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Louis de Berquin Eyike Mbongo
University of Dschang

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Contact: Louis de Berquin Eyike Mbongo - eyike76@gmail.com.
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1. Introduction

Since Schumpeter's work, there has been an unresolved debate about the impact of innovation on employment. In this respect, the specialized literature has two main debates. The first concerns the impact of innovations on the nature of employment. Here, two main ideas clash. For some, innovation will favor only skilled workers, and therefore unskilled jobs must be destroyed as a result of the emergence of an innovation. For others, however, this development is not automatic and some companies offer training courses to their employees. This debate is known in the literature as the ***hypothesis of skill-biased technological change*** (Goos and others, 2009). This is the effect of ICTs on the structure of employment.

This first debate has given rise to another, more general one, which can be summarized by the following question: ***do innovations destroy jobs or, on the contrary, are they a factor of job creation?*** This debate goes back to the classical period and if for some authors the appearance of the innovations would be destructive of jobs in the sense that technology can be substitutable for man, especially for certain manual and routine tasks, for others, the appearance of an innovation is does not destroy employment. Indeed, if it can lead to the destruction of jobs in certain sectors, in a market economy, market mechanisms would create compensation. However, several empirical studies carried out in the context of advanced economies suggest that the emergence of innovation could result in a decrease in the volume of employment, the automation of certain tasks requiring less labor.

The apparition of ICTs and their diffusion is one of the major innovations since the 20th century. As a result, it is important to analyze the effects of this innovation on employment. In this regard, several studies have already been conducted, but most of them focus on advanced economies. This is the case of Raurich and Sorolla (2012), Hutchinson and Persyn (2012) and Driver and Muñoz-Bugarin (2010). These studies are not unanimous on the impact of ICTs on employment.

However, there are very few studies in the context of African economies for two main reasons. First, ICT diffusion in this region is very recent and can be dated in the early 2000s. The second reason is Africa's lagging behind other regions in the use of these technologies. However, there are some studies on this topic and on African economies. This is for example the case of Ebaidalla's paper (2014). These studies analyze the effect of ICT on a group of workers (eg young people).

The purpose of this paper is to evaluate, both theoretically and empirically, the effects of the strong diffusion of ICT on employment in the context of African economies. To do this, we test two main hypotheses in this paper. The first is that the diffusion of ICTs increases employment in African economies. The second is that this diffusion is more favorable to skilled jobs. Our originality here is the definition we propose of skilled jobs in the African context. As the production sector of these technologies is still evolving in these economies, we do not expect to have a large number of ICT specialists. On the other hand, the diffusion of ICT in these economies is more about use (internet and telephony) than creation. This leads us to consider as a qualified job any job that uses these technologies on a daily basis. Our hypothesis here is that the strong diffusion of ICT would be favorable to youth employment in this context.

The first section reviews the main works on the innovation-employment relationship. The second section is devoted to presenting the statistical and econometric tools that are used to test these hypotheses. Finally, the last section presents the main results of our empirical analyses, as well as the resulting economic policy implications.

2. The innovation-employment relationship: a critical examination of the literature

The specialized literature is marked by a lively controversy in relation to the consequences of the occurrence of an innovation on the labor market. Overall, two main schools of thought oppose each other. At first, the neoclassical school of thought which is based on the theory of compensation mechanisms, assumes that technological change does not lead to a decrease in the volume of employment. The second stream presents the negative consequences of technological change on employment.

2.1. The optimistic vision of technological change: the existence of compensation mechanisms

For some economists, technological change would have a positive effect on the total volume of employment. According to these authors, while the direct effect of the emergence of a new technology seems unfavorable to employment, there are compensatory mechanisms that can counterbalance or even reverse this effect (Vivarelli, 2007). Overall, these authors retain three main compensation mechanisms.

The first one is the job creation mechanism through the emergence of new products: this is in fact the main compensation mechanism established in the literature. According to this mechanism, the emergence of a new technology will create a new market for these goods. This will result in a work request (rather specialized) for the supply of the latter. Indeed, according to Katsoulacos (2003), innovation is at the origin of two types of effects: a well-being effect, which means the supply of new goods, and a substitution effect (replacement of products established by the new ones). In the case of ICT for example, the computer age has replaced that of the typewriter. According to this author, the net effect of this innovation on employment depends on the conjunction of these two mechanisms. However, the welfare effect is assumed to be dominant, which means more job creation than destruction.

