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Théophile T. Azomahou and Mbaye Diene

Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT)
email: info@merit.unu.edu | website: http://www.merit.unu.edu

Maastricht Graduate School of Governance (MGSoG)
email: info-governance@maastrichtuniversity.nl | website: http://mgsog.merit.unu.edu

Keizer Karelplein 19, 6211 TC Maastricht, The Netherlands
Tel: (31) (43) 388 4400, Fax: (31) (43) 388 4499

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Income polarization and innovation: Evidence from African economies*

Théophile T. Azomahou[(a)†], Mbaye Diene[(b)]

[(a)] United Nations University (UNU-MERIT) and Maastricht University
Keizer Karelplein 19, 6211 TC Maastricht, the Netherlands

[(b)] University Cheikh-Anta-Diop, CRES
Rue 10 Prolongée. Cité Iba Ndiaye Diadji n° 1-2, Dakar, Sénégal

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Abstract

This paper examines the degree of polarization of GDP per capita of African economies between 1966 and 2008. Based on a nonparametric analysis, we find that countries tend to cluster in two classes of per capita GDP. Relying on the Wolfson's bipolarization measure, the results reveal that bipolarization has been accelerating during the two first decades and is still growing. We relate the evolution of polarization during the period to the business sectors. We find that countries specialization is the driving force of this evolution, namely, agriculture and industry sectors. We also study the innovation-development polarization relation in a VAR framework using patents and trademarks as measures of innovation.

JEL: Polarization of GDP, patents, trademarks, VAR model
Keywords: C32, O34, O47, O55

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†Corresponding author: Azomahou T.T., Tel. +31433884440, Fax +31433884499, E-mail: azomahou@merit.unu.edu, M. Diene, mdiene@cres-sn.org

1 Introduction

The great advances recently made in economic growth theory, coinciding with the introduction of endogenous growth models (Romer, 1986,1987), have led to a rising attention on the issue of economic disparities. The models usually take into account other determinants of growth, different from capital and labor, such as human capital, public expenditures (Lucas, 1988), and innovations (Grossman and Helpman, 1994). Economic growth theories enhanced by the "new economic geography" models (Krugman, 1991, and Fujita and Thisse, 2002) show the importance of spatial disparities in the convergence of economies. Usually, the sigma and beta convergence developed by Barro and Sala-i-Martin (1991,1992) are used for the analysis of the disparities in per capita GDP in the literature. However, Quah (1993,1997) has shown that the convergence methodologies lead to loss of information on the dynamics of income distribution. For example, they cannot capture the changes of relative positions of countries over the period, leaving behind the intra-group mobility.

Analysis of per capita convergence between countries has also been done by some scholars: López-Bazo et al. (1999), Cuadrado and Parellada (2002), Fingleton and López-Bazo (2003), Badinger et al. (2004), Magrini (2004), Miller and Genc (2005), and Meliciani (2006). Bernard and Durlauf (1995) use annual logarithm of real output per capita for 15 OECD countries and test the existence of convergence and common trends, from 1900 to 1987. There is a convergence for a group of countries when they have identical either stochastic or deterministic long-run trends, while common trends allow for proportionality of the stochastic elements. They found that there is no convergence for the countries but evidence for common trends exists. Bernard and Durlauf (1996), Quah (1996) and Anderson (2004) point out that the convergence approaches also ignore the role of the polarization or formation of homogeneous groups within the distributions. The natural clustering around stable steady state equilibria is identified as the formation of "convergence clubs" (Quah, 1996, Baumol, 1986, Galor, 1996, Durlauf and Jonhson, 1995).

Nevertheless, some important issues arise from the studies of convergence such as the existence of threshold effects (Azariadis and Drazen, 1990) or nonlinearity and parameter heterogeneity of human capital (Durlauf and Johnson, 1995, Masanjala and Papageorgiou, 2004, Kalaitzidakis et al., 2001, Ketteni et al., 2007, Ketteni, 2009 and Mamuneas et al., 2006). As regard nonlinearities, Kalaitzidakis et al. (2001) notice that "though intuition and theories point towards a positive effect of human capital on growth, the empirical evidence of the issue is mixed". So, the authors apply semi-parametric estimation techniques that investigate nonlinearities in the relationship between economic growth and human capital (measured by mean of years of schooling). They conclude that the link between the two variables is widely nonlinear. Several empirical studies with different methodological approaches show strong evidence of parameter heterogeneity (Durlauf and Johnson, 1995, Kalaitzidakis et al., 2001, Liu and Stengos, 1999 and Durlauf et al., 2001). Parameter heterogeneity in growth models means, for example, that in a cross-country growth regression, countries have different coefficient estimates (Azariadis and Drazen, 1990, Durlauf, 1993, and Galor and Zeira, 1993).

The objective of this paper is to analyze the polarization of African economies, by using various approaches. The first approach consists in the study of polarization in African countries' per capita GDP distribution between 1966 to 2004. We primarily use a nonparametric analysis and find that the countries tend to cluster in two classes of per capita GDP. Secondly, by using the Wolfson's bipolarization measure, the results reveal that bipolarization has been accelerating during the two first decades and is still growing. We relate the evolution of polarization during the period to the business sectors. We find that the specialization of the countries is the main factor explaining its evolution, namely, in agriculture and industry sectors.

In the second approach, we determine different types of economic polarization in Africa by using the alienation-identification model developed by Duclos et al. (2004). We study a particular form of polarization, based on the alienation that individuals or groups of individuals feel toward each other. This alienation is reinforced by the sense of being within a group. Thus, a distribution of living standards in a population is polarized if homogeneous different groups of individuals are observed. These groups are spread around different modes and it is the case when the population is divided into two groups around the median. This case is called bipolarization. The literature is also interested in the formation of two groups, which is called bipolarization (Foster and Wolfson, 1992, Wolfson, 1994, 1997, Wang and Tsui, 2000). These authors used it formalized the polarization by dividing the population into two groups and the polarization index increases when inequality of the average incomes of both groups increased.

The analysis of polarization has political and economic interest. First, it evaluates the risks of interpersonal alienation between the individual groups, which can arise from a polarized distribution. Alienation is the feeling of difference and exclusion, among individuals whose living standards are not identical. Understanding the economic reasons of a polarized system can facilitate the choice of the measures that policymakers can use to avoid social tensions. In the literature, many authors have focused on the issue of polarization. Among them, are Esteban and Ray (1994), Wolfson (1994), Wang and Tsui (2000), Zhang and Kanbur (2001) and Chakravarty and Majumder (2001). Various measures of polarization are proposed, some of which are family-based indices of entropy (Zhang and Kanbur, 2001), others on the deviation from the median (Alesina and Spolaore, 1997). Duclos et al. (2004) have proposed a polarization measure that combines the principles of identification and alienation. The sum of the antagonisms generated by the two principles gives the polarization effect. Identification is the feeling of an individual who sees himself as an element in a given group. Alienation is the result of the economic resentment on other groups, mainly because of their different living standards. It is different from the social alienation that is more general and that involves both socioeconomic and political factors. For an individual, it means the lack of certain social criteria, compared to other members of society (Bossert and d'Ambrosio, 2004, 2006).

The combination of income, to measure the polarization, is to make discrete elements of a continuum, that is to say, to consider a finite and discrete groups. Generally, there is loss of information on the distribution with the transition from a continuous to a discrete set of the variable of interest (income or GDP for example). The classification of income is arbitrary and the choice of the size of income groups also (Makdissi et al., 2008). The index of Duclos et al. (2004) avoids these practical problems, by using density functions, as we shall see later.

Polarization and inequality are close, but they emphasize different aspects of a distribution, and their changes can sometimes diverge for the same population. For example in a population decomposed into two groups of different incomes, a reduction of the inequality in only one group, creates a greater polarization of the population. Common features of studies on the formation of groups, are based on the facts that: i) polarization implies the existence of two groups; ii) polarization increases in the following two cases: inequality decreases within groups or increases between the groups. Esteban and Ray (1994) propose a measure of polarization based on the identification and alienation by introducing a set of axioms. They consider that polarization is fundamentally linked to the ability of a society to undertake and promote collective decision-making. In 1999, the authors develop a model of conflict where the level of polarization is related to an equilibrium level of conflict. The polarization can also be applied to politics, as shown in the work of Schultz (1996) which, through a model of public goods, shows that the polarization of the preferences of political parties led to an inefficient equilibrium.

