money supply and exchange rate equally increases food prices which reduces real income, saving and investment (Monfared and Akın 2017). In fact, for a country like Nigeria, the exchange rate could be volatile and harmful, given the flexible exchange rate regime (Barguellil, Ben-Salha, and Zmami 2018) which engenders volatility effortlessly. Hence, analysing these macro prices together in a study could be a panacea to solving the consequences of climate change on macro prices in Nigeria, as the prices are highly interdependent. In synopsis, changes in food prices influence interest rate, and interest rate impacts exchange rate negatively. So, also, do exchange rate and interest rate influence food prices (see Arshad and Ali 2016; Adedeji and Foye 2019; Bofinger and Ries 2017) and climate change studies have avowed that international trade and tourism, among others, are drivers of exchange rate instability (Lee et al. 2021; Mckibbin et al. 2017; Tol 2006). Hence, it is imperative to propose relevant and adequate policy initiatives and solutions for this topical issue in Nigeria, in order to position the economy among the emergent world.

Against this backdrop, this study seeks to determine the extent to which climate change affects macro prices in Nigeria by employing a nonlinear autoregressive distributed lag (NARDL) method of econometric analysis using 1960–2019 data. This is because most macro relationships are innately nonlinear (Cosmas, Chitedze, and Mourad 2019; Nisbet, Miner, and Yale 2018) and need to be analysed thus. Moreover, the results of a nonlinear model are not only parsimonious and reliable but also very interpretable, providing a better fit with unbiased estimators and smaller residual errors (Bates and Watts 2007; Nisbet, Miner, and Yale 2018; Foye 2020). In addition, the NARDL allows asymmetry, switching

from short run to long run and vice versa. Specifically, this study contributes to knowledge by analysing the extent to which climate change affects macro prices and also by determining the individual and the relative effects of climate change on macro prices in a nonlinear analysis and in the same study argues for adequate policy initiatives in a vulnerable economy like Nigeria.

The second section of this paper reviews past literature on climate change and macro prices while the third section unveils the research method. The fourth section shows the results and discussion of findings and the last section contains the recommendations and concluding remarks.

Review of Literature

THEORETICAL REVIEW

While other theories associate changes in price level with production, Milton Friedman relates this to monetary factors. The monetarists avow that changes in demand for and supply of money are closely linked to changes in general price level, food prices inclusive. This simply means the supply of money engenders an increase in food prices. The monetarists consider the monetary policy as a better equilibrating tool for any economy than the fiscal policy. On the other hand, the Keynesian school associates changes in price level with aggregate demand components, such as consumption which is a function of income, *ceteris paribus;* investment, a function of interest rate, and saving from income; as well as government spending and international trade. And over time economists have found that many other factors determine change in prices. For instance, foreign exchange, the saving-investment gap, the effects of agricultural output and its value chain, research and development, governance, and the institutional framework, among others, equally determine prices in general (Okoye et al. 2019; Inim, Samuel, and Prince 2020).

In the same vein, the classical theory uses the forces of demand for investment and supply of savings to determine interest rate while the balance of payments (BOP) theory of exchange rate maintains that the rate at which the currency of one country exchanges for another is determined by autonomous domestic price level and money supply. This means that the demand for foreign exchange is provoked by the demand for foreign goods and services, probably as a result of internal inflation. The theory of interest rate started with Fisher in 1930. This states that interest

rate is a 'deviation from the price of the present money in terms of future money due to expected inflation'. This is commonly represented as $i = r + \pi$ (where i is the interest rate, r is the ex-ante real interest rate and π is the expected rate of change in the price level), which is a result of the efficiency of labour and capital as well as time preference of investors in an economy. Further, Fankhauser, Smith, and Tol (1999) and Foye (2014; 2018) have unveiled the relationship between climate change and macroeconomic activities both theoretically and empirically.

EMPIRICAL REVIEW

It is a consensus that macro prices are influenced by climate change (Food and Agriculture Organisation of the United Nations 2019a; Galindo, Reyes, and Alatorre 2015; Iheoma 2014; Mckibbin et al. 2017; Ogbuabor et al. 2020; Bhalia 2021). Thus, there are innumerable studies on the impact of climate change on food prices which is a core portion of the consumer price index and one of the determinants of increase in the general price level, and all of these studies are in agreement that climate change impacts negatively on food prices, given that most regions rely on the environment for food. However, African and Asian countries seem to be more affected because they are most vulnerable to climate change. The implication of this is clear for these countries, as they might be induced to rely more on food imports (see Mckibbin et al. 2017; Igbokwe-Ibeto 2019; Shuaibu 2020 among others). However, Food and Agriculture Organisation of the United Nations (2019b) submitted that this impact could be low in open economies. Specifically, studies by Bandara and Cai (2014), Bradbear and Friel (2013), Hendrix and Haggard (2015), and Stevanović et al. (2016) employed a partial equilibrium approach using a global dynamic computable general equilibrium model, conceptual development, panel ordinary least squares regression, a global partial equilibrium agro-economic model (The Model of Agricultural Production and its Impact on the Environment, or MAGPIE model) and descriptive statistics, respectively, and found that climate change escalates food prices; hence, inflation. However, studies by Kreidenweis et al. (2016) and Stevanović et al. (2016) elucidated that an increase in food prices is not only a result of the direct impact of climate change on agriculture but also that the cost of adapting and mitigating the effects of climate change is germane in the movement of food prices. To this effect, this study seeks to establish the extent of this food price increase in the presence of other macro prices.

On the relationship between climate change and exchange rate, Feyen

TABLE 1 Summary of Empirical Review

(1)	(2)	(3)	(4)	(5)
Climate change and food Prices	Bandara and Cai (2014)	South Asia (Bangladesh, India, Nepal, Pakistan and Sri Lanka)	Partial equilibrium approach using global dynamic computable general equilibrium model	South Asia is one of the most vulnerable regions where climate-induced changes exert a significant negative impact on food prices.
	Howard and Sterner (2014)	USA	Modified Dynamic Integrated Climate-Economy (DICE) model, an integrative assessment model	Accounting for relative prices of agricultural and non-market goods increases the damage estimates of climate change (social cost of carbon) from $38 to about $52, showing that the cost of climate change is greater than reported.
	Hendrix and Haggard (2015)	Developing Countries: 49 countries in Africa and Asia (1961–2010)	Panel ordinary least squares regression	Climate change would induce the reliance of many developing countries on food imports, which would result in food price increase and volatility.
	Raleigh, Choi, and Kniveton (2015)	113 African markets (Jan 1997 to April 2010)	Simultaneous equation models	Climate change increases shortages in food production, thereby increasing food prices and these results in conflicts which lead again to further food price hikes.
	Food and Agriculture Organisation of the United Nations (2016)	Global	Descriptive Statistics	Climate change engenders food price increases and volatility, thereby reducing purchasing power and thus restricting access to food. This in turn affects the lives and livelihoods of poor net food buyers.

Continued on the next page

et al. (2020) employed data spanning from 2005–2017 for panel data analysis of the global economy and found that most countries are vulnerable to climate change and macro-financial risks. Particularly for MENA countries, climate change could reduce foreign exchange earnings as they face the transition and macro-financial vulnerability risks. However, Batten, Sowerbutts, and Tanaka (2020) unveiled in their studies the inter-

TABLE 1 *Continued from the previous page*

(1) (2)	(3)	(4)	(5)
Kreidenweis et al. (2016)	Global	Global partial equilibrium model (MAGPIE model)	Mitigating climate change through afforestation would engender a more than fourfold increase in food prices by 2100, as afforestation competes for available arable land for food crops cultivation.
Stevanović et al. (2016)	Global	Global partial equilibrium agro-economic model (MAGPIE model)	Climate incentive-based mitigation policies reduce the availability of land, which in turn increases production costs and food prices. The preference-based mitigation reduces land scarcity, inhibits emissions leakage, and focuses on the most productive locations, which invariably lowers food prices.
Mckibbin et al. (2017)	Global	Reviews/ descriptive statistics	Increase in food prices could result in inflation; the response of a central bank determines what happens to the exchange rate. In inflation targeting, the interest rate is raised which slows down the economy more, causing the exchange rate to appreciate, making imports cheaper and exports more expensive. An income targeting initiative is more attractive, as it does not create public expectations of higher future inflation.
Aye and Haruna (2018)	Nigeria (1995–2009)	Descriptive statistics and three-stage least square regression method	Climate change especially affects the price of maize negatively in Benue state in Nigeria.
Igbokwe-Ibeto (2019)	Nigeria	Descriptive statistics	Climate change causes hikes in food prices. Worse cases of food crisis are imminent in Nigeria.

