Technological Change, Growth and Income Inequality

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ABSTRACT

This paper aims to prove the links between inequality, economic growth and technological change. The latter combined with human capital makes the distinction between skilled and unskilled workers which leads to the increase in inequality. We thus analyze the theoretical and empirical links between growth, technological change, schooling rates, opening rates, unemployment and income inequality. We conduct two econometric studies for a set of African countries during the periods 1992-2019 and 1995-2019. The studies show that technological change is one of the key elements of economic growth and inequality dynamics. It is a channel through which human capital affects economic growth and also inequality. This result can be explained by the fact that in the presence of technological change only skilled workers can benefit from it, while unskilled workers will be temporarily unemployed in search of a job requiring less skill. Our econometric studies have also shown that economic growth has been accompanied by an increase in inequality in the countries in our sample, and that inequality itself both hinders and reduces this growth.

Keywords: Inequality, Growth, Technology, Innovation
JEL Classifications: O3, F6

1. INTRODUCTION

The relationship between economic growth, technological change and inequality is a subject of crucial interest. This relationship, which is the subject of intense controversy and debate, is central in a context where growth is often a goal for all countries.

The widespread diffusion of new information technologies in the 1990s has considerably improved the capacity to produce and achieve economic growth, but these require highly skilled labour, which leads to rising inequality. The recent increase in wage inequality is generally attributed to skill-based technical change.

Several theories developed by economists explain the relationship between growth and inequality by technological change. Today, there is increasing evidence that excessive inequality can be detrimental to economic growth. Moreover, there is a positive link between inequality and social problems: health problems, school drop-out, etc.

Technical progress has become a source of anxiety for many workers, as agricultural mechanisation, industrial robotics and automation change the demand for labour, in the presence of innovation only highly skilled labour can work, but at the same time new technologies lead to lower production costs and higher productivity which stimulate output and growth. Globalisation and skill-based technological change have emerged as alternative explanations for the rise in wage inequality.

Thus, the adoption of new technologies requires a high level of human capital which is often scarce at the beginning of the process of technological diffusion. Hence, improving human capital is an essential element for economic growth and will reduce inequality.

2. CAUSAL RELATIONSHIP BETWEEN GROWTH AND INEQUALITY

2.1. Impact of Growth

The relationship between growth and inequality is very complex. The analysis of the impacts of growth and income distribution on living standards has been of concern to several economic currents. Traditional growth theory adjusts a direct relationship between economic growth and living standards. From the 1960s to the early 1990s, many articles have been devoted to this causal relationship from growth to inequality. More specifically, economists have often focused on the impact of economic development and growth-promoting policies on reducing inequality.

The first reference work on the link between the level of inequality and economic growth is attributed to Kuznets. He proposed a universal law based on the analysis of the historical evolution of inequality in the development process. Kuznets (1955) is based on the idea that there is only one kind of relationship between income inequality and GDP growth, and the study was conducted on two industrial economies, Germany and the UK. The law proposed by Kuznets is a debate and a field analysis of the link between growth and inequality.

By linking GDP per capita to inequality of income distribution, Simon Kuznets found an inverted U-curve in the 1950s. He assumed that income per capita is an explanatory variable and the inequality of the income distribution is a variable to be explained.

The inverted U-shaped curve shows that the process of economic development reflects the transition from a low productivity agricultural economy to a high productivity industrial economy. In fact, as the economy industrializes, inequality will increase.

Kuznets explained inequality by large-scale inter-sectoral labour transfers. In fact, in the early stages of the development of production, growth is related to increasing income inequality, as some in the population have more chances to obtain profits than others, which leads to increasing inequality. In subsequent stages, growth in production is accompanied by more equal human capital and income distribution. As soon as a certain threshold is exceeded, the trend will be reversed, inequality will stabilise and then decrease until it reaches the lowest level.

According to Kuznets' hypothesis, in this case, when development gains are spread over the whole economy, inequality will be reduced. Kuznets' explanation is derived from the dual economic model. However, the inequality that appears as a phenomenon at the beginning of the growth and development process does not seem to be the case for the large industrialised countries.

Kuznets also showed that the distribution of individuals in less developed countries is more unequal, and he found that the share of higher income groups in the Third World is greater than in the industrialised countries. Confirmation of Kuznets' hypothesis has been the subject of much work by economists analysing the evolution of inequality as a function of development.

