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Inflation shocks and income inequality

An analysis with genetic algorithms and Bayesian quantile regressions

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Abstract

Purpose – The purpose of this paper is to analyze the effects of inflationary shocks on inequality, using data of selected countries of the Middle East and North Africa (MENA).

Design/methodology/approach – Inflationary shocks were measured as deviations from core inflation, based on a genetic algorithm. Bayesian quantile regression was used to estimate the impact of inflationary shocks in different levels of inequality.

Findings – The results showed that inflationary shocks substantially affect countries with higher levels of inequality, thus suggesting that the detrimental impact of inflation is exacerbated by the high division of classes in a country.

Originality/value – The study contributes to the literature about the relationship between inflation and inequality by proposing that not only the sustained increase in prices but also the inflationary shocks – the deviations from core inflation – contribute to the generation of inequality. Also, to the best of the authors knowledge, the relationship between inflation shocks and inequality in the MENA region has never been analyzed before, thus creating a research gap to provide additional empirical evidence about the sources of inequality. Additionally, the authors contribute with a methodological approach to measure inflationary shocks, based on a semelparous genetic algorithm.

Keywords Bayesian methods, MENA region, Inflation and inequality

Paper type Research paper

1. Introduction

The relationship between inequality and inflationary shocks in 11 countries of the Middle East and North Africa (MENA) region was analyzed in order to evaluate if the short-term deviations from core inflation affect income redistribution. The MENA countries were selected for the analysis because the class division in these countries may cause a differential impact of inflationary shocks on purchasing power. Also, in the MENA region, inequality influences poverty and creates social conflicts that lead to revolts, political instability and situations of humanitarian crises[1]; thus, it is relevant to understand the mechanisms that increase inequality in order to reduce violence and guarantee the well-being of millions of persons inhabiting the region.

From an academic point of view, this study contributes to the literature about the relationship between inflation and inequality by proposing that not only the sustained increase in prices but also the inflationary shocks – the deviations from core inflation – contribute to the generation of inequality.

JEL Classification — C11, C21, E31, O57

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Also, to our knowledge, the relationship between inflation shocks and inequality in the MENA region has never been analyzed before, thus creating a research gap to provide additional empirical evidence about the sources of inequality[2]. From a methodological point of view, we also propose a new way of extracting inflationary shocks based on a biologically inspired algorithm of artificial intelligence. Our methodology is based on assessing the effect of inflation shocks on inequality throughout the conditional distribution of inequality.

The results of this study suggest that, besides inflation, deviations from core inflation also affect inequality in the MENA region. Moreover, the deviations from core inflation are only relevant for countries in an extreme situation of inequality. Thus, inflationary shocks are exacerbated by the class-gap created by the ruling elites/family clans that concentrate the economic and/or the political power in developing countries.

The rest of the paper is organized as follows: Section 2 makes a brief review of the relevant literature for the study, Section 3 explains the methods used in the study, Section 4 presents the results and Section 5 concludes the paper.

2. Literature review and hypothesis

The literature relates the generation and deepening of inequality in the MENA region to power relations and the social implications of reforms[3]. Besides these factors, and interlinked with state policies, inflation and inflationary shocks may be also increasing inequality in the MENA region.

2.1 Class relations

According to Wright (1985), class is the main mechanism that determines how resources are distributed and appropriated. In the MENA region, the global class position and the class structure of the ruling elites may be playing a role increasing inequality in each country, because – in line with Marx's and Engel's approach – in the MENA region the ruling classes with economic and political power are aware of their common interests and have the organizational means to promote them. Commander (2017) noted for example that in MENA countries autocrats' control over the public sector allow them to confer employment and patronage over lucrative commercial and financial activities, in benefit of their stalwarts and their families. Kaphahn and Brennan (2017) added that corruption and strict regulation impeded the participation of ordinary citizens in the market, and thus state-led privatization privileged a small elite, contributing to create more inequality. Reforms in the region, for Commander (2017), only favor a relatively narrow elite of cronies and family relations due to the very limited numbers of individuals or companies in control of considerable and valuable assets.

Besides economic motivations, family relationships in the groups of power may also be playing a role in the mechanisms of inequality in the MENA region. This is more in line with Weber's view of status groups rooted in family experience, because while classes without organization lack of achievements, families in the same status-situation need not communicate and organize in order to discriminate against other people, see Bendix (1974). Malik and Awadallah (2013) noted for example that in Gulf economies, boards of listed companies are dominated by a few influential families, and the local capitalist class (Khaleeji) is deeply intertwined with the very process of state and class formation. For Malik and Awadallah (2013), the centralized bureaucratic system of control, discretion and privilege in the state worked well for ruling elites, but failed to deliver prosperity and social justice to ordinary citizens. Thus, the benefits of social development were not equally distributed in the region – as Karshenas *et al.* (2014) noted, even in the self-declared socialist states of Egypt, Syria of Iraq, vast sections of the population in the rural areas and the urban informal sectors were excluded from the process of economic development.