Continued on the next page

dependence of macro prices, using descriptive statistics and conceptual development for the United States of America (USA) in 2006–2019. Their result revealed that climate change affects food and energy prices, engendering inflation which makes a country less competitive, suggesting

TABLE 1 *Continued from the previous page*

(1)	(2)	(3)	(4)	(5)
	Food and Agriculture Organisation of the United Nations (2019b)	Global	Descriptive statistics	Climate change causes food insecurity, hikes in food prices and general price levels. However, the effects could be low in open economies.
	Shuaibu (2020)	Nigeria	Nonlinear ARDL	Climate change affects food production and food prices. The result concludes that asymmetries exist in the long run only.
Climate change and exchange rate	Tol (2006)	16 major regions of the world (1950 to 2200)	Integrated Assessment Model Version 2.7 of the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND)	The impact of climate change is determined by the type of foreign exchange employed in analysis. It is projected that developing countries would grow more slowly when a purchasing power exchange rate is employed than with a market exchange rate. The study argues that the market exchange rate is more appropriate for international trade, and the real exchange rate for international welfare comparisons.
	Economic Commission for Latin America and the Caribbean (2011)	Montserrat (2008–2050)	Descriptive statistics/ a general structural time series model	Montserrat is dependent on tourism which earns more than five times the value of its merchandise exports; and being affected by the consequences of climate change means a decline in foreign exchange earnings which is consequent to the Island's exchange rate.
	Feyen et al. (2020)	Global 1981–2017 and1995–2017 for descriptive statistics; 2005–2017 for panel analysis	Descriptive statistics/ panel data analysis	Countries are vulnerable to climate change, even macro-financial risks. Climate change could reduce foreign exchange earnings in MENA countries, as they face the transition and macro-financial vulnerability risks.

Continued on the next page

a decline in foreign exchange in the long run. Accordingly, attendant climate change and carbon emissions policies affect the monetary policy objectives of the USA. Lee et al. (2021) extended the frontiers of knowl-

TABLE 1 *Continued from the previous page*

(1) (2)	(3)	(4)	(5)
Batten, Sowerbutts, and Tanaka (2020)	United States of America (2006–2019)	Descriptive statistics and conceptual development	Climate change and carbon emissions policies affect monetary policy objectives. Climate change affects food and energy prices, engendering inflation which makes a country less competitive. This suggests a decline in foreign exchange in the long run.
Lee et al. (2021)	76 countries (1970–2017)	Stochastic discount factor approach/ Impulse response from single-equation method	38% of the selected countries which are poorer, less reliant on agriculture, and engage in international trade have their exchange rates appreciate in real terms against the US dollar, especially for landlocked countries, while the real exchange rate depreciates in 17% of the selected countries which are warmer, wealthier, more reliant on agriculture and tourism, and are less open.
Bhalia (2021)	Kenya	Descriptive Statistics	Climate change ravages tea production which is a major source of foreign exchange for Kenya. This means the likelihood of the domestic exchange rate's depreciation against the dollar is strong.

Continued on the next page

edge by carrying out a study on 76 countries consisting of countries that are open to external trade and those that are less open, in the presence of both local and global climate change shocks. They discovered that real exchange rate responds to both global and country-specific temperature shocks. However, only the responses to global shocks systematically show country characteristics, as 38% of the selected countries which are poorer, less reliant on agriculture, and engage in international trade have their exchange rates appreciate in real terms against the US dollar, particularly for landlocked countries. On the other hand, the real exchange rate depreciates in 17% of the selected countries which are warmer, wealthier, more reliant on agriculture and tourism, and are less open to international trade. This suggests that countries that are warmer and most reliant on agriculture suffer the negative consequences of climate change more.

For the final strand in this study, Mckibbin et al. (2017), in their study of climate change and monetary policy, revealed that the effect of climate

TABLE 1 *Continued from the previous page*

(1)	(2)	(3)	(4)	(5)
Climate change and interest rate	Tumwine et al. (2018)	Uganda (24 banks; 2008–2016)	Net interest margin model/panel random-effects regression method	Liquidity, equity capital, market power, and reserve requirement have a positive and significant effect on interest rate while operational efficiency, lending out ratio, concentration, public sector borrowing, and private sector credit harm the interest rate. Climate change is not included in this analysis.
	Bylund and Jonsson (2020)	General	Descriptive statistics	Climate change weakens growth, increases uncertainty, and elevates the risk of disasters which could engender a low long-run real interest rate. The too-low long-run interest rate might make it difficult for apex banks to achieve price stability.
	Bauer and Rudebusch (2021)	General	Descriptive statistics	The study shows that the fundamental anchor for the market-based social discount rate is the equilibrium real interest rate. Empirical interest rate models have declined significantly since the 1990s and this has made the entire term structure of social discount rates to decline as well. This new normal of persistently lower interest rates boosts the social cost of carbon and supports a climate policy with stronger carbon mitigation strategies.
	Rudebusch (2021)	General	Letters	Climate change is a strong source of financial risk for households and businesses. Although there is a great deal of uncertainties, still, central banks have made progress on a path to identify, assess, and manage climate-related financial risks.

NOTES Column headings are as follows: (1) titles, (2) authors, (3) country, (4) theoretical framework/methodology, findings.

change on interest rate is mostly the upshot of the carbon emissions policies employed to mitigate the consequences of climate change. For instance, policy initiatives to stabilise a climate-induced price increase may be targeted at the interest rate; hence, the link between climate change and interest rate might be essentially indirect. However, the implication of raising the interest rate by central banks is further slowdown in economic activities, making imports cheaper and exports more expensive. This sug-

gests that an income-targeting initiative is more attractive and should be a better way of targeting inflation, given that it does not create public expectations of higher future inflation. Further, Bylund and Jonsson (2020) employed descriptive analysis and found that climate change weakens economic growth, increases uncertainty, and elevates the risk of disasters which could engender a low long-run real interest rate. This low long-run interest rate might make it difficult for apex banks to achieve price stability. Just like Bylund and Jonsson (2020), Bauer and Rudebusch (2021) showed that long-run equilibrium real interest rate has declined since the 1990s, causing the entire term structure of social discount rates to decline and confirming the importance of the real interest rate in the present discounted future costs of climate change. This confirms that there is a link between the discount rates, the long-run equilibrium real interest rate and climate policies generally. The lower interest rates boost the social cost of carbon and support a climate policy with stronger carbon mitigation strategies.

Specifically, three strands of the literature are considered in this review. First are studies on the link between climate change and food prices, second are those on foreign exchange, and lastly, those on the relationship between climate change and interest rate. Finally, most studies on climate change and macro prices are cross-country analyses (see Bauer and Rudebusch 2021; Lee et al. 2021; Food and Agriculture Organisation of the United Nations 2019b; Hendrix and Haggard 2015; Raleigh, Choi, and Kniveton 2015; Stevanović et al. 2016) which do not control for the country-specific peculiarity of Nigeria, one of the most vulnerable populations and a very fragile economy. Furthermore, most of the studies are anecdotal, as they only utilised descriptive statistics which lack rigorous methodological control. Others employed integrated assessment models (IAMS) which exaggerate climate values and suffer from technical deficiencies, as it is difficult to specify optimal paths through IAMS (Ackerman et al. 2009).

See Table 1 (pp. 173–177) for the summary of the empirical literature review.

Materials and Methods

There are three theoretical frameworks in this study. For food prices, I follow Huh and Park (2013) on the factors that influence inflation, while for the exchange rate and interest rate I follow Frankel (2007) and Feldstein and Eckstein (1970), respectively. Following Fankhauser and Tol

(2005), I employ climate change as one of the core explanatory variables in this study. Also, trade openness is included because Nigeria is an open economy, and Lee et al. (2021) have equally submitted after studying 76 economies that 38% of the economies who maintained open economy policies experienced currency appreciation.

THEORETICAL FRAMEWORK

The description and measurement of the variables employed in this study are important and therefore stated thus: food prices (FP) and exchange rate (EXR) are measured by consumer price index and Nigeria's naira relative to the United States' dollar, respectively. While money supply (MS) is measured by broad money, interest rate (IR) is measured by the Central Bank of Nigeria's nominal interest rate. Finally, trade openness is measured by percentage of trade to gross domestic product, and climate change (CC) by atmospheric mean temperature.