In this context Kravis (1962) confirms Kuznets' hypothesis that there was a positive correlation between inequality and the level of real per capita income. Since income inequality increased in the early stages of development because the benefits of development are enjoyed by a minority of the population, while with continued growth and the creation of new jobs inequality decreases. Adelman and Morris (1973) also confirmed the increase in distributional inequality in the early stages of development by exploring the Kuznets hypothesis in developing countries.

Similarly, Paukert (1973) examined changes in income distribution during economic development for 56 countries, of which more than 40 were developed. Household incomes before taxes are the data used for estimation. The author showed that the level of inequality, as measured by the Gini indicator, is related to the level of gross domestic product (GDP).

This means that inequality increased sharply when moving from countries with a GDP per capita of less than $100 to the group of countries with a GDP per capita of $101 to $200. Inequality increases further, but less, in the group of countries from $201 to $300. The group of countries with a GDP per capita of more than $2,000 showed a clear reduction in inequality. These results confirmed Kuznets' original hypothesis that inequality increases in the early stages of development and then decreases in the second stage.

On the same basis Ahluwalia (1976) used a sample of 60 countries to examine the relationship between growth and inequality and in particular the inverted-U curve hypothesis. He showed that relative inequality increases in the early stages of development, with a reversal of this trend in the later stages.

In this context Bowman (1997) examined the hypothesis of an inverted U-curve between growth and inequality in some countries (Brazil, Costa Rica, Greece, Japan, Malaysia, South Korea, Taiwan and Turkey). The results obtained show that the hypothesis of an inverse Kuznets U-curve is not always verified in all countries. Indeed, Japan was able to develop without increasing the level of inequality, while Greece proves a case of growth with equity, and did not follow an inverted U as it developed from a less advanced to an almost developed country. So, he concludes that in both Japan and Greece, the initial phases of development have insignificant effects on the level of inequality. But, development had effects on Taiwan as it decreased income inequality. In South Korea, development stabilizes the level of inequality. In Brazil, development leads to a steady increase in inequality.

Similarly, Mikucka et al. (2017) argued that economic growth in rich countries will reduce income equality in the long run. While, Adelman and Cynthia (1973) analyzed the link between growth and social equity only in developing countries.

Amri and Nazamuddin (2018) studied the causal relationship between economic growth and income inequality in 26 provinces in Indonesia over the period 2005-2015. The authors showed that there is a negative and significant relationship between economic

growth and income inequality in the long run, and a positive relationship in the short run.

A second school of thought emphasizes the negative effects of unequal income distribution on growth. The theoretical literature suggests several channels, namely two political-economic and economic explanations.

The theoretical literature has focused on the characteristics of the major channels: the savings and investment channel, political economy, credit market imperfections, social cohesion or political instability.

2.2. The Positive Impact of Inequality on Growth

Economists prove that some inequality is good for growth (Kaldor, 1956; Mirrlees, 1971; Galor and Tsiddon, 1997; Galor and Moav, 2000). For some economists, inequality is good for growth because it encourages individuals to work, invest and innovate: there are several different arguments that support the view that inequality is economically efficient. For example, inequality is necessary to encourage saving and investment: we know that high-income people have a higher propensity to save; however, saving is the basis for investment and the accumulation of physical capital. Therefore, investment depends on saving, and saving will form the core of all economies.

It should be noted that growth does depend on the rate of investment. It is also by rewarding good investment with more profits and thus more inequality that savers are encouraged to choose the most relevant investment.

In this context, Kaldor (1956) showed that the propensity to save increases with income, so the marginal proportion to save is higher for the rich than for the poor. According to Kaldor, there is a positive correlation between the savings rate and the growth rate. But for this channel to work, certain conditions must be met: first, the increase in income of the better-off must not be accompanied by an equivalent decrease in their savings; second, the savings must be devoted to productive investments; third, the increase in investment must result in an increase in growth.

Moderate inequality can be a source of incentive according to some economists, inequality stimulates growth because it provides incentives for innovation and project completion, individuals work efficiently and this has a direct effect on growth, this inequality has led to a trade-off between equity and growth, part of this argument was developed by Okun (1975), Okun's idea is that the market is more efficient when it is unequal. Therefore, the reduction of inequalities leads to a reduction in efficiency. We must therefore choose between equality and efficiency.

2.3. The Negative Impact of Inequality on Growth

Recent studies suggest that the impact of inequality on growth can be positive or negative, depending on the initial GDP per capita (Brueckner and Lederman, 2018) and varying between the short and long run (Halter et al., 2014).

Iyke and Ho (2017) studied income inequality and growth in Italy from 1967 to 2012 using the autoregressive distributed lag estimation (ARDL) technique. Their study found that income inequality affected growth in both the short and long run. In other words, income inequality slowed growth in the country.