2.2 Inflation and inequality

In the case of inflation, this variable has been previously linked to inequality in theoretical and empirical studies. Theoretically, price stability can have an asymmetric incidence of the inflation tax when wealth is unevenly distributed and the portfolio composition of poorer households is skewed toward a larger share of money holdings, because the inflation tax burden would disproportionately fall on the poor (Menna and Tirelli, 2017). Empirically, based on cross-country studies, Al-Marhubi (1997) found *inter alia* that countries with higher average inflation have higher inequality, and Li and Zou (2002) found that inflation worsens income distribution as it increases the income share of the rich. Using data of Brazil from 1982 to 1990 – a period of high inflation rates – Cardoso *et al.* (1995) found that inflation makes inequality wider, pushing the middle income groups into poverty. For Cardoso *et al.* (1995), this result is caused by the loss of value of money, that has a different impact on the rich compared to the poor, as the smooth of consumption it is difficult for people with less resources. Easterly and Fischer (2001) further found that inflation reduces the shares of income that belong to the lowest quintile of the income distribution, thus reducing real minimum wages and increasing poverty. This effect can be enhanced by the differences on the consumption patterns of the population across income groups; see *inter alia* Son and Kakwani (2006).

Based on the previous arguments, the hypothesis of this study is that the social conditions of the MENA region created a context where inflationary shocks disproportionately affect the dominated class in comparison of the ruling class with economic or political power. This re-distributive effect of inflation has been denominated the Cantillon effect (Sieron, 2017) and is related to the fact that inflationary shocks will unevenly impact the class/group of lower income that does not have access to spaces of power or public enterprises of the state.

3. Methods

The study used genetic algorithms and Bayesian quantile regression to evaluate if inflationary shocks have a differential impact on different levels of inequality in the MENA countries. The inflationary shocks were estimated as deviations from core inflation, which was calculated with a semelparous genetic algorithm. Bayesian quantile regressions were used to estimate the impact of inflationary shocks in different income categories. This section describes these methods.

3.1 Bayesian quantile regression

Let y_i be the inequality of each i-country in the selected sample of the MENA region ($i = 1, \ldots, n$), measured by the Gini coefficient, and let $\mathbf{X}_i$ be a $k \times 1$ vector with k-potential explanatory variables of y_i, which includes inflationary shocks. If $q_p(\mathbf{X}_i)$ denotes the pth ($0 < p < 1$) quantile regression function of y_i given $\mathbf{X}_i$, the relationship between $q_p(\mathbf{X}_i)$ and $\mathbf{X}_i$ can be modeled as $q_p(\mathbf{X}_i) = \mathbf{X}_i'\beta_p$, where β_p is a vector of unknown parameters of interest that measure the effect of $\mathbf{X}_i$ on y_i.

The quantile regression model is given by $y_i = \mathbf{X}_i'\beta_p + \epsilon_i$, where ϵ_i is the error term whose distribution (with density $f_p(\cdot)$) is restricted to have the pth quantile equal to zero, that is: $\int_{-\infty}^{0} f_p(\epsilon_i)d\epsilon_i = p$.

Quantile regression estimation for β_p proceeds by minimizing:

$$\sum_{i=1}^{n} \rho_p\left(y_i - \mathbf{X}_i'\beta_p\right), \tag{1}$$

with $\rho_p(\cdot)$ the loss function:

$$\rho_p(u) = u\left\{p - I(u < 0)\right\}, \tag{2}$$

and $I(\cdot)$ the indicator function. The idea of quantile regression was introduced by Koenker and Bassett (1978) and can be reformulated as a linear program to obtain classical estimates by using the following equation (Koenker, 2005):

$$\min_{(u,v,\beta)\,\in\,\mathbb{R}^p\times\mathbb{R}^{2n}_{+}} \{p1'_n u+(1-p)1'_n v \,|\, \mathbf{X}'_i\beta_p+u-v=y\}, \tag{3}$$

where $\{u, v: 1, \ldots, n\}$ are $2n$ artificial (slack) variables that represent the positive and negative parts of the vector of residuals. This approach was used by Asongu and Nwachukwu (2017), who – based on the conditional distribution of inequality and adjusting for human development – found that inflation reduces inequality. Besides the previous approach, the generalized method of moments (GMM) was also used by Meniago and Asongu (2018) to measure the impact of inflation on inequality. In this study, a Bayesian approach was used to estimate the quantile regressions instead of the classical approach of Koenker (2005) or the GMM approach of Meniago and Asongu (2018).

The Bayesian approach was adopted in order to explicitly take into account the uncertainty about inequality and inflation in the MENA region: Commander (2017) indicated that due to a lack of transparency, inequality may be higher than reported in this region, and Ianchovichina *et al.* (2014) highlighted that in MENA countries inequality measures are based on household surveys that suffer from several well-known shortcomings as, e.g. survey respondents that under-report expenditures or deliberately leave out income from illegal or informal activities. Also, according to Ianchovichina *et al.* (2014), household surveys in MENA countries only include a few individuals at the very top of the income distribution, which limits accurately capturing the top 1 percent population that is crucial to estimating inequality. In relation to inflation, in MENA countries this variable can be underestimated if there is a deterioration of the quality of the products in the reference basket or if the mix of goods and services is not updated to reflect changes in preferences (Ianchovichina *et al.*, 2014). Due to these two sources of imprecision in the measures of inequality and inflation, it is necessary to use methods that properly take into account the uncertainty during the estimation of parameters, i.e. Bayesian methods.

