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Théophile T. Azomahou, Mbaye Diene

Consortium pour la Recherche Economique et Sociale
Rue 10 Prolongée Cité Iba Ndiaye Djadji
Lot 1 et 2 - Pyrotechnique - Dakar, Sénégal
CP : 12023 - BP : 7988, Dakar Médina
Tél : (221) 33 864 77 57 - (221) 33 864 73 98 - Fax : (221) 33 864 77 58
Email : cres_ucad@yahoo.fr / cres@cres-sn.org
Information : contact@cres-sn.org / Site Web : www.cres-sn.org

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Income polarization and innovation in African economies

Théophile T. Azomahou[(a)]* and 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 polarization of economic development in African economies. Based on nonparametric and bipolarization frameworks, we find that countries tend to cluster in two classes, and that bipolarization has been accelerating over the period 1966-2008. We relate the evolution of income bipolarization to specialization in a country. The main sectors that tend to reduce income bipolarization are mining and services. We also study the effects of innovation on income polarization. In particular, we analyze short-run and long-run effects of innovation and their inter-relationship with income polarization. We show that the impact of innovation differs depending on its origin and its type. If innovation is resident, then trademarks outweigh patents. On the contrary, if the origin of innovation is non resident, then patents have a greater effect. Moreover, there is an adjustment process between trademarks residents and patents residents. In the short-run, when trademarks residents are too high, they quickly fall back toward patents residents level. We do not observe such adjustments between trademarks non residents and patents non residents. Last, unexpected shocks that affect patents (res. trademarks) have a permanent (res. transitory) effects on income polarization.

JEL Classification: Income polarization, patents, trademarks
Keywords: C32, O15, O34, O47

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-Martín (1991,1992) are used for the analysis of the disparities of per capita GDP in the literature. However, Quah (1993,1997)

*Corresponding author: Azomahou T.T., Tel. +31 433 884 440, Fax +31 433 884 499 (azomahou@merit.unu.edu), M. Diene (mdiene@cres-sn.org).

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 time, leaving behind the intra-group mobility.

The convergence of income between countries has been widely studied by 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) used annual logarithm of real output per capita for 15 OECD countries and tested the existence of convergence and common trends from 1900 to 1987. The authors showed evidence of convergence for a group of countries that have identical either stochastic or deterministic long-run trends, while common trends allow for proportionality of the stochastic elements. They also found that there is no convergence for the countries while evidence for common trends exists. Bernard and Durlauf (1996), Quah (1996b) and Anderson (2004) pointed 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, 1996b, Baumol, 1986, Galor, 1996, Durlauf and Jonhson, 1995). The objective of this paper is to analyze the polarization of African economies while studying the role of innovations in that respect. To the best of our knowledge, developing economies, in particular very poor countries like those in Africa have not yet been considered. However, these economies are severely affected by inequality issues, as we shall see below, polarization and inequality are very closely related concepts. Furthermore, as outlined by Fagerberg and Godinho (2005), innovation can play a crucial role in catching-up.

The analysis of polarization has economic and policy interest. Indeed, understanding the economic reasons of a polarized system can facilitate the choice of the measures that policy makers can implement to reduce inequalities. Several studies have dealt with the issue of polarization: Esteban and Ray (1994), Wolfson (1994), Wang and Tsui (2000), Zhang and Kanbur (2001) and Chakravarty and Majumder (2001). Moreover, the determinants of polarization have been studied: Gradin (2000) examined the sources of polarization of income in Spain, D'Ambrosio (2001) for Italy and Zhang and Kanbur (2001) for China. Duclos et al. (2004) have in turn provided a measure of income polarization for 21 countries using data from the Luxembourg Income Study. Similarly, Seshanna and Decornez (2003) studied income distribution between countries. Ravallion and Chen (1997) evaluated the polarization of a group of 67 countries using the index of Wolfson (1994). Quah (1996b, 1997) found emerging twin peaks or polarization in income distribution in cross-section of countries meaning that, starting from period t, two peaks or modes emerge in income distribution on the horizon $t + \tau$. Johnson (2000) does not find evidence of polarization in the cross-state income distribution for USA. This result suggests that there is a convergence between the US states over the period (1948-1989) of study. Relying on Quah (1996a, 1997), Azomahou et al. (2005) used two datasets on European regions to study the dynamics of income distribution. The data contain series on real GDP per capita in 1950 and 1990 for 90 regions. The second covered 445 regions observed in 1990 and 1996. The authors found evidence of polarization: Regions whose incomes were closely related at an initial period transit subsequently to widely different income levels.

Various measures of polarization have been 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.[1] From a methodological perspective, the use of income variables to measure the polarization ends up with making discrete elements

[1] Alienation is the feeling of difference and exclusion among individuals whose living standards are not identical.

of a continuum, meaning that one considers a finite and discrete groups. Generally, there is a loss of information on the distribution with the transition from a continuous to discrete set of the variable of interest. Indeed, the classification of income is arbitrary and also is the choice of the size of income groups (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 closely related concepts though they emphasize different aspects of a distribution. For example in a population decomposed into two groups of different incomes, a reduction of inequality in only one group may create 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 when inequality decreases within groups or increases between groups. Esteban and Ray (1994) proposed a measure of polarization based on the identification and alienation by introducing a set of axioms. The authors considered that polarization is fundamentally linked to the ability of a society to undertake and promote collective decision-making. The authors developed a model of conflict where the level of polarization is related to an equilibrium level of conflict.[2] 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 shall present the axioms that guide the construction of the index of Duclos et al. (2004) that we use in this work.

Our paper examines the degree of economic polarization in African economies and the role of innovations in that respect. 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 differences in terms of development across the continent. This necessity may be seriously threatened if the African Union and other regional integration institutions were to split into series of well-differentiated economic clusters. The contribution of this paper is of twofold. Firstly, we show that a bipolarization process of the economies emerges. To this end, we primarily estimate non-parametrically the distribution of GDP per capita for 34 African countries, aiming to identify multimodality of the distributions over the period 1966-2008. The precise measure of observed changes in the degree of income distribution over time is then obtained with the Wolfson (1994)'s bipolarization index. The results reveal that bipolarization of economic development has been accelerating during the first two decades and is still growing. We relate the evolution of the bipolarization index to counties' specialization. We find that four sectors are the main driving force of this evolution, namely, agriculture, mining, industries and services.