On the same basis Van der Weide and Milanovic (2018) provide evidence that high levels of inequality reduce the income growth of the poor, but, if anything, promote the growth of the rich based on a study of the United States covering the period from 1960 to 2010.

Breunig and Majeed (2020) re-examined the impact of inequality and economic growth in 152 countries. The study used the GMM for the period from 1956 to 2011 and found that inequality had a negative effect on growth. This negative impact of inequalities on growth was also proven by Klasen and Lamanna (2009).

Similarly, Marrero and Servén (2021) examined through a study made for 158 countries between 1960 and 2010, the links that exist between inequality and growth and between poverty and growth. The authors proved that the indirect effect of inequality on growth through its correlation with poverty is solidly negative.

In the field of empirical work, the opinions are almost unanimous: if inequality affects growth - the results strongly suggest that there is an effect - it is negative. According to these theories, income inequality is harmful to growth through several channels.

2.3.1. The savings and investment channel

In the case of excess savings, the increase in inequality could have a negative effect on growth, in this context Summers (2014), show that the increase in inequality leads to the risk of secular stagnation. According to Summers, secular stagnation is characterized by a persistent state of inability of the economy to simultaneously achieve full employment. Growth is therefore weaker than its potential, so lower inequality leads to lower savings which have a positive impact on growth.

2.3.2. The political economy channel

Alesina and Rodrik (1994) also examined the relationship between inequality and growth, using a sample of 70 countries over the period 1960-1985, The variable they seek to explain is the average growth rate of GNP per capita in different economies, The explanatory variables are: the Gini index, school enrollment and political variables. the results obtained show that there is a negative correlation between inequality and growth for the entire sample.

In this context, Person and Tabellini (1994) formulated a model that links growth to income inequality and political institutions. In this model, redistribution from the richest to the poorest is done through a democratic vote so that the final decision on redistribution is made by the median voter who is the politically decisive voter. They show that in 56 countries over the period 1960-1985, increasing the income share of the richest 20 percent of the population by 0.07 reduces the average annual growth rate, a decrease in the average per capita growth rate of 0.8 percentage points. Since the poorer the median voter becomes, the more redistribution he or she

demands. The result is that income inequality is detrimental to growth. This means that inequality hurts growth because redistribution discourages capital accumulation. So income inequality is detrimental to growth through policy actions and the degree of redistribution.

Similarly, Ostry et al. (2014) examined the relationship between inequality, redistribution, and growth in the medium and long run. Their results show that redistribution can have direct negative effects on the duration of growth.

2.3.3. The social cohesion or political instability channel
There is another theoretical current in economics. According to it, the increase in inequality has a negative effect, since it leads to a reduction in social cohesion on the one hand, and increases political instability on the other. Barro (1991) also finds a negative correlation between an unstable social climate and growth.

In this context, Alesina and Perotti (1996) showed that income inequality increases socio-political instability which in turn decreases investment, given that investment is a key element of growth, the study was carried out on a sample of 71 countries over a period of 25 years (1960-1985) the authors compare the level of inequality at the beginning of the period with the levels of instability and investment measured over the whole period.

In the same context, Barro (2000) estimates the impact of inequality on growth and investment in a panel of countries, and the results show that inequality (measured by the Gini coefficient) slightly affects growth and investment. Barro uses as variables an index of legal security, an index of democracy, the inflation rate, the average number of years of education, the log of the fertility rate, the rate of investment in GDP. Their observations lead them to believe that inequality retards growth in poor countries, but encourages growth in richer regions. When GDP per capita is below about $2,000, inequality would have a negative role on growth. But if the GDP per capita is higher than 2000 dollars, the effect will be positive. Thus Barro (2000) showed that inequality has a negative effect on growth only for poor countries, and a positive effect for rich countries.

Forbes (2000) estimated growth as a function of inequality. The results obtained show a positive relationship between inequality and growth, since an increase in the level of income inequality in a country has a significant positive impact on subsequent economic growth in the short and medium term.

2.3.4. The channel of credit market imperfections
To finance its investments, a company can resort to two methods of financing, either internal financing with its own funds, or external financing by borrowing.

The possibility of obtaining financing, whether internal or external, depends on several factors. The main factors are the wealth and assets of the individual, only those individuals who have initial endowments can make investments.

Galor and Zeira (1993) prove that through this mechanism, the initial distribution of wealth determines the degree of investment in human capital and consequently the income in the long run. Thus, the persistence of inequality is largely due to serious imperfections in the capital market, associated with an unequal distribution of assets, which lead to the continuity of inequality.