In the Bayesian approach to quantile regression, minimizing $\sum_{i=1}^{n}\rho_p\left(y_i-\mathbf{X}'_i\beta_p\right)$ is equivalent to maximizing a likelihood function under the asymmetric Laplace error distribution. A random variable $\mathcal{U}$ is said to follow the asymmetric Laplace distribution if its probability density is given by:

$$f_p(u)=p(1-p)\exp\left(-\rho_p(u)\right). \tag{4}$$

Based on the observations of $\boldsymbol{y}$, the posterior distribution of the parameters of interest β_p will be given by Bayes theorem:

$$\pi\left(\beta_p|y\right)=\mathscr{L}\left(y|\beta_p\right)\pi\left(\beta_p\right), \tag{5}$$

where $\pi(\beta_p)$ is the prior distribution of β_p and $\mathscr{L}(y|\beta_p)$ is the likelihood function, which is based on the asymmetric Laplace distribution (Yu and Moyeed, 2001):

$$\mathscr{L}\left(y|\beta_p\right)=p^n(1-p^n)\exp\left(-\sum_i\rho_p\left(y_i-\mathbf{X}'_i\beta_p\right)\right). \tag{6}$$

Markov Chain Monte Carlo (MCMC) methods can be used to estimate β_p, in the form of a Gibbs sampling algorithm with a location-scale mixture representation of the asymmetric Laplace distribution. Let the linear model be given by $y_i=\mathbf{X}'_i\beta_p+\epsilon_i, (i=1,\ldots,n)$, if ϵ_i follows the asymmetric Laplace distribution with density:

$$f_p(\epsilon_i)=p(1-p)\exp-\rho_p(\epsilon_i), \tag{7}$$

then p will determine the skewness of distribution, and the pth quantile of this distribution is zero. A Gibbs sampling algorithm for the quantile regression model will be based on a mixture representation of the asymmetric Laplace distribution (i.e. a mixture of exponential and normal distributions): Let z be an standard exponential variable and u a standard normal variable. If a random variable ϵ follows the asymmetric Laplace distribution, ϵ can be represented as a location-scale mixture of normals given by:

$$\epsilon = \theta z + \tau\sqrt{z}u, \tag{8}$$

where:

$$\theta = \frac{1-2p}{p(1-p)} \quad \text{and} \quad \tau^2 = \frac{1}{p(1-p)}, \tag{9}$$

and the response y_i can be equivalently rewritten as (Kozumi and Kobayashi, 2011):

$$y_i = \mathbf{X}_i'\beta_p + \theta z_i + \tau\sqrt{z_i}u_i, \tag{10}$$

for $z_i \sim \mathcal{E}(1)$ and $u_i \sim \mathcal{N}(0,1)$ mutually independent and $\mathcal{E}(\cdot)$ and exponential distribution with mean equal to 1. As the conditional distribution of y_i given z_i is normal with mean $\mathbf{X}_i'\beta_p + \theta z_i$ and variance $\tau^2 z_i$, the joint density of $y = (y_1, \ldots, y_n)'$ is given by:

$$f(y|\beta_p, z) \propto \left(\prod_{i=1}^{n} z_i^{-1/2}\right)\exp\left\{-\sum_{i=1}^{n}\frac{\left(y_i - \mathbf{X}_i'\beta_p - \theta z_i\right)^2}{2\tau^2 z_i}\right\}, \tag{11}$$

for $\mathbf{z} = (z_1, \ldots, z_n)'$.

To proceed to a Bayesian analysis, the prior is defined by $\beta_p \sim \mathcal{N}\left(\beta_{p0}, \mathbf{B}_{p0}\right)$, where β_{p0} and $\mathbf{B}_{p0}$ are the prior mean and covariance of β_p, respectively. A Gibbs sampling algorithm for the quantile regression model is then constructed by sampling β_p and $\mathbf{z}$ from their full conditional distributions; the full conditional density of β_p is given by:

$$\beta_p|y, z \sim \mathcal{N}\left(\hat{\beta}_p, \hat{\mathbf{B}}_p,\right) \tag{12}$$

where:

$$\hat{\mathbf{B}}_p^{-1} = \sum_{i=1}^{n}\frac{\mathbf{X}_i\mathbf{X}_i'}{\tau^2 z_i} + \mathbf{B}_{p0}^{-1}, \tag{13}$$

and

$$\hat{\beta}_p = \hat{\mathbf{B}}_p\left\{\sum_{i=1}^{n}\frac{\mathbf{X}_i(y_i - \theta z_i)}{\tau^2 z_i} + \mathbf{B}_{p0}^{-1}\beta_{p0}\right\}, \tag{14}$$

where $\hat{\beta}_p$ will measure the impact of inflationary shocks and other control covariates on income inequality.

3.2 Semelparous genetic algorithm

Inflationary shocks are defined as the difference between observed inflation and core inflation, being core inflation an unobserved medium-to-long-term trend in prices. In this study, a Semelparous Genetic Algorithm was used to estimate core inflation and the inflation shocks: let $\{x_t\}_{t=1}^{T}$ be the time series of the consumer price index, π a vector with the time series of inflation $\{\pi_t\}_{t=1}^{T}$ calculated through $\pi_t = \Delta\log(x_t)$, $\mathbf{t}$ a trend vector, and $\omega_x(\lambda_s)$

the discrete Fourier transform (d.f.t) of π_t on the frequency band $\lambda_s \in [\lambda^a, \lambda^b]$. A semelparous genetic algorithm can be used to construct a spectral measure of core inflation, with core inflation π^c equal to $\pi^c = \pi - \tilde{\pi}$, being $\tilde{\pi}$ a vector of deviations (shocks) in prices. A spectral estimator of $\tilde{\pi}$ is:

$$\hat{\tilde{\pi}} = \pi_\omega - \pi_\omega \left[\left(\mathbf{t}'_\omega \mathbf{t}_\omega \right)^{-1} \mathbf{t}'_\omega \pi_\omega \right], \tag{15}$$

where $\pi_\omega \in \mathbb{R}$ and $\mathbf{t}_\omega \in \mathbb{R}$ come from the inverse d.f.t. of $\omega^{-1}_{pi^r, pi^i}(\lambda_s)$ and $\omega^{-1}_{\mathbf{t}^r, \mathbf{t}^i}(\lambda_s)$. This estimator was suggested by Corbae *et al.* (2002).