Secondly, we study the effects of innovation on income polarization consistently with previous studies that have investigated the effect of innovation on development or economic growth. Furthermore, we examine the type of innovation (patents vs. trademarks) alongside highlighting the effect of the origin of innovation (residents vs. non-residents). Type and origin of innovations are both relevant for African economies for which diaspora and openness are key factors. We then provide two series of estimations: i) effects of innovations on income polarization and ii) short-run and long-run effects of innovations and their inter-relationship with income polarization. In a first approach, we perform a simple OLS regression of GDP polarization on patents and registered trademarks. We also include the linear and square terms of each control to account for possible nonlinearities. We show that the impact of innovation differs depending on its origin and its type. If innovation is resident, then trademarks outweigh patents. However, if the origin of innovation is non resident, then patents have a greater effect.

[2]Polarization can also be applied to politics. Indeed, Schultz (1996) used a model of public goods and showed that the polarization of the preferences of political parties led to an inefficient equilibrium.

To go beyond this first approach, it is desirable not only to understand the role of innovation in the polarization process of African economies, but also to study in a joint framework the determinants of innovation. This can be done by specifying a system of three equations: an income equation whose determinants are among others the innovations as in the first approach, and two equations of innovation for patents and registered trademarks. The implementation of such a framework requires an understanding of the economic mechanism that may lead to differentiated determinants of the two types of innovations. For example, what could explain the production of patents and would not explain the production of registered trademarks. Unfortunately, the data needed to perform such analysis are not yet available. To overcome this difficulty, a simple and tractable approach is to consider a Vector Autoregressive (VAR) or a Vector Error Correction (VEC) framework (in the case of non-stationary time series) without controls. This specification enables to study the relationship between income polarization and innovations alongside accounting for their mutual influences, and short-run and long-run effects of innovations on income polarization as well. Indeed, the short-run effects are given by the VEC adjustment parameters and the long-run effects are reflected by the impulse-response functions. The latter allow to check whether unexpected shocks that affect residents or non-residents trademarks or patents will have transitory or permanent effects on income polarization. We find that there is an adjustment process between trademarks residents and patents residents. In the short-run, when trademarks residents are too high, they quickly fall back toward patents residents level. We do not observe such adjustments between trademarks non residents and patents non residents. Last, unexpected shocks that affect patents will have a permanent effect on income polarization while unexpected shocks that affect trademarks will have only a transitory effect on income polarization.

The paper is organized as follows. Section 2 presents the nonparametric analysis of income distribution. In Section 3, we measure the degree of bipolarization of the countries and examine the transitions of the economies over the period. In Section 4, we analyze the polarization of income. Section 5 offers a VEC analysis to quantify the role of innovation in the polarization of income. Section 6 concludes the study.

2 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). 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 appear 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 (1996b,1997).

Insert Figure 1

As we can see, the African countries have evolved towards a twin-peak situation shown by Quah (1996b) 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

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

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 Bipolarization

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 The concept

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.

Insert Figure 3

The larger the shaded area, the fewer the countries with median 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, $L(0.5)$. 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. 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

3.2 Bipolarization of GDP: explanatory elements

In the previous section, the African regions are divided into two groups according to their GDP per capita. Nevertheless, there are some national characteristics that may explain bipolarization. In order to capture those characteristics, we estimate the bipolarization index of the value added of four sectors: agriculture, mining, industries and services. 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 estimation:

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

where F is a function, t stands for the time, GI_t is the bipolarization index of GDP per capita at time t, AP_t is the bipolarization index in agriculture, MP_t is the bipolarization index in mining sector, IP_t is the bipolarization index for industries and SP_t is the index for services. OLS estimates are reported in Table 3

Insert Table 3

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

4 Polarization

4.1 The framework: Axioms

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 (say 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.

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:

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

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:

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

4.2 Polarization of GDP

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. Recall 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 others. In what follows, we go a step further and study the relation of this polarization to innovation for African economies.

Insert Figure 8

4.3 The relationship between bipolarization and polarization

So far, we have used the two concepts (bipolarization and polarization) and evaluated them empirically because they are different and they capture different aspects of a distribution. Bipolarization restricts its scope to the presence of two poles and polarization can concern more than two poles. We now show their conceptual similarities and differences. Wolfson (1994), Wang and Tsui (2000) and Duclos et al. (2004) have respectively provided two sets of axioms for bipolarization and polarization. The spirit of the axioms is quite identical but differences appear in their implications. Thus, all the axioms of the polarization index (A-1 to A-4) presented in section 4.1 are satisfied by the Wolfson index. Nevertheless the latter also satisfies axioms (B-1 to B-3) that are more restrictive than A-1 to A-4. It is well known that polarization raises when 'within-group' inequality is reduced, and this led Foster and Wolfson (1992) and Wang and Tsui (2000) to state the bipolarity axioms:

B-1 If distributions F and G have the same mean and the same median m and if F is second order stochastically dominates[3] G separately on $[0, m]$ and on $[m, \infty)$. Then F is more polarized than G.

The increased spread axiom satisfied by the bipolarization index meaning that if in a distribution the variables are shifted farther away from the median of the distribution, then polarization increases. It reads as:

B-2 Consider two distributions with the same mean and median m such that $|m - F^1(p)| = |m - G^{-1}(p)|$ for every $p \in [0, 1]$, then G is more polarized than F.

Let us notice that a bipolarization measure that satisfies B-2 must also satisfy A-1 and A-3. Nevertheless the latter doesn't satisfies B-1 and B-2. Another axiom satisfied by the bipolarization indices is the scale invariance axiom:

[3]Consider two distributions of incomes, F_A and F_B, with support contained in the nonnegative real line. Let $D_A^1 = F_A(x)$ and $D_A^s(x) = \int_0^x D_A^{(s-1)}(t)\,\mathrm{d}t$ for any integer $s = 2$. D_B^s is analogously defined. The distribution B dominates stochastically distribution A at order s if $D_A^s \geq D_B^s$.

