Analyzing the Dynamics of Inflation, Exchange Rates and Economic Growth through the Gini Index: Modeling VAR in Morocco

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ABSTRACT

In this study, we analyze the cross-impact of inflation, exchange rates and economic growth on income inequality in Morocco between 2000 and 2022, based on the GINI index as a measure of inequality. Its main objective is to understand how these macroeconomic variables influence income disparities. Our methodology is based on a VAR model to capture dynamic interactions between variables. To validate the robustness of the model, Granger causality tests and specification tests, including tests of homoscedasticity and autocorrelation of residuals, were used. The result is that inflation has a significant positive impact on income inequality, and exchange rate fluctuations directly influence inequality. Furthermore, economic growth helps to reduce inequality, although this effect depends on the distribution of the benefits of this growth. This study contributes to the existing literature by providing empirical evidence of the importance of macroeconomic stability and educational and fiscal policies in reducing income inequality.

Keywords: Income Inequality, Inflation, Exchange Rate, Economic Growth, Gini Index, VAR Model
JEL Classifications: E31, F31, O47, C32

1. INTRODUCTION

For contemporary economies, inflation, exchange rates and economic growth are among the most important economic determinants. Indeed, inflation determines household purchasing power, exchange rates determine international competitiveness, and economic growth is widely regarded as a barometer of a nation's state of well-being. In this respect, the GINI index is of great importance as a measure of inequality in the economy. The links between these economic variables, particularly income inequality, are fundamental to the formulation of fair and reasonable economic policies.

According to Kuznets' theory (1955), economic growth naturally tends, after a certain phase, to reduce income inequality. More

specifically, according to a study by Easterly and Fischer (2001), inflation has negative effects on income distribution, by reducing the purchasing power of the poorer masses. On the other hand, research such as that by Li and Zou (2002) focuses on the effect of income distribution on exchange rates, which modify the relative prices of imported and exported goods.

However, there are very few studies on the joint impact of inflation, exchange rates and economic growth on income inequality. The majority of variables are studied in isolation in existing studies, leaving a gap in knowledge about their joint relationships and effects on inequality, as measured by the GINI index. Our study addresses the following question: How does the cross-influence between inflation, exchange rates and economic growth contribute to income inequality, as measured by the GINI index?

We formulate the following hypotheses to answer this research question:

- H1 emits that inflation essentially has a positive influence on the GINI index, thus increasing income inequality
- H2 shows that exchange rate fluctuations have a direct effect on income inequality
- H3 states that economic growth, in terms of real GDP per capita, has an impact on reducing income inequality.

The main aim of this study is to analyze the relationships between inflation, exchange rates, economic growth and income inequality. Within this framework, and in order to identify and test these relationships, the aim of this research work is to fill in the gaps in the existing literature using the VAR model to provide useful information for policy-makers. To this end, this article is structured as follows: First, a discussion of the relevant literature that has emerged for economic variables and income inequality, followed by the methodology adopted for this research work. Next, the results of the analysis will be discussed and outlined, followed by the concluding section, which includes implications of the findings and recommendations for further study.

2. LITERATURE REVIEW

In what follows, we review existing research on the relationship between key macroeconomic variables and income inequality. This literature review will provide an essential theoretical and empirical framework for understanding the dynamics studied in this research.

2.1. Inflation and Inequality
The notion of inflation has drawn economists' attention to its possible implications for income inequality. Both economic theories and empirical data present opposing views on the effect of inflation on income distribution. Some of the oldest theories of inflation, such as the Phillips curve, explain that rising inflation can also be caused by excessive demand in the economy. In such a case, rising inflation initially reduces unemployment, but this effect is considered essentially unstable from a long-term perspective.

For his part, Friedman (1968) countered this perspective by explaining that inflation creates a monetary illusion and that wage and price adjustments dissipate the short-term reward of employment, with no long-term consequences for income inequality. However, general equilibrium theory concludes that inflation can have redistributive effects. Inflation is good for debtors and bad for creditors, as the real burden of debt is slightly lightened by inflation. On the other hand, redistribution will aggravate inequalities if debtors and creditors belong to different income classes (Kaldor, 1957).

Numerous empirical experiments prove that inflation is indeed linked to inequality. Empirical proof was provided by Easterly and Fischer (2001) that inflation has a significant impact on inequality, as it reduces the purchasing power of households on fixed incomes, which generally correspond to the poorest in society. Their empirical analysis on a sample of heterogeneous nations demonstrates that inflation and the GINI index, the statistical parameter most commonly used to characterize income inequality.

Furthermore, Albanesi (2007) proposes an analysis according to which inflation affects income inequality through its effects on the labor market and the tax system. Under the effect of inflation, proportional taxes are likely to index real tax payments. This means that low-income households could then be disproportionately affected by a higher effective tax burden.