The second one is the channel of lower production costs: while causing the move of workers from the old sectors to the new ones, process innovation favors a decrease in unit costs of production. Under the assumption of perfect competition, the said decline will lead to lower prices. The immediate consequence (at least theoretically) is the increase in demand (and therefore production), ultimately an overall increase in the volume of employment.

Finally, the last mechanism is the consumption channel: this channel is very close to the previous one and is based on the effect of the emergence of an innovation on prices (as described above). Here, lower prices increase the purchasing power and household consumption. It also leads to increased demand and ultimately employment.

Thus, empirical works to verify the validity of these compensation mechanisms have been put forth (Harrisson and others, 2005; Peters, 2004; Garcia and others, 2002). For Harrisson and his coauthors (2005), based on data from a survey conducted in companies in France, the United Kingdom and Germany, the adoption of ICT by them has led to a rise in overall level of employment. They therefore naturally conclude that the compensation mechanisms are indeed effective.

However, the validity of these mechanisms has been the subject of several criticisms, the most important of which is that they are essentially based on the assumption of perfect competition.

2.2. The pessimistic vision of innovation: substitution effects.

These are economists who believe that the adoption and spread of technological innovation will inevitably lead to a drop in the volume of employment. To justify such a point of view, two arguments are most often advanced.

The first is the substitution of unskilled jobs by those with higher skills. In the specialized literature, this argument is known as the ***hypothesis of skill-biased technological change***. This idea can be summarized as follows: technological innovation leads to an increase in the demand for skilled labor, to the detriment of the unskilled one. This has the effect of increasing the existing gaps (in terms of wage difference) between the two types of employment. This hypothesis has been the subject of several empirical verification attempts, the majority of which lead to the assertion of the existence of such a bias (Goos et al., 2009; Freeman 1998).

The second argument is that technological innovation will lead to machine substitution of humans (Rackman 1999; Rifkin 1995; Hammer 1990). For Rifkin (1995), there is evidence of unemployment due to the digitization of economic activities. His argument is that, since computers are used in all sectors, they have led to the disappearance of millions of jobs without the new created to offset these losses. For him, only the knowledge sector benefits in terms of direct jobs (scientists, computer scientists, contractors, technicians ...)

For Hammer (1990), it is in the services sector that there will be the greatest job destruction. Indeed, the services would often offer jobs that can be done autonomously by computer (sales, electronic banking ...) This is also what Rackman (1999) thinks for which e-commerce will cause a drastic drop in sales jobs within companies.

However, the ICTs have an unexpected effect on the structure of employment. ICTs would be the source of the **polarization of the labor market**. This concept refers to the decrease in the number of intermediate jobs, in favor of highly qualified and low-skilled jobs. For example, Goos and Manning (2007) have shown from UK data from 1975 to 1999 that ICT has polarized the UK labor market. A similar result was obtained in the American context (Autor and others, 2006) and in that of the European Union (Goos and others, 2009).

Based on this work, we find that there are few studies analyzing the effect of ICT diffusion on employment in the African context. Existing ones simply analyze the impact of the latter on a category of workers (young people in the case of Ebaidalla, 2014). Ejemeyovwi and others (2018) analyze the relationship between ICT investment, human capital and institution in ECOWAS. The main result of their study is that the investments in ICT favor human capital in this region. This result has some useful implications for the debate concerning the impact of ICT on employment. In fact, human capital is one of the traditional determinant of employment. In addition, recent studies seem to show that the high penetration of ICT in emerging countries has not created enough job opportunities for the vast majority of the population (Ray, 2015). Moreover, in developed countries, the recent redistribution of low-wage manufacturing jobs to skill-intensive jobs in the service sector has benefited highly skilled workers, leaving out workers who lack the skills required by the services sector emerging (Hurley, Fernández-Macias and Storrie, 2013). These two facts justify our study based on the African context.