B-3 Let the distributions F and G have the same median m. Then if $G(x)$ is more polarized than $F(x)$, so is $G(\frac{x}{m})$ relative to $F(\frac{x}{m})$.

B-4 Let F be a distribution with a continuous density f. Then, the bipolarization measure should be of the form:

$$P(F) = \frac{1}{m} \int a(F(x)) x f(x)\, \mathrm{d}x \tag{14}$$

where $a = |x - y|$. As we see, the expression is like the one of the polarization index (Eq. 5). This leads to the statement that the bipolarization can be considered as a particular form of the polarization index, if some very precise axioms are satisfied, as shown above.

5 Income polarization and innovation

Why developing economies should care about innovation? How can innovation affect inequalities? How can developing economies seize the opportunities offered by globalization to harness innovation? In this section, we study the role of innovation in shaping income polarization in African economies.

The role of innovation in development was studied in both the theoretical and the empirical literature of economic growth. Verspagen (2005) discussed the different frameworks (evolutionary vs. new growth theory) that have been adopted by economists to analyze the relationship between innovation and economic growth.[4] 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 are not concerned with 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.[5]

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 recently arouse enthusiasm. It is well known that the patenting process is particularly compelling, long and heavy depending on countries' legal procedure. Therefore, it is very difficult for poor countries to access easily such procedures. Instead, trademarks have a much simpler protocol and are more accessible. Accordingly, trademarks-based indicators are more likely to report on innovation activities in these countries. Therefore, it is interesting to relate these two modes of innovation in order to study their respective contributions to outcome. In a first step, we present the key properties of patent and trademark-based indicators. Then we give a brief description for the data and provide estimates of the contribution of both indicators to the polarization of African economies.

5.1 Key properties of patent and trademark-based indicators

Patents 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

[4] See also Fagerberg et al. (2010) for an interesting review of the role of innovation in development.

[5] The data on R&D expenditure in African economies are poorly documented. Much of the R&D activities undertaken in these countries are due to foreign-owned companies. Moreover public R&D expenditures are almost non existent.

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. A non-resident patent application is from an applicant who is outside the country. As a result, resident filings can underestimate 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 pharmaceutical (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 and mining).

A. An increase in worldwide patents applications

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. According to the World Intellectual Property Organization (WIPO 2011), between 1995 and 2008, patent applications grew by 4.9% a year while they were of 3.7% growth in 1983-1990. The issue of the measurement of innovation activities is nicely discussed by Smith (2005). The author relates major indicators such as R&D and patents to new innovation indicators: sources, instruments and methods of innovation. Guellec and van Pottelsberghe de la Potterie (2007) examined the economic effects of patenting on innovation and the diffusion of technology and growth, with a particular emphasis on the the European patent system.

B. Relevance of trademarks for innovation and development

Trademarks statistics have been used as relevant economic indicators in various studies, mostly for developed economies. Fink et al. (2003) used trademarks to study trade specialization. Greenhalgh et al. (2001) found that smaller firms in the UK were more active in seeking intellectual property protection via trademarks. Schmoch (2003) used German survey trademark data and highlight sectoral differences in the use of trademarks and patents. Baroncelli et al (2004) showed that trademarks can serve as hidden measures of protectionism. Mendonça et al. (2004) used the European Community Innovation Survey (CIS 3) and showed that innovative firms use trademarks more than less innovative ones. The authors documented that trademarks are used more than patents among the innovative firms. The study concluded that trademarks can contribute in capturing relevant aspects of innovation and the process of industrial change. Mendonça et al. (2004) finding is likely to support our view regarding the role of trademarks in developing economies.

Trademarks are also applications filed for registration with a national or regional trademark office. Trademarks are distinctive signs that identify goods or services as those pro-

duced 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

In North Africa, the highest numbers of non residents patents are found in Egypt Arab Republic (19,032), Algeria (6,841) and Morocco (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 Morocco (1,502). In the entire continent, residents trademarks are very important, mainly in Morocco (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. 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 dominated by non residents and the sharp drop occurs in 1985.

Insert Figures 9, 10

5.3 Estimations

Several studies have investigated the innovation-development relation for developing countries. Chen and Puttitanun (2005) studied the relationship between Intellectual Property Rights (IPRs) and economic development using a panel data for developing countries. Their IPRs measure, the so-called Ginarte and Park index (GP index), is 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, square of 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, we wanted to study the effects of innovation on income polarization in African economies. As we have said previously, the debate on the appropriate innovation indicators for poor countries is very bright and their role in the development of these countries is a matter of heated discussion. We consider therefore the two competing indicators: patents and registered trademarks. The data are drawn from the World Bank Africa Database (2008). In what follows we provide two series of estimations: i) effects of innovations on income polarization and ii) short-run and long-run effects of innovations and interrelationship with income polarization.

A. Effects of innovations on income polarization

In a first approach, we perform a simple OLS regression of GDP polarization on patents and registered trademarks. We also include the linear and square terms of each controls to account for possible nonlinearities. We use Newey and West (1987) standard errors for coefficients estimated meaning that the error structure is assumed to be heteroskedastic and possibly autocorrelated up to some lag with unknown form. Here we specified lag 3. Estimation results are reported in Table 5.

Insert Table 5

The F statistic indicates that the adjustment is globally highly significant. Apart from the patents residents control which displays a weak significant inverted U-shape relation with income polarization, all other controls show a significant U-shape relation. This means that a positive impact of trademarks and patents can be observed only starting from a certain threshold. We also observe that while the effects of trademarks controls are statistically more significant than those of patents, the latter are more sizable in terms of coefficient estimates for non residents. Clearly, the effect of patents on income polarization is much more important for non residents. For residents, patents do not impact income polarization whereas trademarks do. This is a rather nice result. Indeed, we show that the impact of innovation differs depending on its origin and its type. If innovation is resident, then trademarks outweigh patents. By cons, if the origin of innovation is non resident, then patents have a greater effect. However, this interpretation must be taken with caution as it is unclear in the data whether non residential patents are from developed countries, even if it is likely.

