Impact of Monetary Policy on Financial Markets Efficiency and Speculative Bubbles: A Non-linear Entropy-based Approach

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Abstract

This paper examines, through the concept of mutual information based on entropy, the impact of monetary policy on the loss of efficiency in the financial markets and speculative bubbles. The proposed information measure is useful to quantify the efficiency with which financial markets respond to the implementation of monetary policy. The findings show that an increase in both money supply and credit growth, as well as a declining of interest rates, generate strong inefficiencies during the initial periods of formation of a bubble. Moreover, empirical evidence suggests that when a loose monetary policy generates inefficiencies, its instruments are not effective to realign the performance of financial markets.

JEL Classification: E5, G14, D84, C60.

Keywords: Monetary policy, speculative bubbles, market efficiency, non-linear models, entropy.

1. Introduction

In recent decades, most of the economies in the world have been impacted by the presence of speculative bubbles in asset prices, to name a few cases: the "kamikaze" bubble generated in the real estate sector in Japan and that would explode in 1990; the "dot-com" bubble occurred in the late nineties to assets related to new technologies; and, of course, the subprime bubble, which burst in 2007 and had its gestation in the real estate sector in the United States. This last event resulted in a global debacle that still has sequels in many economies, making it the largest financial crisis since the Great Depression.

Given the recurring presence of speculative bubbles and the high social costs they cause, several empirical studies have focused on understanding the gestation process of these phenomena. One topic that has gained much interest is to get a better understanding in the various relationships and mechanisms of transmission between monetary policy and explosive growth in asset prices. In this regard, Detken and Smets (2004) analyze the effect of both real and nominal variables before, during, and after an explosive growth in asset prices. These authors find a correlation between the growth of asset prices, economic activity, and growth in both real credit and real money before and during the unusual rise in asset prices; prices fell considerably two years later.

On the other hand, Bordo and Lane (2013) study the relationship between monetary policy, credit expansion, and low inflation with the accelerated increase in the prices of financial assets. Their results confirm a positive relationship between the first two variables, and inflation seems to have a greater effect. Also, Gilchrist and Saito (2006) argue that a monetary policy that responds strongly to inflation could be a sufficient answer to stop a bubble.

At present, the managing of monetary policy, anywhere in the world, has focused in pursuing price stability. We can say that in most cases, the goal has been successfully achieved. However, its effects and repercussions have transcended beyond the own objectives of the monetary authorities. Greenspan (2004) remarks that the paradoxical result of the successful managing of prices in the U.S. was that the applied policy contributed significantly to the formation of the bubble in the late nineties. In this respect, Trichet (2005) points out that the better understanding of the link of speculative bubbles in the prices of financial assets and monetary policy has been one of the most difficult challenges faced by central banks in the early twenty-first century. The discourse is conclusive stating the unambiguous coincidence between low inflation and high asset prices, which economists, from the Bank of International Settlements, called the Paradox of the credibility of Central Bank.

It is clear that the relationship between monetary policy and bubbles in asset prices is a central issue for the authorities responsible for the design and control of monetary guidelines. Therefore, it is logical the arising of questions about the possibility of amending the negative impacts. It is also necessary to quantify the potential costs of the taken actions without ignoring price stability. Unfortunately, even after the devastating effects caused by the U.S. bubble in real-estate prices in late 2008, there are no precise answers to most of these questions.

This paper aims to analyze the different mechanisms through which the implementation of monetary policy generates and transmits inefficiencies on asset valuation in the financial markets. It is also concerned with examining the temporality and

determining whether the monetary policy instruments can be used to recover market efficiency and, thus, reverse the revaluation of assets.

This research also analyzes the relationship between the efficiency of the financial markets, the real money supply, the rate of growth in total loans, the change in the interest rate and the inflation rate for the U.S. economy during 1992-2013, lapse considering the formation and bursting of the two latest bubbles, clearly identified as the "dot-com" and "subprime".

It will be assumed that each of the studied instruments has an effect and a different temporality, so the methodological proposal of this research needs to take several elements from various theoretical visions attempting to explain the effect of each of the considered variables. The classical view of the quantity theory of money is used here to explain the effects of short-term monetary theory and, subsequently, the post Keynesian paradigm will help to explain the failure of the authorities to exercise effective control over monetary policy doing unstoppable the inertia in the revaluation of assets.