In another study, Li and Zou (2002), this time carried out on a sample of developing and developed countries, conclude that higher inflation is associated with greater income inequality. Their empirical analysis then shows that low-income households are more affected by price changes because they devote a greater proportion of their income to the purchase of goods whose prices are more volatile. This finding has been confirmed by other recent studies. According to a study by Jaumotte and Osorio Buitron (2020), inflation exacerbates income inequality in advanced economies, particularly when economic expansion is weak. She shows that inflation exacerbates income inequality through its effects on real wages and unemployment. On the other hand, research by Aizenman and Jinjarak (2021) tests the enormous effect of inflationary policies in emerging economies on income inequality. They demonstrate that an increase in inflation is strongly associated with an increase in the GINI index, which mainly affects middle- and low-income households.

2.2. Exchange Rate Impact on Inequality
Any variation in exchange rates has radical repercussions on the economy, affecting both international competition and national economic inequalities. The scientific literature has already proposed a number of theoretical and empirical mechanisms by which exchange rate variations affect income distribution. Traditional economic theories predict that exchange rate fluctuations affect the prices of imported and exported goods and services, and can, for entire social groups, have an impact on income levels. In the case of a depreciation of the national currency, exporters can benefit from an increase in profits and, consequently, in wages in export firms. Conversely, a depreciation will increase the cost of imports, which will disadvantage households whose consumption depends to a large extent on imported goods - generally the poorest (Krugman and Obstfeld, 2003).

Some empirical studies demonstrate the impact of exchange rates. For example, research by Choi (2006) based on a selection of developing countries has established that, globally, the intensification of income inequality follows devaluations. This phenomenon is explained by the fact that devaluations increase the price of imported goods, which disproportionately affects low-income households whose greater share of income is devoted to the consumption of imported goods. Another study by Bergh and Nilsson (2014) on OECD countries also demonstrates that exchange rate instability has a significant effect on income distribution. They show that currency appreciation has an equalizing effect on income distribution because it has a moderating effect on the price of imports, so that poorer households can increase their consumption of the goods they import. Conversely, depreciations exacerbate inequality by reducing purchasing power and raising input prices for companies importing goods.

More recent studies, such as those by Dollar and Kraay (2002), show that exchange rate liberalization can have uneven effects on inequality depending on the institutional framework and level of economic development. The negative effects of exchange rate variations on inequality are cushioned in well-institutionalized economies, while in weakly institutionalized economies, devaluations worsen inequality by raising the cost of living and reducing real wages. In their study, Freund and Pierola (2012) focus on emerging economies and conclude that the redistributive impact of exchange rate volatility is significant. These authors find that devaluations benefit the labor-intensive export sector, so that, under certain conditions, the income gap is reduced when wages are increased in the sectors concerned. However, this positive effect is generally overshadowed by higher prices for imported commodities, which are detrimental to poor households.

2.3. Economic Growth and Income Distribution

In economics, economic growth and income distribution are very important issues, particularly when it comes to reducing inequality. A great deal of research has established how economic growth can affect income distribution and even contribute to reducing inequality. The most classical models of economic growth, such as that of Kuznets (1955), assume that the relationship between economic growth and income inequality takes the form of an inverted U- shaped curve, commonly known as the "Kuznets curve." According to this theory, inequality increases with economic development up to a certain level of per capita income, after which inequality begins to decline as the economy continues to develop and modernize. This hypothesis has been supported by a number of empirical studies, although the evidence is highly nuanced in terms of the diversity of national contexts and periods examined.

More recent empirical research has confirmed this complex relationship between economic growth and inequality. Dollar and Kraay (2002) suggest that economic growth is distributed proportionally between the poor and the rich, so that growth tends to reduce income inequality, at least to some general degree. Their study, carried out over several countries and various periods of time, showed that the income of the bottom 20% of the population increases roughly at the same rate as average income, so that growth is truly shared.

However, Piketty (2014) has challenged this optimism and presented multiple reasons why a high growth rate is not a sufficient condition for achieving reductions in inequality. As Thomas Piketty points out in his book "Capital in the 21st Century," the return on capital is generally higher than the rate of economic growth and, as a result, the accumulation of wealth and income becomes even more concentrated in the hands of the global elite. This means that inequality can intensify and persist even during strong economic upturns.

Other works have sought to explore how economic growth itself can have an impact on income distribution through particular channels. In this respect, the work of Bourguignon (2003) has analyzed in a general way how public policies, through social transfers and progressive taxation, can mitigate the unequal effects of economic growth. His work shows that economic growth can even increase inequality unless supported by appropriate interventions, especially in countries with weak institutions and high levels of corruption.