B. Short-run and long-run effects of innovations and their inter-relationship with income polarization

To go further in this empirical study, it is desirable not only to understand the role of innovations in the polarization process of African economies, but also to study in a joint framework the determinants of innovation. This can be done by specifying a system of three equations: an income equation whose determinants are among others the innovations as in the previous results (see Table 5), and two equations of innovations for patents and registered trademarks. The implementation of such a framework requires an understanding of the economic mechanism that may lead to differentiated determinants of both innovations. For example, what could explain the production of patents and would not explain the production of registered trademarks. Unfortunately, the data needed to perform such analysis are not yet available.

A simpler tractable approach is to consider a Vector Autoregressive (VAR) model or preferably a Vector Error Correction (VEC) framework (in the case of non-stationary time series) with five components (income polarization, the four patents and registered trademarks indicators) without controls apart from an intercept. This approach allows to study not only the relationship between income polarization and innovations alongside accounting for the mutual influences between them, but also it enables to study short-run long-run effects of innovations on income polarization. The suspicion of a co-integration relationship leading to a VEC framework can be seen from Figures 9 and 10, where the evolution of the series are closely related.[6]

In this approach, there are four usual types of parameters of interest: i) the parameters of the co-integrating equations, ii) the adjustment coefficients, iii) the short-run and long-run coefficients and additionally, iv) the impulse response function. These outputs are provided in Tables 6, 7 and in Figure 12. The first step is to determine the number of co-integrating

[6]See Lütkepohl (2005) and Hamilton (1994) for estimation of VEC models.

relationships. Here, relying on the Johansen (1995) tests (trace statistics), we find two co-integration equations with exact identification of the parameters. The results of the co-integrating equations and the Johansen (1995) tests are reported in Table 6. we strongly reject the null hypothesis of no co-integration and fail to reject the null hypothesis of at most two co-integrating equations. Relying on the five series, we find that there are two co-integrating relationships. To get a better idea of how our model fits, we predict the co-integrating equations and graph them over time. Figure 11 displays these fits. Apart from mids-1980 and 1990 where it is clearly there is a significant brake, the predicted co-integrating fits have the right appearance looking like stationary series.

Insert Table 6

Insert Figure 11

Having determined that there are two co-integrating equations between series, we now wanted to estimate the parameters of a co-integrating VEC model. The results are reported in Table 7. This table contains the estimates of the adjustment coefficients along with short-run parameters for the four five blocks of estimates corresponding to the five series. The notations L. indicate the lag of the corresponding variables. As shown by the Chi-square specification test, equations for residents (both trademark and patents) are globally significant at the conventional levels whereas non residents equations are not.

Insert Table 7

From an economic perspective, the issue is whether innovations (according to the type: trademark v.s. patent, and origin: residents vs. non residents) and income polarization adjust when co-integrating equations are out of equilibrium. As can be seen from the first block of Table 7, the adjustment parameters are significant only for trademarks residents. When the predictions from the co-integrating equations are positive, trademarks residents and trademarks non residents are above their equilibrium value because the coefficients on trademarks residents and trademarks non residents respectively in the co-integrating equations 1 and 2 are positive (see Table 6). In Table 7, the estimate of the coefficient of the adjustment parameter for equation 1 is -1.166. Therefore, in the short-run, when trademarks residents are too high, they quickly fall back toward patents residents level. We do not observe this kind of adjustment between trademarks non residents and patents non residents as the subsequent adjustment coefficients in Table 7 are not significant.

Insert Figure 12

In order to assess the long-run effects of innovations on income polarization, we study the impulse-response functions. These quantities enable to highlight the effects of innovations shocks on income polarization over time. When the effect of shocks dies out over time, the shocks are said to be transitory. When the effect of shocks do not die out over time, the shocks are said to be permanent. The impulse-response functions are plotted in Figure 12. The graphs indicate that an orthogonalized shock to patents has a permanent effect on income polarization but that an orthogonalized shock to trademarks has a transitory effect. According to this model, unexpected shocks that affect patents (residents or non residents) will have a permanent effect on income polarization. However, we observe that this permanent effect is more pronounced for residential patents. Unexpected shocks that affect residents or non residents trademarks will have only a transitory effect on income polarization.

6 Conclusion

This paper examines the degree of polarization of GDP per capita in African countries. We begin primarily by a nonparametric analysis. We find that African countries tend to cluster into two classes. 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 bipolarization 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 of income. 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 income bipolarization is related to specialization of countries. The main sectors that tend to reduce income bipolarization are mining and services. Therefore development policies for services and mining sectors may be very useful in decreasing polarization in Africa.

Another contribution of this paper concerns the study of the effects of innovations on income polarization. We analyze short-run and long-run effects of innovations and their inter-relationship with income polarization. We show that the impact of innovation differs depending on its origin and its type. If innovation is residential, then trademarks outweigh patents. On the contrary, if the origin of innovation is non residential, then patents have a greater effect. Moreover, there is an adjustment process between trademarks residents and patents residents. In the short-run, when trademarks residents are too high, they quickly fall back toward patents residents level. We do not observe such adjustment between trademarks non residents and patents non residents. Last, unexpected shocks that affect patents will have a permanent effect on income polarization while unexpected shocks that affect trademarks will have only a transitory effect on income polarization.

Further analysis including data collection might be necessary to study jointly the differentiate determinants of innovations in African economies. A firm level analysis may deserve more attention.

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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
Gambia, The	1	1	1	1	1
Kenya	1	1	1	1	1
Liberia	21	1	1	1	1
Lesotho	1	1	1	1	1
Morocco	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
Sudan	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

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: Effects of innovations on income polarization

Variable	Coef.	Std. Err.[(a)]
Trademark residents	-0.722***	0.269
Trademark residents square	2.308***	0.863
Trademark non residents	-0.502***	0.161
Trademark non residents square	1.819***	0.581
Patents residents	0.128	0.095
Patents residents square	-0.481*	0.277
Patents non residents	-0.841***	0.323
Patents non residents square	2.463***	0.841
Intercept	0.382***	0.038
# Obs.	29	
F(8, 20)	29.76	
Prob > F	0.000	

Significance levels: *10% , **5% , ***1%
[(a)]Newey and West (1987) standard errors.

