Self-organization and multifractality in inflation and price systems

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Objectives

We propose to study the inflation dynamics from two perspectives:

- identify the distribution of monthly inflation, in order to know some important properties in the evolution of the price system.
- analyze the dynamics of the price index, its volatility and its behavior on different time scales and in the face of different types of shocks.

Introduction

The economy is an open system: it is formed by a large number of economic agents and the environment. Individuals react to external stimuli (from the environment and from other individuals) and internal stimuli in a self-organized way [1]. Self-organized criticality (SOC) [2, 3] supposes that open systems with elements that interact with each other, are organized in the environment of a "stationary" critical state, with no other scales other than those imposed by the size of the system. These critical states are characterized by temporal and spatial power laws. One type of economic phenomenon that could be characterized in this manner is price variations in different markets. These price variations reflect on inflation, which is measured through price indexes (CPI indexes), which can inherit many of the characteristics of the underlying processes. One of the ways in which these characteristics can manifest is through a long memory process with unbounded shocks. On the one hand, there is evidence for different economies that states that the distribution of price variation at the product level is skewed.

Power-laws

The density function of a power-law can be defined as $f(x) = Cx^{-\alpha}$; with $\{\alpha, C\} > 0$.

- We can only calculate the first $(\alpha - 1)$ moments.
- Examples: Zipf's law ($\alpha \simeq 2$), income distribution ($2 < \alpha < 3$).

Research questions

- Does the distribution of price variations of the products that shape the CPI influence the aggregate estimator and its volatility?
- How is the distribution of price variation of the economy in the long term?
- Is the inflationary process in Uruguay characterized by being persistent or does its variations correspond to a random walk process? Is its behavior the same in the face of different kinds of shocks?

Important Result

We obtain robust and consistent results in the sense of understanding the price variations as coming from complex systems. Main results indicate that the hypothesis of a power-law as the distribution of the analyzed series is not rejected, as well as the persistent behavior of price variations is modified by large fluctuations in the system.