All these studies suggest that the polarization can be approached in different ways and the construction of indices depends on the axioms set forth. We will present the axioms that guide the construction of the index of Duclos et al. (2004) that we use in this work. It is worth to notice that many empirical studies have been devoted to the sources of polarization or the same determinants of the variation in distances between the groups. Authors have studied the microeconomic explanation of the polarization, analyzing possible sources of bias. We can cite the work of Gradin (2000), polarization of income and its sources in Spain, D'Ambrosio (2001) in Italy, Zhang and Kanbur (2001) in China. Duclos et al. (2004) have in turn provided a measure of income polarization in 21 countries using data from the Luxembourg Income Study. Similarly, Seshanna and Decornez (2003) have studied the distribution of income in many countries. Ravallion and Chen (1997) evaluated the polarization of a group of 67 countries using the index of Foster Wolfson.

Our paper examines the degree of economic polarization in Africa, using the per capita GDP distribution. The relevance of the issue of polarization in Africa is mainly due to the necessity of achieving economic and social cohesion in the context of the economic integration process underway since the years of independence. It is then necessary to reduce the differences in terms of development across the continent. This necessity may be seriously threatened if the African Union (AU) and other regional integration institutions were to split into series of well-differentiated economic clusters. We show that there exists a bipolarization of the economies by using three methodologies. We primarily estimate non-parametrically the distribution of the per capita GDP (we precisely use the GDP per capita in 2000 constant dollar terms) in 34 African countries, aiming to identify multimodality of the distributions, during the period 1966-2008. But the methodology does not give the precise measure of observed changes in the degree of polarization over time. That is why we secondly analyze the evolution of Wolfson's bipolarization index during the period. We find that the global bipolarization is explained by the polarization into four sectors: agriculture, mining, industries, and services. Lastly, we study the innovation-development polarization relation in a VAR framework using patents and trademarks as measures of innovation. By doing so, we are interesting in the relation between trademarks and patents. Moreover, it is likely that catching-up economies experience an increase in trademark applications prior to an increase in patent applications.

The paper is organized as follows. Section 2 presents the nonparametric analysis of the distribution of per capita GDP in the African countries. In Section 3, we measure the degree of bipolarization of the countries and examine the transitions of the economies during the period. In Section 4, we analyze the polarization on other different variables and see how they contribute to the GDP polarization in Africa. Section 5 offers a VAR analysis to quantify the determinants of innovation indicators. Section 6 concludes the study.

2 A nonparametric analysis of GDP distribution

We examine the external shape of the GDP per capita distribution during the period 1966-2008 for 34 countries. The data are drawn from the World Bank Africa Database (2007 and 2010). We exclude some countries due to data problems. To this end, we have estimated non-parametrically, the density functions of the distribution under consideration. Estimates are based on kernel functions, and in each case, the smoothing parameter is determined following

Silverman (1986, p.48). The estimation results are presented in Figure 1 for the logarithm of GDP per capita from 1996 to 2008. There appears to be different patterns in the evolution of the African countries over time, and Figure 1 displays tendencies to cluster into relatively homogenous classes, which are also commonly referred to as "convergence clubs" by Durlauf and Johnson (1995) and Quah (1996,1997).

Insert Figure 1

Distribution of GDP per capita: Africa

As we can see, the African countries have evolved towards a twin-peak situation shown by Quah (1996) for the world economy. The upper tail has stretched out further during the last two decades. The distribution has also lost mass at the low end, particularly during the last period. So, the poorest countries are not trapped in their relative GDP positions. The third mode that becomes very apparent since 1966 begins to diminish continuously towards the end of the period. From 1986 onwards, only a second mode emerged in all the estimated density functions. This mode was formed by most developed countries, in the south and the north of Africa, such as Morocco, Tunisia, and South Africa. This suggests that these countries are converging toward a higher per capita GDP level than the others.

It is worth noting that the changes in the shape of the distribution of per capita GDP do not derive from volatile movements, as shown by the fact that about three quarters of the countries stay in their income class over a period of ten years, as shown in Table 1. It appears in the transition probabilities that the countries in the third group are mainly located in the north and the south of Africa, with some exceptions such as Gabon and Congo. In the first decades, some countries such as Ivory Coast and Liberia left the second group for the less developed first one. Other countries made transition from the first to the second group among them Egypt, Congo, and Botswana.

Insert Table 1

Transition probability matrices

We make the assumption that the geographically contiguous countries form groups of coalitions that influence the overall polarization of the distribution. We have three coalitions: the Maghreb countries, the south African countries and the sub-Saharan countries.

Insert Figure 2

Contour of distribution capita: Sub-sahara Africa

The contour plot of the Maghreb countries is given by the Figure 2a. During the first period, from 1966 to 1990 they all grow but with a high dispersion. They converge at the second period. The initial interval of variation of the countries' relative GDP per capita is from 0.95 to 1.1. In the last periods, from 2000, the interval reduces to 1.04 to 1.1. It means growth for some countries and stagnation for the others. For the south African countries (Figure 2b), at the first year (1966), there is a concentration between 0.75 and 1, of the relative GDP per capita. The countries are divided into two groups after that year. The first one with four countries in the interval 0.73 and 0.95 while the second one, with higher levels, is contained between 1.15 and 1.25. It appears in Figure 2c, for the sub-Saharan countries a clustering in two intervals. The fist is from 0.71 to 1.05 and the second, from 1.2 to 1.3. A quasi stagnation distinguishes the region from the other ones.

3 Quantification of the level of polarization

The nonparametric and the transition approaches present the limitation that they do not provide information about changes in the degree of polarization over time. To tackle this problem, we use the methodology proposed by Wolfson (1994) in the literature on income distribution.

3.1 Economic bipolarization

Let F be an income distribution of N countries with a mean income value $\bar{y}$ and a median income value y_m. The Wolfson's bipolarization index, given for a population divided in two groups by the median, is

$$W(F) = 4\frac{\bar{y}}{y_m}\left[1 - 2L(0.5) - G(F)\right] \tag{1}$$

where $G(F)$ denotes the Gini coefficient of the income of the distribution F and L is the Lorenz curve at the 50^{th} population percentile. $W(F)$ is proportional to the shaded area in Figure 3. The larger the shaded area, the fewer the countries with middle level GDP per capita, leading to greater polarization. The area is also algebraically equal to the vertical distance between the 45-degree line and the Lorenz curve at the median percentile, $L(0.5)$.

Insert Figure 3

Figure 4 presents the evolution of Wolfson's bipolarization measure over time.

Insert Figure 4

Taking the study period as a whole, the results reveal an increase in the bipolarization of the distribution under consideration. African countries are economically polarized, and there appears to be an increase of the polarization during the first two decades. The trend of increase of polarization is permanent, except in 1988. As illustrated in Table 2, the evolution of bipolarization allows us ton divide the countries into two different economic groups. The first group (quoted 1) comprises the countries which remain below the regional per capita GDP during all the periods 1966-1976-1985-1993-2003-2008. Within this group are countries as Benin, Burkina-Faso, Burundi, Central African Republic, Chad, Congo Democratic Republic, The Gambia, Togo, and so forth. The group 2 (quoted 2) is the set of countries that have their level of GDP per capita higher the regional one during all the period: Algeria, Morocco, Egypt, Tunisia, South Africa, and so forth. Consequently, with the exception of Gabon and Congo, we can suppose that we have three geographical groups: the sub- Saharan countries, the Maghreb countries, and the Southern African countries. The growing bipolarization means that the development of the first two groups of countries does not have visible and direct effect on the remaining countries. It means also that there are not very tight economic relationships, such as mobility of the factors or international exchanges, between these two groups and the rest of the countries in the continent. In Table 2, scoring 12 means the country is going from group 1 to group 2, and 21 means the opposite.

Insert Table 2

Two groups transition patterns

3.2 Explanatory elements of bipolarization

In the previous section, the African regions are divided into two groups according to their per capita GDP. Nevertheless, there are other national characteristics, besides per capita GDP, that may explain polarization. For purposes of capturing those characteristics, we estimate the polarization index on the value added of the four sectors: agriculture, mining, industries, and services in order to understand the dynamics of global polarization. The sectors with the greatest bipolarization levels are mining and services. This implies that natural resources make the countries different. We run the following simple dynamic estimation:

$$GIt = F(AP_t, AP_{t-1}, MP_t, IP_t, IP_{t-1}, SP_t, SP_{t-1}) \tag{2}$$

Where F is a function, t stands for the time, GI_t is the global index at time t, AP_t is the polarization index in agriculture, MP_t is the polarization index in mining sector, IP_t is the polarization index for industries and SP_t is the index for services. OLS estimates are reported in Table 3

Insert Table 3

Determinants of bipolarization

The main sectors that tend to reduce bipolarization are mining and the services. Agriculture and industries and their lagged bipolarization level, contribute to enhance the global clustering between the African countries. Mines and the services tend to reduce bipolarization. It is possible to run other regressions by changing the variable or by supposing nonlinearities in the relation. But the simple model emphasizes that most of the African countries have similarities in services and mines.