Flug et al. (1998) have shown that economic instability and credit rationing affect investment in physical and human capital.

3. THE IMPACT OF TECHNOLOGICAL CHANGE

3.1. The Impact of Technological Change on Growth
Economic growth is an objective aimed at by all countries since it is a fundamental factor in the fight against poverty thanks to the creation of new jobs, which makes it possible to improve living conditions, and it is a process that results in an improvement in economic performance over a long period. The latter is the result of the accumulation of factors of production and an improvement in their productive efficiency, which is closely linked to technical progress, since it improves productive capacity.

The theory of economic growth has been trying for more than a century to explain the fundamental reasons for the enrichment of some nations and the impoverishment of others. Innovation is seen as a key source of economic growth of labor in all economic theories and approaches. It is inevitable that innovation plays a key role in long-term economic growth (Aghion and Howitt, 1992; Schumpeter, 1942; Solow, 1957).

In the same sense, the empirical work of Solow (1957) shows that technical progress contributes between 50% and 75% to the growth of the United States. Similarly, according to Aghion (2002) innovation is the main engine of growth, which is the same for Bosworth and Collins (2003). Innovation is recognized as an essential engine of economic growth and development. This idea is confirmed by the work Bala-Subrahmanya et al. (2010) these authors show that innovative small and medium-sized enterprises (SMEs) have recorded higher growth than non-innovative SMEs, not only in terms of turnover but also employment and investment in the three sectors. Technological innovation is an important means of boosting the economic efficiency of SMEs and a source for achieving sustainable development. The same ideas put forward by Philippe and Celine (2017) prove that long-term growth results from innovation.

Thus, we can conclude that labor productivity has increased due to automation and technical progress that allow industry to produce equivalent quantities with fewer hours of work. So, one of the main benefits of innovation is its contribution to economic growth because innovation can lead to higher productivity, which means that the same input generates greater output, the increase in the quantities of products comes from an improvement in the efficiency of the factors of production that are used through technological changes which allows for intensive growth. Thus, innovation and adaptation of new

technologies are the engines of productivity and therefore of long-term economic growth.

Thirtle et al. (2003) used the Malmquist Sequential Index to calculate productivity indices (PMF) in agriculture and the commercial sector for 18 districts in Botswana during the period 1981-1996, the authors found that the increase in agricultural productivity of regions in Botswana is mainly due to technological change.

Similarly, Wright and Shih (2010) show that agricultural innovation can help improve soil qualities. It can also help to improve knowledge on sustainable resource management, thus agricultural technological innovations are created for more yield, more quality and quantity of production and for product diversification.

Autor (2014) showed that innovation can help improve productivities. In this context, Abraham (2020) studied over the period 1982-2014 for the countries of the West African Economic and Monetary Union, the levels of productivity before the use of new technologies in the agricultural sector and after the introduction of technological innovation. The author was interested in the study of technological efficiency on total factor productivity. The results show that technological changes are the main factors of growth, he considers them as fundamental factors of economic growth.

3.2. The Impact of Technological Change on Inequality
Despite the fact that technological innovation is an essential factor in the achievement of economic growth in the long term, since it increases productivity, as we have already mentioned, it also leads to certain negative effects on the economy.

The nature of the relationship between technological change and inequality is disputed because of the often very divergent results. The economic literature in fact gives several different approaches to the contribution of technological change to inequality.

Technological progress, biased in favour of the most qualified has led to a destruction of low-skilled jobs while qualified workers benefit from technological innovations. This hypothesis is validated by numerous empirical studies. Among the works that are interested in verifying the impact of technological changes on wage inequalities, we can cite The work of Lawrence and Slaughter (1993), which looks at the situation in the United States between 1973 and 1979, and the results obtained show that the wage gap increased.

According to these authors, technological progress was concentrated in skill-intensive industries. They argue that the increase in wage inequality can be explained by skill-based technical change, so technological change may be biased by increasing the demand for highly skilled and experienced labor and lowering the demand for unskilled and inexperienced workers. Lawrence and Slaughter conclude that the increase in

the uses of computers and technology in the production process was the cause of the relative increase in the wages of skilled workers.