As it was observed above, the channels through which monetary policy influences on asset prices are very diverse and with very different temporality. Therefore a linear analysis such as that of econometric type is not capturing the interdependence between variables. After highlighting the non-linearity of the phenomenon under study, in the second part of this research the methodology to measure the efficiency of financial markets will be described; being the main tool of analysis the coefficient of mutual information, which was, originally, used to measure the amount of information associated with a dynamic communication system.

The concept of mutual information coefficient responds to the essential assumption that the market reaction to similar stimuli is consistent over time and, therefore, the system

generates a stable alphabet. It is also assumed that: the market gradually incorporates available information; the agents are not homogeneous in analytical capacity and risk tolerance; and the rate at which information is incorporated and disseminated is not homogeneous for all agents. This is, undoubtedly, related to what Keynes called "Animal Spirits".

Claude Shannon (1948) describes the entropy as the mean value of the information provided by each symbol that is emitted by a source. In the work of Pincus (1991), Shannon entropy is used to measure the stability of a system. Meanwhile, Ludwig (2006) states the degree of uncertainty of a random system is measurable by means of entropy.

Recent studies have used different variants of the concept of entropy as an attempt to quantify the efficiency of financial markets. In the work of Wang and Han (2012), and Alvarez and Rodriguez (2012) the hypothesis of efficient financial markets is adequate to be described by entropy. Finally, In Risso (2008) the concept of Shannon entropy is applied to measure the evolution of the U.S. housing market behavior.

This paper uses the coefficient of mutual information as an alternative methodology to quantify the efficiency with which financial markets respond to the implementation of monetary policy. With this coefficient, it is possible to equip the authorities of elements that enable them to identify, at an early stage, the formation of a bubble.

The third section of this research describes the results of the empirical application of the proposed methodology in the period 1992-2013; being this period when two of the biggest bubbles have occurred in recent times, namely the dot-com and subprime. Both cases will be analyzed for the U.S. case. Finally, in the fourth section of this document final conclusions are presented, adding a brief discussion on future research.

2.1 Monetary policy and financial markets efficiency

The hypothesis of Efficient Financial Markets, introduced by Fama (1970), states that an efficient financial market is one in which the prices of financial assets reflect always and completely all available information. Fama (1965) also refers to an efficient financial market as one in which the changes in asset prices are of random type; more specifically prices follow a random walk. In the presence of high randomness, a financial market would be working at full efficiency because it reflects the entire spectrum of expectations formed from the existing information on the economic and financial situation. Under this premise, in an efficient market, at any point of time, the price of an asset will always be a good estimate of its intrinsic value.[i] Therefore, it is not possible to observe periods of revaluation in which asset prices rise away from their core values. In other words, it is impossible the existence of "irrational" speculative bubbles.[ii] Nevertheless, it is now generally accepted that markets hardly meet such conditions. There are several theories trying to explain the reasons why a market may lose efficiency. This paper argues that the implementation of an expansionary monetary policy have an effect on public expectations and, therefore, can transfer distortions affecting the ability of agents in valuing asset prices.

Next, we describe some of the transmission mechanisms. First, we analyze the effect of inflation in financial markets. This issue can be approached from different perspectives.[iii] First, the Austrian school vision will be used, which indicates that the bubbles are more likely to occur in scenarios where monetary policy has created an environment of confidence in price stability.[iv] In this regard, Greenspan (2004) highlights that the low levels of inflation contribute to exacerbate the value of financial assets, attributing an important role to expectations. According to the former Chairman of the

Federal Reserve from 1987 to 2006, inflation control generated the expectation of increasing macroeconomic stability by helping to reduce the perception of risk and exacerbating optimism among the investing public. This allows increasing profit expectations among analysts, accelerating stock prices increases. This is what constitutes the Paradox of Credibility of Central Bank[v], stated by the Bank for International Settlements. Several empirical studies as Christiano (2010) and Bordo (2013) have shown the correlation between low levels of inflation and bubbles in asset prices. It will be shown later that the estimates obtained by this research indicate that periods of low inflation are consistent with a sustained loss of information, which leads to the loss of efficiency in the financial markets.