4 Measuring the macroeconomic polarization

In this section, we present the axioms of the index of polarization that we use to measure the global polarization in Africa. Let us call basic densities the density functions that are not normalized (by population), symmetric, with only one mode, and have compact and disjoint supports. It is possible to express the polarization index from axioms based on these basic densities. Taking as a variable of interest income, Duclos et al. (2004) propose the following axioms that give a particular form of the index. Let us define a t-squeeze of f as follows:

$$f^t(x) = t^{-1} f(t^{-1}[x - (1 - s)\mu]) \tag{3}$$

f being a basic density with mean μ and let $t \in (0, 1]$. The t-squeeze is a mean-preserving reduction of the spread of f.

- A-1 If a distribution has only a single density function, then a squeeze of that density cannot increase polarization. This means that from a basic density, we can obtain another distribution, the latter being obtained by "squeezing" the two sides of the first density. This compression reduces alienation and the difference between individuals, which has a negative impact on polarization. In addition, it has the positive effect of increasing identification. Both effects must be offset.

Insert Figure 5

A-2 If a symmetric distribution is composed of three basic densities derived from the same kernel, with mutually disjoint supports, then a symmetrical squeeze of the two side densities does not reduce the polarization. Thus a local squeezing does not reduce the polarization. This means that if two distributions F and G have the same mean and the same median (denoted m) and F stochastically dominates G in the second order in the interval $[0, m]$ and $[m, \infty]$, then F should be more polarized than G. Notice that the kernel is the function used to approximate the density function of a variable. It is Gaussian if the function of the normal distribution is used.

Insert Figure 6

A-3 If a symmetric distribution is composed of four basic densities derived from the same kernel, with mutually disjoint supports, lateral sliding in opposite directions, both increases the density of the medium polarization. Thus, the increase in inequality between groups generates a greater polarization. In the case of polarization, this means that if a distribution, the income of each individual is away from the median, as it is higher or lower, then the bias should increase.

Insert Figure 7

A-4 If we have $P(F) \geq P(G)$ and p a positive real, then $P(pF) \geq P(pG)$ where P is the polarization index. If a distribution is more polarized than another one, that situation remains when the scales of the two populations are reduced or increased in the same order. These axioms lead to a particular form of $P(F)$. Consider a population composed of G groups and normalized to unity. F is the cumulative density curve of the distribution of income across the population and F_j is the non-normalized one of the group $j : F(x) = \sum_j F_j(x)$. F and f_j denote the densities of the distributions and $I = \lambda_j(x, F)$, is the identification function of each individual j, $A = \delta_{jk}(x, y)$ is the alienation of j towards group k.

The polarization index measures the overall antagonisms of all individuals. The antagonism is the alienation weighted by the identification. The function $T(I, A)$ that can be measured is defined by:

$$P(F) = \sum_j \sum_k \int_x \int_y T(I, A) \, \mathrm{d}F_j(x) \mathrm{d}F_k(y) \tag{4}$$

Assuming that $G = 1$, the distribution is represented by basic densities f. A measure of the polarization P is given by:

$$P_\alpha(F) = \int_x \int_y f(x)^{1+\alpha} f(y) |y - x| \, \mathrm{d}x\mathrm{d}y \tag{5}$$

The parameter α reflects the weight given to the identification and we have $\alpha \in [0.25, 1]$. The index described in equation (5) can be rewritten as

$$P_\alpha(F) = \int_y f(y)^\alpha a(y) \, \mathrm{d}F(y)$$

where $a(y)$ is given by

$$a(y) = \int_{-\infty}^{+\infty} |y - x| f(x) \, \mathrm{d}x = \mu + y(2F(y) - 1) - 2B(y) \tag{6}$$

where μ denotes the average, and

$$B(y) = \int_{-\infty}^{y} x f(x)\,\mathrm{d}x \tag{7}$$

The index $P_\alpha(F)$ has several advantages, including the fact that it can be used for survey data. For its statistical estimation, the variable of interest is divided into groups whose sizes are estimated non-parametrically by the kernel method. The advantage is that it is not useful to identify the form or the nature of the distribution function. If the variable of interest is derived from a sample of n independent identically distributed observations, then polarization index is estimated by:

$$P_\alpha(F) = \int \hat{f}(y)^\alpha \hat{a}(y)\,\mathrm{d}\hat{F}(y) = \frac{1}{n}\sum_{i=1} n\hat{f}_i(y)^\alpha \hat{a}(y_i) \tag{8}$$

where y_i is the quantile for values between $(i-1)/n$ and i/n. The average of these two limits is taken to evaluate F:

$$\hat{F}(y_i) = \frac{1}{2n}(2i-1) \tag{9}$$

with

$$\hat{a}(y_i) = \hat{\mu} + y_i(2\hat{F}_i - 1) - \frac{1}{n}\left(2\sum_{j=1}^{i-1} y_j + y_i\right) \tag{10}$$

and

$$\hat{B}(y_i) = \frac{1}{n}\left(\sum_{j=1}^{i-1} y_j + \frac{i-(i-1)}{2} y_i\right) \tag{11}$$

The distribution is estimated by the method of Gaussian kernel and it is shown that the distribution of $\sqrt{n}\left(\hat{P}_\alpha(\hat{F}) - P_\alpha(F)\right)$ follows an asymptotic $N(0, V_\alpha)$ whose variance is:

$$V_\alpha = \underset{f(y)}{\mathrm{Var}}\left[(1+\alpha)f(y)^\alpha a(y) + y\int f(x)^{1+\alpha}\,\mathrm{d}x + 2\int_y^\infty (x-y)f(x)^{1+\alpha}\mathrm{d}x\right] \tag{12}$$

Let us denote $\bar{i}_\alpha$ and $\bar{a}$ the averages of the identification and the alienation, and by ρ their standard covariance. The polarization index is written as:

$$P_\alpha^{DER}(f) = \bar{i}_\alpha \bar{a}(1+\rho). \tag{13}$$

Insert Figure 8

Evolution of GDP per capita polarization index

Figure 8 displays the polarization index of GDP per capita. This polarization is globally increasing over time, reflecting a kind of persistence of the phenomenon over time. Remind that polarization is inequality of development. As a result, Figure 8 suggests that inequality in development is increasing over time among African economies, meaning that some countries are performing well independently of other. In what follows, we go a step further and study the relation of this polarization to innovation for African economies.

5 Innovation and polarization

In this section, we study the role of innovation in polarization process of African economies. The role of innovation in development was studied in both the theoretical and the empirical literature of economic growth. Fagerberg et al. (2010) provide an interesting review. Especially in the literature on endogenous growth, these studies emphasize the role of R&D and human capital as drivers of economic growth and development. To this end, the two facets of R&D were often cited: R&D as stimulating innovation and as a facilitator of imitation (Griffith et al., 2004). However, if several studies have examined the case of poor countries in general, the situation of African countries has received very little attention. Here we study not the role of R&D (which is an input to innovation), but the role of two outputs of innovation in the polarization process of African economies: namely patents and trademarks.

Patents and trademarks are two indicators of innovation whose functions are distinct, but with some similarities. Patents have been developed and studied extensively in developed countries. Some countries like China today arouse enthusiasm. We know that the patenting process is particularly compelling, long and heavy depending on country's legal procedure. It is therefore very difficult for poor countries to access them easily. Instead, trademarks have a much simpler protocol and are more accessible. It is therefore interesting to relate these two modes of innovation, to study their respective contributions to outcome. In a first step, we return to a general overview on patents and trademarks. Then we give a brief description for the data under use and last, we provide an estimate of the contribution of both indicators is the polarization of these economies.

5.1 Overall overview on patents and trademarks

The Patent variables are the applications filed with a national patent office for exclusive rights for an invention. An invention is considered as a product or a process that provides new ways of doing something or offers new technical solutions to a problem. A patent provides protection for the invention to the owner of the patent for a limited period, generally 20 years.