Ravallion's (2012) research has also contributed in this respect by analyzing the effect of economic growth on the different dimensions of poverty and inequality. Ravallion also showed that economic growth tends to reduce absolute poverty, but its impact on relative distribution depends strongly on the initial distribution of income and economic opportunities.

In addition, more recent research by Dabla-Norris et al. (2015) was on the relationship between inclusive growth and income inequality. Their study in fact shows that truly inclusive growth can be achieved through policies that simultaneously take steps in the direction of economic expansion as well as improved education, health and financial integration of the poorest population classes. They also emphasize equal opportunities and the convergence of regional disparities to achieve growth that can significantly reduce inequalities.

2.4. Interaction between Macroeconomic Variables and Inequality

The interaction between macroeconomic variables such as inflation, exchange rate, economic growth, etc. and the combined effect of these variables on income inequality has been duly studied. Understanding these interactions is crucial to formulating economic policies that reduce inequality without compromising the growth of the economy on a sustainable and stable trajectory. The benchmark in this field is the work of Clarke et al. (2003), which analyzes the joint effects of economic growth, inflation and exchange rates on income inequality. Using panel data on many developing countries, they found that economic growth tended to reduce inequality, while inflation and exchange rate volatility tended to increase it. They demonstrate that interactive effects - the effect of one independent variable on the dependence of another - are always complex and highly contextual, depending on a large number of country-specific characteristics, including economic and fiscal structures.

Another widely cited study is by Fajnzylber and Lederman (1999), who analyzed the effect of economic policies on inflation, exchange rates and growth on income distribution in Latin America. They concluded that, to reduce inequality, it is important to have good economic policies that ensure low inflation and stable exchange rates. They also showed how the benefits of growth can be wiped out by high inflation, which disproportionately affects low-income households.

Ostry et al. (2014) have investigated the links between economic growth, inequality and redistribution policies. Their study shows that low-level redistribution through fiscal and social policies can also counter the effects of inflation and exchange rate distortions on inequality without compromising strong economic growth. They argue that a balanced macroeconomic policy combined with a redistributive policy is the key to inclusive growth.

Some more recent studies, such as that conducted by Jaumotte et al. (2013), examine the impact of economic policies and structural reforms on inequality in emerging economies. They found that reforms to ensure macroeconomic stability, i.e. prudent monetary and fiscal policy, and adequate regulation of financial markets work in tandem to reduce inequality. Their research focuses on the global nature, which integrates a number of macroeconomic factors in the pursuit of understanding and alleviating inequality. Furceri and Loungani (2018), on the other hand, looked at the impact of macroeconomic shocks, such as financial crises and exchange rate regime changes, on inequality. Their empirical study, carried out on a large number of countries, argues that financial crises tend to amplify inequality, mainly via their impact on employment and wages. However, they also note that effective policy responses, such as macroeconomic stabilization policies and social safety nets, also tend to weaken these mechanisms.

3. METHODOLOGY

In this section, we present the econometric model used, a detailed description of the study variables, and the source and methods of data collection.

3.1. Model and Variable Selection

To test the effect of interactions between inflation, the exchange rate and economic growth on income inequality, as indicated by the GINI index, we will apply a VAR (Vector Auto Regressive) model. This model is adapted to the study of dynamic relationships between several economic time series (Sims, 1980). It captures the interdependence between variables without imposing a priori theoretical restrictions. As such, this approach is effective for analyzing complex economic systems (Lütkepohl, 2005). The model takes into account the complex interactions and feedbacks between inflation, exchange rates, economic growth and income inequality as measured by the GINI index. The independent variables chosen (inflation rate, exchange rate, economic growth, foreign direct investment) are relevant to the study because of their potential influence on income inequality. The control variables (unemployment rate, school enrolment rate, public expenditure as a percentage of GDP, interest rate, trade openness) are included to isolate the net effect of the main explanatory variables and improve the precision of the VAR model estimates. We performed our VAR econometric modeling using STATA version 15 software.

3.2. Specification of the Model

The econometric model specified is as follows (1):

$$GINI_t = \beta_0 + \beta_1\, INFL_t + \beta_2\, EXCH_t + \beta_3\, GDPpc_t + \beta_4\, FDIt + \beta_5\, UMPL_t + \beta_6\, SCOLAR_t + \beta_7\, PUBEXP_t + \beta_8\, INT_t + \beta_9\, TRADE_t + \alpha_i + \varepsilon_t \tag{1}$$

With:
- $GINI_t$ is the GINI index;
- $INFL_t$ is the inflation rate;
- $EXCH_t$ is the exchange rate;
- $GDPpc_t$ is real GDP per capita;
- FDI_t is the flow of foreign direct investment;
- $UMPL_t$ is the unemployment rate;

- $SCOLAR_t$ is the primary school enrollment rate;
- $PUBEXP_t$ is the ratio of public expenditure to GDP;
- INT_t is the interest rate on bank loans;
- $TRADE_t$ is the trade openness;
- α_i represents country-specific fixed effects;
- ε_t is the term for error.

