Chaos, granularity, and instability in economic systems of countries with emerging market economies: relationships between GDP growth rate and increasing internal inequality

Desogus, Marco and Casu, Elisa

University of Cagliari, Independent research

2022

Chaos, granularity, and instability in economic systems of countries with emerging market economies: relationships between GDP growth rate and increasing internal inequality

Marco Desogus

Department of Economics and Business Science
University of Cagliari, Italy

Elisa Casu

Independent Economist and Senior Advisor
Unifidi Sardegna, Italy

Abstract

Starting from empirical observations of macroeconomic data from emerging market economies recorded in the second decade of the 2000s, an economic analysis was conducted on these economies' prerogatives and prospects, with special attention given to possible risks of systemic instability and the general soundness of their social and socio-economic structures. These assessments seem particularly relevant, not only for the countries in question, but because of their growing influence in determining international economic balance in the network of relations with developed countries at large.

Indeed, alongside good performance trends in production growth, distribution of new wealth that has exacerbated inequalities can be discerned. Moreover, emerging countries' economic policies often show a general accommodation to the sole objective of production growth, whilst neglecting to maintain equilibrium within the combined arrangement of all (other) macroeconomic variables.

Hence, at first we investigated the constitutive dynamics of these phenomena, using an income diffusion model based on a Pareto probability distribution, then on rheology for the analysis of the peculiar new wealth flows distributed over these countries' populations as well as any spontaneous redistribution effects induced by transactions among resident agents. At that point, applying the Dynamic New Keynesian model, we represented the system and studied solutions. Finally, we offer a proposal for constant government monitoring of each system, adopting control procedures capable of intervening – by way of economic and monetary policy instruments – where trends showed certain critical levels of instability in the economic system, which are observable from the trajectory diagrams.

Keywords: Emerging Market Economies, Macroeconomic Dynamics, Monetary Policy Control, Wealth Distribution, Local Stabilization Systems

JEL Codes: C02, C61, E01, E63, O47

1. Introduction

The focus of this paper begins from the hypothesis that – especially in emerging countries – an increase in internal inequality correlates with a certain rise in annual GDP growth rate [34], [04]. The idea is that the greater the wealth produced, at times of positive percentage change (recorded within the series of ratios between the years n and the years $n-1$ of absolute GDP values), the more the flows of that same wealth become increasingly *granular* in form, with the spontaneous behaviour of the distributive *effort* differing among the agents (residents) involved in that country's general business activity [45]. This is because, during peak fluctuations, it has been noted that the newly dispensed wealth is poorly *absorbed*, there being little time to smooth out the transition, resulting in the formation of income "granules". Specifically, concentrations of new wealth can be observed, albeit with an asymptotic trend, among those population segments that originally had more significant holdings of fixed assets. This is motivated by Keynesian wage *viscosity* [32], [20], [38] among the lower and middle classes, which can be partially mitigated by adaptive macroeconomic policies [26], which are however lacking *ipso facto* in countries with emerging economies.

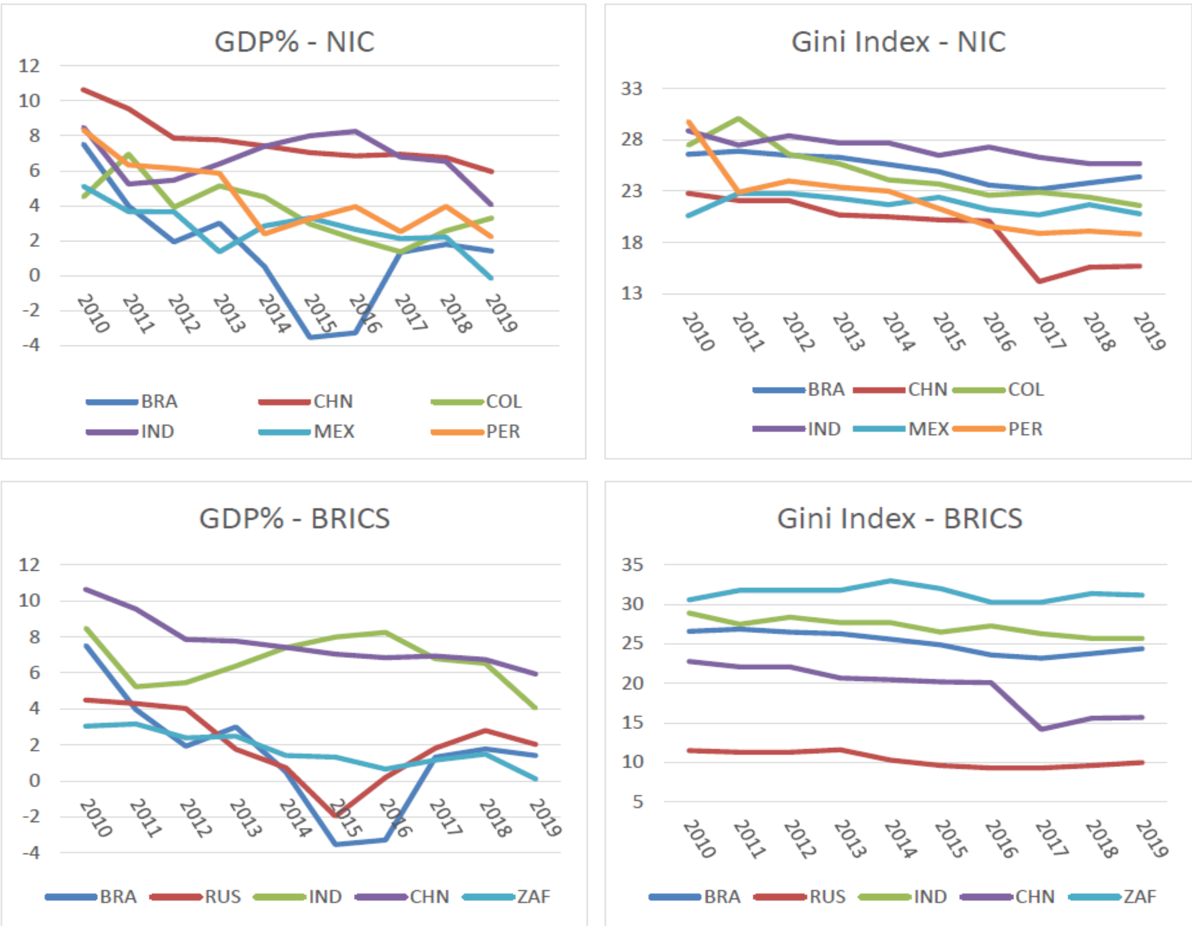
PROPOSITION: What happens can be represented by the rheological image of the (granular) flow of wealth, icastically epitomised as moving along a cylindrical conduit with a "cone-like" narrowing,