A resident patent application is one for which the first-named applicant or assignee is a resident of the country concerned. Non-resident patent application is from an applicant who is outside the country. The consequence is that the resident filings can overestimate the number of new inventions. But they are a reliable indicator of underlying inventive activity. Patent filings by non-residents mean the internationalization of technology and markets. Generally, because of commercial considerations, applicants decide to file a patent application for the same invention in other countries. The sectors where patents are developed, are: electricity and electronics (electrical devices, engineering, audio-visual technology), instruments (optics, analysis, measurement, control technology), chemistry and pharmaceuticals (biotechnology, agriculture and food), process engineering (materials processing, textiles, paper, agricultural and food processing), machinery, mechanics and transport, (machine tools, mechanical components), consumer goods and civil engineering (equipment, building, mining).

a) *An increase of worldwide patents applications*

The patent activities still remain concentrated in high-income countries, though growth in applications from middle- and low-income economies appears in the past decade. Historically the numbers of patents applications stood stable until the 1970s, but substantial growth appears in the applications from Brazil, China and India, from the mid-1990s. There are three reasons for the increase of patents applications in the world since the mid-

1990s. i) The acceleration of technological progress (essentially computer technology), that may generate greater economic prosperity, ii) the changing nature of innovation systems and companies' shifting patenting strategies, iii) the increase of international trade and the heightened need for companies to protect their inventions. The fact show that between 1995 and 2008, patent applications grew by 4.9% a year while they were of 3.7% growth in 1983-1990 (WIPO, 2011).

b) *Relevance of trademarks for innovation and development*

The Trademark variables are also applications filed for registration of a trademark with a national or regional trademark office. Trademarks are distinctive signs that identify goods or services as those produced or provided by a specific economic agent. Trademarks protect owners of the mark by ensuring exclusive right to use it to identify goods or services or to authorize its use in return for payment. Trademarks can be maintained indefinitely as long as the trademark holder pays the renewal fees. An estimated 3.66 million applications were filed globally, consisting of 2.78 million resident and 0.88 million non-resident applications. The growth of the applications is of about 12% in 2010 - the largest growth since 2000 - after having declined over the previous two years.

Unlike patents, Middle-income countries file a higher number of trademark applications per GDP than high income countries. There has been a growing trend of total trademark applications in the world, between 1985 and 2007. An average of 31% of all trademark applications from 1985 to 2010 was filed by non-resident applicants. However, since 2007, this share has decreased from 30% to 24% because of the large number of resident trademark applications in China. The main sectors of trademark applications are Agricultural products and services (15.4%), Scientific research, Information and Communication technology (14%), Textiles - Clothing and Accessories (13.7%), Leisure, Education, Training: (11.5%), Management, Communications, Real estate and Financial services (11.1%).

As is the case for patents, differences in trademark activity across economies reflect their size. Trademarks applications are relevant as innovation indicators for developing countries. Particularly, they mean growing trade activities, firm performance, and they can lead to catching up economies, leading to a reduction of global polarization and inequality among countries (Centi and Rubio, 2005) It is worth noting that trademarks and patents are not separate and independent variables. They may have many interactions. For example, trademarks can reinforce the protection provided to patented goods, and in a sense prolonging the protection originally provided by the patents, and contributing then to the financial return obtained from inventions. There also are benefits from trademark information in the provision of commercial insights to complement the information obtained from patents . Then there exist a synergism between the patent and the trademark applications (Rujas, 1999).

Trademarks have also social benefits as they help identify the quality of goods for consumers. Essentially, trademarks reduce the purchase errors and the costs of attempting to avoid such errors. However, several forms of social costs are associated with trademarks, as shown by Greer (1979) who studied a model where he suggested that identification of quality and source be separated wherever possible, in the maximization of benefits and the minimization of costs. Private benefits can also rise from trademarks (Chudnovsky, 1979), especially for the developing countries hosting non resident trademark applications.

5.2 Distribution of patents and trademarks

We present the distribution of the two categories of variables in Table 4. What is remarkable is that South Africa dominates the entire African continent, where during all the period from 1960 to 2008, the number of applications are respectively: 159,477 and 339,437 for the patents and trademarks of non residents; 86,816 and 379,388 for the patents and trademarks of residents. The patents of residents are relatively more important for South Africa than the ones of non residents. The same observation can be made for the trademark. The numbers of patents of residents and non residents are higher in North Africa than in sub-Saharan Africa, excluding South Africa.

Insert Table 4

Distribution of the patents and trademarks in the African regions

In North Africa, the highest numbers of non residents patents are found in Egypt Arab Republic (19,032), Algeria (6,841) and Morroco (6,365); the same for Kenya (1,134) and Nigeria (677) in sub-Saharan Africa excluding South Africa. The countries within the two regions that have the highest levels of residents patents are the Egypt Arab Republic (8,169) and Morroco (1,502). In the entire continent, residents trademarks are very important, mainly in Morroco (34,411), Algeria (19,830), Kenya (8,258), Tunisia (6,699), Egypt (2,972) and Mali (2,888). It is worth noting that Tunisia (14,067) and Kenya (11,905) have the highest numbers of non residents trademarks.

After having studied the cross correlation of the polarization indices, we see that the relationship between GDP and patents from non residents is substantially positive with one. It means that the two series have a delayed link. It is worth noting that there is a negative relation five years later. The correlation between GDP and patents of non residents is always negative and is strong with two years delay. Contrarily, the relation between GDP and patents of residents is almost always negative with a strong level after two years delay.

We plot in Figures 9 and 10 the evolution over time of the polarization indices of patents and trademarks. Two salient features can be put forward in the evolution of patents (Figure 9). Before 1994, while the patent index for residents is stable and above that of non residents, the latter is increasing until reaching the former and going above. The second feature is that there is the sharp decline in 1997 and 2006 meaning the inequality has narrowed both for residents and non residents with a very strong magnitude for residents. As for trademarks (Figure 10), residents index is also dominates non residents and the sharp decline hold in 1985.

Insert Figure 9

Evolution of GDP per capita and patents index

Insert Figure 10

Evolution of GDP per capita and trademarks index

5.3 Estimation

Several studies have investigated the innovation-development relation for developing countries. Chen and Puttitanun (2005) studied the relationship between IPRs and economic development using a panel data for developing countries. Their IPRs measure is the the GP index developed by Park and Ginarte (1997). This index is composed of five patents laws from 64 developing countries: duration of protection, extent of coverage, membership in international patent agreements, provisions for loss of protection, and enforcement measures. The index scale ranges from

0 to 5, with higher numbers reflecting stronger levels of protection. Chen and Puttitanun (2005) considered a system of two triangular simultaneous equation system, one for IPRs protection and one for domestic innovation, where IPRs is treated as endogenous. The control variables include GDP, squared GDP, education, trade, dummy variable for WTO membership. The innovation indicator considered by Chen and Puttitanun (2005) is patents applications. Consistently with their theoretical framework, Chen and Puttitanun (2005) found evidence that innovations in developing countries are positively and significantly impacted by IPRs, and the levels of IPRs display a U-shaped relationship with per capita GDP.

The approach adopted here is rather different. As we have indicated above, our goal is to analyze the determinants of the polarization of innovation in African countries within a time series framework. It is worth to notice that R&D expenditures have been used as measure of innovation, which is rather measure the input of innovation. Other measures of innovation are the number of patent applications and/or patents granted, and trademarks, which are inventive outputs. As documented earlier, trademarks are particularly relevant in developing countries. This raises several questions: Do catching-up economies experience an increase in resident trademark applications prior to an increase in resident patent applications? what is the relation between trademarks and trade? To what extent do trade flows correspond to flows in trademark registrations? In this empirical investigation, we consider both polarization index of patents and trademarks as innovation variables of interest. Accordingly, it is desirable that the analysis is conducted jointly. VAR models suited well this purpose. The general VAR model with exogenous variables is written as

$$\mathbf{y}_t = \mathbf{A}\mathbf{Y}_{t-1} + \mathbf{B}_0\mathbf{x}_t + \mathbf{u}_t \tag{14}$$

where $\mathbf{y}_t$, is the $K \times 1$ vector of endogenous variables, here polarization index of trademarks and patents for residents and non-residents, meaning that $K = 4$, $\mathbf{A}$ is a $K \times Kp$ matrix of coefficients, $\mathbf{B}_0$ is a $K \times M$ matrix of coefficients, $\mathbf{x}_t$ is the $M \times 1$ vector of exogenous variables (polarization index of GDP, openness, remittances and revenue), $\mathbf{u}_t$ is the $K \times 1$ vector of white noise innovations and $\mathbf{Y}_t = \left(\mathbf{y}_t, \cdots, \mathbf{y}_{t-p+1}\right)'$. The variable Revenue is all the central government revenues as percentage of GDP, excluding grants. The variable Remittances includes all the transfers made by migrants who are employed or intend to remain employed for more than a year in another economy in which they are considered as residents. It is also taken as percentage of the GDP. The Openness is the sum of the exports and imports divided by the GDP. All these amounts are in constant 2000 US dollars. It worthwhile noticing that other controls that one would like to include in the analysis are R&D expenditures and higher education. Clearly, both can be viewed as relevant innovation inputs. However, data on R&D expenditures are not available for most developing countries. Moreover, for the sample at hand, higher education data are not available. The data are drawn from the World Bank Africa Database (2007 and 2010).