Main results

1. Products' prices: Follows a power-law, with $2 < \alpha < 3$. Consequences on the estimation of these parameters (Figure 1).
2. Headline inflation: In the long term, follows a power law with $3 < \alpha < 4$. Relationship between interactions and interventions. SOC? (Figure 2)
3. The evolution of prices in Uruguay is characterized by persistence, linked to indexation. Its behavior is different according to the size of the shocks, while it does not depend on the time scales. The persistence is verified even without autocorrelations (Figure 3).
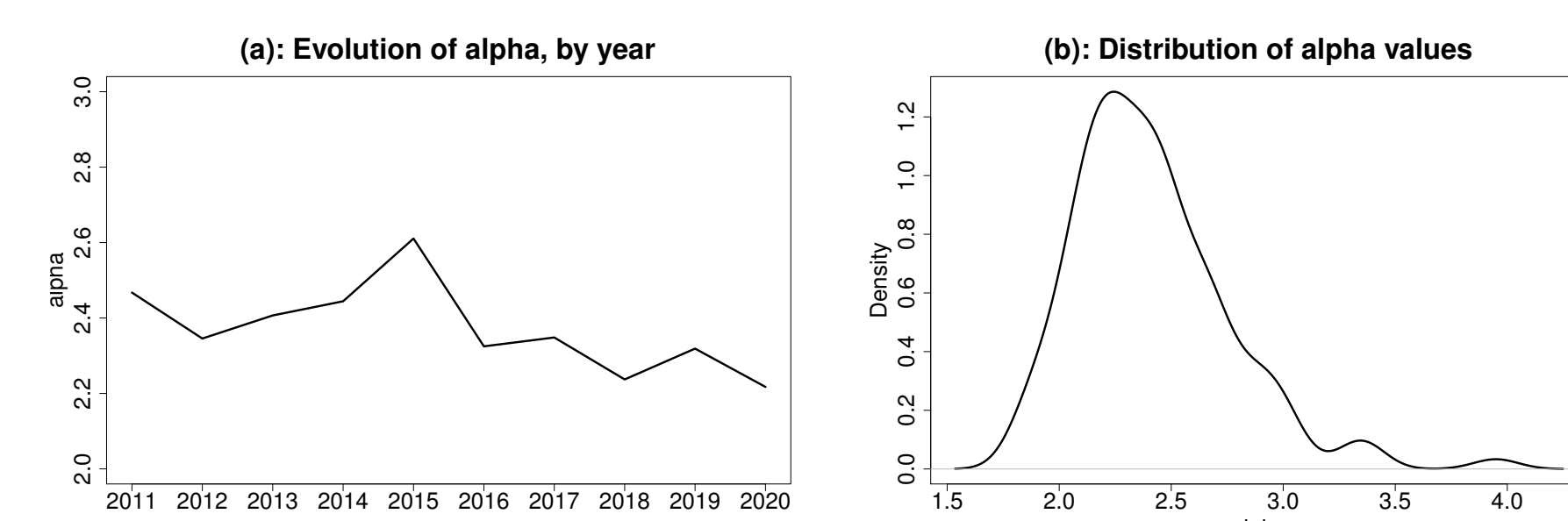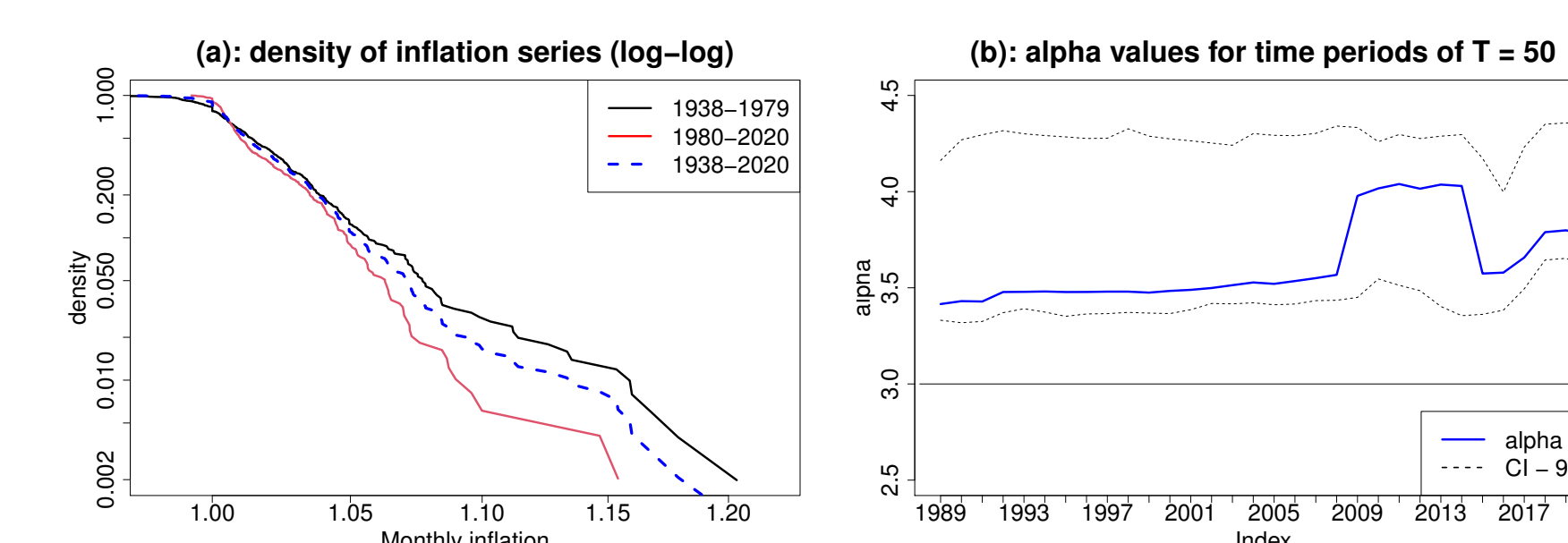
Figure 2:(a): density of the CPI series in first differences, on a logarithmic scale; (b): value of α for time windows of 50 years.
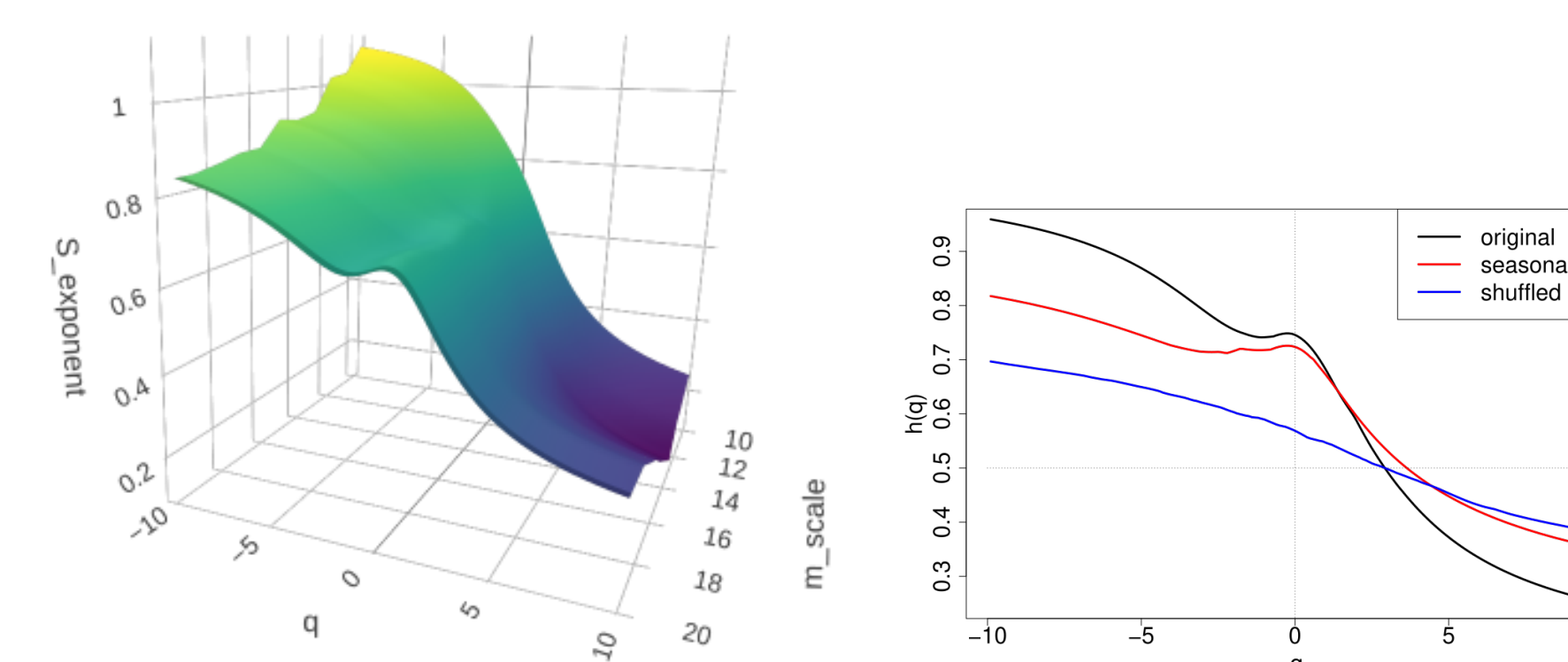
Figure 3:Left: h (q, s) for monthly inflation. 1970-01 to 2020-12. Right: h(q) plot for monthly inflation, original, shuffled and seasonally adjusted. 1970-01 to 2020-12.

Figure 1:(a):Evolution of α, years between 2011 to 2020; (b): Distribution of α, months between 2011-01 to 2020-12

Data

- Series of the Consumer Price Index (CPI) generated by the National Institute of Statistics of Uruguay, with aggregated and disaggregated data.
- headline indicator: from 1937-07 to 2020-12.
- disaggregated indicator at the product level:
  - from 2010-12 to 2020-12, 374 products.
- First differences are applied to the original series, both to the aggregated and disaggregated data.

Conclusion

For the different scales and periods used, the distribution of the series analyzed follows a power-law. The volatility of the intra-month product price variation has consequences on the degree of uncertainty of the point estimate of the aggregate indicator and also implies the possibility of large fluctuations in the relative prices of the economy. The inflationary process in Uruguay has periods of high inflation and high volatility. This analysis shows that there is a non-zero probability of large fluctuations in price changes.

These fluctuations are not white noise, but their behavior (persistent or reversion to the mean) depends on the entity of the shock. This result is generated from the interactions between agents and their interventions on the environment to influence the behavior of the index.

References

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