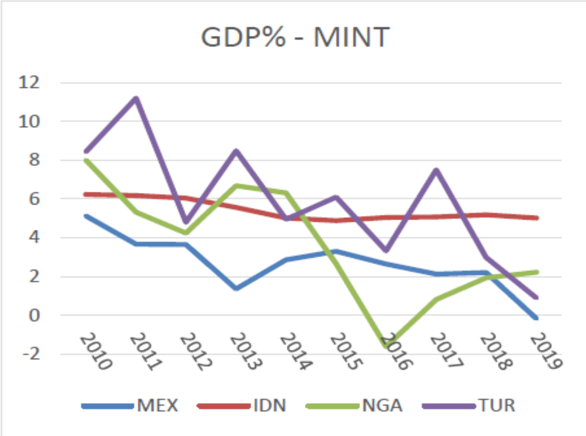
where, in addition to the higher rate of attraction concentrated in the central part of the “exit” section (funnel-flow regime) [60], [09], the phenomenon of *wall stress peaks* is felt, where, for example, the majority of the population whose wages are characterised by viscosity can be found. In the distribution of income flows among residents, once a certain positive variation in the growth of production between the years n and the years $n-1$, there is a transition from a state of active effort with a predominantly horizontal component, to a state of passive effort with a vertical component [59], with significant pockets of new wealth oriented towards the richest segments of the population (top managers and capitalists), with a concomitant increase in inequality [54].
The model proposed aims to localise the distributive *passage* of the new shares of wealth produced in countries with emerging economies, in the economic space within which all the gradients of flow dynamics are concentrated. The exponential dependence of the viscosity that appears from the (granular) motion of income exchanges leads in fact towards the results in hypothesis.
PROOF: This has been demonstrated by observing the empirical data first gathered from the so-called “NIC” (Newly Industrialized Countries: Brazil, Colombia, Mexico, Peru, China, and India), replicated – with substantial validation of the model – on the BRICS (Brazil, Russia, India, China, and South Africa) and the MINT (Mexico, Indonesia, Nigeria, and Turkey) groups, as will be shown later in this paper (see Figure 1 and Table 1).

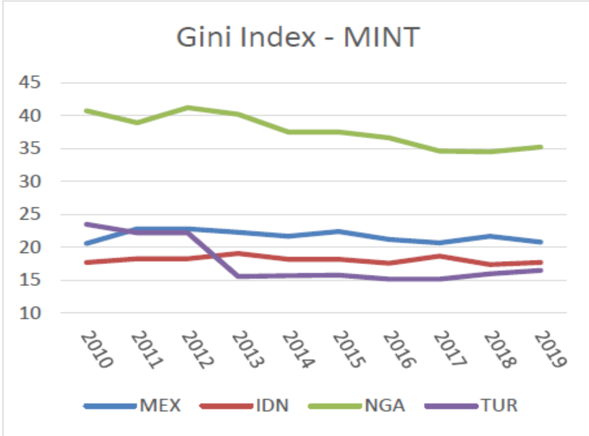
2. Objectives, materials, method and arguments

We focused on the observation and evaluation of macroeconomic data specific to countries with emerging market economies, and in particular on the relative trends of GDP growth rates and changes in the Gini Index between 2010 and 2018, so as to capture any viable correlation between the phenomena and to construct a descriptive model that might also represent a tool useful for prediction and control [57], [52].

Figure 1: Graphs comparing GDP growth rate trends and Gini Index trends in NIC, BRICS and MINT countries, respectively. Our own calculations based on World Bank (GDP) and UN – United Nations Development Programme (Gini index) data. Datasets are in the appendix.







The past decade represents one of the most interesting periods for the analysis that concerns us. Confined between the end of the "endogenous" economic-financial crisis among 2008 and 2009 and the beginning of the "exogenous" crisis brought about by the SARS CoViD-19 pandemic, this decade with its implications of geo-political, geo-economic and social changes on the world stage, certainly saw the NIC, BRICS and MINT countries become protagonists, fully deserving of all due respect, also in view of their impact on supranational equilibria and specifically concerning the United States and Europe [33], [07].
These emerging economies do in fact constitute a complex reality. Their influence on the system of international relations, whether directly through networks of bilateral relations and exchanges, or locally on regional areas, extends to production sectors of greatest interest to American and European public and private operators. If on the one hand, these circumstances increasingly affect policies in the systems involved, on the other, they offer important new opportunities for growth and progress.
With regard to the profound changes in global progress taking place, it is generally agreed that over the medium-term, some BRICS coordination states, such as China and India, might well assume primary roles in world development. Furthermore, BRICS initiatives to expand their membership to new nations (BRICS Plus strategy) and to new areas of cooperation (Africa and Eurasia) may strongly influence both world economy governance systems as well as the terms and conditions of development [05], [29], [58]. To correctly comprehend the scope of these new perspectives, our primary objective was to investigate the internal effects of the acceleration in economic growth that has characterised these countries, in an attempt to clarify and extract the societal and socio-economic implications and understand the prerogatives of stability and even "resilience" of these country-systems, as well as the risks and impacts on this world order, which is in constant evolution.
There have also been many common commitments made among the so-called "Western" nations and the BRICS-MINT countries, defined at summit meetings of Heads of State and Governments (e.g., G20), and on approved platforms within international institutions, first and foremost the UN 2030 Agenda on Sustainable Development [23].
First, we should look at how to generally describe new wealth distribution in the resident population.

2.1. Pareto distribution of income

ASSUMPTION 1(2.1): First we need to recall the Pareto probability distribution of income diffusion in a given population [37], [14], with polynomial decay [19]:

$$\begin{cases} F(w) = 0 & \text{if } w < \lambda \\ F(w) = 1 - (h/w)^p & \text{if } w \geq \lambda \end{cases} \qquad (1)$$

with λ as the positive constant, and where w is the income of a population 'P' distributed with a density $f(w)$.

DEVELOPMENT (2.1): For $w \gg 1$, we will have

$$1 - F(w) = \int_{w}^{+\infty} f(w)dw \cong w^{-p} \qquad (2)$$

where p is Pareto's index (graphically, on a bi-logarithmic scale, $-p$ represents the angular coefficient of the function): if $p \leq 1$, the mean value will be infinite. If $p > 1$, then the mean value will be finite, and the variance will tend toward infinity. A random non-Gaussian phenomenon is described in this distribution, wherein, compared to a generic positive point of the value l, the decay of the probability to not fall within the band $(-l, l)$ is polynomial with l. There is a 'power tail' that characterizes the distribution of wealth, which is evidently broken down unequally among the agents pertaining to the population 'P', showing a class (more or less small) of the concentration of great wealth in the hands of a few [53]. This phenomenon can be traced back to the generic quality of socio-economic systems – markedly lacking strong redistributive measures and policies – and reaches outcomes even more compatible with the Pareto distribution equation, precisely in countries with emerging economies, due to the aforementioned granularity observed in the flows of new wealth and in the field of peculiar motion as described above.

PROPOSITION 1(2.1): Especially in these countries the richest segment of the population follows the power law referred to in (2). However, the same cannot be said of the remaining, less affluent – and more numerous – components of the population [17], which on the contrary – taking up the previous example – is assigned a probability of being outside of $(-l, l)$, which decays exponentially with l, and which is a Gibbs distribution [27]. Comparing the different statistical behaviours of these two phenomena illustrates the growing trend of inequality as new shares of wealth enter the system following certain positive "jumps" in the GDP growth rate. Actually, the discriminating factor is not GDP growth. If growth were merely linear or nearly linear and consistent with the growth of physical capital, the Gini Index would present with sufficient stability [28]. What has been noted to be correlatively significant is the influence of the acceleration of the changes in the GDP growth rate on the increase (or the decrease, if the first and second derivatives of the function – with time in years in the abscissa and the rate of change in the ordinate – are both negative) of the inequality coefficient.