Equation (14) is estimated by maximum likelihood (Lütkepohl, 2005 and Hamilton, 1994). Parameters estimates are reported in Table 5. Four blocks of estimation appear in this table, each corresponding to a measure of polarization index of patent and trademark. The notations L1 and l2 indicate the lags at order 1 and 2 to of the corresponding variables. As indicated in the Chi-square specification test, non-residents trademark equation is not significant. By cons, residents trademark equation shows a global significance at the conventional level of 5%. Despite this, only the lag 2 for non-residents trademarks has a significant positive effect on residents trademark. Recall that the variables used here are the polarization index. In other words, the polarization index of residents trademarks increases with that of non-residents trademarks. Regarding patents, the chi-square specification test indicates that both equations are significant at 5% and 1% respectively for residents and non-residents. Thus, while the polarization index of patents residents increases with the lag 1 for patent non-residents, the lag 2 of the same reduced this polarization. At the same time, we observe in the last equation that the patents filed by residents contribute to reduce the polarization observed in patents filed by non-residents. Finally, an increase of the polarization index in the openness and remittances increases the polarization of non-residents patents.

Insert Table 5

VAR estimation results: Determinants of innovation in Africa

Table 6 reported the impulse response function (IRF). The IRF measures the effect of a shock to an endogenous variable on itself or on another endogenous variable (see Lütkepohl, 2005, pp. 51-63, and Hamilton, 1994, pp. 318-323, for formal definitions). I particular, here we report the estimates of the cumulative dynamic multipliers, which describe the impact of a unit change in an exogenous variable on each endogenous over time. We also reported 95% lower and upper bounds. The results indicate that the cumulative dynamic multipliers are significant.

Insert Table 6

Impulse response function: Cumulative dynamic-multiplier

6 Conclusion

This paper examines the degree of polarization in the per capita GDP distribution in the African countries between 1966 and 2004 from complementary approaches. We begin primarily by a nonparametric analysis. We find that African countries tend to cluster into two classes over the period. However, the level of intra-distribution mobility, is low and can be attributed mainly to the sub-Saharan countries. Indeed, the geographical location of the countries plays an important role in the explanation of the bi-polarization patterns. Secondly, we construct the evolution of the level of polarization over time, completing the nonparametric approach by using the methodology proposed by Wolfson (1994). The results reveal a growing bipolarization. The Maghreb Arab countries and the southern African countries constitute a cluster, while the sub-Saharan countries make up a second one. The growth of polarization is related to countries' specialization during the period. Essentially, its evolution is the outcome of agriculture and industry. Therefore development policies for services and mining sectors may be very useful in decreasing polarization in Africa. Lastly, while establishing the link between patents and trademarks, our study does not detect the determinants of trademarks. However, one might think that trademarks play an important role in developing economies. Further analysis including data collection might be necessary to target such determinants like the role institutions in African economies aiming at facilitating the development and the management of trademarks. A firm level analysis may deserve attention.

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Appendix: Tables and Figures

Table 1: Transition probability matrices

		GDP 1976		
# Countries	GDP 1966	$[0.6, 1)$	$[1, 1.4]$	Total
25	$[0.6, 1)$	0.735	0	0.735
9	$[1, 1.4]$	0.059	0.206	0.265
34	Total	0.794	0.206	1
		GDP 1985		
# Countries	GDP 1976	$[0.6, 1)$	$[1, 1.4]$	Total
27	$[0.6, 1)$	0.676	0.118	0.794
7	$[1, 1.4]$	0.029	0.176	0.206
34	Total	0.706	0.294	1
		GDP 1996		
# Countries	GDP 1985	$[0.6, 1)$	$[1, 1.4]$	Total
24	$[0.6, 1)$	0.706	0	0.706
10	$[1, 1.4]$	0.029	0.265	0.294
34	Total	0.735	0.265	1
		GDP 2003		
# Countries	GDP 1996	$[0.6, 1)$	$[1, 1.4]$	Total
25	$[0.6, 1)$	0.735	0	0.735
9	$[1, 1.4]$	0.029	0.235	0.265
34	Total	0.765	0.235	1
		GDP 2008		
# Countries	GDP 2003	$[0.6, 1)$	$[1, 1.4]$	Total
26	$[0.6, 1)$	0.676	0.029	0,764
8	$[1, 1.4]$	0	0.235	0.235
34	Total	0.676	0.264	1

Table 2: Two groups transition patterns

Countries	1976	1985	1996	2003	2008
Burundi	1	1	1	1	1
Benin	1	1	1	1	1
Burkina Faso	1	1	1	1	1
Botswana	1	12	2	2	2
Central A Republic	1	1	1	1	1
Ivory Coast	2	1	1	1	1
Cameroon	1	12	21	1	1
Congo	21	2	2	21	2
Algeria	2	2	2	2	2
Egypt	1	12	2	2	2
Gabon	2	2	2	2	2
Ghana	1	1	1	1	1
Gambie, The	1	1	1	1	1
Kenya	1	1	1	1	1
Liberia	21	1	1	1	1
Lesotho	1	1	1	1	1
Morroco	2	2	2	2	2
Madagascar	1	1	1	1	1
Mauritania	1	1	1	1	1
Malawi	1	1	1	1	1
Niger	1	1	1	1	1
Nigeria	1	1	1	1	1
Rwanda	1	1	1	1	1
Soudan	1	1	1	1	1
Senegal	1	1	1	1	1
Sierra Leone	1	1	1	1	1
Seychelles	2	2	2	2	2
Chad	1	1	1	1	1
Togo	1	1	1	1	1
Tunisia	2	2	2	2	2
South Africa	2	2	2	2	2
Zanzibar	1	1	1	1	1
Zambia	1	1	1	1	1
Zimbabwe	1	1	1	1	1

Table 3: Determinants of bipolarization: OLS estimation

Variable	Coef.	Std. Err.
AP_t	0.034***	0.009
AP_{t-1}	0.043***	0.010
MP_t	-0.0007***	0.0002
MP_{t-1}	-0.0004**	0.0002
IP_t	0.0006	0.002
IP_{t-1}	0.006***	0.002
SP_t	0.002	0.005
SP_{t-1}	-0.005	0.002
# Obs.	32	
$\bar{R}^2$	0.998	

Significance levels: * : 10% , ** : 5% , *** : 1%

Table 4: Distribution of the patents and trademarks in the African regions (percentage)

Regions	Patents non residents	Patents residents	Trademarks non residents	Trademarks residents
North Africa	22.776	13.067	18.040	16.846
Sub-Saharan Africa excluding South Africa	6.088	1.383	28.675	8.517
South Africa	71.135	85.548	53.283	74.637
Total	100	1000	100	100

Table 5: VAR estimation results: Determinants of innovation in Africa

Equation & Variable	Coef.	Std. Err.
Trademarks Residents		
L1.Trademarks Residents	-0.349	0.327
L2.Trademarks Residents	0.005	0.255
L1.Trademarks non-Residents	0.587***	0.188
L2.Trademarks non-Residents	0.342	0.214
L1.Patents Residents	-0.125	0.153
L2.Patens Residents	-0.233	0.147
L1.Patents non-Residents	0.009	0.259
L2.Patents non-Residents	0.102	0.252
GDP per capita	-1.175	2.767
Openness	-0.039	0.205
Remittances	-0.094	0.501
Revenue	-0.440	0.614
Intercept	0.477	0.508
Trademarks non-Residents		
L1.Trademarks Residents	-0.040	0.632
L2.Trademarks Residents	-0.295	0.494
L1.Trademarks non-Residents	0.075	0.362

Continued on next page...