3. Methodology of the study

The aim of this work is to analyze the impact of the very strong diffusion of ICT on the process of creation / destruction of jobs in the context of African economies, we built a model based on the work of Ebaidalla (2014) and Feldman (2009).As a result, the overall form of the equations that will be estimated is given as:

$$Y_{it} = \beta_0 + \beta_1 Int_{it} + \beta_2 Mob_{it} + \beta_3 Loggdppc_{it} + \beta_4 Trde_{it} + \beta_5 Edu_{it} + \beta_5 Logpop_{it} + \beta_5 Inf_{it} + \beta_5 Transf_{it} + \varepsilon_{it} \quad (1)$$

In this equation, the index i denotes the country while the index t represents the year. Variable Y represents our explained variable. Int is the proportion of individuals with access to the Internet. Mob represents the proportion of individuals with access to mobile telephony. The Loggdppc variable represents the Gross Domestic Product per capita (in logarithm); Trde

represents the degree of trade openness of the country while the Edu variable is a measure of the stock of human capital available in country i at period t. The Logpop variable represents the total population (in logarithm); Inf is the rate of inflation and Transf captures the inflow of funds from the diaspora.

In this equation, the explained variable is the level of employment. It will be captured by two proxies: the proportion of the overall population that has a job (as defined by the ILO), and the level of unemployment and the proportion of young people in employment. This second variable will allow us to test the ***hypothesis of skill-biased technological change*** in the African context. Indeed, since young people are the segment of the population most affected by this innovation, this hypothesis can be interpreted as follows: *the diffusion of ICT favors young employment at the expense of the employment of seniors.*

3.1. The estimation method

Traditionally, fixed and random effects estimators are used to estimate models on panel data. However, these estimators have proven to be inappropriate when there is an endogeneity bias. Thus, to take this risk into account, the Dynamic General Moment Method has been developed to overcome the shortcomings of traditional estimators (FE, RE). Overall, there are two main advantages to using the dynamic GMM method. First of all, this method makes it possible to take into account the temporal dynamics (that is to say, models in which the explanatory variable lags are among the exogenous variables). The second advantage is that this estimation technique allows us to treat all exogenous variables as potentially endogenous. Thus, it makes it possible to (imperfectly) solve the problem of finding instruments (in case of endogeneity of certain exogenous variables).

There are two dynamic GMM estimators: the first difference GMMs developed by Arellano and Bond (1991) and the system GMM (Blundell and Bond 1998, Arellano and Bover 1995). However, the literature has identified a problem related to the use of GMMs in first difference: in some cases, series lags are not reliable instruments (Bond et al., 2001). As a result, the GMM estimator in the system seems better than the first difference one. We will therefore use this estimator in our empirical analyzes. However, to ensure the validity of the instruments used, we perform two complementary tests: the over-identification restriction test and series correlation test. As a robustness, we will compare the results obtained by the system GMM estimator to those provided by the GMM differential estimator and the FE estimator.

3.2. The data

The data used to carry out the empirical analyzes are drawn from two main secondary sources: the WDI database of the World Bank for macroeconomic variables and the ILO's base for employment figures. Our panel is based on 20 African countries for the period 1995-2015. This choice of the countries is based on the availability of data on the considered period. Also, for the coherence of the sample, we do not consider countries like Nigeria or South Africa who are more advanced than the others. The list of countries considered in this study is available in appendix. The following table summarizes the main descriptive statistics of the series used.

Table 1: Descriptive statistics of the series

Variables		Mean	Stand dev	Min	Max	Observations
Empl	Overall	66.21556	10.45805	39.7	85.8	N=360
	between		10.68035	43.75	84.28	n=18
	Within		1.15674	59.43556	70.43556	T=20
Youthempl	Overall	48.91083	13.56291	15.8	75.7	N=360
	Between		13.79861	20	74.1	n=18
	Within		1.911795	42.88583	58.28583	T=20
Loggdppc	Overall	6.757581	1.088641	4.9577	9.661155	N=400