Table 1: The table shows the Bravais-Pearson indices (*r*) [03] calculated between the GDP growth rate and Gini index series for countries with emerging economies. The correlation is always verified, generally with moderate to strong intensity (somewhat weaker for Indonesia, Mexico, and South Africa). Our own calculations based on World Bank and UN - United Nations Development Programme data.

Country		***r***	***p-value*** $(\alpha = 0.05)$
Brazil	BRA	0.5874897	0.028495
China	CHN	0.7198035	0.024406
Colombia	COL	0.8413678	0.020990
Indonesia	IDN	0.1217074	0.045277
India	IND	0.3328643	0.037305
Mexico	MEX	0.2037366	0.042132
Nigeria	NGA	0.7151232	0.024545
Peru	PER	0.8240154	0.021457
Russian Federation	RUS	0.6440049	0.026703
Turkey	TUR	0.4576018	0.032851
South Africa	ZAF	0.1902949	0.042644

2.2. A rheological analogy about new wealth flows

PROPOSITION 1(2.2): The dynamics of granular wealth flows, generated by positive changes in the GDP growth rate in countries with emerging economies, are moved by the definition of the entity of agitation of all income exchanges among agents, including those created by new productive actions [48].

ASSUMPTION 1(2.2): This measure describes income fluctuations within the population and can be expressed as the mean squared of the wealth vector w, rather as $\vartheta = < w^2 > /3$, and can provide an indication of the local mobility of granules of wealth.

A *denser* form of wealth flows is associated with the GDP upward growth trend, as noted above, whose main distribution mechanism – over the course of each year, i.e., at least in the short-term – is therefore not markedly affected by transactions among agents. Nevertheless, these transactions represent a more *liquid* component of the overall flow. Thus, they contribute to an additional simultaneous phase of these income movements (which are thus intrinsically multi-phase), even though we may reasonably approximate the continuous and single-phase approach, considering – in this first step of the analysis of the phenomena discussed here – these *interstitial* contributions (binary transactions among agents) negligible.

ASSUMPTION 2(2.2): We will also assume that the income flow will not be subject to depreciation or impairment between the intervals ($\rho \sim \text{cost.}$) and that the tensor of the distribution stress – as referred to above – is symmetric. Therefore, the Navier Stokes equation [40], [11], supplemented by an appropriate balance of fluctuating wealth can be referred to.

With these assumptions, we can write the conservation equations [56]:

- $\nabla \overline{w} = 0$
- $\hat{\rho}\partial_t(\overline{w}) + \hat{\rho}\overline{w}\,\nabla\overline{w} = -\nabla\xi - \nabla\Pi + \hat{\rho}\zeta$

From which, by adding a fluctuating wealth budget:

$$\frac{3}{2}\hat{\rho}\partial_t(\vartheta) + \frac{3}{2}\hat{\rho}\overline{w}\,\nabla\vartheta = -\frac{\Pi}{\nabla\overline{w}} - \nabla\hat{q}^{\Gamma} - z^{\Gamma} \qquad (3)$$

Where:

- ρ indicates the *density* of the flow of wealth, i.e., the correspondence with one's measure of monetary value (which, as noted above, is assumed constant);
- ξ represents the isotropic component of the stress tensor;
- Π represents the deviatoric component of the stress tensor;
- ζ is the attraction vector of income from fixed capital and from investment in financial markets;
- q^{Γ} is the fluctuating flow of wealth (Γ measuring the state of *agitation* of wealth granules, i.e., their speed of transmission in the form of income between resident agents, depending on their size. This is a scalar quantity);
- z^{Γ} indicates the speed of profusion, for each economic system, of the fluctuating wealth (period of *dissipation* of the newly injected income flows, i.e., the time lapse between the generation of the flow and its transformation into savings or consumption). This (also) depends on the level of inflation and the macroeconomic interest rate.

ASSUMPTION 3(2.2): The local flow viscosity of new granular wealth can be described by means of a sub-model, from which emerge the constitutive relations – of a generalised Newtonian type [51] – among the variables ϑ and w:

$$\Pi_{ij} = -\eta\left(\frac{\partial w_i}{\partial y_j} + \frac{\partial w_j}{\partial y_i}\right) \qquad (4)$$

where y represents the output, and η indicates wage viscosity [47], which evidently depends on the *fluctuating* motion of incomes within the population and by virtue of the relationship with pricing (in the absence of significant monetary policies); in other words, the viscosity of a wage is the measure of its resistance to deformation at a given speed:

$$\eta = \eta'\rho d_{\xi}^2 \qquad (5)$$

and

$$\eta' = \eta_0 e^{\left(\vartheta^*/\vartheta\right)} \qquad (6)$$

where

- η_0 is a pre-exponential term and provides an indication of the transition state;
- ϑ^* represents a benchmark measure of income fluctuation in the resident population, and is scalable as a function of the attraction of income from capital and financial investments (ζ) and the density of the granules in the new wealth flows d_{ξ}: $\vartheta^* = \kappa_{\vartheta}\zeta d_{\xi}$
- κ is the parameter representing how *diffuse* the fluctuating wealth is, which is constant for the relation $\kappa = \kappa'\rho d_{\xi}^2 = cost.$

Similarly, the term z^{Γ} is thus defined:

$$z^{\Gamma} = \alpha\xi|\dot{\gamma}| \qquad (7)$$

DEVELOPMENT (2.2): In equation (7), α is a coefficient that indicates the more or less close connection among the granules of the new wealth flow. If, for example, the increase in GDP, in a country with an emerging economy is connected – for a significant percentage – to the use of a new technology or a specific knowledge base or even a process and product innovation, stronger *links* will form between the income granules in the proportionally barycentric flow on the firms holding the relevant patents, know-how, trademarks or licences. The greater the overall constraint brought about by such links, the faster will be the transformation of new income into savings or consumption. $\dot{\gamma}$ describes the *deformation* of the dynamics of the flow of wealth brought about mainly by endogenous impulses due to the *ex-ante* structure of each socio-economic system being evaluated. The exogenous effect of fiscal and monetary economic policies is neglected for the purposes of this model – at least at this stage of the argument.