The estimator $\hat{\tilde{\pi}}$ properly isolates the low-frequency shocks in inflation when the frequency band $\lambda_s \in \{\lambda^a, \lambda^b\}$ maximizes the signal-to-noise ratio $\eth_x$, with μ the average of the core inflation signal and σ^2 the mean squared error of the statistical fluctuation around μ, see Schroeder (1999).

Box 1 shows the Semelparous Genetic Algorithm used in this paper to find the values of $\lambda_s \in \{\lambda^a, \lambda^b\}$ that maximize $\eth_x$. In the algorithm, there is an extinction process with a single reproductive episode before death (i.e. semelparity), just as in the reproductive strategy of the cephalopodous *Octopus mimus* (Plate 1): the females of the *Octopus mimus* stop feeding before spawning and dye after the birth of paralarvae; Zamora and Olivares (2004) noted that this behavior is related to the histological changes associated with the reproductive event of the *Octopus mimus*, as the ovary of this species, after spawning, does not have the cells to enable a new reproductive cycle. The drastic biochemical alterations and the irreversible structural deterioration of the muscle and the digestive gland decrease the life expectancy of this species and induce degenerative changes after reproduction.

In $g = 0$, a random initial population of i-couples of frequencies $\lambda^a_{g,i}$ and $\lambda^b_{g,i} (i = 1, 2, \ldots, p)$ is created, using a continuos uniform distribution function $\mathcal{U}(\cdot)$. Each couple is used to estimate spectral measures of the core inflation π^c_i and the signal-to-noise ratios $\eth_{\pi^c, i}$ associated to these i-cores.

In a process similar to natural selection, a fraction $(1-d)$ of the population p is selected. Emulating the survival of the fittest (Darwin, 1866), the leftovers are discarded with a d mortality rate. The sub-population of survivors are couples of $\lambda^a_{g,i}$ and $\lambda^b_{g,i}$ with the highest signal-to-noise ratios.

Evolution is allowed through the reproduction and mutation of the survivors. A new generation of couples $\lambda^a_{g+1,i}$ and $\lambda^b_{g+1,i}$ is generated from the convex combination of diploid cells:

$$\lambda^a_{g+1,i} = \theta \lambda^a_{g,i} + (1-\theta) \lambda^b_{g,i} + \varpi m_i, \tag{16}$$

Box 1. Semelparous genetic algorithm based on the behavior of the *Octupus Mimus*.

Genesis:
1. In $g = 0$, a population $i = 1, 2, \ldots, p$ is created, with $\lambda^a_{g,i} \sim \mathcal{U}(\cdot)$, $\lambda^b_{g,i} \sim \mathcal{U}(\cdot)$
2. $\mathbf{x}^c_i = \pi - \pi_\omega - \mathbf{t}_\omega [(\mathbf{t}'_\omega \mathbf{t}_\omega)^{-1} \mathbf{t}'_\omega \pi_\omega]$ is estimated,
3. $\eth_{\pi,i}$ is calculated,

Natural selection:
4. $\eth_{\pi,i}$ is sorted ($\eth_{\pi,(1)} \leqslant \eth_{\pi,(2)} \leqslant \cdots \leqslant \eth_{\pi,(p)}$). Then, $(1-d)p$ $(0 < d < 1)$ individuals are selected, with $\lambda^a_{g,(j)}$ and $\lambda^b_{g,(j)}$ $(j = 1, 2, \ldots, (1-d)p)$ of p, $\eth_{\pi,(1)} \leqslant \eth_{\pi,(2)} \leqslant \cdots \leqslant \eth_{\pi,(1-d)p)}$

Evolution (mutation):
5. Given $\theta \sim \mathscr{B}(\cdot, \cdot)$, $\varpi \in [0, 1]$ and $m_i \sim \mathcal{N}(0, 1)$,
$\lambda^a_{g+1,i} = \theta \lambda^a_{g,i} + (1-\theta) \lambda^b_{g,i} + \varpi m_i$,
$\lambda^b_{g+1,i} = \theta \lambda^b_{g,i} + (1-\theta) \lambda^a_{g,i} + \varpi m_i$.
6. Steps 2 to 5 are repeated during $g = 0, 1 \ldots, j$-generations.

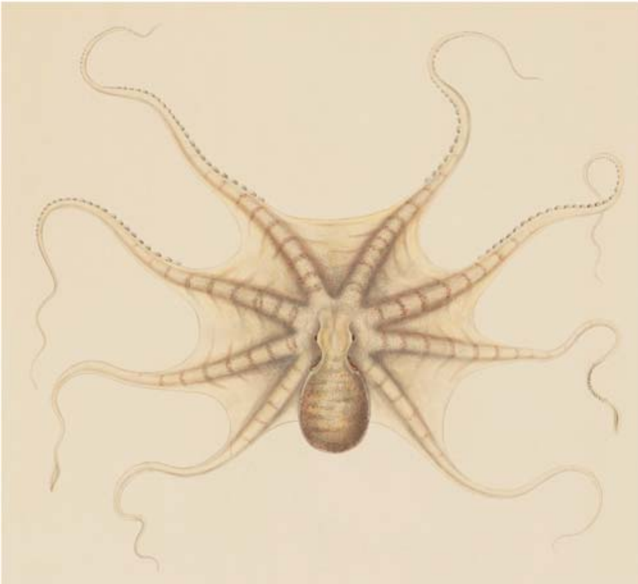

Plate 1.
Octupus mimus illustration from the book Molluscs and Shells (1852–1856) of Augustus Addison Gould