Table 6: Results of the co-integrating equations

Variable	Coef.	Std. Err.
Equation 1		
Trademarks residents	1	
Trademarks non residents		
Patents residents	2.055***	0.478
Patents non residents	-0.898	0.584
GDP	5.472	3.323
Intercept	-1.651**	0.745
Equation 2		
Trademarks residents		
Trademarks non residents	1	
Patents residents	2.063***	0.525
Patents non residents	-0.763	0.640
GDP	3.394	3.645
Intercept	-1.211	0.817
Johansen tests		
Equation 1: $\chi_2(3) = 19.707$	P> $\chi_2 = 0.0002$	
Equation 2: $\chi_2(3) = 17.111$	P> $\chi_2 = 0.0007$	
Trace statistic = 9.886	5% critical value: 14.410	

Significancy: *10% , **5% , ***1%

Table 7: Short-run and long-run effects of innovations and interrelationship with income polarization: Vector Error Correction (VEC) estimation

Equation & Variable[(a)]	Coef.	Std. Err.
ΔTrademarks residents		
Adjustment parameter Eq. 1	-1.166***	0.305
Adjustment parameter Eq. 2	0.908***	0.293
L.Trademarks residents	-0.027	0.175
L.Trademarks non residents	-0.297	0.201
L.Patents residents	0.205*	0.110
L.Patents non residents	-0.119	0.191
L.GDP	-0.876	2.466
Intercept	-0.0005	0.002
ΔTrademarks non residents		
Adjustment parameter Eq. 1	0.079	0.617
Adjustment parameter Eq. 2	-0.329	0.593
L.Trademarks residents	-0.194	0.354
L.Trademarks non residents	-0.295	0.407
L.Patents residents	0.012	0.223
L.Patents non residents	0.105	0.385
L.GDP	-2.516	4.987
Intercept	0.0001	0.004
ΔPatents residents		
Adjustment parameter Eq. 1	0.548	0.565
Adjustment parameter Eq. 2	-0.508	0.543
L.Trademarks residents	-0.099	0.324
L.Trademarks non residents	0.369	0.373
L.Patents residents	-0.933***	0.204
L.Patents non residents	1.226***	0.353
L.GDP	-2.983	4.567
Intercept	-0.001	0.004
ΔPatents non residents		
Adjustment parameter Eq. 1	0.094	0.435
Adjustment parameter Eq. 2	-0.148	0.418
L.Trademarks residents	-0.091	0.249
L.Trademarks non residents	0.133	0.287
L.Patents residents	-0.294*	0.157
L.Patents non residents	0.243	0.271
L.GDP	-1.302	3.514
Intercept	0.001	0.003
ΔGDP		
Adjustment parameter Eq. 1	0.006	0.019
Adjustment parameter Eq. 2	0.025	0.018
L.Trademarks residents	-0.022**	0.011
L.Trademarks non residents	-0.007	0.012
L.Patents residents	-0.008	0.006
L.Patents non residents	0.012	0.012
L.GDP	-0.163	0.155
Intercept	0.0004***	0.0001
Sample	27 (1982-2008)	
Log likelihood	487.4029	
Information criteria		
AIC	-32.696	

Continued on next page...

Table 7 – continued

Statistics & Equation	Coef.	Std. Err.
HQIC	-32.040	
SBIC	-30.488	
Specification test: model	$\chi_2(8)$	$P > \chi_2$
ΔTrademarks residents	26.867	0.000
ΔTrademarks non residents	9.272	0.319
ΔPatents residents	26.726	0.000
ΔPatents non residents	5.375	0.716
ΔGDP	35.095	0.000

$^{(a)}$The symbol Δ means that by definition of the VEC model, the variables are taken in difference. The symbol L. means lag. Significance levels : *10%, **5%, ***1%