On the same basis, Krueger (1993) examined the relationship between computer use in the workplace and wage levels in the United States, using individual data for 13,000 U.S. employees over the period 1984-1993. He tried to establish a direct link between the technologies used and wages. The results obtained show that in 1984 workers who used computers in the work process received 18.5% higher wages than other workers. Krueger also found that the wage premium associated with computer use increased by 20.6 percent in 1989. Thus Krueger attributes the increase in the wage differential among workers to the introduction of technology. Since higher wages will go to the most skilled workers. Ferall (1995) has also demonstrated the link between job responsibility levels and the distribution of income.

In this context, Aghion and Howitt (1992-1994) have developed a model in which there are several sectors. According to these authors, growth results exclusively from technological progress, which in turn results from competition between firms seeking to innovate.

In fact, technological progress makes it possible to increase the technical efficiency of one category of workers over another. In this context, it should be noted that the scarcity of skilled labor leads to an increase in the wages of skilled workers, while the wages of other workers remain at their initial level, which leads to wage inequality.

The only way for society to engage in more research is to remove the work of simple physical force, these workers must seek new employment in another sector hence the removal of human intervention in the production process. The new technologies, then contribute to a destruction of employment that leads to the increase of inequalities.

Kharlamova et al. (2018) studied how technological change affects income inequality in European countries. Two periods are studied: the first, from 2006 to 2017 and the second, from 2010 to 2017, which characterizes a new economic era after the global financial crisis. The author has shown that the more economically developed a country is, the less impact on income inequality can be initiated by technological change. Similarly, the deeper the income inequality in a country, the more it reacts to technological change, but the impact on inequality can be both positive and negative.

Similarly, Tang et al. (2022) provide evidence of the direct and positive relationship between technological innovations and inequality for a balanced sample of panel data from 73 countries around the world. The inequality-technology innovation relationship is moderated by government spending, manufacturing, agricultural employment, and export diversification.

4. TECHNOLOGY GROWTH AND INEQUALITY: EMPIRICAL VERIFICATION

4.1. Selected Literature Review

Economic growth	*Ahluwalia (1976) uses a sample of 60 countries to corroborate the proposition that relative inequality increases in the early stages of development, with a reversal in the later stages. The sample analyzed is composed of 60 countries, among which 6 are socialist and 40 are developing. Its model was estimated in the period 1960-1970. The results verify the Kuznets hypothesis. *Person and Tabellini (1994), they tested inequality on the basis of a cross-sectional regression for 56 countries and a group of 9 highly industrialized countries. They found a negative correlation between GDP per capita and inequality. The estimate shows a negative effect of inequality on GDP per capita. This means that an increase of 0.07 in the income ratio reduces the average annual growth rate by 0.5 percentage points. *Clarke (1995) also shows that there is a negative and significant correlation between initial income inequality and the long-term growth rate. *Bourguignon (1993) focused on 35 developing countries and compared their growth ratios and 5 explanatory variables, including inequality. His estimate shows a negative correlation between unequal income distribution and macroeconomic performance. *Banerjee and Duflo (2003), using non-parametric methods, show that the growth rate as a function of the net change in inequality is inverted U-shaped.
Human capital	*Nelson and Phelps (1966) put forward the idea that it is human capital that allows the economy to adapt more or less quickly to technological change, that is the engine of long-term growth. *Research by Horowitz and Sherman (1980) on the performance of technicians in American shipyards shows that work teams with higher average levels of education can increase their productivity more than work teams with lower average levels of education. *Marris (1982) with a study of 66 developing countries shows that when the investment is combined with investment in human capital, the overall investment will contribute better to economic growth. Thus, education (training) will be a complement to physical investment, through which much of its impact on growth will pass. *Benhabib and Spiegel (1994) confirm the results of the Nelson and Phelps (1966) hypothesis, showing that the stock of human capital affects the speed of adoption of technology, to catch up with the most advanced countries. *Teixeira and Fortuna (2003) examined the relationship between human capital, innovation and economic growth in Portugal during the period 1960-2001. The results show that human capital and innovation efforts are extremely important for the Portuguese economic growth process. *Haunshek and Woessmann (2008) highlighted two main mechanisms through which education affects economic growth. Same result found by Hawkes and Ugur (2012) who argued that human capital ingenuity has a wide range of benefits for the national economy, communities and individuals. For example, quality education and health systems, low crime rates, and environmental protection laws and policies are important determinants of economic growth and development.
Innovations	*Coe and Helpman (1995) studied the relationship between R and D and productivity in 22 industrialized economies from 1971 to 1990, by linking increases in total factor productivity (TFP) to changes in R and D stocks. Their results confirmed that there is a positive correlation between a country's R and D stock and productivity. In fact, the R and D stock in seven countries increased by 1% with an increase in productivity in the main industrialized countries of 0.23%. Moreover, these authors found that spending in each country significantly affects the productivity of other countries. *Jeremy et al. (1997) find that the increase in the rate of technological change of specific investment has induced an increase in the demand for skilled workers relative to unskilled workers which leads to the increase in inequality. *Krusell et al. (2000) see that technological change leads to wage inequality by increasing the demand for skilled workers despite the increase in their supply. *Gould et al. (2001) show that residual inequality in the lower-skilled groups increases more rapidly in the 1970s and 1980s than in the higher-skilled groups. *Violante (2008) technological change can lead to an increase in the relative productivity of a certain type of work that creates a demand gap between skilled and unskilled workers. *Tang et al. (2022) proved the direct and positive link between technological innovations and inequality for a balanced sample of panel data from 73 countries around the world.
Inflation	Hansen (1999) through dynamic panel models, they find that inflation has a nonlinear effect on economic growth. The results and tests indicate that above the threshold level of inflation of 19.6%, any increase in inflation reduces economic growth. *Khan and Senhadji (2000) find a negative relationship between inflation and growth for inflation above the threshold level of 1 to 3 percent in industrialized countries and 7 to 11 percent in developing countries. *Shamim and Golam (2005) conducted a study on the relationship between inflation and economic growth in Bangladesh. The results of this analysis show that there is a significant negative long-run relationship between inflation and economic growth. *Using a panel data set for industrialized countries Omay and Kan (2010) find that there is a statistically significant negative relationship between inflation and growth in inflation rates above the 2.52% threshold.