Model 1 (Food Prices as Dependent Variable)

Following Huh and Park (2013) on the relevant regressors for Food Prices (FP) in this study, I specify $\text{FP} = f(\text{EXR}, \text{MS}, \text{IR}, \text{TO}, \text{CC})$ where (i) the Exchange Rate (EXR) against the dollar can affect local food prices by altering import prices, (ii) Money Supply (MS) is included to reflect inflationary pressures on the general price level, (iii) Interest Rate (IR) is incorporated because a change in interest rate changes demand for money and hence food prices (high interest rates reduce firms' desire to carry inventory (Frankel 2014), and (iv) International trade (TO) is included, first because Nigeria is an open economy and second, because high food prices could engender increased import and vice versa (Lee et al. 2021). Finally, (v) Climate Change (CC) variable (average temperature) is included because climate change affects food production and food prices (Shuaibu 2020).

Model 2 (Foreign Exchange as Dependent Variable)

Following Frankel (2007) on the relevant regressors for Exchange Rate (EXR), I specify Model 2 as $\text{EXR} = f(\text{FP}, \text{MS}, \text{IR}, \text{TO}, \text{CC})$. This simply reveils that: (i) Changes in price level, in this case food prices, would cause changes in dollar exchange rate: a country with lower commodity prices would experience appreciation in foreign currency, as lower prices encourage exports; hence, foreign exchange. (ii) On the other hand, changes

in interest rate affect exchange rate; this is because increases in interest rate provide higher rates to lenders and this attracts foreign capital, hence increase in money supply. (iii) Furthermore, engagement in trade increases net export, therefore trade openness is included in this model. (iv) Average temperature is equally included in the exchange rate model to capture climate change, given the fact that climate change policies affect monetary policy objectives and inflation which makes an economy less competitive in trade when compared to other economies (Batten, Sowerbutts, and Tanaka 2020).

Model 3 (Interest Rate as Dependent Variable)

Following Feldstein and Eckstein (1970) on the relevant fundamental determinants of interest rate (IR) for this study, I specify $\text{IR} = f(\text{MS}, \text{FP}, \text{EXR}, \text{TO}, \text{CC})$ where the basic Keynesian liquidity preference theory advances that there is a relationship between the quantity of money, the level of income and the rate of interest which is empirically expressed in a money demand function.

However, a more appropriate relationship is that of interest rate and money supply which equally determines the changes in price level but not a continuous rise in price level (in this model food prices (FP) is therefore employed). Likewise, a higher interest rate attracts trade and increases foreign exchange. Very recently, the uncertainties and risk associated with climate change have made it a topical issue in macro-financial models; hence we also include climate change in the interest rate model (Bylund and Jonsson 2020).

SPECIFICATION OF MODELS

Given that macroeconomic variables are essentially nonlinear and their processes are well recognised and established in literature (Cosmas, Chitedze, and Mourad 2019; Nisbet, Miner, and Yale 2018; Shin, Yu, and Greenwood-Nimmo 2014), the explanatory variables of the three models in this study are, therefore, specified following Shin, Yu, and Greenwood-Nimmo (2014) and Foye, Adedeji, and Babatunde (2020). First, I specify generic partial sums x_t^+ and x_t^- around zero with the view to distinguishing between positive and negative changes in the rate of growth of x_t. This is because the imposition of long-run symmetry where the relationship is actually nonlinear will inhibit efforts to test for the presence of a stable long-run relationship and this can result in spurious dynamic responses. In the same vein, it is important to capture asymmetries cor-

rectly. This will help to unveil probable differences in the responses of economic agents to positive and negative shocks.

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0)$$
$$x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j, 0) \tag{1}$$

Furthermore, I develop a parametric dynamic model for combined long-run and short-run asymmetries by extending the ARDL method of Pesaran and Shin (1999) and Pesaran, Shin, and Smith (2001); therefore, the nonlinear ARDL model is specified thus:

$$y_t = \sum_{i=1}^{p} \gamma_i y_{t-i} + \varepsilon_t \sum_{j=0}^{m} (\varphi_j^+ \Delta x_{t-j}^+ + \varphi_j^- \Delta x_{t-j}^-) + \varepsilon_t, \tag{2}$$

where x_t is the $k \times 1$ vector of multiple regressors, φ_j^+ and φ_j^- are the asymmetric distributed-lag parameters, and ε_t is white noise. I rewrite Equation (2) in an error correction format as

$$\Delta y_t = \alpha_0 + \theta_{yy} y_{t-1} + \theta_{yx}^+ x_{t-1}^+ + \theta_{yx}^- x_{t-1}^- + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \sum_{j=0}^{m-1} (\varphi_j^+ \Delta x_{t-j}^+ + \varphi_j^- \Delta x_{t-j}^-) + \varepsilon_t, \tag{3}$$

where x_t^+ and x_t^- are the positive and negative movements of variables in x_t in the long run, θ_{yx}^+ is the long-run cointegrating relationship between y_t and x_t^+, and θ_{yx}^- is the long-run cointegrating relationship between y_t and x_t^-.

y_t, x_t^+, and x_t^- form the nonlinear long-run equilibrium while the last summation term is the asymmetric error correction process of the nonlinear model. $\theta_{yx}^+ = \theta_{yx}^-$ represents the long-run symmetry and $\sum_{j=0}^{m-1} \varphi^+ = \sum_{j=0}^{m-1} \varphi^-$ the short-run symmetry; and can be tested using the standard Wald tests. Following Shin, Yu, and Greenwood-Nimmo (2014), the bounds test of ARDL is applied to nonlinear ARDL, and also the Pesaran critical values are equally appropriate and employed in determining cointegration. The critical values are selected based on the number of variables before decomposition into partial sums.

Therefore, I rearrange and respecify the basic three models implicitly:

$$\text{FP} = f(\text{CC}, \text{MS}, \text{IR}, \text{EXR}, \text{TO}, \mathcal{U}) \tag{4}$$

$$\text{EXR} = f(\text{CC}, \text{MS}, \text{IR}, \text{FP}, \text{TO}, \mathcal{U}) \tag{5}$$

$$\text{IR} = f(\text{CC}, \text{MS}, \text{FP}, \text{EXR}, \text{TO}, \mathcal{U}) \tag{6}$$

Equations (7), (8), and (9) are the econometric representation of Equations (4), (5), and (6):

$$\text{FP} = \phi_0 + \phi_1 \text{CC}_t + \phi_2 \text{MS}_t + \phi_3 \text{IR}_t + \phi_4 \text{EXR} + \phi_5 \text{TO}_t + \varepsilon_t \tag{7}$$

$$\text{EXR} = \phi_0 + \phi_1 \text{CC}_t + \phi_2 \text{MS}_t + \phi_3 \text{IR}_t + \phi_4 \text{FP} + \phi_5 \text{TO}_t + \varepsilon_t \tag{8}$$

$$\text{IR} = \phi_0 + \phi_1 \text{CC} \phi_t + \phi_2 \text{MS}_t + \phi_3 \text{FP}_t + \phi_4 \text{EXR} + \phi_5 \text{TO}_t + \varepsilon_t \tag{9}$$

The general form of the asymmetric ARDL model is then represented thus:

$$\begin{aligned} \text{FP} = {} & \phi_0 + \phi_1 \text{CC} \phi_t^+ + \phi_2 \text{CC}_t^- + \phi_3 \text{MS} \phi_t^+ + \phi_4 \text{MS}_t^- + \phi_5 \text{IR}_t^+ \\ & + \phi_6 \text{IR}_t^- + \phi_7 \text{EXR}_t^+ + \phi_8 \text{EXR}_t^- + \phi_9 \text{TO}_t + \varepsilon_t \end{aligned} \tag{10}$$

$$\begin{aligned} \text{EXR} = {} & \phi_0 + \phi_1 \text{CC}_t^+ + \phi_2 \text{CC}_t^- + \phi_3 \text{MS}_t^+ + \phi_4 \text{MS}_t^- + \phi_5 \text{IR}_t^+ + \\ & + \phi_6 \text{IR}_t^- + \phi_7 \text{FP}_t^+ + \phi_8 \text{FP}_t^- + \phi_9 \text{TO}_t + \varepsilon_t \end{aligned} \tag{11}$$

$$\begin{aligned} \text{IR} = {} & \phi_0 + \phi_1 \text{CC}_t^+ + \phi_2 \text{CC}_t^- + \phi_3 \text{MS}_t^+ + \phi_4 \text{MS}_t^- + \phi_5 \text{FP}_t^+ + \\ & + \phi_6 \text{FP\_}t^- + \phi_7 \text{EXR}_t^+ + \phi_8 \text{EXR}_t^- + \phi_9 \text{TO}_t + \varepsilon_t, \end{aligned} \tag{12}$$

where FP is Food Prices (measured by consumer price index), CC is Climate change (measured with atmospheric mean temperature), MS is Money Supply (measured by broad money), IR is Interest Rate (measured by the Central Bank of Nigeria's nominal interest rate), EXR is Exchange rate (measured by Nigeria's naira relative to the United States' dollar), TO is Trade openness (measured by percentage of trade to gross domestic product), $\phi_1 - \phi_9$ is Vector of long-term parameters, and ε_t is Error term.