ASSUMPTION 4(2.2): Furthermore, we assume that the flow of fluctuating wealth q^{Γ} is linearly dependent on the gradient of the measure of income fluctuations within the population:

$$q^{\Gamma} = -\kappa\nabla\vartheta \qquad (8)$$

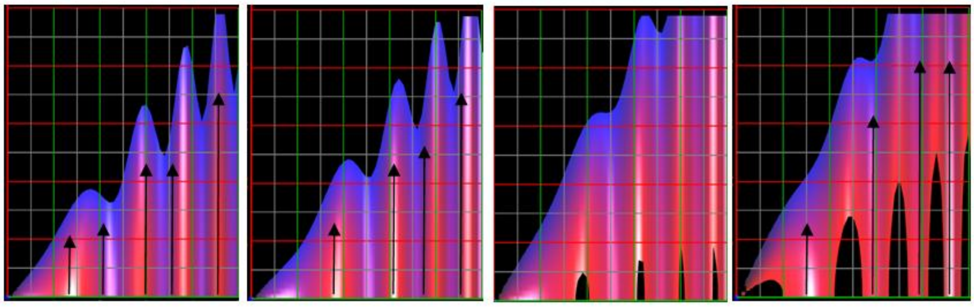
Again, considering both the term of increased production of fluctuating income brought about by moments of increased local mobility of wealth granules, and the term of dissipation of new income flows injected into the system, we will have:

$$\dot{Q} = \frac{\Pi}{\nabla \overline{w}} - z^{\Gamma} \qquad (9)$$

That is to say:

$$\dot{Q} = |\dot{\gamma}|(\eta|\dot{\gamma}| - \alpha\xi) = |\dot{\gamma}|(|\upsilon|) - \alpha\xi \qquad (10)$$

Figure 2: Graphical simulation of the motion field (upwards) of fluctuating income through four progressive snapshots of the granular flow in a semi-cone. On the left-hand side of each box, we see the wall resistance, where the majority of the population lives. On the right-hand side, towards the – few – largest holders of capital and technology, we see the phenomenon of the increasing speed of attraction (funnel flow regime). Our own processing.



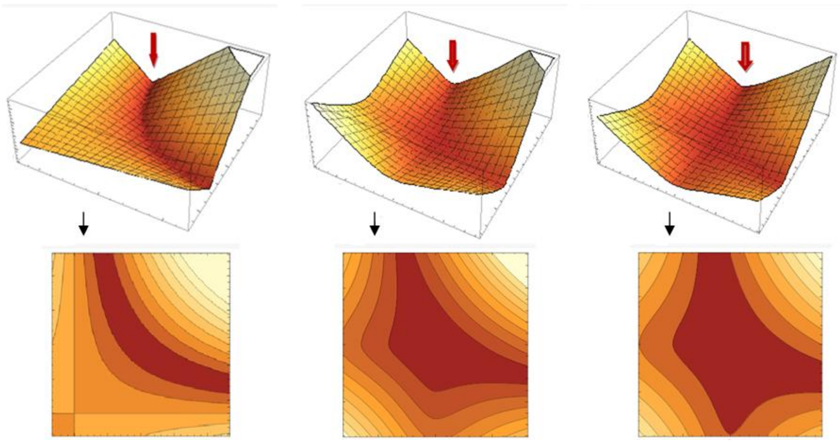
With regard to (10), it is now necessary to mention the contribution of binary transactions between agents (more on this below), which affect the relative motion of wealth and can condition the dynamics of the flow. We have three possible situations:

1) $|\upsilon| = \alpha\xi$: the summation of the effects of binary transactions between agents does not alter the dynamics of the new wealth flow;
2) $|\upsilon| > \alpha\xi$: the summation of transactions between agents reduces the granularity of the new wealth flow;
3) $|\upsilon| < \alpha\xi$: the transactions between agents cause an increasing variation in the granularity of the new wealth flow.

Given the conservation relations, from these developments we can finally rewrite the balance equation of fluctuating wealth:

$$\frac{3}{2}\hat{\rho}\partial_t(\vartheta) + \frac{3}{2}\hat{\rho}\overline{w}\,\nabla\vartheta = \kappa\nabla\vartheta + \dot{Q} \qquad (11)$$

Figure 3: Graphical representations of the concentration dynamics of the new granular flow of wealth, at three successive moments when the phenomenon manifests itself. The figures below correspond to each of the above and present the viewpoint from their respective contour lines. The section in red shows the wealthiest segment of the population (with maintenance of the constant number of agents belonging to each band, in each snapshot), and gradually decreasing by income classes in relation to the degradation of the colour. The width of the area of each level indicates the amount of income assigned to each income bracket of the population. In the trend, a marked growth in wealth achieved by the red band can be noted. Our own processing.



In what follows, we can see what interventions might be feasible – starting from the budget equation (11) – to influence the dynamics of the distribution of new wealth towards greater equalisation, while maintaining the pace of economic growth. We will proceed with an argument on the contribution of binary transactions between agents; then, the Dynamic New Keynesian model will be applied to the analysed phenomena [06], [31].

2.3. Effects of binary transactions

PROPOSITION 1(2.3): Inside any system, the interactions between its agents – through the reciprocity of transactions – behave as follows. At each instant of time $t \geq 0$, let us assume, without considering distinctive features between agents, that each agent has some wealth $w \geq 0$. Let us also imagine that, as a result of the exchanges, part of the wealth of each participating agent is transferred to its counterpart.

ASSUMPTION 1(2.3): Thus, if two agents A and B turn out to be respectively endowed with wealth w_A and w_B, as a result of their interaction we would observe a change in w_A^* and w_B^*, according to the linear transaction rule:

$$w_A^* = \frac{1}{2}(w_A + w_B + |w_A - w_B|\mathrm{v}) \quad \text{and} \quad w_B^* = \frac{1}{2}(w_A + w_B - |w_A - w_B|\mathrm{v}) \qquad (12)$$

where v is the arbitrary vector of $\mathbb{R}^3$.

Through the positive random exchange coefficients a_1, a_2, b_1, b_2, we will have

$$w_A^* = a_1 w_A + b_1 w_B \quad \text{and} \quad w_B^* = a_2 w_A + b_2 w_B \qquad (13)$$

Which precisely represent the new wealth in the hands of A and B following the reciprocal transfers made between the agents [50].

DEVELOPMENT (2.3): Let us consider N agents comprising the system, intrinsically endowed with a closed and defined *volumetric* feature: like particles, each agent interacts by virtue of a *velocity* and according to a *spatial position vector* in $\mathbb{R}^3$. In economic terms, these peculiarities can be identified within the interacting agents' initial wealth conditions, their individual protection indexes – that is, each agent's inclination to risk only a part of his/her own wealth [13] – and in the random risk components [21]. The limits of this approach are certainly evident. If in fact the rules and outcomes of binary collisions between particles are established by the laws of mechanics, what happens in transactions between economic agents suffers from the lack of unique features, which can clearly only be modelled through assumptions that can be verified ex-post. Nevertheless, macroscopic equilibrium solutions derived from a kinetic approach are verified and deemed satisfactorily reliable by comparisons with historical data series in real economies, as reported extensively in the literature [24].

ASSUMPTION 2(2.3): Let the *collision mass* and *frequency* be both unitary and equal for all agents involved: the phenomenon is thus represented by the Boltzmann integro-differential equation [08] modelled according to the law of evolution over time of each agent's *density* $f(w,t)$ of the wealth w of each agent over time t:

$$\frac{\partial f(w,t)}{\partial t} = G(f,f)(w,t) = G_+(f,f)(w,t) - f(w,t) \qquad (14)$$

The collision term '$G(f,f)(w,t)$' shows the variations in *density* caused by the transactions between the agents. On the whole, equation (14) shows us that, over time t, the density changes only because of internal interactions (binary collisions). The "corrected" term G_+ also shows the action of transactions on the observable quantities.