4.2. Model, Variables and Sample Specification

Econometrically, we have attempted to analyze the relationship between growth and inequality by focusing on two-way causality while emphasizing the role of trade openness and technological innovation.

We estimate the following model:

$$GINI_{i,t} = \beta1 + \beta2\ INF_{i,t} + \beta3\ GRW_{i,t} + \beta4\ KHU_{i,t} + \beta5\ INV_{i,t} + \beta6\ TEC_{i,t} + \beta7\ TEC^2_{i,t} + U_{i,t}$$

The variables used are presented in the following Table 1:

The data used to estimate the model are taken from the World development indicators WDI. Our first model focuses on the effect of economic growth, technological innovations, human capital, investment and inflation on inequality. The model is estimated for the period 1992 -2019. We proceed with a sample of 21 developing countries with 588 observations. The countries in our sample are: Tunisia, Mauritania, Zimbabwe, Cote d'Ivoire, Ghana, Nigeria, Morocco, Algeria, Niger, Mozambique, Angola, Uganda, Kenya, Senegal, Cameroon, Gabon, Malawi, Sudan, South Africa, Burkina Faso, Togo.

4.3. Econometric Results

The classical methods of panel estimation are fixed effects or random effects. The estimated coefficients are significantly different in the two cases. The Hausman (1978) specification test can be a means of evaluation.

The Hausman (1978) specification test makes it possible to discriminate fixed effects from random effects. This test considers that for a model with fixed individual effects, the i are correlated with the explanatory variables, whereas for the model with random individual effects, they are independent. In the case of a model with fixed individual effects, we must use the Within estimator. It should be noted that the software used for data processing is E-VIEWS.

The results of the Hausman test with variable effect model show that the probability is zero, so we reject the hypothesis that the model is random effect and we choose the fixed effect model. The results of the Hausman test are presented in Table 2.

To ensure the non-autocorrelation of the errors we have opted for the Pesaran CD test. The probability relative to Pesaran CD =0.7 which proves the non autocorrelation of the errors.

By estimating the fixed effect model we obtained the following results:

The regression presented in Table 3 shows that economic growth, inflation rate and technological change positively affect the GINI index.

This means that these variables increase inequality, so a one unit increase in economic growth results in a 0.0914 increase in inequality. Thus, we can conclude that economic growth was accompanied by an increase in inequality in the countries in our sample. This result confirms the results found in the article by Kuznets (1955): by linking GDP per capita to the inequality of income distribution, Kuznets assumed an inverted U curve.Indeed, he assumed that income per capita is taken as an explanatory variable and by using the inequality of income distribution as a variable to be explained, the result shows that when the economy industrializes, inequality will increase.