	between		1.030735	5.548431	9.183643	n=20
	Within		.416311	5.770116	7.776074	T=20
Ouv	Overall	85.73131	37.70075	18.18636	225.0231	N= 365
	between		36.3932	18.8284	160.4955	n=20
	Within		16.96344	-18.45625	150.2589	T=18.25
Int	Overall	5.188008	9.130446	0	54.26	N= 386
	Between		6.463572	.5369365	25.40858	n=20
	Within		31.49718	-45.77841	34.03943	T=19.3
Mob	OVERALL	27.64518	35.46044	0	162.1932	N= 498
	Between		16.66587	9.375838	73.48987	n=20
	Within		31.49718	-45.77841	116.3485	T=19.9
Infl	Overall	8.494636	11.93263	-20.62722	112.6936	N=400
	between		7.122719	1.023179	27.5199	n=20
	Within		9.698985	-19.51679	93.66839	T=20
Transfert	Overall	3.059523	4.093374	.0046123	22.46387	N=355
	Between		3.86976	.2147844	12.7943	n=19
	Within		1.936698	-2.686848	13.36938	T=18.6842
Primcom	Overall	60.97864	24.85814	14.06659	115.0273	N= 323
	Between		23.35207	27.08052	12.71943	n=20
	Within		10.54566	26.15286	13.36938	T=16.15
Logpop	Overall	15.30607	1.1507814	11.22929	17.11933	N=400
	Between		1.537946	11.33306	16.86698	n=20
	Within		.1444158	14.95605	15.6698	T=20

Source: author using STATA (2013)

The result of the descriptive statistics shows that the standard deviation of employment is small, indicating a low disparity in employment among African countries. The standard deviation of the youth employment is higher than the standard deviation of the total employment, meaning there is more divergence between those countries regarding the youth employment. Also, the standard deviation of the internet users is small, indicating that African countries have a similar path considering the access to internet. Concerning the access to the mobile telephony, there is more divergence between the selected countries.

4. The main results

This section is composed of two sub-sections, each of which relates to a specific question. Thus, the first deals with the effect of the widespread diffusion of ICT on employment in general in SSA, while the second analyzes the validity of the ***hypothesis of skill-biased technological change*** in the African context.

ICT diffusion: a catalyst for employment in SSA

The following table presents the results of the estimates in Equation 1, using as a dependent variable the proportion of the employed labor force. This equation was estimated using both GMM estimators, with robustness verified by comparing these results to those provided by the traditional fixed effects estimator.

Table 2: Digital determinants of employment in SSA

VARIABLES	(1) GMMSYS	(2) FE	(3) GMMDIF
L.empl	0.843***		0.151***
	(0.0264)		(0.0490)
Loggdppc	1.296***	0.468	0.728
	(0.338)	(0.465)	(0.315)
Trde	0.00111**	0.0189*	0.0121***

	(0.000584)	(0.0105)	(0.00460)
Int	-0.00174	0.0346	0.0230
	(0.0256)	(0.0365)	(0.0187)
Mob	0.0176**	0.0219**	0.00851**
	(0.00795)	(0.00927)	(0.000633)
Inflation	-0.000457	-0.0114**	-0.000215
	(0.00938)	(0.00486)	(0.00593)
Remittancesr	-0.0407	-0.0397	-0.0759**
	(0.0445)	(0.0743)	(0.0322)
Primcompl	0.00321	-0.0117	0.0127
	(0.0101)	(0.0116)	(0.00913)
Logpop	0.841*	7.189***	3.283***
	(0.433)	(1.978)	(1.212)
Constant	5.285	-47.06	13.99
	(7.615)	(29.53)	(17.13)
Observations	234	239	227
Sargan (prob)	0.503		0.345
R-squared		0.335	
Number of code	20	20	20

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: author using Stata 13 software

Overall, it can be seen from this table that the estimates do not suffer from instrument validity problems (the probabilities associated with the Sargan test are all greater than 10%). In connection with the macroeconomic variables, we can witness that they have all the expected signs, and therefore conform to the specialized literature. For example, considering the standard of living (captured by the log of GDP per capita), the coefficients are all positive (and significant at the 1% threshold for the system GMM estimator). This shows that strong economic growth is accompanied by an improvement in the labor market and more jobs. Thus, Okun's law seems to be verified in the context of the economies of sub-Saharan Africa. Such a result had already been obtained by Ebaidalla (2014), with regard to youth employment. Similarly, trade openness is a determinant of employment in the context. Indeed, all the coefficients associated with this variable are positive and statistically non-zero. This is also consistent with the predictions of the theory. Similarly, trade openness appears as a driver of employment in the context of African economies. Indeed, all the associated coefficients are positive and significant (at different thresholds of significance). This result is not surprising and is, on the contrary, consistent with theoretical intuitions. Indeed, opening up trade, giving access to new markets, and increasing competition, favors the production of new products. This will ultimately be good for the job. Another macroeconomic variable that explains employment in the African context is demography, captured here by the natural logarithm of the total population of the country. Indeed, the coefficients associated with this variable are all positive and significant. This result can be interpreted as follows: the more a country is populated, the higher the amount of labor there.