Getting back to (13) – then with w_A^* and w_B^* being the post-transaction wealth belonging to agents A and B – $\varphi = \varphi(w)$ being the wealth function from which each of the above-mentioned observable quantities can be determined and adding onto w, we will obtain the corresponding law of variation over time:

$$\int_0^{+\infty} \varphi(w) G_+(f,f)(w) dw \qquad (15)$$

which, on the mean value of the random quantities $\langle \varphi(w_A^*) + \varphi(w_B^*) \rangle$, is equal to

$$\frac{1}{2} \iint_0^{+\infty} \langle \varphi(w_A^*) + \varphi(w_B^*) \rangle f(w_A) f(w_B) dw_A dw_B \qquad (16)$$

Therefore, the variation of the observable quantities will be given by:

$$\frac{d}{dt} \int_0^{+\infty} \varphi(w) f(w,t) dw = \int_0^{+\infty} \varphi(w)[G_+(f,f) - f](w,t) dw \qquad (17)$$

And since $f(w)$ is the function of probability density:

$$\int_0^{+\infty} \varphi(w) f(w) dw = \frac{1}{2} \iint_0^{+\infty} \langle \varphi(w_A^*) + \varphi(w_B^*) \rangle f(w_A) f(w_B) dw_A dw_B \qquad (18)$$

From these last two equations we can reflect on the quantities of wealth $\varphi(w)$ not subject to variations following the interaction/transaction

$$\langle \varphi(w_A^*) + \varphi(w_B^*) \rangle = \varphi(w_A) + \varphi(w_B) \qquad (19)$$

Which is verified for $\varphi(w) = 1$ and for $\varphi(w) = w$.
And again, the relation:

$$\langle w_A^* + w_B^* \rangle = w_A + w_B \qquad (20)$$

is met by two possible solutions:

1) $w_A^* + w_B^* = w_A + w_B$
2) $w_A^* + w_B^* \neq w_A + w_B$

In the first case, we see conservative transactions "at each point", where one agent wins and the other loses. In the second situation, while the total quantity of the system is still conserved, both agents can achieve a gain or a loss.
Much of the literature [35], [16], [55], [15] focuses on the conservative properties of transactions and on maintaining equilibrium in the system. What appears, however, is their ineffectiveness, considering the aggregate of transactions in a certain period and the average of their effects, to significantly affect the general structure of the dynamics of the flow of wealth in distribution, particularly in the presence of granularity [46].

2.4. Dynamic New Keynesian Model

PROPOSITION 1(2.4): Among emerging countries, the market economies' structures are basically characterised by monopoly-oligopoly competition scenarios [44].
ASSUMPTION 1(2.4): This assumption leads us to a line of reasoning and assessment based on the Dynamic New Keynesian (DNK) model.

$$(1+\beta)\pi_t = \beta E_t \pi_{t+1} + \pi_{t-1} + \theta y_t + s_t^\pi \qquad (21)$$

$$R_t - E_t \pi_{t+1} = \sigma(E_t y_{t+1} - y_t) + P(\psi_h - 1)h_t \qquad (22)$$

$$R_t = (1-\tau_R)\left(\tau_\pi \pi_t + \tau_y y_t\right) + \tau_R R_{t-1} + s_t^R \qquad (23)$$

In (21): Neo-Keynesian Phillips curve (NKPC), and (22): Investment-Saving (IS) curve, also called a log-linearized Euler equation [43], [12],

- β denotes the discount factor;
- π represents the inflation rate: π_t can be measured with the GDP deflator;
- E_t represents the expected value of the flow of profits from the production system;
- y_t is the output gap;
- θ is the parameter that conditions the impact of y_t on current inflation π_t;
- s_t^πindicates the supply shock, which follows the autoregressive (AR) process $s_t^\pi = \psi_\pi s_{t-1}^\pi + \varepsilon_t^\pi$, with $0 \le \psi_\pi \le 1$ and $\varepsilon_t^\pi \sim d(0, \sigma_\pi^2)$ represents the shock to independent and identically distributed variables (iid);
- R is the real interest rate;
- σ indicates the degree of risk aversion.

ASSUMPTION 2(2.4): The inverse of the Frisch elasticity [42] of labour supply (ν_t) is included in the convolution, since the assumed isoelastic household utility function is

$$U(C_t M_T) = \frac{C_t^{1-\varsigma}}{1-\varsigma} - \frac{V_t^{1+\nu}}{1+\nu} \qquad (24)$$

with ς being the inverse of the intertemporal elasticity of substitution of consumption and V the labour supply.
ASSUMPTION 3(2.4): Since, assuming that constant returns to scale (CRS) technologies are available:

$$y_t = A_t V_t \qquad (25)$$

and

$$A_t = A_t^{P_\varsigma} e^{U_{\varsigma,\nu}} \qquad (26)$$

A_t represents the aggregate productivity index and (26) describes its evolution according to a stochastic log-stationary process. P is the price level. According to the model, the amount of labour factor employed will be such that the real marginal costs equal the real wage per unit of efficiency [36], [25], [10].
Once again, in (22),

- $P = \frac{\sigma(1+m)}{(\sigma+m)}$;
- h_t represents the technology shock and also follows an AR process of the type $h_t = \psi_h h_{t-1} + \varepsilon_t^h$, with $0 \le \psi_h \le 1$ and, again, an iid shock $\varepsilon_t^h \sim d(0, \sigma_h^2)$.

Finally, in (23) the Taylor rule is referred to, where:

- τ_R denotes the inertia on the real interest rate;
- τ_π represents the sensitivity of monetary policy to inflation;
- τ_y represents the responsiveness of monetary policy to the output gap;
- s_t^R indicates the monetary policy shock, which leads to the stochastic evolution of the policy rate. This also follows an AR process: $s_t^R = \psi_R s_{t-1}^R + \varepsilon_t^R$ with $0 \leq \psi_R \leq 1$ and iid shock $\varepsilon_t^R \sim d(0, \sigma_R^2)$.

DEVELOPMENT (2.4): With these assumptions, it is significant to focus on enterprises' price-setting mechanisms. In addition to the intrinsic demand constraint, the larger issue concerning the frequency of price adjustments arises. Optimal behaviour would be following a time-independent stochastic rule (i.e., without taking the implications of what happened in previous intervals into consideration).