The impact of technological change on inequality is positive and significant. Thus, the increase of one unit of technological change results in an increase of 0.612 of inequality. This result can be explained by the fact that in the presence of technological change

Table 1: The variables of the econometric model 1

Explanation	Indication	Variables
Inequality	Gini index	GINI
Inflation	Inflation rate	INF
Economic growth	Annual growth rate of gross domestic product	GRW
Human capital	Tertiary education enrollment rate	KHU
Investment	Investment as a percentage of GDP	INV
Technological change	Research and development expenditure as a percentage of GDP	TEC

Table 2: Results of the Hausman test

Test summary	Chi-square. Statistic	Chi-square.d.f.	Prob.
Cross-section random	92.523776	6	0.0000

Table 3: Dependent variable: GINI

Variables	Coefficients
C	40.080 (7.546)
INF	0.320 (3.502)
GRW	0.0914 (6.636)
KHU	−2.271 (−7.437)
INV	−0.077 (−3.914)
TEC	0.612 (4.853)
TEC*TEC	−0.018 (−7.669)
R^2	0.908

Values in parentheses represent Student's coefficients

only the skilled worker can find a job, the unskilled worker is in a situation of unemployment. This result confirms the work of Conciaçao et al. (2005) who found a positive relationship between technology and inequality.

Regarding the impact of inflation on inequality, it is positive and significant, so that an increase of one unit of inflation translates into an increase of 0.320 of inequality. Similarly Albanesi (2007) found a strong positive correlation between inflation and income inequality in 51 industrialized and developing countries between 1966 and 1990. These results do not confirm the results of Maestri and Roventini (2012) who found that inflation reduces average wealth and income inequality. Similarly, Heer and Maussner (2004) provided evidence that higher inflation marginally reduces inequality.

Regarding the other two variables (human capital and investment), the negative signs of their coefficients show that the tertiary enrollment rate reflected by KHU and investment allows inequality to be reduced. Similarly, increasing the enrollment rate by one unit reduces inequality by 2.2741. So investment in education can also reduce inequality. However, investment in human capital does reduce inequality.

Park (1996) and De Gregorio and Lee (2002), find that greater educational dispersion has an unequalizing effect on the income distribution while higher educational attainment has an equalizing effect on the income distribution. The Checchi (2001) analysis confirms that educational achievement has a strong impact on income inequality. Goldin and Katz (2009) shows that a slowdown in education caused an increase in wage inequality in

the U.S.Lustig et al. (2013) explain that the decline in labor income inequality was associated with higher education and, therefore, with a more equitable educational distribution.

The impact spent on research and development as a percentage of GDP on inequality is positive and significant. But after a certain level of R and D spending, the trend may be reversed and inequality may decrease, which confirms Kuznets' theory: for an increasing inequality with the onset of the development process, then decreasing afterwards.

5. IMPACT OF INEQUALITIES AND TECHNOLOGICAL CHANGES ON GROWTH

In order to analyze the effect of inequalities and technological innovations on economic growth, we have chosen to use the EVIEWS 10 software.

5.1. Presentation of the Model
We propose the following model:

$$GRW_{i,t} = \alpha_i + \beta_1 KHU_{i,t} + \beta_2 TEC_{i,t} + \beta_3 OUV_{i,t} + \beta_4 INF_{i,t} + \beta_5 INV_{i,t} + \beta_6 GINI_{i,t} + U_{i,t}$$

"i" represents each country and "t" represents each time period (with t =1, 2.,T).

The variables are shown in the Table 4 below:

5.2. Result of Estimation
Our second model explains the effect of inequality on economic growth for the period from 1995 to 2019. We proceed with a sample of 21 developing countries.

For our considered sample, the Hausman test statistic shows that the model is in fixed effect.

The Pesaran CD test shows that the probability = 0.97 which shows that the errors are not self- correlated. Based on the same sample related to the estimation of the model (1) the results of the estimation are presented Table 5.

The econometric regression presented in Table 5 shows that human capital, technological change, openness and investment positively affect economic growth. This means that these variables increase the annual growth rate of gross domestic product.

The estimated direct effect of human capital on economic growth expressed in terms of gross domestic product per capita is positive and significant. The model revealed a positive, statistically significant relationship between GDP, human capital and innovation capacity as expected by economic theory.