Climate change (global warming) is measured in the same context for every country using mean atmospheric temperature because climate change is a global phenomenon (Abidoye and Odusola 2015; Foye 2018; Foye and Benjamin 2021; Kiley 2021). Climate change in this sense is different from short-term weather patterns which are important for studies on agricultural productivity. Also, it is worthy of note to emphasise that rainfall patterns are driven by the earth's temperature (see Foye 2014; United States Environmental Protection Agency n.d.b). Hence, the key focus and measure of climate change in this study is the mean atmo-

spheric temperature which has low frequency, and the macro prices are dependent on it in these models; therefore, the employment of annual data is appropriate for this study (Cheung et al. 2017; Yeo and Kim 2014).

Integrating Equation 1 into the NARDL model for the three models, I have:

$$\begin{aligned}
\text{FP} = {} & \gamma + \eta_0 \text{FP}_{t-1} + \eta_1 \text{CC}^+_{t-1} + \eta_2 \text{CC}^-_{t-1} + \eta_3 \text{MS}^+_{t-1} + \eta_4 \text{MS}^-_{t-1} \\
& + \eta_5 \text{IR}^+_{t-1} + \eta_6 \text{IR}^-_{t-1} + \eta_7 \text{EXR}^+_{t-1} + \eta_8 \text{EXR}^-_{t-1} + \eta_9 \text{TO}_{t-1} \\
& + \sum_{i=1}^{p} \theta_i \Delta \text{FP}_{t-i} + \sum_{i=0}^{q} (\vartheta_i^+ \Delta \text{CC}^+_{t-i} + \vartheta_i^- \Delta \text{CC}^-_{t-i}) \\
& + \sum_{i=0}^{r} (\lambda_i^+ \Delta \text{MS}^+_{t-1} + \lambda_i^- \Delta \text{MS}^-_{t-1}) + \sum_{i=0}^{s} (\varphi_i^+ \Delta \text{IR}^+_{t-i} + \varphi_i^- \Delta \text{IR}^-_{t-i}) \\
& + \sum_{i=0}^{t} (\psi_i^+ \Delta \text{EXR}^+_{t-i} + \psi_i^- \Delta \text{EXR}^-_{t-i}) + \sum_{i=1}^{u} \Omega_i \Delta \text{TO}_{t-i} + \mu_t, \qquad (13) \\
\text{EXR} = {} & \gamma + \eta_0 \text{EXR}_{t-1} + \eta_1 \text{CC}^+_{t-1} + \eta_2 \text{CC}^-_{t-1} + \eta_3 \text{MS}^+_{t-1} + \eta_4 \text{MS}^-_{t-1} \\
& + \eta_5 \text{IR}^+_{t-1} + \eta_6 \text{IR}^-_{t-1} + \eta_7 \text{FP}^+_{t-1} + \eta_8 \text{FP} + \eta_9 \text{TO}_{t-1} \\
& + \sum_{i=1}^{p} \theta_i \Delta \ln \text{EXR}_{t-i} + \sum_{i=0}^{q} (\vartheta_i^+ \Delta \text{CC}^+_{t-i} + \vartheta_i^- \Delta \text{CC}^-_{t-i}) \\
& + \sum_{i=0}^{r} (\lambda_i^+ \Delta \text{MS}^+_{t-1} + \lambda_i^- \Delta \text{MS}^-_{t-1}) + \sum_{i=0}^{s} (\varphi_i^+ \Delta \text{IRT-I}^+ + \varphi_i^- \Delta \text{IR}^-_{t-i}) \\
& + \sum_{i=0}^{t} (\psi_i^+ \Delta \text{FP}^+_{t-i} + \psi_i^- \Delta \text{FP}^-_{t-i}) + \sum_{i=1}^{u} \Omega_i \Delta \text{TO}_{t-i} + \mu_t, \qquad (14) \\
\text{IR} = {} & \gamma + \eta_0 \text{IR}_{t-1} + \eta_1 \text{CC}^+_{t-1} + \eta_2 \text{CC}^-_{t-1} + \eta_3 \text{MS}^+_{t-1} + \eta_4 \text{MS}^-_{t-1} \\
& + \eta_5 \text{IR}^+_{t-1} + \eta_6 \text{IR}^-_{t-1} + \eta_7 \text{FP}^+_{t-1} + \eta_8 \text{FP} + \eta_9 \text{TO}_{t-1} \\
& + \sum_{i=1}^{p} \theta_i \Delta \text{IR}_{t-i} + \sum_{i=0}^{q} (\vartheta_i^+ \Delta \text{CC}^+_{t-i} + \vartheta_i^- \Delta \text{CC}^-_{t-i}) \\
& + \sum_{i=1}^{r} (\lambda_i^+ \Delta \text{MS}^+_{t-1} + \lambda_i^- \Delta \text{MS}^-_{t-1}) + \sum_{i=0}^{s} (\varphi_i^+ \Delta \text{FP}^+_{t-i} + \varphi_i^- \Delta \text{FP}^-_{t-i}) \\
& + \sum_{i=0}^{t} (\psi_i^+ \Delta \text{EXR}^+_{t-i} + \psi_i^- \Delta \text{EXR}^-_{t-i}) + \sum_{i=1}^{u} \Omega_i \Delta \text{TO}_{t-i} + \mu_t, \qquad (15)
\end{aligned}$$

where p, q, r, s, t, and u are the lag orders; $\phi_i = \eta_i^+$ and η_i^- are the

long-run impacts of the increases and decreases of the first four pairs of long-term regressors on FP, EXR and IR respectively. Also, each pair of $\sum_{i=0}^{q} \theta_i^+$ and $\sum_{i=0}^{q} \theta_i^-$, $\sum_{i=0}^{r} \lambda_i^+$ and $\sum_{i=0}^{r} \lambda_i^-$, $\sum_{i=0}^{s} \lambda_i^+$ and $\sum_{i=0}^{s} \varphi_i^-$, $\sum_{i=0}^{t} \psi_i^+$ and $\sum_{i=0}^{t} \psi_i^-$ capture the short-run impacts of the increases and decreases of the short-term regressors on FP, EXR, and IR, respectively. Furthermore, I extend Equations (13)–(15) by including an endogenous structural breaks dummy variable ($\sum_{r=1}^{v} \delta D_{rt}$) to capture significant events that could induce structural change in the variables employed in this study given that the observational period of the data covers decades which hold structural events such as Nigeria's structural adjustment programme of 1986, the political instability of 1993–1994, the bank recapitalisation of 1991 and 1994, the global melt down of 2008, the collapse of oil prices and output of 2014, among others. Therefore the $D_{rt} = 1$ for $t > T_D$, and $D_{rt} = 0$, where the time period is t and T_D are the structural break dates when $r = 1, 2, 3, \ldots, k$ and δ_r is the coefficient of the structural break dummy. The Bai-Perron test (Bai and Perron 2003) which determines multiple breaks endogenously is employed in this study to overcome bias associated with regression results in the presence of structural breaks.