$$\lambda^b_{g+1,i} = \theta\lambda^b_{g,i} + (1-\theta)\lambda^a_{g,i} + \varpi m_i, \tag{17}$$

i.e. every generation after creation has two sets of chromosomes (λ^a, λ^b) and one of these dominates the offspring. The contribution of each chromosome to the next generation is given by $\theta \sim \mathscr{B}(\cdot,\cdot)$, with $\mathscr{B}(\cdot)$ a β distribution function. $\varpi \in [0, 1]$ is a mutation degree defined by the random variable $m_i \sim \mathcal{N}(0,1)$.

Due to the reproduction of the fittest, the new generation of spectral frequencies has values similar to those of the optimal previous generation, but mutation allows certain amendments to avoid local optima.

With the new generation of size $(1-d)p$, new estimates of core inflation are obtained. The steps 2 two 6 are then repeated during the next $g = 1, \ldots, j$-generations, until only one couple λ^a_j and λ^b_j survives. This last couple of survivors are the optimal values of λ_s that allow both a proper extraction of core inflation and the deviations from the core.

4. Results

World Bank data of inequality, inflation, GDP per capita, elderly population, female labor, government consumption, foreign direct investment, rural population, age population dependency, technology use – using internet use as a proxy – and data on the external balance were used to measure the impact of inflation shocks on income inequality in 11 countries of the MENA region: Djibouti, Egypt, Iraq, Jordan, Mauritania, Morocco, Qatar, Sudan, Syria, Tunisia and Yemen. These countries were selected due to its data availability between the years 2000 and 2014.

Figure 1 shows the Gini index of the selected countries, calculated as an annual average from 2000 to 2014 using the available data of each country. The lower inequality in the sample of countries is observed in Iraq (29.07) and the higher in Qatar (41.1).

Figure 2 shows the monthly series of the consumer price indices (CPI) of the 11 countries from January 2009 to December 2013. A steeper trend in the increase of prices is observed in

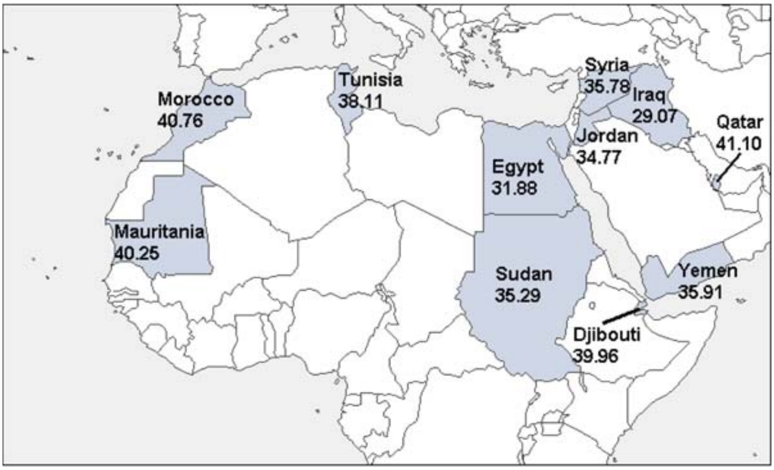

Figure 1. Gini coefficient in selected MENA countries

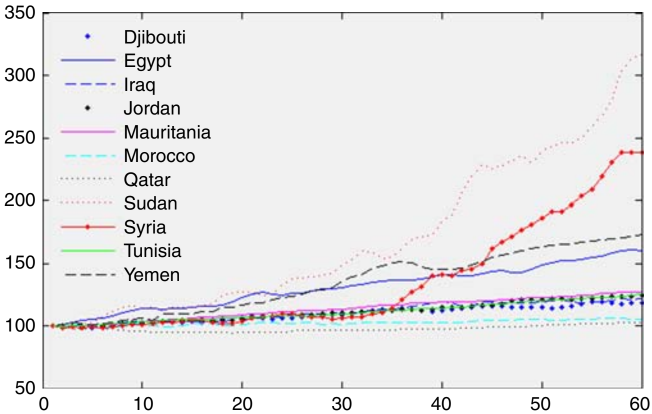

Figure 2. Consumer price index in selected MENA countries

Sudan and Syria, compared to other countries. Table I shows the results of using Semelparous Genetic Algorithms (henceforth, SGA) to estimate the core trend in CPI in the selected countries. An initial population of 100 couples of λ^a and λ^b were used in the SGA, with a mutation degree of $\varpi = 0.15$ and a mortality rate of 80 percent. Local extinction to a single optimal couple $\hat{\lambda}^a$ and $\hat{\lambda}^b$ was achieved after three generations. These parameters were selected to achieve extinction after three generations. Similar results were obtained by trying different parameters of the initial population, the mutation degree and the mortality rate; these results are available upon request.