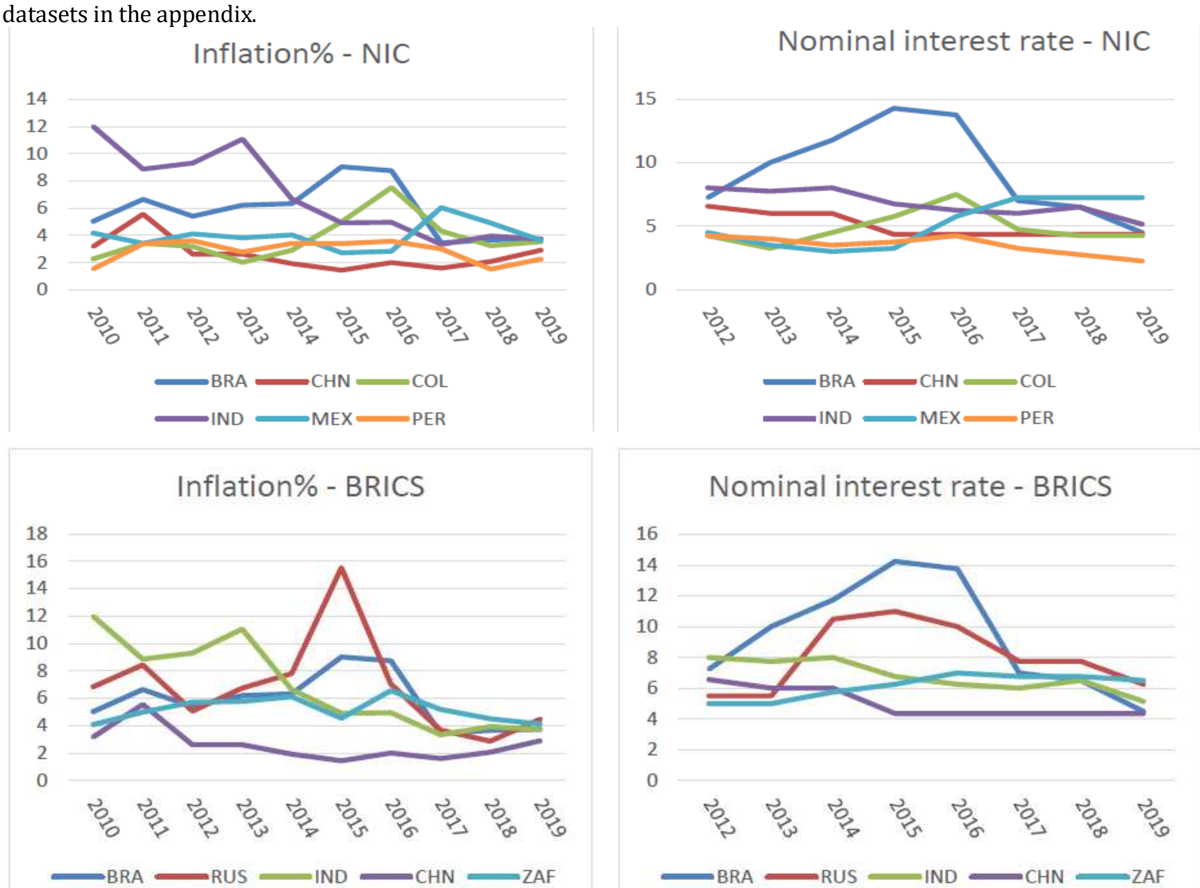
Clearly, each of the shocks identified above requires an appropriate change in prices by all enterprises: if only a subset of these were to respond this way, the others would be forced to vary their output levels [30]. The occurrence of such asymmetry would impact the allocation of resources in the economic system, leading to inefficiencies that could even reduce the acceleration of economic growth in the countries we are considering in this paper.

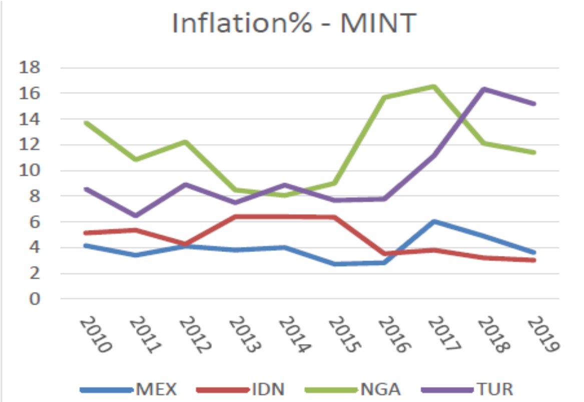
Setting prices by firms operating in such a scenario also requires a medium-term strategy. Indeed, it is not enough to consider only the marginal costs of the period t, but also those same marginal costs' future development should be forecast. In other words, the dynamic problem comprises not only the maximisation of current profits, but rather of the discounted expected value of the entire flow of future profits [39].

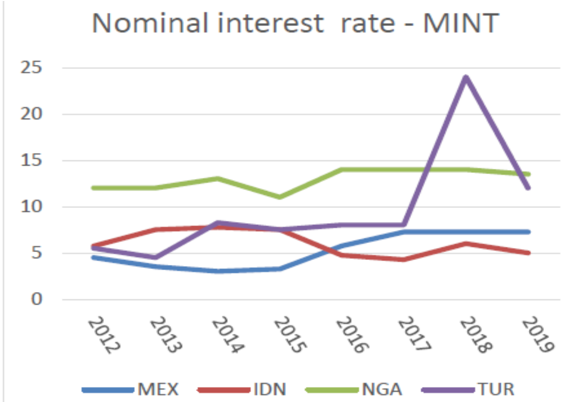
PROPOSITION 2(2.4): One can see in this regard, therefore, a *breeding ground* of general macroeconomic disequilibrium in emerging systems, wherein policy makers intervene very little – on average – on interest rates, in order to avoid perturbations of the type s_t^R – and as a consequence s_t^π– which would bring the output level, over the short- and medium-term, out of line with its maximum potential. This reduction in the adjustment capacity of monetary policy is caused by the same macroeconomic structure of emerging countries in the time frames in which economic growth and development take place.

PROOF: Observation of the trends in Figure 4.

Figure 4: Graphs comparing the trends for inflation rates and the nominal interest rates set by monetary policy in NIC, BRICS and MINT countries, respectively. Our own calculations based on World Bank and National Central Banks data: datasets in the appendix.







This, however, still due to wage viscosity, confirms the emergence, over the same time frame, of higher levels of socio-economic inequality in the presence of rapid GDP growth.
The stationary stage is reached over the long-term in this economy, once maturity and consolidation of the same economies have been achieved on an international scale, only approximately according to Solow's model [22].

2.5. Instability and systems of control

ASSUMPTION 1(2.5): Indeed, we can identify the (dynamic) economic system described by:

$$\dot{x} = F(x, \mu) \qquad (27)$$

with:

- $x \in \mathbb{R}^n$ system state vector;
- $\mu \in \mathbb{R}^m$ system operating parameters vector;
- $F: \Omega \subseteq \mathbb{R}^n \rightarrow \Omega \subseteq \mathbb{R}^n$ system vector field.