DATA AND TECHNIQUES OF ANALYSIS

This study employs the NARDL bounds testing technique in the analysis of three macro-price models in Nigeria from 1960 to 2019. This observational period is large enough to make room for the required degrees of freedom. Annual time-series data on food prices (measured by consumer price index), exchange rate, and interest rate (measured by the Central Bank of Nigeria's monetary policy rate) are sourced from Central Bank of Nigeria (CBN 2020) while data for broad money supply, trade openness, and climate change are obtained from the World Development Indicators (The World Bank n.d.) and climate knowledge portal of 2020. The EViews 10 statistical package is used in the analysis of the data. I ascertain that variables with the second order of integration [I(2)] are not included in the models to avoid their crashing which could result in invalid estimated bounds F-statistics (Pesaran 1997; Haug and Ucal 2019; Allen and McAleer 2021). Therefore, I employ Kapetanios, Shin, and Snell (2003), and Kruse (2011) tests to ensure there is no I(2) series in the models. This is done after observing the summary statistics which show the distribution of the data being employed. The nonlinear ARDL performs better in determining cointegration in small samples (Iyke and Ho 2017)

TABLE 2 Summary Statistics with Raw Data

Item	FP	EXR	IR	CC	MS	TO
Mean	39.99	61.43	10.14	26.98	4580.00	31.96
Median	2.33	7.70	10.00	26.99	50.50	32.45
Maximum	267.51	306.92	26.00	27.83	34800.00	53.28
Minimum	0.07	0.55	3.50	26.21	0.28	9.14
Std. Dev.	65.58	87.01	5.19	0.39	9090.00	11.39
Skewness	1.88	1.38	0.57	−0.09	2.04	−0.15
Kurtosis	5.80	4.05	2.79	2.35	5.98	2.25
Jarque-Bera	55.00	21.73	3.33	1.12	63.79	1.65
(Prob.)	(0.00)	(0.00)	(0.19)	(0.57)	(0.00)	(0.44)

NOTES The first five cells under MS in the raw results are in trillion naira.

and its framework can test for symmetry in the short run and long run. It is noteworthy to highlight that the presence of symmetry reduces the NARDL equation to an ARDL equation. The NARDL model is parsimoniously specified to maintain adequate degrees of freedom. This study employs automatic lag length selection based on the Akaike Information Criterion. The data obtained for Models 1–3 cover the periods of 1960–2019.

Results and Discussion

DESCRIPTIVE STATISTICS

Data observation is very important in economic modelling. It helps to overcome the challenge of spurious regression caused by outliers and the abnormal distribution of data. Table 2 shows the summary statistics of the raw data for Models 1–3. IR, CC, and TO are normally distributed with Jarque-Bera probability values that are greater than a 0.05 level of significance while FP, EXR, and MS are not normally distributed. This observation can also be seen in the kurtosis and skewness of the variables. The kurtosis of almost 3 suggests that the series is in the range of normalcy (not peaked and not flat). Also, a non-zero value of skewness means variables are not normally distributed which is the case for the latter variables mentioned above.

Therefore, I take the natural log of the variables except those that are already in percentages (IR and TO) to achieve normal distribution of all the variables (Wooldridge 2018; see the results for the logged variable in table 3). The highest mean and median are 4580 and 50.5 trillion for MS re-

TABLE 3 Summary Statistics with Logged Data

Item	LNFP	LNEXR	IR	LNCC	LNMS	TO
Mean	1.14	2.12	10.14	3.30	25.19	31.96
Median	0.85	2.04	10.00	3.30	24.63	32.45
Maximum	5.59	5.73	26.00	3.33	31.18	53.28
Minimum	−2.72	−0.60	3.50	3.27	19.44	9.14
Std. Dev.	2.92	2.45	5.19	0.01	3.86	11.39
Skewness	0.07	0.16	0.57	−0.12	0.06	−0.15
Kurtosis	1.43	1.30	2.79	2.35	1.69	2.25
Jarque-Bera	6.19	7.53	3.33	1.18	4.36	1.65
(Prob.)	(0.05)	(0.02)	(0.19)	(0.55)	(0.11)	(0.44)

spectively while for IR they are the least at 10.14 and 10 in the same order. The first five cells under MS in the raw results are in trillion naira. The close values of the mean and median for the different variables are strong proofs that the data are normally distributed (see Holmes, Illowsky, and Dean 2017). The mean and the median values also authenticate that our population sample is large enough to reduce bias in the variance of our models. Finally, the maximum and the minimum values are not outliers, as they are still in close range with the observations of the respective variables.

Nevertheless, to have interpretable results and valid regression output, the data employed in this study are in natural logarithm except for IR and TO which are in rates (see Ogun 2021; Wooldridge 2018).

UNIT ROOT AND COINTEGRATION TESTS

Unit Root Tests

Although the regular linear unit root tests show that all variables are either stationary at level [I(1)] or first difference [I(1)] with no I(2) series, nevertheless the power of the test is too low to make a nonlinear stationarity conclusion (see Güriş 2017). Therefore, I employ Kapetanios, Shin, and Snell (2003), and Kruse (2011) to determine the nonlinear stationarity properties of the variables used in this study. The unit root test proposed by Kruse (2011) is an extension and better fit of Kapetanios, Shin, and Snell (2003). Specifically, Kapetanios, Shin, and Snell (2003) is a technique of testing for non-stationarity against a global alternative of a stationary nonlinear exponential smooth transition autoregressive (ESTAR) process. The Kruse nonlinear unit root test examines the ESTAR character-

TABLE 4 Nonlinear Unit Root Test Results

Variables	KSS	Kruse	Remarks	Variables	KSS	Kruse	Remarks
LNFP	−1.87	−1.73	Non stationary	LNCC	0.22	−3.42	Non stationary
LNEXR	−1.48	−2.66	Non stationary	LNMS	−1.99	−3.33	Non stationary
IR	−1.13	−5.49	Non stationary	TO	−2.94	−3.76	Non stationary

NOTES The 5 percent critical values for KSS and Kruse (2011). Tests are −2.88 and 9.57, respectively (see Hepsag 2017).

TABLE 5 Unit Root Test With Structural Breaks

Series	Vogesland test decision			Final decision
	Break year	I(0)	I(1)	
LNFP	1995	−2.78	−5.13*	I(1)
LNEXR	1999	4.46*	−8.31	I(0)
IR	1993	−4.06	12.52*	I(1)
LNCC	2000	−5.37*	11.99	I(0)
LNMS	2007	−1.82	−5.65*	I(1)
TO	1981	−3.53	−9.56*	I(1)
5% critical values		4.44	4.44	

istics against the null hypothesis of a unit root. The ESTAR and the Kruse equations used in determining the nonlinear stationarity properties of the variables in this study are $Y_t = \alpha Y_{t-1} + \beta Y_{t-1}[1 - \exp\{-\theta(Y_{t-1} - C)^2\}] + \varepsilon_t$ and $\Delta Y_t = \gamma_1 Y_{t-1}^3 + \gamma_2 Y_{t-1}^2 + \sum_{j=1}^{p} \delta_j \Delta Y_{t-j} + \varepsilon_t$, respectively. The Kruse equation extends the ESTAR's by using the Taylor approximation to test the null of unit root (see Foye 2020 and table 4).

In addition, the Vogesland unit root test which handles structural breaks is equally used to ensure there is no I(2) series in the models (see results in table 5).

Nonlinear ARDL Bounds Cointegration Tests

The nonlinear ARDL is employed when variables are I(0) or I(1) or a combination of both. The method equally corrects for endogeneity and serial correlation while allowing for possible asymmetry in the explanatory variables (see Foye, Adedeji, and Babatunde 2020; Pesaran and Shin 1999). This methodology of bounds test shows whether there is a long-run relationship among the variables of each model. The advantages of NARDL and the implications are well documented in Nusair (2016).

TABLE 6 Nonlinear ARDL Bounds Cointegration Test Results

Models: dep. variables	Est. *F*-statistic, NARDL	Decision
Model 1: LNFP	5.28***	Reject H0: Cointegration exists
Model 2: LNEXR	6.56***	Reject H0: Cointegration exists
Model 3: LNINT	7.07***	Reject H0: Cointegration exists

Model 1 has inflation as its dependent variable, Model 2 the exchange rate, and Model 3 employs interest rate as its dependent variable. Table 6 holds the bounds test results for the three models.

The *F*-statistics for all the models reveal that a long-run relationship exists among the variables, as their *F*-statistics of 5.28, 6.56, and 7.07 are greater than the Pesaran, Shin, and Smith (2001) critical values at a 95% confidence interval. This means there is evidence of cointegration in asymmetric modelling. This will allow dynamic analysis of climate change with the selected macro prices in Nigeria.