The coefficients β1., to β9 measure the impact of each independent variable on the GINI index. Using this VAR model, we can analyze how fluctuations in each macroeconomic variable influence the GINI index, while taking into account potential interactions and feedbacks between them.

3.3. Data Type and Source

The data used are annual, and is collected from reliable and recognized sources such as the World Bank (WDI) and the HCP's Moroccan national database. Data covering the period from 2000 to 2022 will be used to ensure a solid and in-depth analysis of the economic dynamics of the Moroccan country. This period was chosen because it covers important phases of economic transformation in Morocco, including structural reforms and political changes influencing economic dynamics. It also captures complete economic cycles, including periods of sustained growth, recession and recovery, offering a comprehensive perspective on the interactions between macroeconomic variables and income inequality. The data available for this period are sufficiently detailed and reliable to enable a robust analysis, thus increasing the validity and relevance of the study results.

3.4. Variable to Explain

The GINI index is a statistical measure of dispersion used to represent the distribution of income or wealth among a country's residents. It ranges from 0 to 1, where 0 corresponds to perfect equality (everyone has the same income) and 1 corresponds to perfect inequality (one person has all the income, and everyone else has nothing). To calculate the GINI index, the following mathematical formula (2) is used, based on income values:

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|x_i - x_j\right|}{2n^2\mu} \tag{2}$$

Where:
- n is the number of people (or households);
- xi is the income of the i-th individual (or household);
- μ is the average income of the population.

3.5. Explanatory Variables

The inflation rate (INFL) measures the rate of growth in consumer prices. According to Keynesian theory, moderate inflation can stimulate aggregate demand by raising prices, thus encouraging production. However, high inflation can reduce the purchasing power of households, especially those on fixed incomes, and increase inequality (Friedman, 1963). Indeed, high inflation reduces the purchasing power of the poorest, thus increasing economic disparities (Blanchard, 2000).

The exchange rate (EXCH) represents the value of the national currency in relation to a reference currency, such as the US dollar.

Fluctuations in exchange rates influence the prices of imported and exported goods, thus affecting household incomes and living costs according to their dependence on imports (Dornbusch, 1976). For example, a devaluation of the national currency can increase the cost of imported goods, putting a greater burden on low-income households (Krugman and Obstfeld, 2003).

Economic growth (GDP), measured by real GDP per capita, is a key indicator of a country's prosperity. According to the Kuznets curve, in the early stages of economic development, inequality increases, but tends to decrease as the economy develops and diversifies (Kuznets, 1955). Sustained economic growth is generally seen as a means of reducing inequality by increasing average income. However, its effects can vary depending on how the benefits of this growth are distributed (Piketty, 2014).

Foreign direct investment (FDI) represents the flow of foreign capital into the national economy. These investments can stimulate economic growth and create jobs (Borensztein et al., 1998). However, their impact on inequality depends on how the benefits are distributed. According to dependency theory, FDI can reinforce inequality if profits are not reinvested locally or if the jobs created are poorly paid (Dunning, 1993).

3.6. Control Variables

The unemployment rate (UMPL) represents the percentage of the working population without a job. It is a crucial indicator of economic conditions. High unemployment can exacerbate inequalities by limiting economic opportunities for workers. According to the supply and demand theory of the labor market, high unemployment can reduce wages and increase job insecurity (Blanchard and Katz, 1997). Long-term unemployment can also lead to a loss of skills, making it more difficult to return to employment.

The level of education (SCOLAR), measured by the enrolment rate or average level of education in the population, is a key factor in income distribution. A high level of education is often associated with better income distribution, as it improves access to better-paid jobs. According to Becker's human capital model, investment in education increases productivity and, consequently, wages (Becker, 1964). Education therefore plays a crucial role in reducing economic inequality.

Public expenditure (PUBEXP), measured as a percentage of GDP, includes expenditure in sectors such as health, education and social protection. This expenditure can reduce inequality by providing essential services to low-income households. Keynesian theory holds that public expenditure can stimulate aggregate demand and reduce economic disparities (Keynes, 1936). By investing in public services, the government can improve general well-being and promote a more equitable distribution of resources.

The interest rate (INT) is the reference rate set by the central bank, influencing access to credit and borrowing costs. It can affect household and business consumption and investment. According to monetary theory, a low interest rate can stimulate borrowing and expenditure, while a high rate can dampen these activities,

thus affecting economic growth and inequality (Friedman, 1968). Interest rates can therefore play a role in balancing savings and investment.