SGA selected a lower frequency band of $\hat{\lambda}^a = 2$ months for all the countries in the sample, but the upper frequency $\hat{\lambda}^b$ is different among nations, with countries as Syria having a long-term inflation trend up to 13 months, whereas countries like Morocco have a medium-term core-inflation trend of 2 to 5 months. Figure 3 shows an example of the SGA estimation procedure for Tunisia, where the inflation trend moves between 2 and 6 months. From an initial population of 100 random pairs of $\hat{\lambda}^a$ and $\hat{\lambda}^b$ (Figure 3(a)), the algorithm reduces the population to 20 pairs (Figure 3(b)) and then to a single optimal couple (Figure 3(c)). Core inflation is

Table I.
Shocks in prices ($\sigma_{\hat{\pi}}$): selected MENA countries

Country	$\hat{\lambda}^a$	$\hat{\lambda}^b$	$\sigma_{\hat{\pi}}$
Djibouti	2	12	0.89
Egypt, Arab Republic	2	11	0.93
Iraq	2	8	0.69
Jordan	2	10	0.63
Mauritania	2	8	0.18
Morocco	2	5	0.37
Qatar	2	9	0.31
Sudan	2	11	3.33
Syrian Arab Republic	2	13	2.80
Tunisia	2	6	0.19
Yemen, Rep.	2	10	1.27

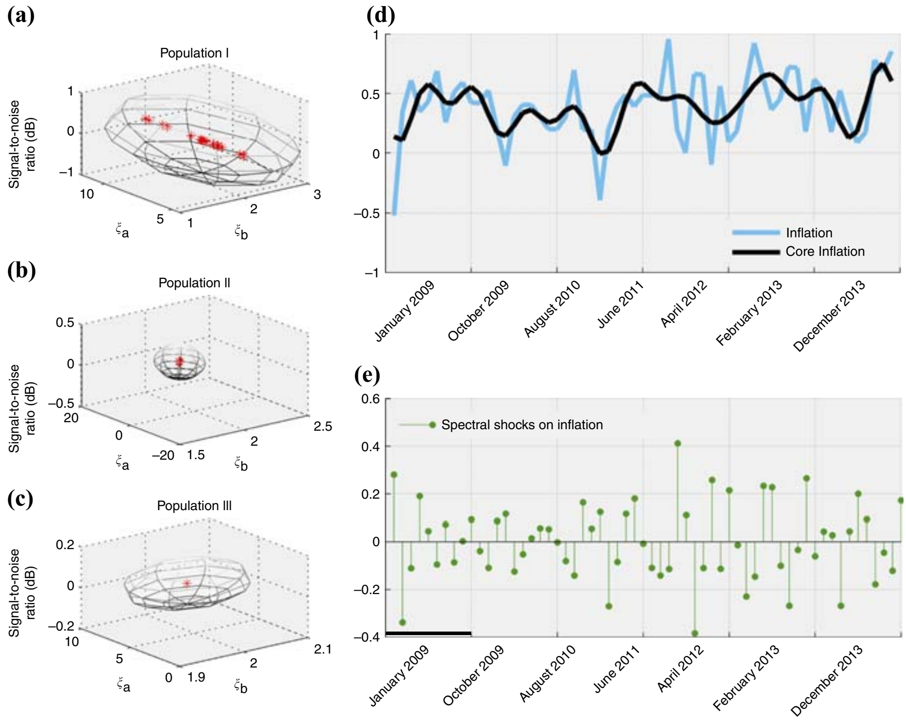

Figure 3.
Tunisia: estimation of core inflation with SGA and deviations in prices

estimated with this single optimal couple (Figure 3(d)); the differences between observed inflation and core inflation are the spectral shocks in inflation (Figure 3(e)). Results for the other countries in the sample are available upon request.

A point estimator of the shocks in prices ($\sigma_{\hat{\pi}}$) was calculated with the standard deviation of the spectral noise in prices (i.e. the deviations from core inflation) in each country. Sudan, Syria and Yemen present the highest shocks in prices, while Morocco, Qatar Mauritania and Tunisia have considerably lower deviations from the core, i.e. price shocks in these countries were lower compared to other regions in the Arab world (Table I).

The shocks in prices ($\sigma_{\hat{\hat{\pi}}}$) were used in a Bayesian quantile regression to estimate the impact of the deviations in prices in the selected countries of the MENA region. Gini coefficients were used to measure inequality. GDP per capita (at constant 2005 USDs), the ratio of the population of 65 years or more over the working-age population, female labor force (as a percentage of total labor force), general government final consumption expenditure (as percentage of GDP), net inflows of foreign direct investment (as a percentage of GDP), rural population (as a percentage of total population), the young-age dependency ratio (as a percentage of working-age population), internet users (per 100 people) and external balance on goods and services (as a percentage of GDP) were used as control covariates. In the Bayesian regression, $\beta_{p0} = (0, 1, 0, 1, 5, 0, -1, 5, 5, 0, 1)$, $\mathbf{B}_{p0} = \mathbb{I}_{11}$ – with $\mathbb{I}_k$ a $k \times k$ identity matrix – and a shape and scale parameter of 10 and 0.01, respectively, were used as priors. The election of the variables and the elicitation of the priors was based on previous empirical evidence about variables related to inequality[4]. In total, 11,000 runs of the MCMC chain were simulated and the first 1,000 draws were discarded as the burn-in period.

Figure 4 and Table II show the results of the Bayesian estimation. The 95% credible intervals – conditional on the assumptions of the study – suggest that the effects of the shocks in prices are only relevant for countries with inequality above the five decile, i.e. those countries with a Gini coefficient higher than $\mathcal{D}_5 = 0.36$. The income distribution effect of inflation increases as inequality increases (Figure 4) and in $\mathcal{D}_5 = 0.36$ and below this decile, the 95% credible intervals start crossing zero, thus suggesting that the shocks in inflation do not affect income distribution in countries with higher equality.