Table 7 shows the results of the nonlinear ARDL and the diagnostic tests for the three models. The selected models are ARDL(3, 0, 0, 3, 0, 2, 0, 3, 0, 2, 1), ARDL(2, 4, 3, 0, 4, 4, 4, 4, 3, 3) and ARDL(1, 0, 0, 0, 0, 2, 0, 2, 1, 0) for Models 1, 2, and 3, respectively. The lower right segment holds the results of the diagnostic tests. The serial correlation (Breusch-Godfrey) and stability (Cusum and Cusum of squares) tests are the main diagnostic tests of NARDL analysis. The probability values for the serial correlation results for all the models are greater than a 0.05 level of significance, authenticating the validity and reliability of the results. Likewise, the blue rays in the Cusum, and Cusum of squares results for all the models lie within the bootstrap area at a 95 percent confidence interval, signifying that the models are stable. In addition, the heteroscedasticity (Breusch-Pagan-Godfrey) test ensures that the variances of our models are constant, as a varying variance can invalidate the test of significance because the standard errors become biased, as well as the inference. However, the diagnostic test results for these analyses show that the disturbance errors for all the models are homoscedastic, having constant variance at a ≥0.05 significant level. This means the residuals of the analyses do not suffer from serial correlation, heteroscedasticity, or model misspecification errors. Finally, the lower section holds the results of the Wald's tests for the null hypothesis of no short-run and long-run asymmetry. Although three levels of significance are shown in this study, inferences are drawn based on a 0.05 level of significance.

TABLE 7 Results of Nonlinear ARDL Models

Variable	Short-run coefficients			Variable	Short-run coefficients		
	(1)	(2)	(3)		(1)	(2)	(3)
C	−0.78***	0.16	6.83**	D(IR_NEG(−2))		−0.02**	
D(LNFP(−1))	0.51***			D(IR_NEG(−3))		−0.02***	
D(LNFP(−2))	−0.22			D(LNFP_POS)		0.11	
D(LNEXR(−1))		0.17		D(LNFP_POS(−1))		−0.41**	
IR(−1)			0.73***	D(LNFP_POS(−2))		−0.71***	
D(LNEXR_POS)	−0.02		3.01***	D(LNFP_POS(−3))		−0.24	
D(LNEXR_POS(−1))	−0.14***		−1.70*	D(LNFP_NEG)		−1.25	
D(LNEXR_NEG)	0.74			D(LNFP_NEG(−1))		3.49	
D(LNEXR_NEG(−1))	0.21			D(LNFP_NEG(−2))		4.47	
D(LNEXR_NEG(−2))	0.86			D(LNFP_NEG(−3))		3.36	
D(LNCC_POS)	—	−2.18		D(LNMS)	0.13	−0.01	
D(LNCC_POS(−1))		10.55		D(LNMS(−1))	0.00	0.01***	
D(LNCC_POS(−2))		12.18**		D(LNMS(−2))	−0.29***	0.01***	
D(LNCC_POS(−3))		8.17**		D(TO)		0.01**	0.97
D(LNCC_NEG)		8.74*		D(TO(−1))		0.53***	1.38*
D(LNCC_NEG(−1))		18.52***		D(TO(−2))		−0.67**	
D(LNCC_NEG(−2))		9.43**		D(TO(−3))		−0.88***	
D(IR_POS)	−0.02**	−0.02		D(DM1)	0.46***	1.52***	8.07***
D(IR_POS(−1))	−0.01*	−0.01		D(DM1(−1))	0.41***	0.16	
D(IR_POS(−2))	−0.02**	−0.02		D(DM1(−2))		0.24	
D(IR_NEG)		−0.02***		D(DM2)	0.04		
D(IR_NEG(−1))		−0.01					

Continued on the next page

LONG-RUN AND SHORT-RUN NONLINEAR ARDL ANALYSIS

Results of Models 1–3

The results in table 7 reveal that there is a dynamic nonlinear relationship between climate change and macro prices (food prices and exchange rate, and climate change and exchange rate in the short run). Also, these nonlinear links exist for climate change and all the macro prices (food prices, exchange rate, interest rate) investigated in this study, in the long run, although not all are significant. These results are not unexpected and the results are thoroughly discussed in this section.

The short-run results of the NARDL reveal the outcomes of the positive and the negative shocks of regressors to exchange rate. Model 1 in the short run shows that increase in exchange rate reduces food prices

TABLE 7 *Continued from the previous page*

Variable	Long-run coefficients			Variable	Long-run coefficients		
	(1)	(2)	(3)		(1)	(2)	(3)
LNCC_POS	−2.66	−23.30	−53.61	LNFP_NEG		−4.34	7.91
LNCC_NEG	−2.91	−27.79**	−18.93	LNMS(−1)	0.91***		
IR_POS	−0.08	0.02		TO	−0.01*	−0.03***	−1.29
IR_NEG	0.06**	−0.05***		DM1(−1)	0.75***	2.90***	−9.96***
LNEXR_POS	0.72***		1.54	DM2(−1)	−0.48*	0.92**	−8.45***
LNEXR_NEG	2.33		1.51	ECT(−1)	−0.34***	−0.54***	−0.73***
LNFP_POS		−0.15	3.49				

Test	Diagnostics results		
	(1)	(2)	(3)
Breusch-Godfrey LM serial correlation test	0.06	0.14	0.39
Breusch-Pagan-Godfrey heteroscedasticity test	0.40	0.62	0.16
Ramsey Reset functional form and misspecification error test	0.58	0.93	0.87
CUSUM & CUSUM	≤ 0.05	≤ 0.05	≤ 0.05
Jarque-Bera	(0.84)	(0.37)	(0.12)

NOTES Column headings are as follows: (1) model 1, (2) model 2, (3) model 3. Models are defined by the dependent variables.

by 0.14%, suggesting that a domestic increase in food prices might not be due to exchange rate premium pass-through effects as submitted by the African Development Bank. However, as exchange rate falls in the long run, food prices reduce, confirming Nigeria's reliance on importation of food. These results also support theoretical literature on interest rate-saving behaviour. A unit increase in interest rate increases food prices by 3.49% while a decline in interest rate engenders a 7.91% decrease in food prices. This result suggests the presence of supply-side shocks resulting in increases/decreases in cost of borrowing for investment and eventual increase/decrease in food prices; however, the result is not significant at a 95% confidence interval. The result also corroborates the work of Durevall, Loening, and Ayalew Birru (2013) and the monetarists' view that a decrease in money supply increases the interest rate, reduces investment in food production, and hence engenders a hike in food prices. This is observed in the continuous rise in food prices in Nigeria, given the efforts of the Central Bank of Nigeria in tightening the monetary policy rate to improve the value of the naira. Climate change is not significant in explaining food prices in both the short run and long run but the direction of its movement with food prices is expected, as climate change in-

creases food prices, and the fall in climate change still reveals an increase in food prices. This is because the damage caused by climate change could take years to reverse, coupled with the fact that Nigeria is more reliant on crude oil than agriculture. Moreover, the value chain development system employed in Nigeria is not anchored by natives; hence, policies submitted still benefit importation, rather than building the real sector.

For Model 2, the exchange rate model, the results show that positive shocks to climate change increase the amount of naira that is exchanged for a unit of dollar. Specifically, the units of naira that will be exchanged for a dollar will increase by an average of 10.55% to 12.18 %. In the same vein, as climate change falls, the amount of naira that is exchanged for a unit of dollar decreases; this is a positive causal effect, as the outcome moves in the same direction as the climate variable (a unit decline in LNCC reduces the units of naira that can be exchanged for dollars by 8.74% and 18.52% over time, respectively). In the same vein, reversing the effect of climate change in the long run could be slow; therefore a fall in climate change still shows an increase of 27.79% in the amount of naira exchanged for a dollar in Nigeria. This suggests that global warming reduces exports and foreign exchange earnings. This result agrees with Batten, Sowerbutts, and Tanaka (2020) and Feyen et al. (2020). Also, a unit fall in interest rate discourages capital inflow by 0.02% in the short run and 0.05% in the long run. Furthermore, the results corroborate the fact that a rise in prices weakens exchange rate – a one percentage point increase in food prices reduces exchange rate by 0.71%. This suggests that an increase in food prices devalues domestic currency, as the higher the rate of rise in prices, the faster the exchange rate pass-through effect (this result is equally the same in the long run). This agrees with Olamide, Ogujiuba, and Maredza (2022). Finally, international trade improves foreign exchange earnings and this is a consensus in economic research.