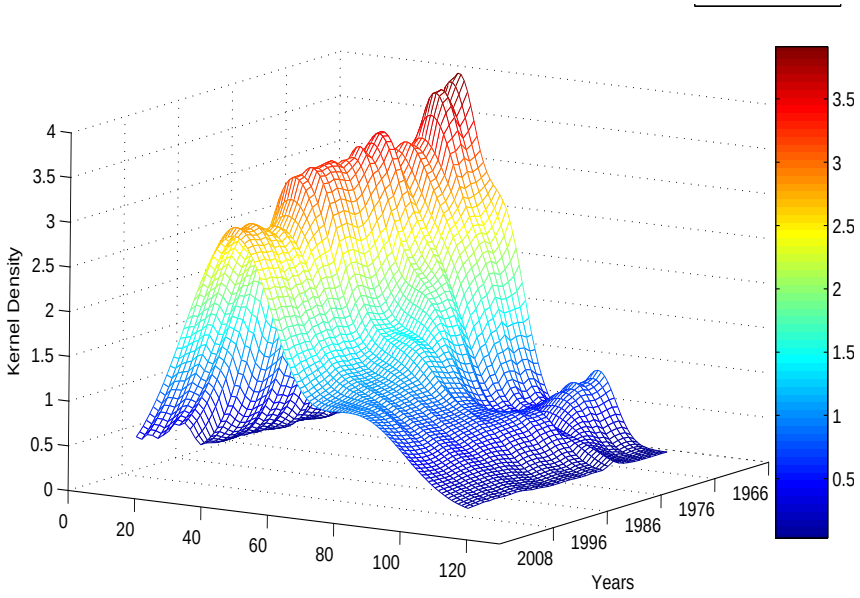

Figure 1: Distribution of GDP per capita

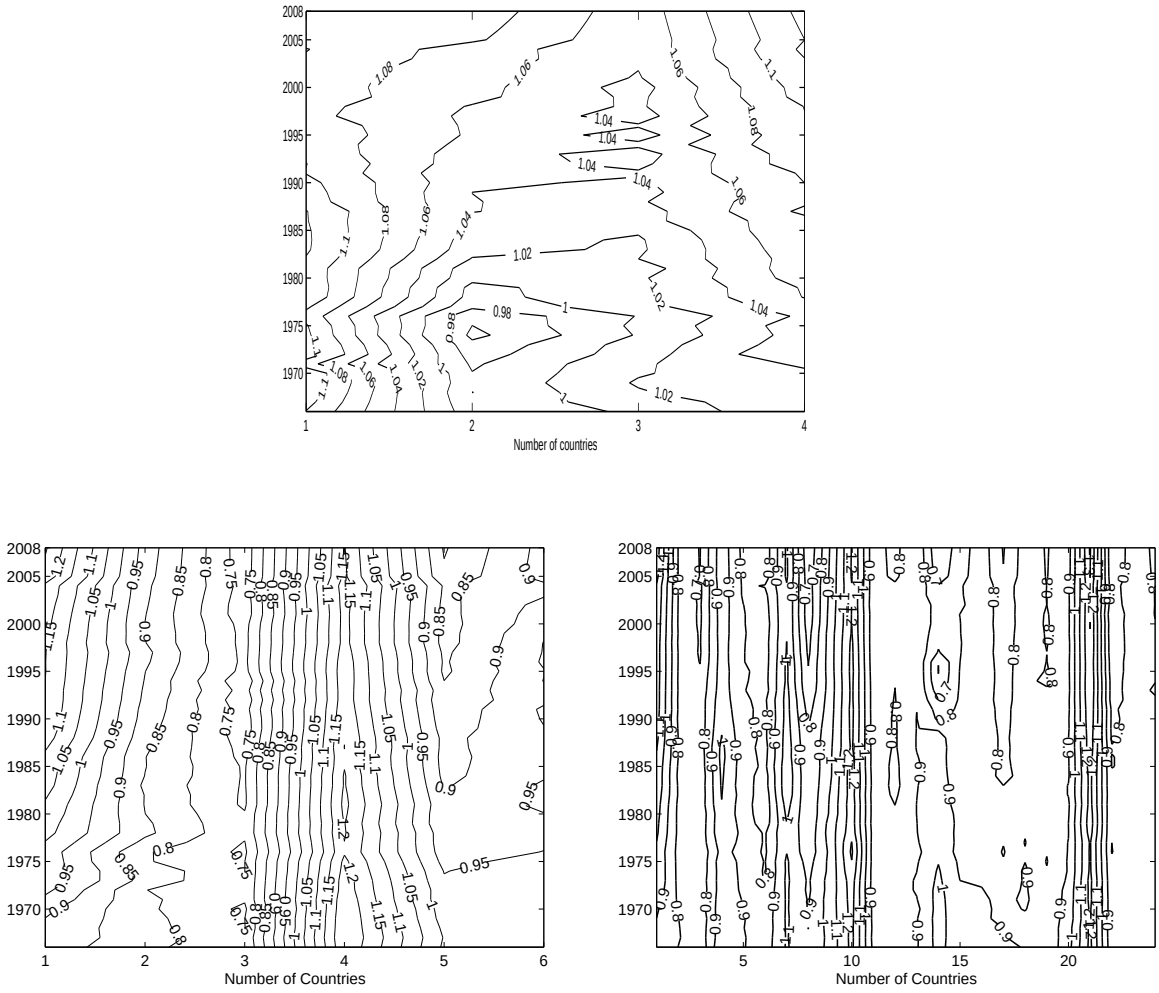

Figure 2: Contour of distribution of GDP per capita [Top]: Maghreb countries. [Bottom-left]: South African countries. [Bottom-right]: Sub-Saharan countries. x-number of countries, y-years