In terms of control covariates, Table II shows that the impact of GDP per capita on inequality is positive and relevant with a 95 percent probability for all the quantiles of income distribution, while variables as the elderly population share and government consumption are only relevant to explain inequality in countries with higher levels of inequality. In contrast, technology use is relevant for countries with low levels of inequality.

The positive correlation between GDP per capita and inequality can be explained by the early stage of development of the countries considered in the sample: as Barro (2000)

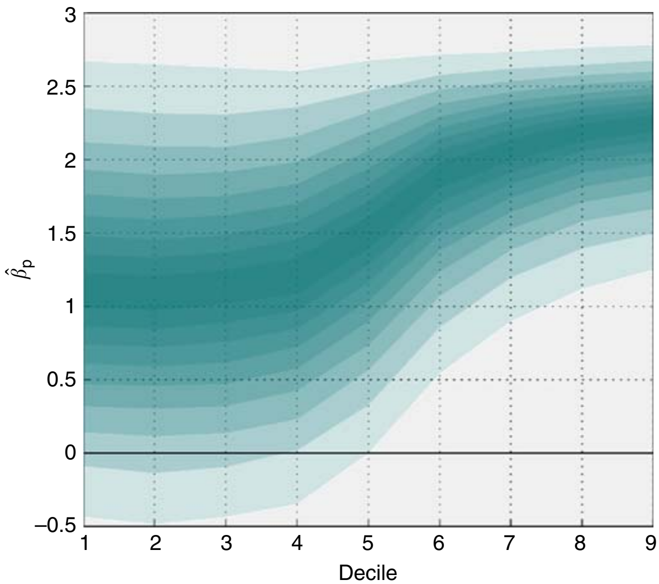

Figure 4. Quantile results of the impact of the deviation in prices on income inequality in selected MENA countries

Table II.
Bayesian quantile regression estimates

	Decile				
	$\mathcal{D}_1$	$\mathcal{D}_3$	$\mathcal{D}_5$	$\mathcal{D}_7$	$\mathcal{D}_9$
Constant	−0.0293 (−1.66, 1.59)	0.0383 (−1.68, 1.62)	0.0176 (−1.64, 1.67)	0.0655 (−1.63, 1.72)	0.0578 (−1.56, 1.73)
Inflation shocks	1.1139 (−0.44, 2.67)	1.1132 (−0.44, 2.63)	1.4435 (0, 2.67)	1.9763 (0.9, 2.74)	2.1573 (1.25, 2.78)
GDP per capita	0.0003 (1.2e−4, 4.6e−4)	0.0003 (1.3e−4, 4.6e−4)	0.0004 (2.3e−4, 4.8e−4)	0.0004 (3.1e−4, 4.9e−4)	0.0004 (3.3e−4, 4.9e−4)
Elderly population share	−0.3173 (−0.82, 0.45)	0.1505 (−0.75, 0.63)	0.4999 (−0.25, 1.13)	0.8274 (0.38, 1.27)	0.8887 (0.52, 1.31)
Female labor	0.1219 (−0.31, 0.61)	0.1152 (−0.3, 0.59)	0.0487 (−0.43, 0.42)	0.2357 (−0.51, 0.2)	0.2897 (−0.53, 0.12)
Government consumption	0.7071 (−0.24, 1.55)	0.7562 (−0.12, 1.56)	1.0461 (0.08, 1.86)	1.3445 (0.31, 2.07)	1.4539 (0.42, 2.12)
Foreing direct investment	−0.346 (−0.65, 0.03)	0.2946 (−0.67, 0.13)	0.081 (−0.59, 0.32)	0.0284 (−0.54, 0.32)	0.0026 (−0.49, 0.32)
Rural population	0.016 (−0.35, 0.3)	0.0479 (−0.28, 0.34)	0.1985 (−0.19, 0.52)	0.3131 (−0.1, 0.6)	0.355 (−0.05, 0.62)
Dependency ratio	0.2267 (−0.02, 0.51)	0.1921 (−0.07, 0.47)	0.0446 (−0.25, 0.4)	0.0514 (−0.32, 0.33)	0.0872 (−0.34, 0.29)
Technology use	0.4999 (0.28, 0.72)	0.4557 (0.21, 0.69)	0.288 (0.04, 0.58)	0.1959 (−0.01, 0.49)	0.166 (−0.02, 0.44)
External balance	−0.3379 (−0.68, 0.01)	0.2934 (−0.63, 0.07)	0.1716 (−0.51, 0.11)	0.116 (−0.44, 0.11)	0.0896 (−0.4, 0.13)

Note: 95% credible intervals below each point estimate showed, initially GDP per capita has a rising influence over inequality, but during a later stage of development, this relationship tends to disappear due to the improved distribution of income. The importance of the elderly population share for inequality can be related to the fewer job opportunities available for this group of people and can also be caused by the pension system in a country (Lee *et al.*, 2013). Government consumption can have a significant effect on income inequality if provides conditions to generate jobs, though it depends on the governance and efficiency of the government (Afonso *et al.*, 2010).

In the case of internet users, a positive relationship between this variable and inequality was found in countries where inequality is between the first and third decile. For Barro (2000), the insertion of new technologies as internet could initially increase inequality, but nonetheless Zhou *et al.* (2011) found a negative relationship between the share of internet users and the Gini index when evaluating the influence of globalization on inequality. This contradictory evidence suggests that further research is needed to properly evalute the impact of technology on inequality.