Lastly, the direction of the short-run results of Model 3 for exchange rate and trade follows the results in Model 2; however, all coefficients of the decomposition are insignificant in explaining interest rate in Nigeria. This suggests the relationship between the regressors and interest rate could be indirect. This is in line with Mckibbin et al. (2017), who revealed that the effect of climate change on interest rate is mostly the upshot of the carbon emissions policies engaged to mitigate the consequences of climate change.

In conclusion, the error correction terms (ECTS) of 0.34, 0.54 and 0.73 for Models 1, 2 and 3 are negative and significant at the 0.05 level, as well as

TABLE 8 Results of Wald and Multiplier Graphs for Model 1

(1)	(2)	(3)	(4)	(5)	(6)
Model 1 (food prices)	LNCC	—	0.49	—	Evidence of long-run symmetry
	IR	—	0.04**	—	Evidence of asymmetry in the long run
	LNEXR	0.03**	0.69	0.07*	Evidence of short-run asymmetry and long-run symmetry
Model 2 (ex-change rate)	LNCC	0.29	0.60	0.09*	Evidence of short-run and long-run symmetry
	IR	—	0.03**	—	Evidence of long-run asymmetry
	LNFP	0.00***	0.50	0.00***	Evidence of asymmetry in the short run and symmetry in the long run
Model 3 (interest rate)	LNCC	—	0.45	—	Evidence of symmetry in the long run, climate change did not appear in the short run
	LNFP	—	0.92	—	Evidence of symmetry in the long run while food prices did not appear in the short run
	LNEXR	—	1.00	—	Evidence of symmetry in the long run, exchange rate did not appear in the short run

NOTES Column headings are as follows: (1) model, (2) variable, (3) short-run probability, (4) long-run probability, (5) joint probability, (5) conclusion. Null Hypothesis: No short and long-run asymmetry. ***, **, and, * represent levels of significance at 1%, 5%, and 10%, respectively.

less than 1, authenticating that long-run relationships exist among these variables. This means that 34%, 54% and 73% of disequilibrium errors in the previous year for each model are corrected in the current year.

Furthermore, table 8, which holds Wald's tests of asymmetry results, equally confirms that an asymmetric relationship exists between food prices and all the positive and negative long-run regressors (LNEXR, IR, LNCC), both in the short run and long run, except for the IR model in Wald's results. Furthermore, only exchange rate in Model 1, and climate change and food prices in Model 2, show joint asymmetric relationships (see table 8).

Relative Effects of Climate Change on Macro Prices

The beta coefficient measures the changes in the macro prices (food prices, exchange rate, and interest rate) that correspond to a unit change in the climate variable, holding other explanatory variables constant and

TABLE 9 Relative Effects of Climate Change on Macro Prices

Series	LNCC	$\dot{\beta}$
LNFP	−2.46(0.01/2.92)	−0.008*
IR	3.01(0.01/5.19)	0.006
LNEXR	1.18(0.01/2.45)	0.005

NOTES * significance at 10%.

measuring all changes in standard deviation units. This helps to determine the relative effects of the outcome from the different explanatory variables, as we employ Equation (16).

$$\dot{\beta} = \hat{\beta}\frac{S_x}{S_y}, \tag{16}$$

where $\dot{\beta}$ is beta coefficient, $\hat{\beta}$ is estimated beta, S_x is standard deviation of xth explanatory variable, and S_y is standard deviation of the dependent variable.

Given the fact that the long-run error correction results have shown that climate change has a significant impact on macro prices for all the models, then following the absolute values, the results show that the beta coefficient of 0.008 for food prices is the only significant coefficient at a 95% confidence interval. This confirms that climate has a major influence on food prices among the macro prices. Its influence on exchange rate is the least at 0.005. This corroborates the fact that climate change is not only an environmental challenge (Foye 2014) but also a monetary challenge now, being a source of financial risk. Hence, it is very important to reduce human-induced climate change and its consequences to stabilise the financial sector.

DISCUSSION OF RESULTS

The study employs nonlinear ARDL in validating that most macro variables are essentially nonlinear in three models of different macro prices (food prices, exchange rate, and interest rate), meaning that positive and negative factors of macro prices influence one another (Shin, Yu, and Greenwood-Nimmo 2014). Furthermore, the study determines the relative effects of climate change on these macro prices. Before the regression analysis, I took the log of the variables that are not in rates to ensure the data are normally distributed and for easy interpretation of results (see Ogun 2021; Wooldridge 2018). All the unit root tests (with or without structural breaks) reveal that all variables are all stationary at first differ-

ence I(1). To be precise, the NARDL unit root test reveals that all the variables are not stationary. Furthermore, cointegration of variables is established, using the NARDL bounds tests for the three models. The results for the models are significant at a 95% confidence interval with *F*-statistics of 5.28, 6.56, and 7.07 which are greater than the Pesaran, Shin, and Smith (2001) critical values, respectively. I proceed to analyse both the error correction model and the long-run NARDL, as advanced by Shin, Yu, and Greenwood-Nimmo (2014). Before drawing inferences, the validity of the models is established through different diagnostic tests: serial correlation, heteroscedasticity, and model specification. The probability values of all the tests are found to be greater than the 0.05 level, confirming the validity and the reliability of the models. Also, the cumulative sum (CUSUM) and its squares (CUSUM2) are significant at a 95 percent confidence interval, confirming the structural stability of the models.

The error correction terms for all Models 1–3 are −0.34, −0.54, and −0.73, respectively. These values are all significant at less than the 0.05 level, authenticating the bounds tests results. The error correction terms suggest that the speed of adjustment of a short-run disequilibrium for each model to its long-run equilibrium is 34%, 54%, and 73%, respectively. Models 1 and 2 with food prices and exchange rate as their dependent variables, respectively, reject the null of no long-run and short-run asymmetry, in that order, for IR and EXR, and for IR and FP, respectively, at the 0.05 level of significance. This suggests evidence of asymmetry, meaning that the models are best analysed using nonlinear ARDL. On the other hand, the results for Model 3 with interest rate as its dependent variable accept the null of no long-run and short-run asymmetry. This indicates that Model 3 is best analysed using a linear model which is a suggestion for further studies. Using the Wald test, asymmetry is equally confirmed in Models 1 and 2 for the macro prices employed alternatively in the long run and short run, except for the CC variable which exhibits pure symmetry both in the short and the long run. The third model, with interest rate as a dependent variable, also shows evidence of symmetry for both food prices and exchange rate, suggesting that interest rate has a linear influence on climate change, food prices, and exchange rate.

The results of the first model (relationship between food prices and climate change) is incongruous with the studies by Food and Agriculture Organisation of the United Nations (2019a), Hendrix and Haggard (2015), Kreidenweis et al. (2016), and Stevanović et al. (2016) that show climate change increases food prices in the long run. This might be as a

result of Nigeria's reliance on imported foods. In addition, the literature has shown that trade openness is a buffer to reduced food prices; results in this study have shown that trade openness has initial positive impacts on the exchange rate until later when it starts to depreciate the domestic currency, suggesting that the over-reliance on oil at the expense of real sector growth remains a challenge in Nigeria. Despite the restriction on some food crops to build domestic food production, the impacts of climate change and the monoculture nature of Nigeria keep having negative consequences on macro prices in Nigeria. Furthermore, climate change reveals a positive impact on exchange rate in Nigeria, suggesting that the drive for growth, given the stage of development in Nigeria and its over-reliance on fossil fuels, might hinder mitigation efforts. This result agrees with Lee et al. (2021) in the short run and also with the results of Batten, Sowerbutts, and Tanaka (2020) and Feyen et al. (2020) in the long run, as a fall in climate change engenders increased exchange rate. Hence, the need to encourage consistent and continuous climate mitigation is germane in avoiding the volatility of macro prices. Finally, neither the negative nor the positive factors of climate change, exchange rate, and food prices have significant effects on interest rate in Nigeria, suggesting that the relationship between climate change and interest rate is policy driven.

In all, the results in this study suggest the continual need for a green economy (renewable energy sources and other energy-efficient technologies) to combat climate change in the pursuit of macro-financial growth in Nigeria.