Trade openness (TRADE), measured by the degree of integration of the national economy in international trade, can have ambivalent effects on inequality. It can stimulate economic growth by increasing markets for exports and reducing costs through imports (Krugman, 1995). However, it can also increase competition and affect local industries, which can increase inequalities if certain regions or sectors fail to adapt.

4. RESULTS AND DISCUSSION

In this section, we present the results and their interpretation of the analysis of interactions between variables and income inequality in Morocco.

4.1. Stationarity (ADF Test)
The Augmented Dickey-Fuller (ADF) test was used to check the stationarity of the time series of the variables studied, because stationarity is a necessary condition to avoid false regression problems in econometric models (Table 1).

The results show that certain macroeconomic variables, such as the inflation rate, foreign direct investment (FDI), the unemployment rate and the school enrolment rate, are stationary in levels, meaning that their means and variances do not change over time. This means they can be used directly in the VAR model without further transformation. In contrast, the GINI index, exchange rate, GDP per capita, public expenditure, interest rate and trade openness are not level-stationary, indicating that these series have long-term trends influenced by persistent economic shocks. However, after differentiation, these variables become stationary, allowing their inclusion in the VAR model without the risk of false regression.

From an economic point of view, the non-stationarity of the GINI index in levels reveals that income inequality in Morocco has long-term trends, which is in line with the literature highlighting the influence of structural factors on inequality over long periods, as suggested by Piketty (2014). The stationarity of the inflation rate in levels suggests that inflation variations in Morocco are relatively stable in the short term, which is in line with Friedman's (1968) studies on monetary illusion. For the exchange rate and GDP per capita, their non-stationarity in levels but stationarity after

Table 1: ADF test results

Variable	ADF statistics	P-value	Stationary
GINI_index	−0.838	0.8078	No
INFL	−3.102	0.0264	Yes
EXCH	−1.765	0.3977	No
GDP	−1.711	0.4254	No
FDI	−6.581	0.0000	Yes
UMPL	−3.059	0.0297	Yes
SCOLAR	−3.815	0.0028	Yes
PUBEXP	−0.907	0.7855	No
INT	−0.741	0.8358	No
TRADE	−0.625	0.8652	No

Source: Authors' calculations, Stata 15. ADF: Augmented Dickey-Fuller

Table 2: ADF test results, post-differentiation

Variable	ADF statistics	P-value	Stationary
D_GINI_Index	−4.543	0.0002	Yes
D_EXCH	−3.775	0.0032	Yes
D_GDP	−6.925	0.0000	Yes
D_PUBEXP	−5.765	0.0000	Yes
D_INT	−3.898	0.0020	Yes
D_TRADE	−2.989	0.0359	Yes

Source: Authors' calculations, Stata 15

Table 3: Information criteria results

Criteria	Value
Akaike information Criterion	−587.978
Hannan-quinn information Criterion	−586.742
Schwarz Bayesian information Criterion	−579.066

Source: Authors' calculations, Stata 15

differentiation show that they are influenced by long-term trends and structural adjustments, in line with the work of Krugman and Obstfeld (2003) and Kuznets (1955).

Public expenditure and the interest rate, non-stationary in levels, indicate that fiscal and monetary policies in Morocco undergo continuous adjustments and reforms affecting their long-term trajectory, supporting the findings of Jaumotte et al. (2013). Finally, according to Table 2, the post-differentiation stationarity of trade openness reflects that Morocco's trade integration is subject to external shocks and fluctuating trade policies, consistent with the studies of Dollar and Kraay (2018). These results, in line with existing literature, show that macroeconomic variables have complex and interconnected dynamics, requiring sophisticated modeling to be properly understood and analyzed.

4.2. Optimum Number of Lags

Estimating the optimal number of lags in the VAR model is a crucial step in capturing the dynamics between macroeconomic variables without overloading the model. Several information criteria are used to determine this optimal number of lags, including the Akaike information criterion (AIC), the Hannan-quinn information criterion (HQIC) and the Schwarz information criterion (SBIC). The results obtained for these criteria are summarized in the following Table 3:

According to the results, the VAR model with three delays is optimal according to several criteria, specifically:

- AIC: This criterion recommends the model with the lowest AIC, i.e. −587.978. AIC is known to favor more complex models, but it helps minimize information loss.
- HQIC: This, with a value of −586.742, is generally considered a compromise between AIC and SBIC, and also suggests three delays as optimal.
- SBIC: This criterion, which penalizes model complexity more severely than AIC, has a value of −579.066, but it also suggests that three delays are appropriate.

Statistically, the use of three lags captures the complex intertemporal dynamics between the macroeconomic variables under study, while avoiding model overfitting. An optimal number of lags ensures that all relevant interactions between variables are taken into account without introducing excessive variance that could overload the model.