Equation &	Coef.	Std. Err.
L2.Trademarks non-Residents	0.188	0.414
L1.Patents Residents	0.001	0.295
L2.Patens Residents	0.006	0.285
L1.Patents non-Residents	0.007	0.500
L2.Patents non-Residents	0.007	0.486
GDP per capita	2.664	5.347
Openness	-0.275	0.396
Remittances	-0.679	0.969
Revenue	0.207	1.187
Intercept	-0.272	0.982
Patents Residents		
L1.Trademarks Residents	0.625	0.511
L2.Trademarks Residents	0.002	0.399
L1.Trademarks non-Residents	-0.107	0.293
L2.Trademarks non-Residents	-0.490	0.335
L1.Patents Residents	-0.081	0.238
L2.Patens Residents	0.512**	0.230
L1.Patents non-Residents	1.039***	0.404
L2.Patents non-Residents	-0.837**	0.393
GDP per capita	-5.750	4.322
Openness	0.190	0.320
Remittances	0.996	0.783
Revenue	1.193	0.960
Intercept	0.953	0.794
Patents non-Residents		
L1.Trademarks Residents	-0.093	0.236
L2.Trademarks Residents	-0.058	0.184
L1.Trademarks non-Residents	0.148	0.135
L2.Trademarks non-Residents	0.001	0.154
L1.Patents Residents	-0.252**	0.110
L2.Patens Residents	0.069	0.106
L1.Patents non-Residents	0.605***	0.186
L2.Patents non-Residents	-0.182	0.181
GDP per capita	-2.950	1.992
Openness	0.456***	0.148
Remittances	2.107***	0.361
Revenue	0.501	0.442
Intercept	0.195	0.366
Sample		1982-2008
Log likelihood		356.128
AIC		-22.528
HQIC		-21.785
SBIC		-20.032
Specification test	χ_2	$p > \chi_2$
Trademarks Residents	23.700	0.022
Trademarks non-Residents	2.734	0.997
Patents Residents	21.576	0.042
Patents non-Residents	85.452	0.000

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Table 6: Impulse response: Cumulative dynamic-multiplier function

	Trademarks Res.			Trademarks non-Res.			Patents Res.			Patents non-Res.		
Step	CDM[(a)]	Lower[(b)]	Upper[(b)]	CDM[(a)]	Lower[(b)]	Upper[(b)]	CDM[(a)]	Lower[(b)]	Upper[(b)]	CDM[(a)]	Lower[(b)]	Upper[(b)]
GDP												
0	-1.175	-6.598	4.247	2.664	-7.815	13.144	-5.749	-14.221	2.721	-2.949	-6.854	0.955
1	1.491	-7.594	10.576	2.884	-8.968	14.738	-9.368	-20.377	1.640	-2.780	-9.297	3.736
2	3.088	-8.178	14.355	3.585	-8.882	16.053	-9.042	-20.197	2.113	-1.769	-8.334	4.795
3	3.858	-7.261	14.979	2.815	-8.433	14.064	-9.193	-20.410	2.022	-1.718	-8.178	4.741
4	3.431	-7.465	14.329	2.396	-8.605	13.397	-9.585	-21.504	2.334	-2.087	-8.585	4.409
5	3.161	-7.523	13.846	2.006	-9.441	13.454	-9.900	-22.684	2.882	-2.300	-9.239	4.638
6	2.972	-8.072	14.017	2.028	-9.545	13.602	-9.909	-23.139	3.319	-2.317	-9.484	4.850
7	2.969	-8.099	14.037	2.040	-9.629	13.710	-9.840	-23.164	3.483	-2.272	-9.476	4.932
8	2.976	-8.127	14.079	2.101	-9.399	13.603	-9.803	-23.126	3.518	-2.246	-9.398	4.904
9	2.997	-7.957	13.953	2.110	-9.345	13.566	-9.791	-23.119	3.537	-2.235	-9.358	4.887
10	3.008	-7.903	13.921	2.120	-9.271	13.511	-9.800	-23.141	3.540	-2.235	-9.348	4.878
11	3.012	-7.849	13.875	2.115	-9.304	13.536	-9.800	-23.148	3.548	-2.234	-9.349	4.879
12	3.014	-7.862	13.891	2.113	-9.315	13.542	-9.806	-23.156	3.544	-2.236	-9.351	4.877
Openness												
0	-0.039	-0.441	0.362	-0.275	-1.051	0.500	0.189	-0.437	0.817	0.455	0.166	0.744
1	-0.206	-0.836	0.423	-0.290	-1.079	0.498	0.652	-0.099	1.404	0.646	0.197	1.095
2	-0.305	-1.112	0.500	-0.319	-1.278	0.640	0.561	-0.279	1.401	0.590	0.113	1.068
3	-0.371	-1.229	0.486	-0.267	-1.191	0.655	0.536	-0.367	1.440	0.592	0.070	1.113
4	-0.309	-1.194	0.574	-0.238	-1.140	0.663	0.506	-0.434	1.447	0.622	0.099	1.145
5	-0.286	-1.136	0.562	-0.209	-1.086	0.668	0.536	-0.432	1.506	0.648	0.115	1.182
6	-0.260	-1.116	0.594	-0.220	-1.102	0.661	0.518	-0.493	1.530	0.648	0.104	1.191
7	-0.268	-1.112	0.575	-0.223	-1.115	0.668	0.515	-0.514	1.546	0.644	0.088	1.200
8	-0.266	-1.124	0.591	-0.233	-1.128	0.662	0.503	-0.534	1.542	0.640	0.083	1.197
9	-0.272	-1.123	0.578	-0.232	-1.127	0.663	0.506	-0.532	1.544	0.640	0.083	1.196
10	-0.271	-1.125	0.583	-0.234	-1.127	0.658	0.504	-0.535	1.544	0.639	0.085	1.194

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Table 6 – continued

	Trademarks Res.			Trademarks non-Res.			Patents Res.			Patents non-Res.		
Step	CDM[(a)]	Lower[(b)]	Upper[(b)]	CDM[(a)]	Lower[(b)]	Upper[(b)]	CDM[(a)]	Lower[(b)]	Upper[(b)]	CDM[(a)]	Lower[(b)]	Upper[(b)]
11	-0.273	-1.121	0.575	-0.232	-1.125	0.659	0.506	-0.534	1.546	0.640	0.085	1.195
12	-0.272	-1.122	0.578	-0.233	-1.125	0.658	0.505	-0.536	1.546	0.640	0.085	1.195
Remittances												
0	-0.093	-1.076	0.889	-0.678	-2.577	1.220	0.995	-0.539	2.530	2.106	1.399	2.814
1	-0.564	-2.259	1.131	-0.709	-3.102	1.683	3.117	0.951	5.282	3.039	1.831	4.247
2	-0.925	-3.502	1.652	-0.764	-4.234	2.705	2.702	-0.315	5.720	2.798	1.126	4.470
3	-1.193	-4.382	1.995	-0.604	-4.294	3.085	2.586	-0.860	6.032	2.786	0.781	4.791
4	-0.939	-4.427	2.548	-0.489	-4.173	3.194	2.414	-1.211	6.040	2.893	0.833	4.952
5	-0.859	-4.357	2.638	-0.382	-4.035	3.270	2.556	-1.306	6.419	3.004	0.873	5.135
6	-0.749	-4.255	2.756	-0.430	-4.030	3.170	2.466	-1.583	6.517	2.998	0.798	5.198
7	-0.789	-4.241	2.662	-0.440	-4.031	3.151	2.468	-1.663	6.600	2.985	0.747	5.223
8	-0.777	-4.210	2.656	-0.481	-4.022	3.059	2.413	-1.720	6.547	2.967	0.741	5.194
9	-0.804	-4.190	2.582	-0.475	-4.013	3.062	2.428	-1.704	6.560	2.968	0.757	5.179
10	-0.796	-4.170	2.577	-0.485	-4.009	3.038	2.416	-1.714	6.548	2.967	0.764	5.170
11	-0.805	-4.168	2.558	-0.477	-4.018	3.063	2.426	-1.710	6.563	2.969	0.766	5.173
12	-0.799	-4.169	2.570	-0.480	-4.023	3.061	2.422	-1.714	6.559	2.969	0.765	5.174
Revenue												
0	-0.440	-1.644	0.764	0.207	-2.120	2.534	1.192	-0.688	3.074	0.501	-0.365	1.368
1	-0.309	-2.373	1.754	0.245	-2.468	2.959	1.320	-1.184	3.824	0.575	-0.909	2.060
2	-0.505	-3.251	2.240	0.422	-2.805	3.651	1.553	-1.285	4.391	0.598	-1.029	2.226
3	-0.370	-3.256	2.515	0.414	-2.595	3.424	1.401	-1.573	4.376	0.585	-1.126	2.297
4	-0.395	-3.331	2.540	0.500	-2.496	3.497	1.498	-1.685	4.682	0.625	-1.108	2.360
5	-0.316	-3.114	2.482	0.466	-2.385	3.318	1.445	-1.814	4.704	0.624	-1.162	2.412
6	-0.346	-3.137	2.443	0.485	-2.370	3.340	1.475	-1.855	4.806	0.626	-1.161	2.413
7	-0.327	-3.034	2.379	0.457	-2.364	3.278	1.443	-1.873	4.761	0.616	-1.170	2.404
8	-0.347	-3.071	2.377	0.467	-2.369	3.303	1.456	-1.872	4.785	0.616	-1.155	2.389
9	-0.339	-3.030	2.351	0.457	-2.379	3.295	1.447	-1.871	4.766	0.615	-1.157	2.387
10	-0.346	-3.061	2.368	0.464	-2.383	3.312	1.454	-1.872	4.781	0.616	-1.152	2.385

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Table 6 – continued

Step	Trademarks Res.			Trademarks non-Res.			Patents Res.			Patents non-Res.		
	CDM[a]	Lower[b]	Upper[b]	CDM[a]	Lower[b]	Upper[b]	CDM[a]	Lower[b]	Upper[b]	CDM[a]	Lower[b]	Upper[b]
11	-0.342	-3.045	2.360	0.460	-2.391	3.312	1.451	-1.871	4.773	0.616	-1.155	2.388
12	-0.344	-3.062	2.374	0.463	-2.389	3.317	1.453	-1.872	4.779	0.616	-1.154	2.388

Note [a]: Cumulative Dynamic-Multiplier (CDM). [b]: 95% lower and upper bounds.