Conclusion and Policy Implications

This paper reveals very reliable estimates for food prices, exchange rate, and interest rate in relation to climate change in Nigeria by departing from the studies that employed integrated assessment results which gives assumed estimates (Tol 2006). Also, the study employs the appropriate model, a nonlinear ARDL model, in the analysis of nonlinear macro prices. However, the study reveals the fact that interest rate performs more efficiently in a linear model in the long run, given that the results rejected the null hypothesis of asymmetry. Hence, the interest rate model is symmetrical and therefore can be analysed by employing a linear model. Most importantly, the study reveals that contemporaneous LNFP moves in tandem with EXR in the short run while contemporaneous positive and negative LNCC moves in the same and opposite direction with food prices in the long run, respectively, though not significantly. This sug-

gests that it is only concerted and consistent mitigation strategies that can engender a green economy that favours lower food prices. On the other hand, an increase in IR reduces food prices, and an increase in money supply makes food prices affordable; however, the lag and long-run response of food prices agree with both theory and *a priori* expectations. The implication of this is that undertaking policy initiatives and strategies based on symmetry could be inadequate, given the fact that asymmetry allows for other effective alternatives in policy engagements. Furthermore, climate change did not show asymmetry in its relationship with exchange rate in the long run although asymmetry is observed in the short-run lags; as expected, IR shows a positive relationship with the exchange rate, as domestic currency appreciates as a result of capital inflow from the rest of the world. Finally, as trade expands in the short run, the exchange rate appreciates marginally; however, it falls in the long run. Obviously, this is expected and the implication is clear, as overreliance on fossil fuel remains a battle begging to be overcome in Nigeria. Hence, this paper concludes that a dynamic relationship exists between macro prices and climate change in Nigeria, underscoring the importance of prompt redesigning of macroeconomic policies to capture climate change for growth and sustainable development.

This study recommends that the Nigerian government and policymakers should ratify and pursue policy initiatives and strategies based on asymmetry for climate change, food prices and exchange rate. As regards the negative influence of climate change on macro prices, Nigeria should begin to carry out a mitigation and vulnerability analysis in both the financial and real sectors to forestall the negative consequences of climate change. Furthermore, the country needs a total embrace of green technologies, technology transfer and specialisation through trade interactions to encourage green growth. The mitigation process should not only be the transition of Nigeria from fossil fuel use but also the gradual end of exporting oil to other countries which in effect is a way of encouraging burning of fossil fuels in other countries. In fact, it cannot be overemphasised that Nigeria now needs to rely more on robotic green technology to protect the financial sector from uncertainties. Moreover, the real sector needs to be revived to improve on foreign exchange earnings. In effect, Nigeria needs natives, and not non-natives, to develop its value chain development system if its agricultural sector will ever resuscitate the manufacturing sector for healthy growth and stability of the financial and real sectors. In addition, since climate change is a global phenomenon

and Nigeria is one of the most vulnerable populations, the government should mandate foreign partners to equally adopt green technologies. Finally, the submission of an interim report by Nigeria in May 2021 is a good step in the right direction. This means Nigeria is beginning to build environmentally friendly structures to keep the country on the path of sustainable growth and development.

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Razvitost bank in brezposelnost v Keniji: empirična raziskava

Sheilla Nyasha, Nicholas M. Odhiambo in Mercy T. Musakwa

Ta študija je empirično raziskala vpliv razvitosti bank na brezposelnost v Keniji na osnovi časovnih serij od leta 1991 do 2019. Z uporabo modela ARDL (Autoregressive Distributed Lag) so rezultati analize pokazali, da je v Keniji vpliv razvitosti bank na brezposelnost, čeprav časovno nespremenljiv, v veliki meri odvisen od nadomestne spremenljivke, uporabljene za merjenje stopnje razvitosti bank. V skladu s pričakovanji je bilo ugotovljeno, da razvitost bank – če jo merimo s tekočimi obveznostmi, z bančnimi depoziti, depozitnim bančnim denarjem in indeksom razvitosti bančništva – negativno vpliva na brezposelnost v Keniji. Če pa razvitost bank merimo z domačimi krediti, ki jih banke dajejo zasebnemu sektorju, se izkaže, da je njen vpliv na brezposelnost statistično nepomemben. Ti rezultati veljajo dosledno in tako dolgoročno kot tudi kratkoročno.

Ključne besede: brezposelnost, razvitost bank, na bankah temelječ finančni razvoj, finančni razvoj, Kenija, ARDL
Klasifikacija JEL: E24, G2
Managing Global Transitions 20 (2): 85–107

Uvedba EU-sistema pozavarovanja za primer brezposelnosti: zaščita dohodka in vzdrževanje porabe

Aleš Trunk in Igor Stubelj

Članek obravnava vzdržnost morebitne uvedbe pozavarovanja za primer brezposelnosti v državah Evropske unije v smislu ohranjanja ravni potrošnje brezposelnih in spodbujanja ekonomske učinkovitosti. Na podlagi pregleda literature, analize sistema pozavarovanja v ZDA in analize obstoječega zavarovanja za primer brezposelnosti v EU smo razvili model sistema pozavarovanja za primer brezposelnosti v EU. S simulacijo modela, ki temelji na podatkih obstoječega sistema zavarovanja EU-20 za primer brezposelnosti v obdobju 2003–2019, smo določili znesek pozavarovalnih izplačil državam in potrebno višino prispevkov, pri čemer smo uporabili različne načine definiranja sprožilcev plačila. Dokazali smo, da bi sistem pozavarovanja za primer brezposelnosti z neposrednim vplivom na dohodek brezposelnih prispeval k boljši zaščiti dohodka in hkrati deloval kot avtomatski stabilizator gospodarstva.

Ključne besede: recesija, brezposelnost, zavarovanje, pozavarovanje, Evropska unija, simulacija modela, potrošnja, avtomatski stabilizator
Klasifikacija JEL: J64, E24, E63
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Uporaba nočne osvetljenosti kot pokazatelja gospodarske rasti v Afriki: ali gre za dobro zamisel?

Nicolene Hamman in Andrew Phiri

V tem prispevku se sprašujemo, ali lahko podatke o nočni osvetljenosti uporabimo kot alternativno mero za BDP v 49 afriških državah, zato smo z empirično analizo ugotavljali razmerja med podatki o nočni osvetljenosti in BDP. Za razliko od prejšnjih raziskav smo uporabili kointegracijske cenilke za frekvenčne vrste na osnovi skupin združenega povprečja (*Pooled Mean Group Cross Sectional Cointegration Estimators* – PMG) in metodo koherence valčkov (*Wavelet Coherence Tools*), da bi preučili kointegracijska razmerja in časovnofrekvenčno sinhronizacijo med BDP in intenzivnostjo nočne osvetljenosti DMSP-OLS (*Defense Meteorological Program – Operational Line-Scan System*) na podlagi letnih podatkov od leta 1992 do 2012. Našli smo malo dokazov o pomembnejših razmerjih med nočno osvetljenostjo in BDP v posameznih afriških državah, zato nosilce politik opozarjamo, naj za sintetične mere gospodarske rasti striktno uporabljajo podatke DMSP-OLS. Na koncu nakažemo možne usmeritve prihodnjih raziskav.

Ključne besede: nočna osvetljenost DMSP-OLS , gospodarska rast, analiza complex wavelet, Morlet wavelets, Afrika
Klasifikacija JEL: C02, C23, E01, O55
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Podnebne spremembe in makrocene v Nigeriji: nelinearna analiza

Victoria Foye

Raziskava analizira vplive podnebnih sprememb na makrocene (cene hrane, obrestna mera in menjalni tečaj). Uporabili smo sekundarne podatke za obdobje 1960–2019 in nelinearni model ARDL. Rezultati kažejo, da med uporabljenimi spremenljivkami obstaja dolgoročna povezava. Poleg tega asimetrija med cenami hrane in menjalnim tečajem obstaja samo kratkoročno, medtem ko za vse makrocene, razen za obrestno mero kot odvisno spremenljivko, obstaja samo dolgoročno. Tudi relativni učinki podnebnih sprememb na makrocene na cene hrane vplivajo z največjim učinkom. Potrebne so podnebne politike v finančnem in realnem sektorju, da bi ublažili učinek podnebnih sprememb na

makrocene. Zato pričujoča raziskava priporoča, naj nigerijska vlada in nosilci politik ratificirajo ter zasledujejo politične pobude in strategije, temelječe tako na negativnih kot pozitivnih spremembah makrocen.

Ključne besede: asimetrija, podnebne spremembe, makrocene, nelinearni model ARDL
Klasifikacija JEL: E31, E43, F31, Q54
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