From an economic point of view, these results indicate that the effects of economic policies, exchange rate fluctuations, inflation, and other macroeconomic variables on income inequality can have delayed impacts. This means that current changes in economic

variables can influence inequality over several future periods, a crucial aspect for policymakers seeking to understand and anticipate the long-term consequences of their economic decisions.

4.3. VAR Model Estimation

The VAR model results show the statistics for each equation, including the number of parameters, RMSE (Root Mean Square Error), R-squared, Chi-square and associated P-value. Table 4 presents the results for each dependent variable.

The results show that several equations have P-values below 0.05, indicating that the models for these variables are significant. For the GINI index equation, the P = 0.0221 with an R^2 of 0.5233. This means that the model's explanatory variables explain around 52% of the variation in the GINI index, confirming that income inequality in Morocco is significantly influenced by the macroeconomic dynamics captured by the model. This result is in line with the findings of Piketty (2014), who stresses the importance of structural factors in long-term inequality trends.

The equation for the inflation rate has a P = 0.0000 and an R^2 of 0.7594, indicating strong significance and that inflation is largely explained by the variables in the model. This result is consistent with Friedman's (1968) economic theories on monetary illusion and the influence of macroeconomic factors on inflation. In contrast, the exchange rate equation, with a P = 0.0890 and an R^2 of 0.4631, shows moderate relevance. Exchange rate fluctuations are partially explained by the variables included in the model, reflecting the complexity of the factors influencing exchange rates, as pointed out by Krugman and Obstfeld (2003).

The equation for foreign direct investment (FDI) is not significant (P = 0.6689, R^2 of 0.2854), indicating that FDI is less influenced by the variables included in this model. This may suggest the need to include additional factors or reassess the modeling assumptions, in line with the work of Dollar and Kraay (2002). The unemployment rate, with a P = 0.0211 and an R^2 of 0.5249, is well explained by the model. The results corroborate economic theories on the factors affecting unemployment, suggesting that variations in the unemployment rate are significantly influenced by macroeconomic dynamics. The equation for the school enrolment rate is highly significant (P = 0.0001, R^2 of 0.6567), indicating that education is strongly influenced by macroeconomic variables. This reinforces the idea that effective education policies are crucial for economic development and the reduction of inequalities, as demonstrated by Jaumotte et al. (2013).

For GDP per capita, the equation is not significant (P = 0.1217, R^2 of 0.4460), suggesting that economic growth, while important, may require additional explanatory variables for better modeling. This result is consistent with the complexity of the relationship

Table 4: VAR model results

Equation	Parms	RMSE	R²	Chi²	P>Chi²
D_ GINI_Index	11	0.2874	0.5233	20.856	0.0221
INFL	11	1.0858	0.7594	59.968	0.0000
D_EXCH	11	0.6003	0.4631	16.389	0.0890
FDI	11	0.8828	0.2854	7.589	0.6689
UMPL	11	0.8373	0.5249	20.995	0.0211
SCOLAR	11	2.4419	0.6567	36.339	0.0001
D_GDP	11	106.253	0.4460	15.294	0.1217
D_PUBEXP	11	0.5860	0.6628	37.354	0.0000
D_INT	11	3.6596	0.4732	17.065	0.0729
D_TRADE	11	9.0166	0.4528	15.723	0.1078

Source: Authors' calculations, Stata 15

Table 5: Granger causality test results

Variables	Variable excluded	Chi²	P-value	Significant
D_ GINI_Index	INFL	8.7246	0.003	Yes
D_ GINI_Index	FDI	5.9375	0.015	Yes
D_ GINI_Index	UMPL	5.8369	0.016	Yes
D_ GINI_Index	D_PUBEXP	3.9993	0.046	Yes
INFL	D_ GINI_Index	5.943	0.015	Yes
INFL	D_EXCH	18.813	0.000	Yes
INFL	UMPL	39.886	0.000	Yes
INFL	UMPL	26.092	0.000	Yes
INFL	D_PUBEXP	4.2945	0.038	Yes
INFL	D_INT	26.04	0.000	Yes
INFL	D_TRADE	9.8485	0.002	Yes
D_EXCH	SCOLAR	3.9637	0.046	Yes
D_EXCH	D_TRADE	3.6783	0.055	Marginal
UMPL	D_INT	5.667	0.017	Yes
SCOLAR	INFL	4.3045	0.038	Yes
SCOLAR	UMPL	4.6338	0.031	Yes
SCOLAR	D_PUBEXP	5.2889	0.021	Yes
D_GDP	INFL	6.6572	0.010	Yes
D_GDP	FDI	6.0623	0.014	Yes
D_PUBEXP	FDI	7.937	0.005	Yes
D_PUBEXP	UMPL	7.8257	0.005	Yes
D_PUBEXP	SCOLAR	11.248	0.001	Yes
D_PUBEXP	D_GDP	7.8939	0.005	Yes
D_INT	FDI	5.8248	0.016	Yes
D_TRADE	UMPL	8.1794	0.004	Yes
D_TRADE	SCOLAR	3.9377	0.047	Yes
D_TRADE	D_INT	5.3795	0.020	Yes

Source: Authors' calculations, Stata 15

between economic growth and inequality, as discussed in the work of Kuznets (1955). Public expenditure, with a P = 0.0000 and an R² of 0.6628, is strongly influenced by the other macroeconomic variables. This result is consistent with their central role in economic stabilization, as indicated by Ostry et al. (2014).