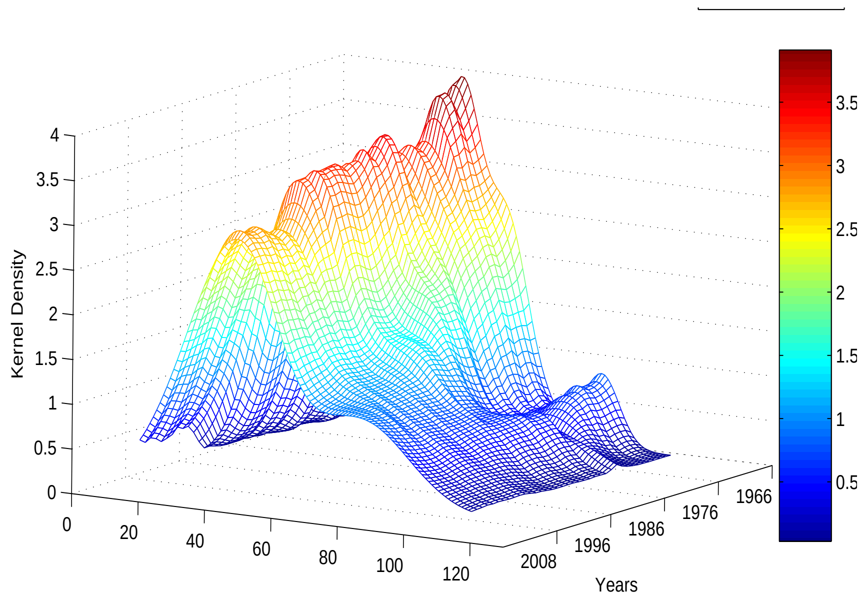

Figure 1: Distribution of GDP per capita

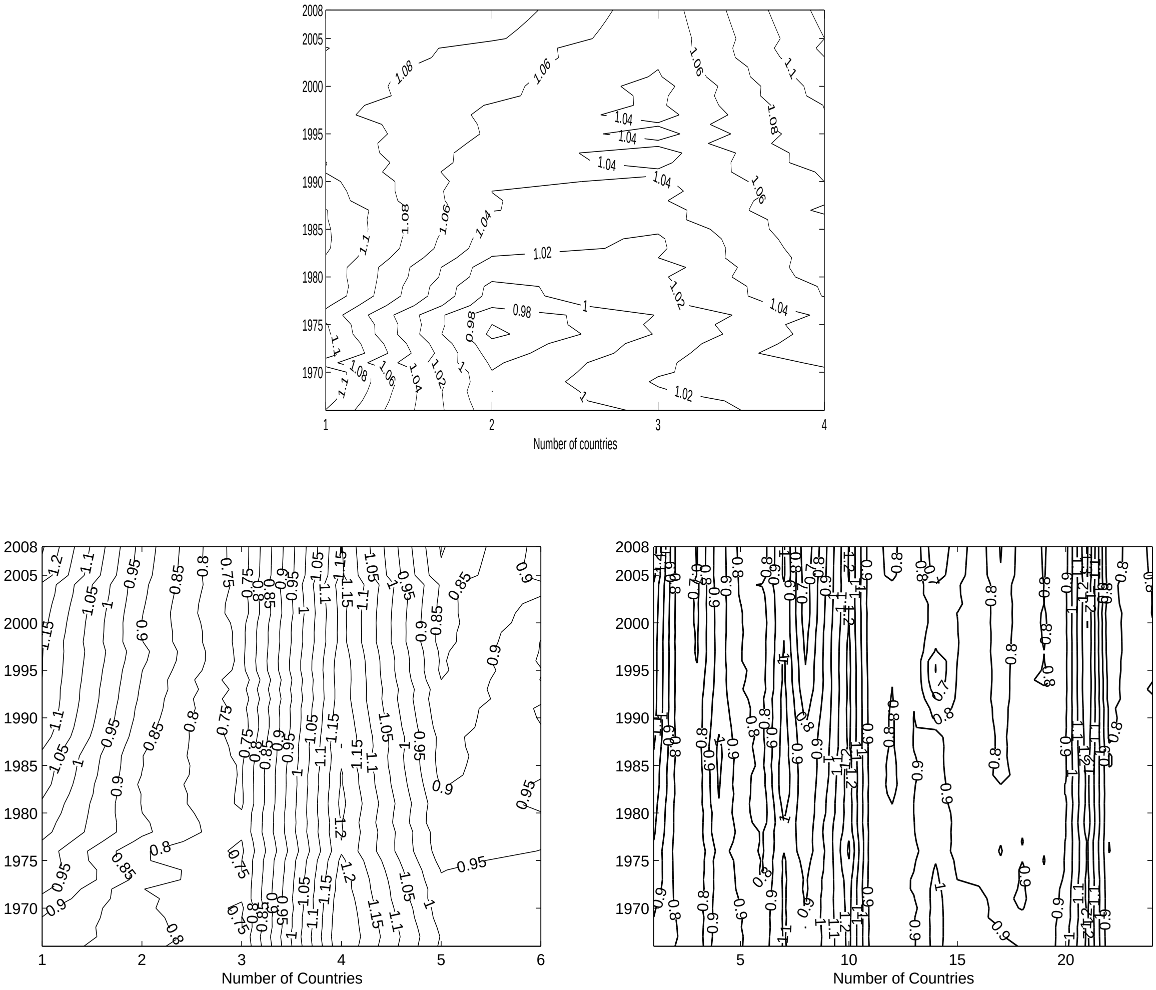

Figure 2: Contour of distribution of GDP per capita [Top (a)]: Maghreb countries. [Bottom-left (b)]: South African countries. [Bottom-right]: Sub-Saharan countries