Another instrument of monetary policy, considered in this study, is the money supply in real terms. In order to examine its effect we use the Financial Fragility Hypothesis from Minshy Hyman (1992). Under this framework, an increase in the amount of money in the economy creates an environment of prosperity generating high public expectations about the future asset returns.[vi] In this way, the continuous rapid growth in asset prices seems to be justified. For this reason, firms respond by requesting higher levels of funding due to the certainty that asset prices will continue to grow. In fact, as the boom advances, the increase in asset prices boost will be the main manner to pay credits. According to the second theorem of the financial fragility, in the long run most of the firms will be involved with unstable funding systems (Ponzi schemes type), which results in the need to show a higher future cash flow to hire new loans. We can then see that a credit expansion generates short and medium term expectations that give rise to shift investment towards certain types of assets, but this process remains in the long-term time due to the

dynamics of the financial system in which the combination of debt and bonds to finance capital accumulation is based.[vii] In this context, it would be reasonable that a simple application of a restrictive monetary policy could reduce the exacerbated optimism of the public; however, the process does not have an obvious solution, then, as will be seen later, once expectations are generated they are fed back as in offline mechanism of variations in the amount of money in the economy.

One explanation for the transmission of credit expansion and the decrease in the interest rate can be found under the post Keynesian view of monetary economics, which is concerned with studying the relationships between money, uncertainty and time. Lavoie (2007) points out that the main feature of the post Keynesian monetary economics is the existence of endogenous money.[viii] This feature is explained by the ability of commercial banks to lend resources to firms for the production process.

The above ideas became popular under the vision of the post Keynesian school. There are two approaches, one under the name "horizontalists"[ix] and the other known as "structuralists" or theory of liquidity preference. In both paradigms the challenge is how to conduct policy in a world of endogenous money.[x] Garcia (1990) in describing the effect of the preference for liquidity assumes that credit supply is not infinitely elastic as a result of the existence of uncertainty in the market. The perception of risk requires banks to add a surcharge to the cost of credit. In response firms will be forced to maintain higher levels of profitability and show larger collateral for contracting new debts. In other words, for getting new loans firms must present higher future income flows. In this context, the discretionary nature of monetary policy, as conceived under the vision of the quantity theory of money[xi], is lost and, therefore, it is also lost the ability of an opportune

intervention in the market to change the public expectative. Additionally, in the presence of risk and uncertainty, firms tend to revalue their assets by an increase in credit or market risk, which requires a surcharge to boost the prices of financial assets. Consequently, the monetary authorities cannot control the associated liquidity excess. If the process coincides with a period of uncertainty that creates the perception of risk among agents, then the requirement of a surcharge and the need to show more valuable collaterals for contacting new debts feeding back the formation of speculative bubbles .

The explosive growth of credit, basic feature of post Keynesian monetary analysis, transforms bonanza into fragility as firms are committed to a high percentage of debt. At this point, the economic conditions afford evidence that the prices of assets that have been used as collateral for loans have been irrationally away from their fundamental value. Therefore, the bubble is evident but also unmanageable, which coincides with times of low mutual information between market returns and loans. In summary, the concept of uncertainty to which the post Keynesian vision describes as causing liquidity preference appears to be the explanation of the formation of speculative bubbles. This uncertainty can be explained in various ways, the post Keynesians attributes it to credit risk, *i.e*., to the default caused by the huge volume of credits issued by the central bank. This study did not use the number of defaults on commercial loans because, unfortunately, their timing does not match the rest of the variables used in this work.

Once reviewed the state of the art of the possible explanations that economic theory can give to enlighten the phenomenon of bubble formation, we will provide a brief review, in the next section, on the main concepts on Shannon's (1948) information theory, emphasizing the mutual information coefficient and its relation to measuring market

efficiency. Subsequently, we select the macroeconomic variables for this study, and examine the way how they explain the timing of the transmission mechanism previously described.