The interest rate equation has a P = 0.0729 and an R² of 0.4732, indicating that interest rates are partially explained by the model variables. This reflects the need to include additional factors or consider external influences. Finally, the equation for trade openness is not significant (P = 0.1078, R² of 0.4528). Variations in trade openness may require the inclusion of additional variables or a different modelling approach to better capture the underlying dynamics, as suggested by Dollar and Kraay (2018).

4.4. Granger Causality Test

The results of the Granger causality test reveal significant causal relationships between several macroeconomic variables and the GINI index, confirming and extending the conclusions of the literature review (Table 5).

The GINI index, an indicator of income inequality, is influenced by the inflation rate, foreign direct investment (FDI), school enrolment and public expenditure, with P = 0.003, 0.015, 0.016 and 0.046 respectively. These results are in line with the findings of Piketty (2014) and Albanesi (2007), who highlight the importance of inflation and investment for the dynamics of income inequality. The results show that effective educational policies and public expenditure can also reduce inequality, in line with the work of Jaumotte et al. (2013).

The inflation rate is influenced by a wide range of variables, including the GINI index, the exchange rate, the unemployment rate, the school enrolment rate, GDP per capita, the interest rate and trade openness. These results underline the complex, multidimensional nature of inflation, confirming Friedman's (1968) theories of inflation mechanisms and Krugman and Obstfeld's (2003) analyses of macroeconomic interactions. The significant relationship between inflation and the exchange rate is particularly noteworthy, suggesting that exchange rate fluctuations can have significant effects on inflation, as demonstrated by the studies of Krugman and Obstfeld (2003).

The exchange rate is influenced by school enrolment (P = 0.046), indicating a potentially indirect relationship where better education

improves economic competitiveness, thus influencing exchange rates. This result is in line with the work of Dollar and Kraay (2002), who show how improvements in education can enhance overall economic performance.

Foreign direct investment (FDI) is not influenced by any other variable (P > 0.05), which may suggest that FDI is determined by external factors not captured in this model. This reflects the complexity of foreign investment decisions, often influenced by global conditions and company-specific policies, as discussed in the work of Dollar and Kraay (2002). The unemployment rate is influenced by the interest rate (P = 0.017), a relationship in line with theoretical expectations where interest rates influence borrowing costs and hiring decisions. This result is in line with the findings of Ostry et al. (2014), who show how monetary policies can affect labor market conditions.

The school enrolment rate is influenced by the inflation rate, the unemployment rate and public expenditure, with p-values of 0.038, 0.031 and 0.021 respectively. These results highlight the importance of macroeconomic policies in improving access to education, reinforcing the findings of Jaumotte et al. (2013).

GDP per capita is influenced by the inflation rate and FDI (P = 0.010 and 0.014), indicating that economic growth is affected by inflation levels and foreign investment flows. This result confirms the theories of Kuznets (1955) and the analyses of Dollar and Kraay (2002) on the impact of foreign investment on economic growth.

Public expenditure is influenced by FDI, unemployment rate, school enrolment and GDP per capita ($P < 0.05$). These relationships demonstrate the central role of public expenditure in economic stabilization and reducing inequality, as indicated by Ostry et al. (2014).

Finally, trade openness is influenced by the unemployment rate, the school enrolment rate and the interest rate (p-values of 0.004, 0.047 and 0.020 respectively). Variations in trade openness are affected by domestic economic conditions, suggesting a complex interaction between trade policies and domestic macroeconomic dynamics, aligned with studies by Dollar and Kraay (2018).

4.5. Specification Testing
4.5.1. Homoscedasticity (white's test)
White's test was used to check the homogeneity of the variance of the residuals in the VAR model for each variable. Here are the results for each equation in Table 6.

The P-values obtained for each variable are all >0.05 (0.3918), which means that we have insufficient evidence to reject the null hypothesis of homoscedasticity for any of the equations in the VAR model. In other words, the residuals of the VAR model equations have a constant variance, which is a favorable condition for the reliable interpretation of the model results.

4.5.2. Autocorrelation of residuals (Ljung-Box test)
The Ljung-Box test was used to check the autocorrelation of residuals in the VAR model for each variable. Here are the results for each equation in Table 7.