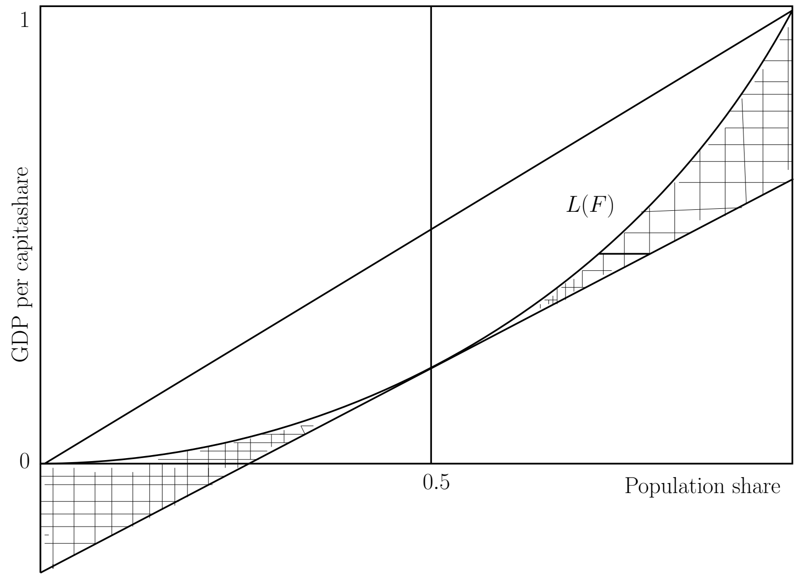

Figure 3: The bipolarization index

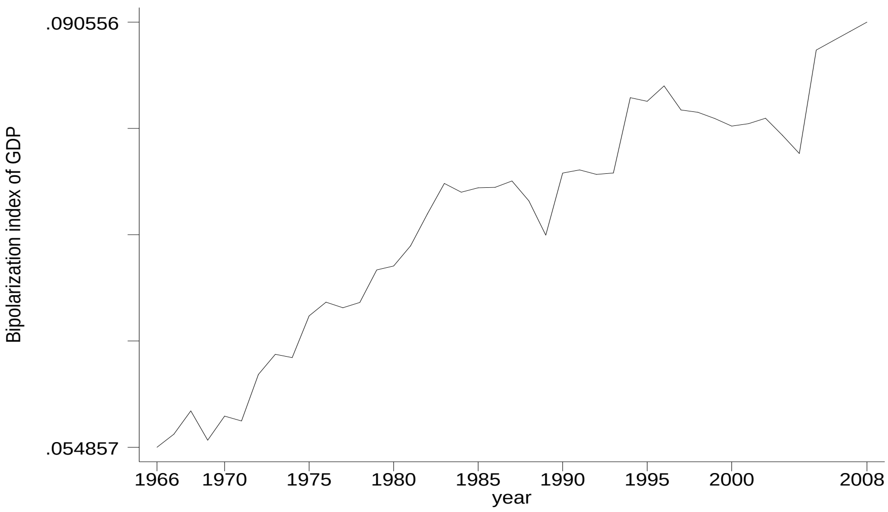

Figure 4: Evolution of the Wolfson bipolarization index of GDP

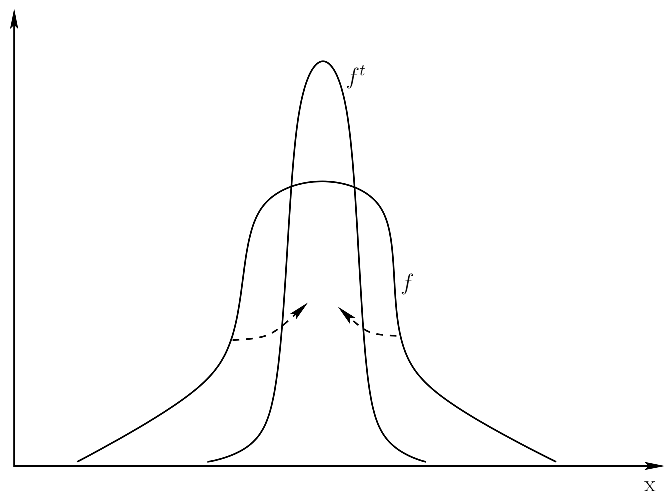

Figure 5: A single squeeze of a density function and the reduction of polarization

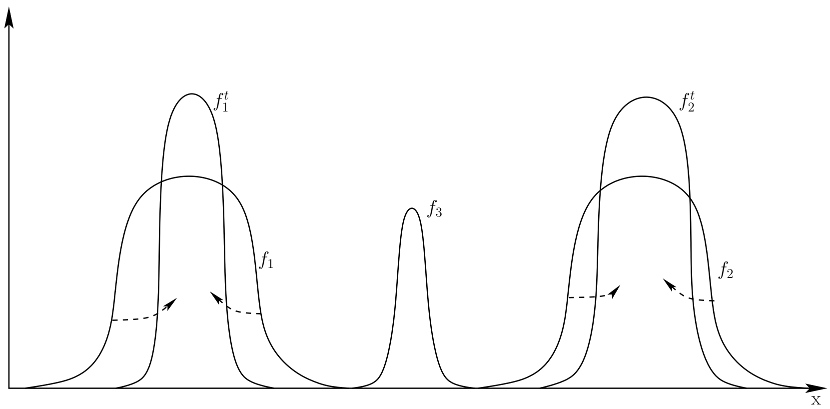

Figure 6: A symmetric slide of the density functions and the rise of polarization

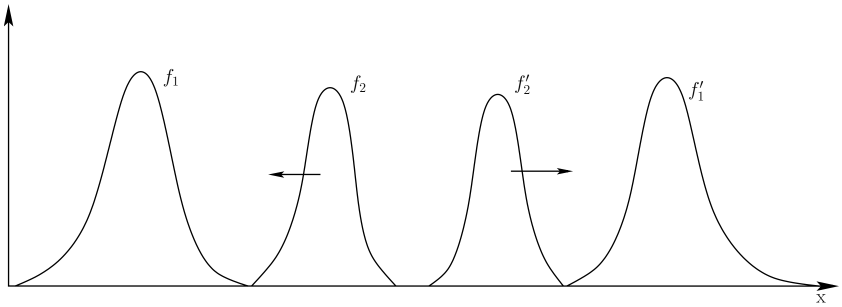

Figure 7: A double squeeze and the increase of polarization

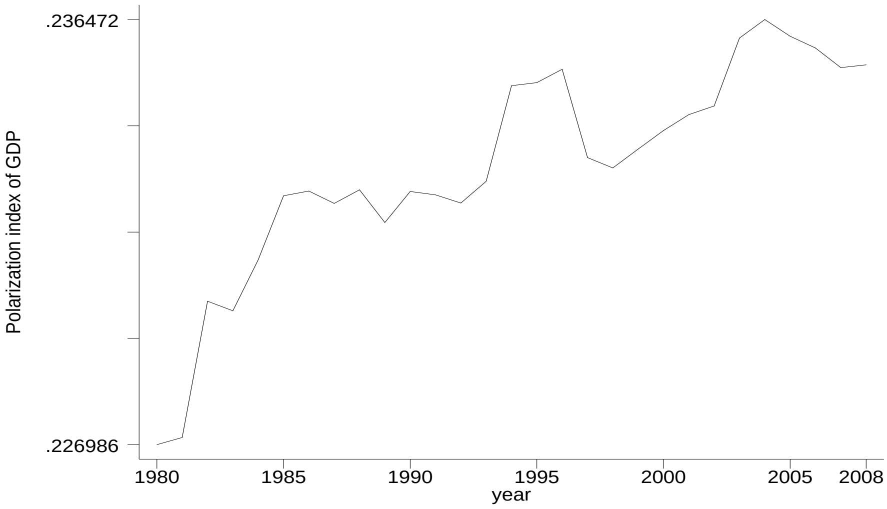

Figure 8: Evolution of GDP per capita polarization index

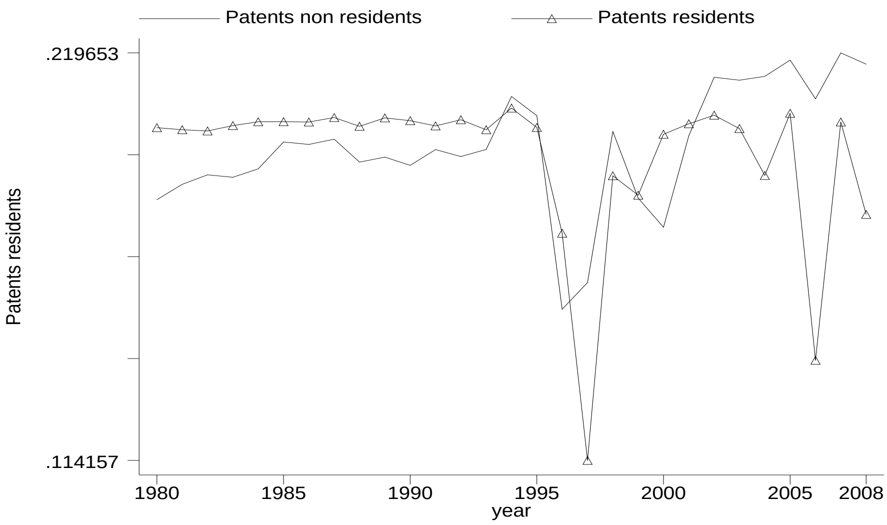

Figure 9: Evolution of GDP per capita and patents index

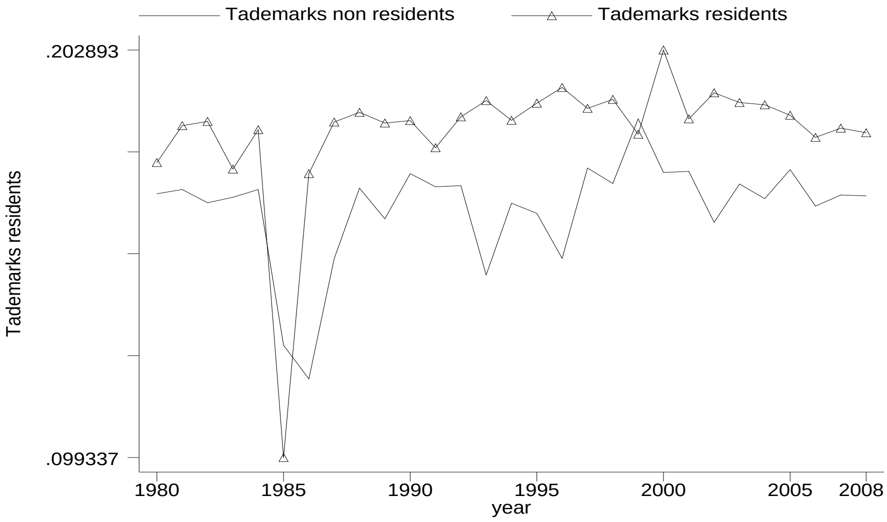

Figure 10: Evolution of GDP per capita and trademarks index

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