On the other hand, our estimates show that migrant remittances received by African countries are negatively correlated with the level of employment in these countries. Indeed, the coefficients associated with this variable are negative whatever the estimator used, and that associated with the GMM difference estimator is significant at the 5% threshold. This result suggests that these funds, since they are generally used to provide for the basic needs of the poorest households, the young members of these households, being assured of having a fairly regular pension, are generally not ready to accept the first job offered to them. On the contrary, they are willing to remain unemployed for a period of time, while living on that token and

looking for a "stable" job. In the case of older members, they just do not have the motivation to look for a job and often just live on that income.
In relation to the variables capturing the diffusion of ICT, we can say that, globally, the digital is a determinant of employment in the chosen context. Indeed, for mobile telephony, all coefficients are positive and significant regardless of the chosen estimator. Ebaidalla (2014) had already achieved such a result, as did the World Bank (2017) in the context of all of Africa. The main explanation is that the adoption of this technology is creating new jobs, either directly as agents of the telecommunication companies that offer this service, or indirectly when this service is used in the provision of other services.
However, the coefficients associated with the variable capturing the diffusion of the Internet are not significant. This result is in line with the African context of low penetration of this tool, especially in rural areas, compared to mobile telephony, which has really entered in the daily lives of urban and rural populations on the continent. This low level of internet penetration reduces job creation opportunities in this area. As an illustration, the online sales company JUMIA has only been able to establish itself in a dozen African countries, lack of sufficient coverage of the Internet in other countries. Thus, far from showing that the Internet plays no role in reducing unemployment in Africa, this result rather demonstrates the importance that must be attached to its development.
In the rest of this section, we will test the validity of the hypothesis of skill-biased technological change in the African context. To do so, we will begin by recalling the interpretation we make of this hypothesis in the context of African economies.

Test of the hypothesis of skill-biased technological change in SSA

The idea behind the existence of a technological bias can be summarized as follows: *technological innovation leads to an increase in the demand for skilled labor, to the detriment of unskilled labor*. There would be, because of the occurrence of a technological innovation, substitution of unskilled labor by skilled labor. This hypothesis has been the subject of several empirical studies in the context of advanced economies[1]. Overall, to test this hypothesis, the authors compare the evolution of jobs skilled and unskilled, in terms of volumes and wages. It generally appears that there is a technological bias in these economies.
In the context of African economies, there are no similar studies to our knowledge. There are several reasons for this state of things. The main one is the lack of reliable sources of information on the quality of employment. Overall, only statistics on employment by level of study are sometimes available for some countries. As a result, in particular, information on the use of ICTs in African enterprises is difficult to obtain. Another reason may be that Africa is emerging as an ICT consumer. Indeed, innovations in this area are still marginal. Virtually all people use only these services in their personal capacity.
From the realities of the African context presented above, we looked for an original way to test this hypothesis in the context of these economies. To do so, we proposed a contextual reinterpretation of this hypothesis. This reinterpretation is as follows: *in the African context, as young people are the biggest consumers of ICT, the diffusion of ICT should be favorable to youth employment.*
This interpretation allows us to test the relationship between ICT literacy and employment. Moreover, it is of interest in the African context. Indeed, youth constitutes the majority of the population on the continent. Yet youth employment is proving to be a major problem in almost every country on the continent. We must find appropriate solutions to promote the employability of youth on the continent.
In a practical way, the empirical strategy employed here is the estimation of a model in which the explained variable is a measure of youth employment. To do this, the model we estimate is

[1] For an overview of the empirical literature on technology bias, see Goos and others (2009)

similar to that of Equation 1, the main difference being the dependent variable. Given the lack of data on youth employment for almost all of the countries in our sample, our dependent variable here is the youth unemployment rate. Similarly, to estimate this model, we use the same estimators as those used for previous empirical analyzes. These are the Generalized System and Difference Moments estimators, as well as the fixed effects estimators. The following table gives us the results of the estimates of this model.