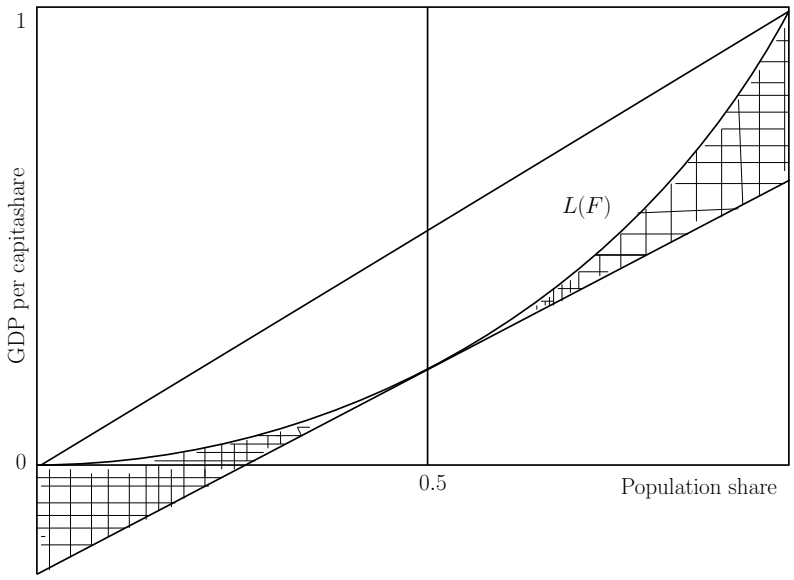

Figure 3: The bipolarization index

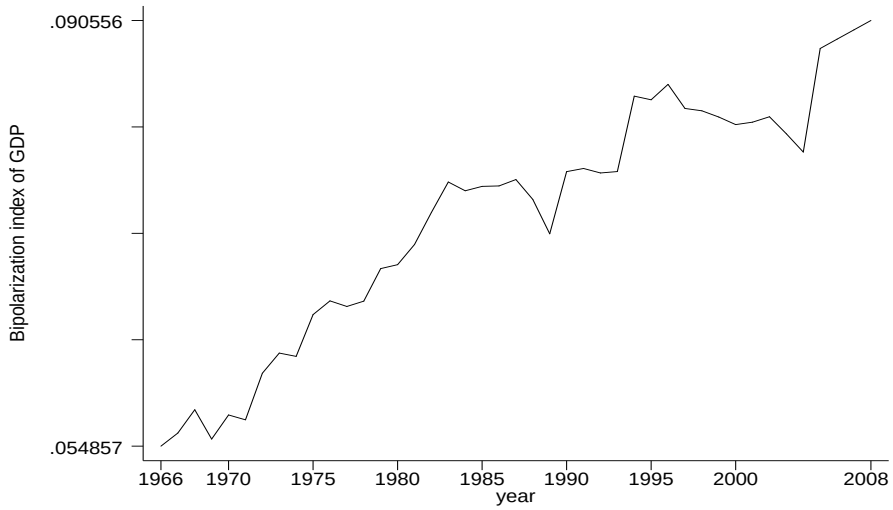

Figure 4: Evolution of the Wolfson's bipolarization index of GDP per capita

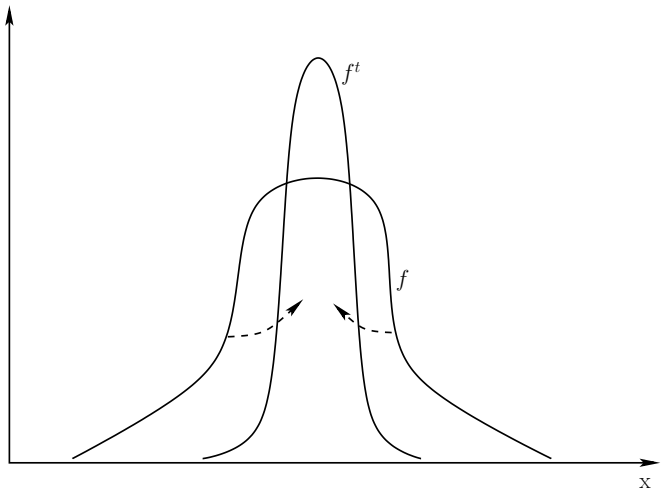

Figure 5: A single squeeze of a density function and the reduction of polarization

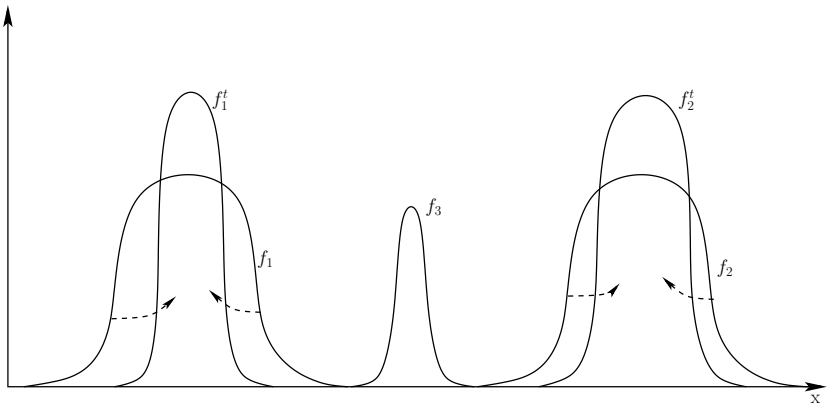

Figure 6: A symmetric slide of the density functions and the rise of polarization