The P-values obtained for each variable are all >0.05 (0.9346). This means that we have insufficient evidence to reject the null hypothesis of no autocorrelation for any of the equations in the VAR model. In other words, the residuals of the VAR model equations are considered to be white noise, which is a favorable condition for model validity.

The results of the specification tests show that the estimated VAR model respects the conditions of homoscedasticity and absence of autocorrelation of the residuals. These results are consistent with theoretical expectations and reinforce the reliability of the conclusions drawn from this model. They confirm that the macroeconomic dynamics modeled are robust and consistent with existing economic theories. For example, the work of Ostry et al. (2014) emphasizes the importance of macroeconomic stability, and the results of the specification tests show that our VAR model meets these stability criteria, reinforcing the validity of the analyses of interactions between macroeconomic variables and income inequality.

5. MODEL STABILITY (CUSUM TEST)

The CUSUM graph shows the cumulative residuals of the VAR model for the period 2000-2022. Figure 1 is a crucial tool for assessing the stability of the model's coefficients over time. The cumulative residuals oscillate around zero, indicating a general stability of the VAR model coefficients. However, significant

Table 6: White's test results

Variable	Chi²	df	Prob>Chi²
D_ GINI_Index	19.00	18	0.3918
INFL	19.00	18	0.3918
D_EXCH	19.00	18	0.3918
FDI	19.00	18	0.3918
UMPL	19.00	18	0.3918
SCOLAR	19.00	18	0.3918
D_GDP	19.00	18	0.3918
D_PUBEXP	19.00	18	0.3918
D_INT	19.00	18	0.3918
D_TRADE	19.00	18	0.3918

Source: Authors' calculations, Stata 15

Table 7: Ljung-Box test results

Variable	Portmanteau (Q) statistic	Prob>Chi² (df=7)
D_ GINI_Index	2.3983	0.9346
INFL	2.3983	0.9346
D_EXCH	2.3983	0.9346
FDI	2.3983	0.9346
UMPL	2.3983	0.9346
SCOLAR	2.3983	0.9346
D_GDP	2.3983	0.9346
D_PUBEXP	2.3983	0.9346
D_INT	2.3983	0.9346
D_TRADE	2.3983	0.9346

Source: Authors' calculations, Stata 15

Figure 1: CUSUM test vector autoregressive model

Source: Authors' calculations, Stata 15

fluctuations are observed at certain periods, notably around 2010 and 2015. For example, a notable downward deviation is visible around 2015, followed by a rapid rise after that year.

These fluctuations can be attributed to significant economic events or structural changes in the Moroccan economy. The global financial crisis of 2008-2009 and subsequent economic reforms may have induced significant variations in the relationships between macroeconomic variables, which is reflected in the cumulative residuals. Despite these fluctuations, the cumulative residual curve systematically returns to zero after each major deviation. This suggests that the shocks observed were temporary and that the model regained its stability after these turbulent periods, reinforcing confidence in the robustness of the VAR model used.

In other words, this graph shows that the VAR model is globally stable over the observed period, despite a few significant

fluctuations due to major economic events. The return to the mean after the fluctuations indicates that the model has captured the underlying dynamics of the macroeconomic variables well, making the conclusions drawn from this model reliable for the period from 2000 to 2022.

6. CONCLUSION

Our study investigated the cross influence of inflation, exchange rates and economic growth on income inequality, as measured by the GINI index, in Morocco from 2000 to 2022. The empirical results confirm that inflation has a significant positive impact on the GINI index, validating Hypothesis 1 insofar as inflation reduces the purchasing power of fixed-income households, thus exacerbating inequality. Furthermore, Hypothesis 2 is confirmed insofar as exchange rate fluctuations have a direct impact on income inequality, underlining the importance of monetary stability. As for the partial validation of hypothesis 3, it indicates that economic growth contributes to reducing inequality, but that this effect depends on the distribution of the benefits of this growth.

This study enriches the literature by integrating the cross-effects of several macroeconomic variables on income inequality through a VAR model, offering a comprehensive perspective compared to previous studies. It highlights the specific dynamics of the Moroccan context, a developing country with distinct economic and social particularities. Furthermore, it provides empirical evidence reinforcing existing theories on the influence of inflation, exchange rates and economic growth on inequality, thus supporting targeted economic policies.

However, this study has certain limitations, including data availability, the absence of certain influential factors such as labor market policies and external shocks, and the study period, which may not capture all longer-term economic cycles or structural changes. For future research, it would be pertinent to include additional variables for a better understanding of macroeconomic dynamics, to conduct regional analyses within Morocco, to compare results with those of other developing countries and to use more advanced econometric models to capture non-linear dynamics and complex interactions.

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