Table 3: ICT and youth unemployment in Africa

VARIABLES	(1) GMMSYS	(2) GMMDIF	(3) FE
L.youthempl	0.943***	0.640***	
	(0.0208)	(0.0478)	
Loggdppc	-1.786***	-0.383	0.318
	(0.357)	(0.493)	(0.574)
Trade	-0.0128*	-0.00527	-0.0182**
	(0.00693)	(0.00773)	(0.00894)
Int	-0.00520	-0.0329	-0.111***
	(0.0275)	(0.0302)	(0.0362)
Mob	-0.0296***	-0.147***	-0.0173*
	(0.00826)	(0.0101)	(0.00915)
Inflation	0.0247***	0.0146	0.0107
	(0.00899)	(0.00932)	(0.0115)
Remittancesr	0.0121	0.126**	0.133**
	(0.0542)	(0.0564)	(0.0608)
Primcompl	0.000140	0.0309**	-0.0154
	(0.0110)	(0.0148)	(0.0149)
Logpop	0.483	3.548*	4.982**
	(0.398)	(1.981)	(2.041)
Constant	20.15***	72.53**	-27.60
	(7.200)	(28.86)	(29.38)
Observations	234	217	239
R-squared			0.279
Sargan (prob)	0.439	0.197	
Number of code	20	20	20

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: author, from Stata 2013 software

Our results suggest two types of conclusions. First, the results obtained in these estimations are consistent with those obtained previously in the explanation of overall unemployment in Africa. Thus, it appears that economic growth can substantially reduce youth unemployment. The same is true of commercial openness.

Population growth, on the other hand, increases youth unemployment in the African context. This result is not surprising; on the contrary, it is rather intuitive. Similarly, migrant remittances received by African states seem to explain youth unemployment positively. The explanation previously proposed in terms of the effect of this rent on the labor supply behavior of individuals remains globally valid, even in the context of young people.

For variables capturing ICT diffusion, all coefficients are negative regardless of the chosen estimator. In addition, all the coefficients associated with the variable mobile phone are significant and for the variable "Internet penetration", only the one associated with the fixed effects estimator is significant (but at the 1% threshold). These results suggest that digital technologies play an important role in the fight against youth unemployment in the African

context. As a result, we can conclude that the ***hypothesis of skill-biased technological change*** bias is validated in the context of African countries.

5. Conclusion

The main objective of this paper was to analyze the effects of the high diffusion of ICT observed in African economies since the early 2000s on the volume and structure of employment. Indeed, the literature is not unanimous on the consequences of the occurrence of a technological innovation on employment. Thus, some authors, based on the theory of compensation, think that innovation would be favorable to total employment. Thus, empirical work to verify the validity of these compensation mechanisms has multiplied (Harrisson et al., 2005; Peters, 2004; Garcia et al., 2002). Beside them, some, rather pessimistic, see in innovation a source of destruction of jobs, especially the least qualified. This idea is known in the literature as the ***hypothesis of skill-biased technological change*** (Goos et al., 2009).

From this theoretical controversy, two main ideas were verified in this study. The first is the impact of ICT diffusion on the total volume of employment in Africa. To do this, we constructed and estimated a linear model in panel data. The estimators used are GMM and fixed effects. These estimates suggest that ICT diffusion in Africa is broadly favorable to employment. Similarly, we have seen that these technologies lead to a fall in unemployment in the same context.

The second idea is that of the existence of a technological bias in the African context. To do this, we reinterpreted this hypothesis as the existence of an inverse relationship between ICT and youth unemployment, the latter being the most affected by this strong diffusion of ICT. Again, we estimated a dynamic panel model by the GMM estimators. These estimations suggest that ICT diffusion is negatively correlated with youth unemployment.

Therefore, to fight against youth unemployment, the authorities could promote the emergence of a true digital economy in this region. This begins with the provision of basic ICT infrastructure. It also means implementing a favorable framework for the development of Start-up.

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Appendix

The list of the countries considered in the sample

Burkina Faso, Botswana, Burundi, Cabo Verde, Cameroon, Congo, Cote d'Ivoire, Gambia, Guinea, Lesotho, Madagascar, Malawi, Mali, Maurice, Mozambique, Niger, Senegal, Seychelles, Swaziland, Togo.