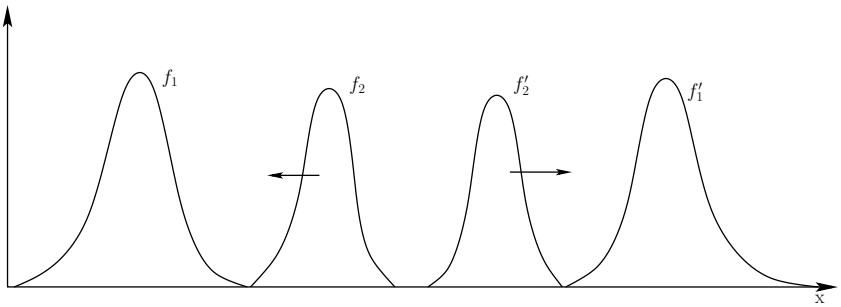

Figure 7: A double squeeze and the increase of polarization

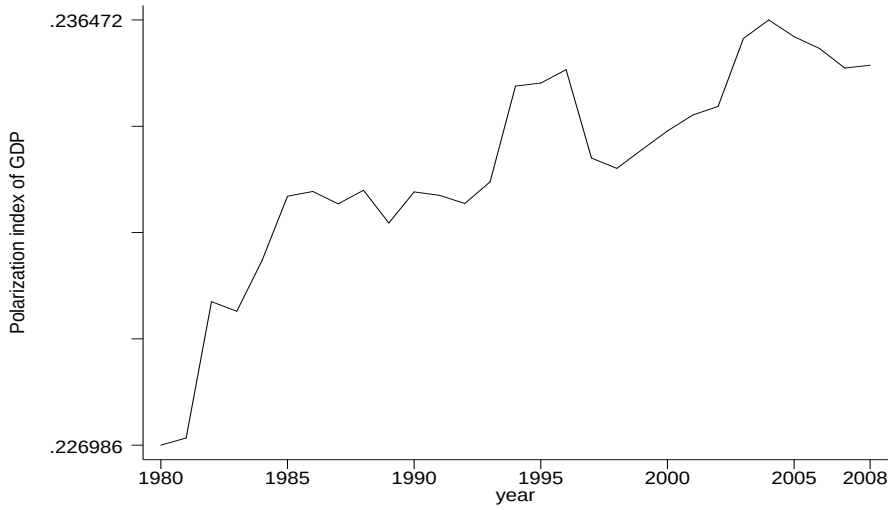

Figure 8: Evolution of GDP per capita polarization index

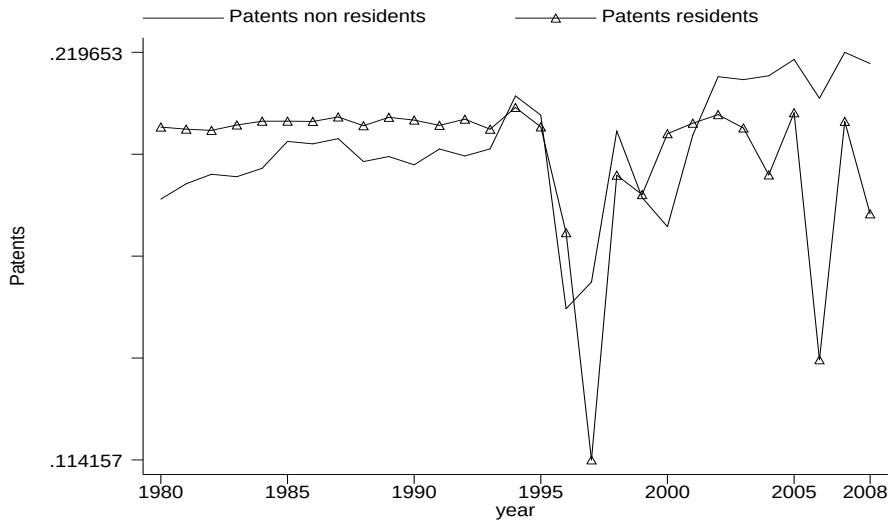

Figure 9: Evolution of patents polarization index

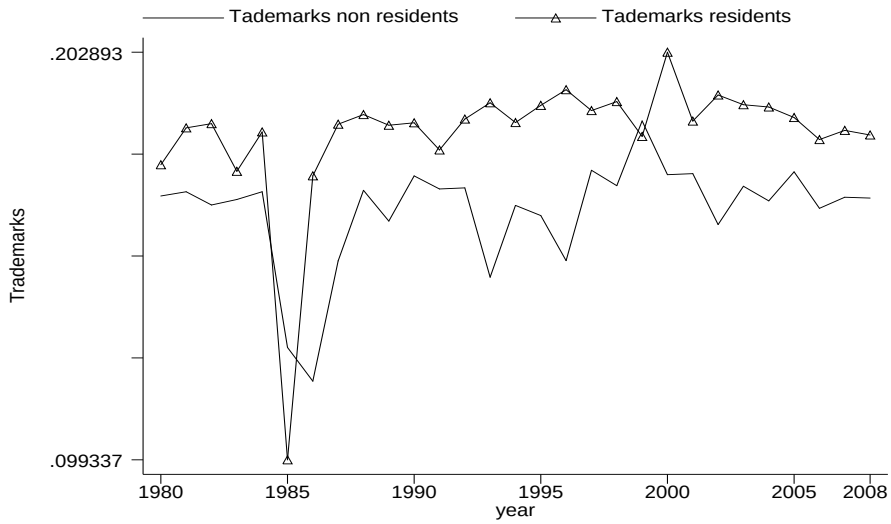

Figure 10: Evolution of trademarks polarization index

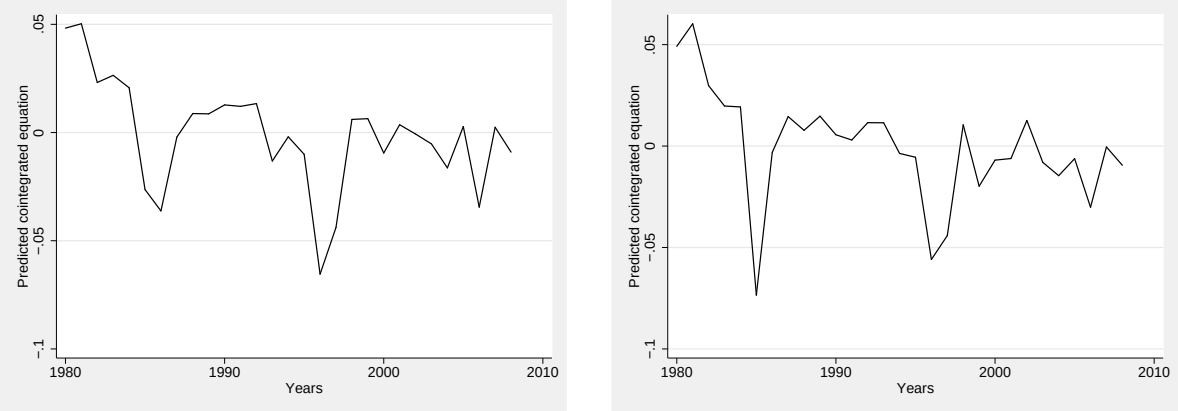

Figure 11: Prediction of the co-integrating equations [Left: co-integrating equation 1, Right: co-integrating equation 2]

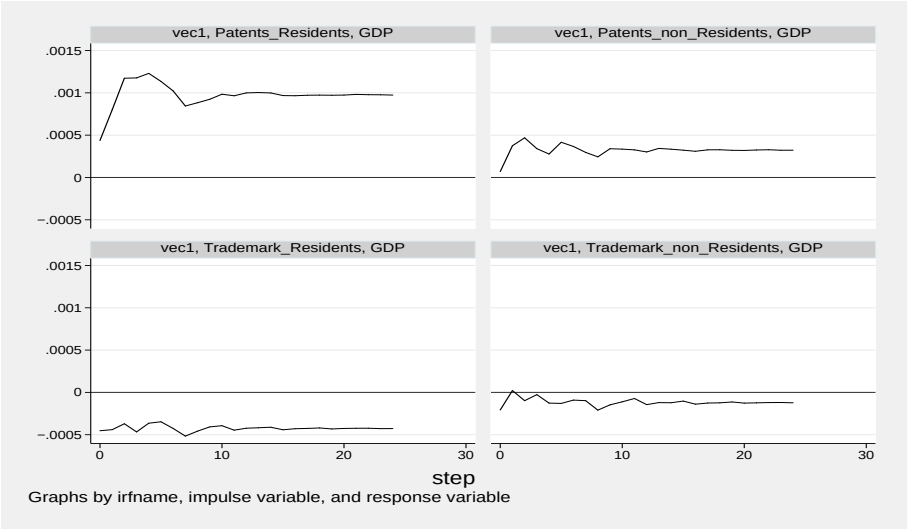

Figure 12: Impulse-response functions. [Top-left]: Effect of patents residents shock on income polarization. [Top-right]: Effect of patents non residents shock on income polarization. [Bottom-left]: Effect of trademarks residents shock on income polarization. [Bottom-right]: Effect of trademarks non residents shock on income polarization