2.2 Efficiency in the financial markets and the coefficient of mutual information

Claude Shannon (1948) proposed, in his theory of information, a reformulated concept, of entropy, which is useful on coding alphabets.[xii] In his research, entropy is described as the mean value of the information provided by each symbol that is emitted by a source.[xiii] More precisely, Let X be a discrete random variable with mass probability density $p(x)$, then entropy is defined as

$$H\ \ X\ \ = -\sum_{x}^{N} p\ \ x\ \ \ln(p(X))$$

where X may take N possible values. Under this framework, average entropy is a measure of the randomness or uncertainty in the behavior of the random variable, and it is understood as the predictability of the tested process. In fact, if the analyzed information source provides constant values, the new information issued is null and therefore the entropy is zero leading to a perfect knowledge by traders in the market. This quantity has the following features:

$0 \leq H(X) \leq \ln(N)$. The entropy of an information source is not negative and is bounded above. This means that the source cannot lose information, and cannot submit an unlimited amount of information (for a limited number of symbols). Within the financial theory, this

means that agents have not forgotten and they have increasing flows of information, which is currently modeled by an increasing filtration (Karatzas and Shreve, 1998).

1) $H(X) = 0$ if for some x' $p(x') = 1$. In this case, the remaining probabilities are zero and, therefore, there is no surprise and entropy becomes zero, coinciding with the loss of randomness in the formation of both price and total loss of market efficiency.
2) $H(X) = \ln(N) \Leftrightarrow p(x) = 1/N, \forall x$. When all symbols are equally probable, the uncertainty of what will happen will be high and, therefore, the upper limit of entropy is reached.

Thus, it is expected that in an efficient market, economic agents use all information provided by the market. In this context it is not possible the existence of trends in the prices of financial assets and entropy will take its maximum value. If the price evolution begins to be deterministic, the entropy decreases showing the possible formation of speculative bubbles. The loss of randomness implies the existence of events (read in this case monetary policy) that strongly influence public expectations.

Cruz-Aké *et al*. (2014) describe entropy as a measure of adaptation to the economic environment. A phenomenon that provides much information responds with a high degree of randomness, while a quasi-deterministic economic event can be understood as a separated process from the rest of the system. Wan and Han (2012) use entropy as a statistic to quantify the disorder and uncertainty of a complex dynamic system.

The concept of entropy has several variants, and this paper assumes that there are two discrete random variables, whose behavior is conditioned on a reciprocal basis through a system of mutual information. More precisely, mutual entropy $I(X;Y)$ for a pair of discrete random variables with joint mass probability density $p(X,Y)$ is defined by

$$I(X;Y) = H(X) - H(X|Y) = \sum_{x,y} p(x,y) \ln \frac{p(x,y)}{p(x)p(y)} \quad (2)$$

The above coefficient defines the relationship between two random variables and it has the following properties:

1. $I(X;Y) \geq 0$, that is, the coefficient of mutual information is a positive quantity and can only be zero when events X and Y are independent. In this circumstance a zero value for the coefficient of information indicates that monetary policy and the market return are independent phenomena.
2. $I(X;Y) = I(Y;X)$, that is, the coefficient of mutual information is symmetrical in X y Y. This parameter quantifies the relationship between variables but does not specify the direction of causality between variables.
3. When the dependency between variables is complete, the coefficient of mutual information is equal to the entropy of any of them.

The next section reports the results of the empirical analysis based on mutual information shared by different instruments of monetary policy and financial market performance.