5. Discussion

We evaluated the impact of short-term inflation shocks on income inequality in selected countries of the MENA region. Our results suggest that inflation shocks have a differentiated impact on inequality, as the 95% credible intervals – conditional on the assumptions of the study – show that inflation only affects countries with higher levels of inequality, with an increasing effect as inequality rises. Similar results were found by *inter alia* Cardoso *et al.* (1995), Li and Zou (2002), Albanesi (2007) and Bulir (1998). Bulir (1998), for example, found that in countries with an inflation higher than 5 percent, monetary policies aimed to stabilized prices are more effective to reduce economic inequality, compared to countries with low levels of inflation. Albanesi (2007) concludes that this non-linear relationship between inflation and inequality, with a higher slope of the relation at higher inequality, arises in countries with more inequality because in these countries there is a bigger gap between high- and low-income households, reducing the bargain capacity of low-income families and, thus, making them more vulnerable to inflation shocks. The findings also imply that the strong division of classes in the MENA region – encouraged by ruling elites or family clans with economic/political power – contributed to increase the impact of inflation shocks on inequality, because, as the shocks are mainly caused by changes in food prices, the effect of inflationary shocks is higher for poor families, due to the composition of the consumer basket in these households.

Different policies can be implemented to reduce the impact of inflationary shocks on inequality in the MENA region. First, structural social policies aimed to reduce the gap between classes will also reduce the sensitivity to shocks in food prices for the families in the lower quintiles of income. Also, as Malik and Awadallah (2013) noted, transport costs make up to 40 percent food prices in the region, and thus a better infrastructure can connect agricultural markets and mitigate fluctuations in food prices. Also, in countries with non-neutral effect of money, central banks can optimize their policy to reduce the effect of inflation on inequality, since Furceri *et al.* (2017) found that monetary policy shocks can increase income inequality, and that this effect is asymmetric because a tightening of monetary policy raises inequality more than an easing of policy lowers it. Finally, Ghossoub and Reed (2017) proposed that the re-distributive impact of inflation depends on the extent of financial development, because economies with small stock markets contribute the most to income inequality. Future studies can thus analyze the role of monetary policy and the financial sector in the formation of inequality, since Coibion *et al.* (2012) found that the financial-segmentation channel of inflation redistributes wealth toward those agents most connected to financial markets.

Notes

1. Ncube *et al.* (2014) found for example that income inequality reduces economic growth and increases poverty in the MENA region, and Kaphahn and Brennan (2017) examined the conditions that contributed to the recent instability in North Africa and found that inequality is among the main conditions contributing to the political turmoil that lead to outbreaks of revolutionary or ethnic war, adverse regime change or genocide.
2. Only the study of Neaime and Gaysset (2017) seems to have analyzed before the relation between inflation and inequality in the MENA region. The study of Neaime and Gaysset (2017) nonetheless is of a wide scope and did not analyzed the impact of inflationary shocks on inequality, i.e. Neaime and Gaysset (2017) did not take into account the deviations from core inflation as an additional source of shocks on inequality.
3. El-Said and Harrigan (2006) highlighted that poverty, and inequities have been more severe in countries that followed the IMF and the World Bank recommendations, as e.g. Morocco, Tunisia, Jordan Egypt or Algeria. In Jordan, for example, the IMF recommendation of channeling resources toward repayment of foreign debt reduce the space to direct those resources to social sectors. This neo-liberal structural change influenced by IMF and World Bank strengthen the domestic ruling class in the Arab Countries according to Bogaert (2013). The changes promoted by the IMF and the World Bank may have also promoted the existence of a transnational capitalistic class, which was defined by Robinson and Harris (2000) as a new ruling hegemonic power class that are the owners of transnational corporations and financial institutions.
4. GDP per capita of a country was suggested as a determinant of inequality by Barro (2000). According to Barro (2000), at early stages of development, the relation between the level of per capita product and the extent of inequality tends to be positive, but in more advance levels of development the full relationship between an indicator of inequality, as the Gini coefficient and the level of per capita product is described by a Kuznets curve.

   In the case of the share of population older than 65 years old, this variable was selected as a covariate because a positive correlation between elderliness and income distribution was found by Alfonso *et al.* and Lee *et al.* (2013). Female labor was selected as a covariate because female labor participation was found as a positive determinant of inequality by Acar and Dogruel (2012) in a study realized with seven MENA countries, using panel data; Acar and Dogruel (2012) argued that earning inequalities between men and women could cause that effect. In terms of government consumption, Afonso *et al.* (2010) found that public policies significantly affect income distribution, directly via social spending and indirectly via high quality education/human capital and sound economic institutions. Rural population is related to the geographical determinants of inequality in the Arab region analyzed by Hassine (2015) using household survey data.

   Technology could be determinant of inequality, and can in fact raise inequality, according to Barro (2000), if technology implies an advantage for the people who can afford technological innovations, as e.g. internet access. Nonetheless, the effect of technological innovations depends on how long the innovation was introduce into the economy. The degree of openness of an economy was also mentioned by Barro (2000) as a determinant of inequality, because when a country is endowed with human and physical a decrease on the wages of unskilled workers is observed, but in countries that are relatively highly endowed in unskilled labor, greater openness to trade would tend to raise the relative wages of unskilled labor and lead, accordingly, to less income inequality.

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