PROPOSITION 1(2.5): The nonlinear system in (27) is structurally stable when – at the set of values for the parameter μ – there exists a $\chi > 0$ such that a homeomorphism exists between the same system and

$$\dot{x} = \tilde{F}(x, \mu) \qquad (28)$$

for all vector fields $\tilde{F}: \Omega \subseteq \mathbb{R}^n \rightarrow \Omega \subseteq \mathbb{R}^n$ with $\|F(x, \mu) - \tilde{F}(x, \mu)\| < \chi$. This means that there exists a transformation $o: \Omega \subseteq \mathbb{R}^n \rightarrow \Omega \subseteq \mathbb{R}^n$, continuous with its inverse, which changes the trajectories – whilst preserving the direction – of the system in (27) into those belonging to (28).
PROPOSITION 2(2.5): In the absence of structural stability – as observed in the systems of countries with emerging economies – one finds oneself in a condition of bifurcation: i.e., the system – which is in a condition of chaotic economic growth – is exposed to significant (and even subdued) changes in the stability, number, and nature of solutions.
DEVELOPMENT – PART 1 – (2.5): The bifurcation emerges locally (origin of the state space), at a stationary point where, in general, for $\chi = 0$ the result is $F(0, \chi) = 0$, and the Jacobian matrix of the field F at that point, $J_0 = \left.\frac{\partial F}{\partial x}\right|_{x=0, \chi=0}$, has at least one eigenvalue with the real part zero [49]. One or more eigenvalues λ_i^c with the real part zero are called critical eigenvalues and, at which point, a local bifurcation of the system occurs. If the critical eigenvalue presented by the matrix J_0 is real, there is a real bifurcation, with branches of stationary regime solutions and no periodic regime solutions: the latter can be found at a Hopf bifurcation, i.e., when only one pair of conjugate complex eigenvalues of the Jacobian J_0 crosses the imaginary axis, whilst all other eigenvalues exhibit a negative real part.
Analysing these findings can be useful for the activation of forms of stability control, through monetary policy, especially as the *fluctuations* of macroeconomic variables increase and before the system goes out of control.
Essentially, we have noted that one of the key factors for a country's economic emergence, once it has *de facto* assumed the necessary technological standing, is a *light* economic policy, which does not constrain output levels to a predetermined maximum, and which has social costs – in the short- and medium-term – in terms of income inequality and possible periods of contraction in domestic consumption. However, such a relaxation of the *reins* of the economy by the government would require a rigorous scientific approach, supported by permanent analyses of the system's dynamics.
PROPOSITION 3(2.5): Locally, control laws can intervene by modifying the asymptotic behaviour near a Hops bifurcation, in particular by stabilising a critical point at a transcritical bifurcation: when the associated critical eigenvalue is (still) controllable, through a non-linear closed-loop control law

(with inclusion of second and third order terms in the state variables), it is possible to convert it into a supercritical bifurcation [02].
Nevertheless, in moving away from the bifurcation point, undesirable effects and stresses may occur to the extent that the stability characteristics of the system's solutions are compromised. This, too, requires the constant monitoring of the dynamics by policy makers cited above.
ASSUMPTION 2(2.5): We apply a wash-out filter, which has been deemed interesting for its ability to function even in situations of uncertainty (figuratively, a sudden predisposition to "whatever it takes" of the then ECB President Draghi [01]: in the intervals of growing instability it is necessary to activate the optimal control procedure, through a stringent activation of monetary policy instruments to the extent and direction required by the state of the system):

$$H(s) = \frac{\varrho(s)}{x(s)} = \frac{s}{s+d} \qquad (30)$$

DEVELOPMENT – PART 2 – (2.5): Equation (30) is the transfer function of the linear dynamic system represented by the filter; d is the inverse of the filter time constant, and ϱ is the output vector of a wash-out filter [18].
Positing:

$$r(s) = \frac{1}{s+d}x(s) \qquad (31)$$

we can describe the dynamics of the filter with:

$$\dot{r} = x - dr \qquad (32)$$

and

$$\varrho = x - dr \qquad (33)$$

Looking again at (27), we can write:

$$\dot{x} = F(x, \mu_R) \qquad (34)$$

with $\mu_R \in \mathbb{R}^m$ a manipulable variable (representing monetary aggregates).
ASSUMPTION 3(2.5): Let us assume that when $\mu_R = 0$ one will be at the stationary point x_Q, wherein the system is managed through the closed-loop control law:

$$\mu_R = -\phi(x - x_Q) \qquad (35)$$

From which it can be deduced that $\mu_R = 0$ when $x = x_Q$. In other words, the control operation has not altered the stationary condition of the point x_Q in the system referred to in (34). If there is a condition of uncertainty in the field predictions $F: \Omega \subseteq \mathbb{R}^n \to \Omega \subseteq \mathbb{R}^n$, an inferential procedure can be implemented to estimate the stationary point x_Q, arriving at $x_Q^{'} \approx x_Q$:

$$\mu_R = -\phi(x - x_Q^{'}) \qquad (36)$$

In (36) the outcome of the management (or control) procedure does not result in cancellation at point x_Q; in these cases, it may be appropriate to proceed with the control law:

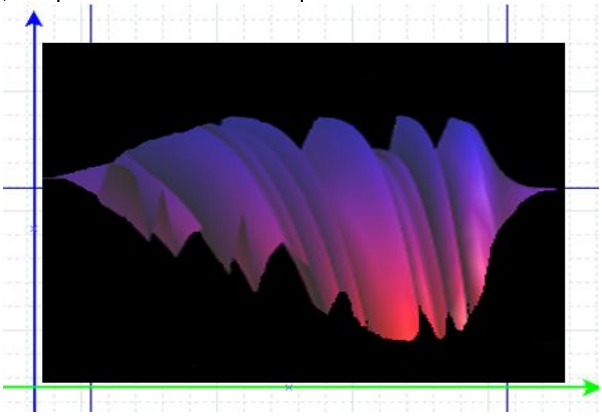
$$\mu_R = -\phi\varrho \qquad (37)$$

With ϱ expressible as:

$$\varrho = (x - x_Q) - d(r - r_Q) \qquad (38)$$

where, in the case of a stationary regime, $r = r_Q = \frac{x_Q}{d}$, the filter's output vector is nullified in correspondence with the stationary points, and this ensures that the structure of the diagram of the system's regime solutions will not be altered.

Figure 5: Representation of the system dynamics between the transcritical (spontaneous) bifurcation point and the supercritical bifurcation that results after the application of the control law: following the successful intervention of policy makers, a rapid reduction in the amplitude of the oscillations can be seen.



3. Conclusions

The analysis conducted on countries with emerging economies (NIC, BRICS and MINT) has shown – in the case of the remarkable contribution to the world economy over the interval considered in the introduction – evidence of a *predatory* character in investments, technologies and market positioning, and the incumbency of significant internal imbalances as counterpoint.

Monetary policies tend to be loose, with little action on inflation and a general disorder in the management of transitions. There also appears to be a sustained dependence on foreign trade and foreign capital and financing. Technological availability is centralised on a small number of economic players, as is the location of commodity sectors, and accelerating GDP growth has led to granular wealth flows, resulting in increased domestic inequality. The economic fundamentals show structural imbalances, with risks to social and political stability; there is also a trend towards a gradual reduction in infrastructure investments.

In the course of our research, it was noted how, on the one hand, internal transactions among agents do not bring about substantial ameliorative changes in the distribution of wealth; on the other hand – through the DNK model – macroeconomic policy interventions aimed at attempts to rebalance macroeconomic variables – taking the current circumstances of the economic systems considered here into account – would lead to a depression of the growth impulses of production [41]. Therefore, our suggestion to policy makers is to implement constant monitoring procedures on the fluctuations in the economic system's dynamics and to administer control interventions (a closed-loop control method with a wash-out filter has been proposed) beyond a certain threshold level – pre-accepted – of the deviations from the moments of objective stability of the system.