This result is reasonable because human capital directly affects economic growth by improving worker productivity in production. On the other hand, human capital contributes more to innovation

Table 4: Explanatory variables of econometric model 2

Explanation	Indication	Variables
Economic growth	Annual growth rate of gross domestic product	GRW
Human capital	Tertiary education enrollment rate	KHU
Research and development	Research and development expenditure as a percentage of GDP	TEC
Ouverture	Taux d'ouverture	OUV
Inflation	Inflation rate	INF
Investissement	Investment as a percentage of GDP	INV
Inequality	Gini index	GINI

Table 5: Dependent variable GRW

Variables	Coefficients
C	2.1988 (27.663)
KHU	0.4019 (4.168)
TEC	0.1188 (7.477)
OUV	0.0044 (2.784)
INF	−0.2338 (−3.470)
INV	0.8666 (4.162)
GINI	−0.3217 (−5.006)

Values in parentheses represent student coefficients

and adaptation of technology, which is an essential factor for economic growth. This result confirms the result of Nelson and Phelps (1966) who shows that human capital allows the economy to adapt to technological innovations which are the engine of long term growth. Similar results are also presented by the analysis of Bassanini and Scarpetta (2001) who found in an OECD data set for the period 1971 to 1998 that increasing the length of schooling by one year leads to an increase in GDP per capita of 6 percent. The analysis conducted by Elena (2015) highlighted the importance of human capital in ensuring economic growth expressed in terms of gross domestic product per capita in 2015.

Our results contradict those of other economists who have provided evidence that human capital has a non-significant effect on growth. This conclusion is also supported by several other studies (Liu and Stengos 1999; Delgado et al. 2014) that could not establish the statistically significant relationship between human capital with countries' growth rates. Also, Pritchett (2001), found no relationship between the increase in human capital and the growth rate of GDP per capita for his sample of developing countries.

The results presented in Table 5 clearly indicate that technological change is statistically significant and explains the variability of economic growth in the countries in our sample. This is because technological change allows for the production of either more goods or better quality goods using the same amount of inputs. Thus, an increase of one unit of technological change results in an increase of 0.118 in economic growth. This result confirms the empirical work of MNIF (2015) and Aghion (2002) proving that innovation is the main engine of growth, which is the same for Bosworth and Collins (2003). Innovation is recognized as a key driver of economic growth and development. Similar results are also presented by the analysis conducted by Thirtle et al. (2003) who used the Malmquist sequence index to calculate productivity indices (PMF) in the agricultural and commercial sectors for 18

districts of Botswana during the period 1981-1996, the authors found that the increase in agricultural productivity of the regions in Botswana is mainly due to technological change.

Our results also show that openness has a positive impact on economic growth. Thus, a one-unit increase in openness results in a 0.004 increase in economic growth. These results are consistent with the expected signs and help confirm the result of Harrison (1996) who proved similar findings using a variety of openness indicators. Using different estimation methods, the results obtained suggest a positive relationship between the degree of openness and growth.

For the other two variables (inflation and inequality), the negative signs of their coefficients show that inflation and inequality seem to have negative effects on economic growth. From these estimates, we see that inflation negatively affects the economic growth rate: an increase of one unit in inflation leads to a decrease of 0.233 in economic growth. This is consistent with Khan and Senhadji (2000) who found a negative relationship between inflation and growth for inflation above a threshold of 1 to 3 percent in industrialized countries and 7 to 11 percent for developing countries.

This result is not consistent with the result found in the work of Dotsey and Sarte (2000) finding that inflation increases average growth through a precautionary savings motive. The results obtained in this study are similar to those obtained by Fountas and Karanasos (2007) and Fountas (2010) who find that inflation is not detrimental to economic growth in the countries industry.

The impact of inequality on economic growth is negative and significant. This result confirms those of Alesina and Rodrik (1994) who concluded, in a study of 170 countries during the period 1960-1985, that there is a negative impact of inequality on per capita income growth. The authors suggested that an increase in the Gini coefficient caused a decline in the average per capita growth rate of 0.8 percentage points. Similarly, Person and Tabellini (1994) conducted a study of the relationship between inequality and growth in the case of 56 countries, nine of which are developed in the post-war period. They concluded that a 0.07 increase in the income share of the richest 20 percent of population reduces the average annual growth rate. Similarly, Summers (2014) shows that rising inequality leads to the risk of secular stagnation.

6. CONCLUSION

We are interested in the theoretical and empirical aspects of the relationship between inequality, technological change and growth. For this reason, we presented a brief overview of some of the work. Then, we moved on to our empirical validation based on two specified models. Before interpreting the results obtained, we presented: the sample of countries studied, the variables in question, the data sources and the specified model.

We found a negative effect of inequality on economic growth and a positive effect of technological change on inequality. In this framework, innovations lead to an unequal demand for skilled and unskilled labor, which affirms the thesis of skill-biased technological change and confirms the strong complementarity between capital and skilled labor.

The negative signs of the coefficients on the variables tertiary education rate reflected by KHU and investment show that human capital and investment can reduce inequality.

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