3.1. Management implications

The data and analyses reported here could also be used as an evaluation tool for companies, foreign with respect to the observed countries, that make or intend to enter into investment transactions or trade relations with one or more NIC, BRICS or MINT states. A more structured attention to the dynamics of the relevant economic systems, and of the expected trajectories with respect to stability points, may in fact facilitate better management of risks and portfolio positioning, more correct allocation of provisions, and more precise forecasts of expected net performance.

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Appendix

DATASET 1 (relative to figure 1): GDP GROWTH (ANNUAL %)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
BRA	7.5282	3.9744	1.9212	3.0048	0.5040	-3.5458	-3.2759	1.3229	1.7837	1.4112
CHN	10.6359	9.5508	7.8637	7.7662	7.4258	7.0413	6.8488	6.9472	6.7498	5.9497
COL	4.4947	6.9479	3.9126	5.1340	4.4990	2.9559	2.0874	1.3594	2.5643	3.2811
IDN	6.2239	6.1698	6.0301	5.5573	5.0067	4.8763	5.0331	5.0698	5.1743	5.0182
IND	8.4976	5.2413	5.4564	6.3861	7.4102	7.9963	8.2563	6.7954	6.5330	4.0416
MEX	5.1181	3.6630	3.6423	1.3541	2.8498	3.2932	2.6305	2.1131	2.1950	-0.1766
NGA	8.0057	5.3079	4.2301	6.6713	6.3097	2.6527	-1.6169	0.8059	1.9228	2.2084
PER	8.3325	6.3272	6.1397	5.8525	2.3822	3.2522	3.9533	2.5188	3.9692	2.2040
RUS	4.5000	4.3000	4.0241	1.7554	0.7363	-1.9727	0.1937	1.8258	2.8072	2.0330
TUR	8.4271	11.2001	4.7885	8.4858	4.9397	6.0845	3.3231	7.5020	2.9799	0.8896
ZAF	3.0397	3.1686	2.3962	2.4855	1.4138	1.3219	0.6646	1.1579	1.4876	0.1131

DATASET 2 (relative to figure 1): GINI INDEX

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
BRA	26.60	26.90	26.50	26.30	25.60	24.90	23.60	23.20	23.80	24.40
CHN	22.80	22.10	22.10	20.70	20.50	20.20	20.10	14.20	15.60	15.70
COL	27.50	30.10	26.60	25.70	24.10	23.70	22.60	22.90	22.40	21.60
IDN	17.70	18.30	18.30	19.10	18.20	18.20	17.60	18.70	17.40	17.70
IND	28.90	27.50	28.40	27.70	27.70	26.50	27.30	26.30	25.70	25.70
MEX	20.60	22.80	22.80	22.30	21.70	22.40	21.20	20.70	21.70	20.80
NGA	40.70	38.90	41.20	40.20	37.50	37.50	36.60	34.60	34.50	35.20
PER	29.80	22.90	24.00	23.40	23.00	21.30	19.60	18.90	19.10	18.80
RUS	11.50	11.30	11.30	11.60	10.30	9.60	9.30	9.30	9.60	10.00
TUR	23.50	22.20	22.20	15.60	15.70	15.80	15.20	15.20	16.00	16.50
ZAF	30.60	31.80	31.80	31.80	33.00	32.00	30.30	30.30	31.40	31.20

DATASET 3 (relative to figure 4): INFLATION RATE %

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
BRA	5.0387	6.6364	5.4035	6.2043	6.3290	9.0299	8.7391	3.4464	3.6649	3.7330
CHN	3.1753	5.5539	2.6195	2.6211	1.9216	1.4370	2.0000	1.5931	2.0748	2.8992
COL	2.2712	3.4176	3.1673	2.0181	2.8978	4.9902	7.5143	4.3121	3.2402	3.5255
IDN	5.1342	5.3560	4.2795	6.4125	6.3949	6.3631	3.5258	3.8088	3.1983	3.0306
IND	11.9894	8.8584	9.3124	11.0637	6.6495	4.9070	4.9482	3.3282	3.9451	3.7233
MEX	4.1567	3.4074	4.1115	3.8064	4.0186	2.7206	2.8217	6.0415	4.8994	3.6360
NGA	13.7202	10.8400	12.2178	8.4758	8.0625	9.0094	15.6753	16.5235	12.0947	11.3968
PER	1.5283	3.3693	3.6112	2.7679	3.4119	3.3981	3.5572	2.9949	1.5092	2.2521
RUS	6.8494	8.4405	5.0747	6.7537	7.8234	15.5344	7.0424	3.6833	2.8783	4.4704
TUR	8.5664	6.4719	8.8916	7.4931	8.8546	7.6709	7.7751	11.1443	16.3325	15.1768
ZAF	4.0897	4.9993	5.7247	5.7845	6.1298	4.5406	6.5714	5.1842	4.5172	4.1202

DATASET 4 (relative to figure 4): NOMINAL INTEREST RATE %

	2012	2013	2014	2015	2016	2017	2018	2019
BRA	7.25	10.00	11.75	14.25	13.75	7.00	6.50	4.50
CHN	6.56	6.00	6.00	4.35	4.35	4.35	4.35	4.35
COL	4.25	3.25	4.50	5.75	7.50	4.75	4.25	4.25
IDN	5.75	7.50	7.75	7.50	4.75	4.25	6.00	5.00
IND	8.00	7.75	8.00	6.75	6.25	6.00	6.50	5.15
MEX	4.50	3.50	3.00	3.25	5.75	7.25	7.25	7.25
NGA	12.00	12.00	13.00	11.00	14.00	14.00	14.00	13.50
PER	4.25	4.00	3.50	3.75	4.25	3.25	2.75	2.25
RUS	5.50	5.50	10.50	11.00	10.00	7.75	7.75	6.25
TUR	5.50	4.50	8.25	7.50	8.00	8.00	24.00	12.00
ZAF	5.00	5.00	5.75	6.25	7.00	6.75	6.75	6.50

Authors' profiles:

Marco Desogus - PhD in Economics; Research Fellow at Dept. of Economics and Business Science University of Cagliari, Italy.
Economist and Credit Financial Advisor Practitioner.

Address: via Donizetti, 22 09128 Cagliari, Italy.
E-mail: marcodesogus@gmail.com

Elisa Casu - BSc in Economics; Independent Economist.
Senior Credit Financial Advisor at Unifidi Sardegna - Cagliari, Italy.

Address: via Machiavelli, 85 09131 Cagliari, Italy.
E-mail: elisacasu84@gmail.com

For COI Statement: Compliance with Ethical Standards.

Funding: The authors declare that their research has been entirely self-funded.

Conflict of Interest: The authors declare that they have no conflict of interest.

Credit author statement:

Marco Desogus: Conceptualization; Methodology; Mathematical Modelling; Writing, Reviewing and Editing; Supervision.

Elisa Casu: Data Collection, Curation, Systematization, and Investigation; Software and Graphics.

We thank the anonymous reviewers for their careful reading of our manuscript and for their comments and suggestions.