4. Transmission of Monetary Policy on the Formation of Speculative Bubbles, Empirical Evidence

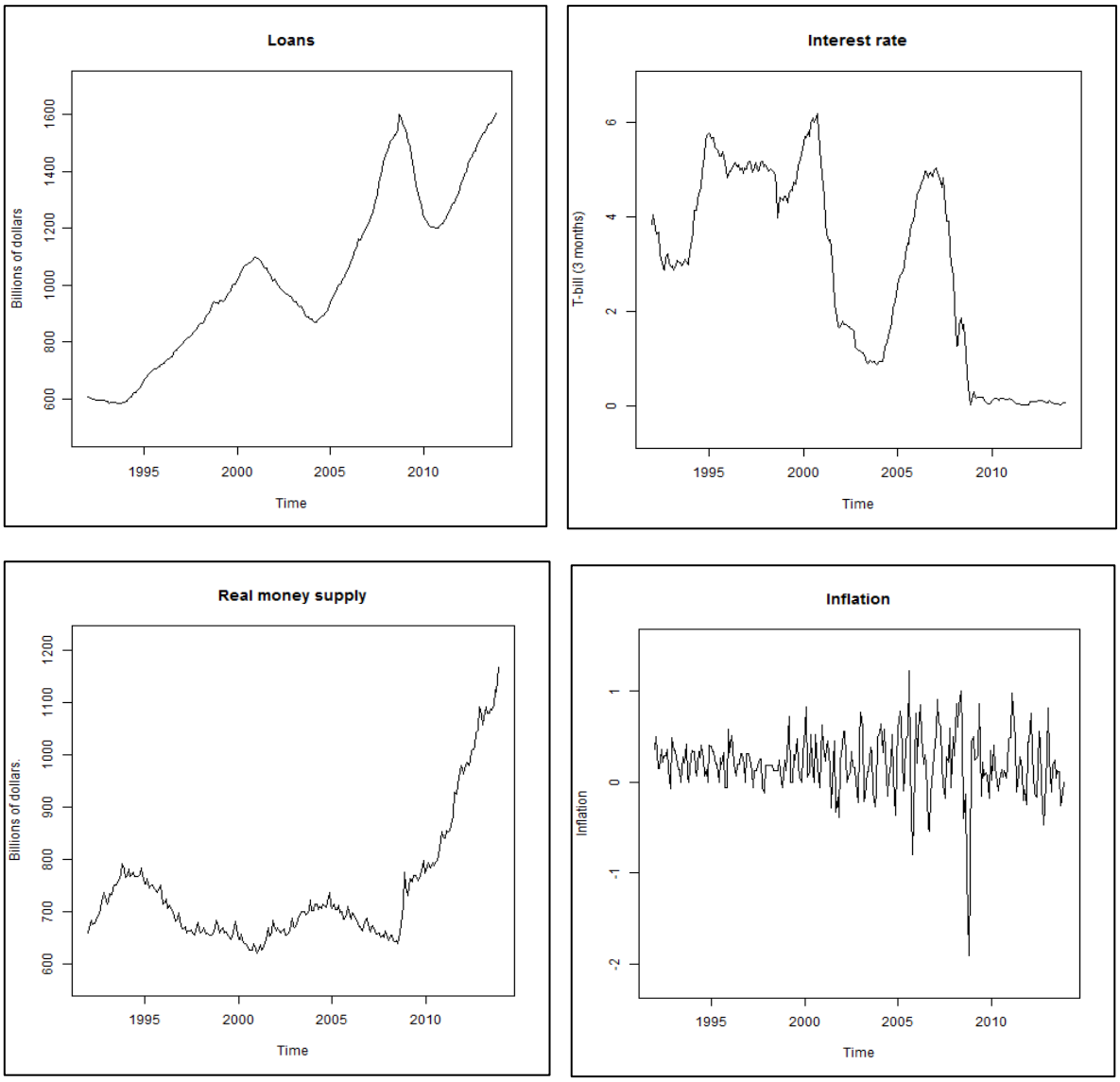
This section examines the dynamics of the coefficient of mutual information of several relevant variables relative to the performance of the Dow Jones Industrial Average (DJIA) during the period 1992-2013. In this period were located two of the most significant, of

recent times, bubbles, the dot-com occurred in the second half of the nineties and the housing bubble or subprime bubble that would eventually burst in 2008.

To assess the impact of monetary policy on the efficiency with which financial markets perform and according to the theoretical framework exposed four variables are analyzed: money supply in real terms (M1), interest rate of *Treasury Bills* of a three-month term (r), inflation rate (π) and industrial and commercial total loans granted by commercial banks (L).

Monetary policy in the United States, according to Greenspan (2004), was characterized by a context aimed at controlling inflation, among the main characteristics in such a policy stand out: the higher degree of competitiveness from the processes of globalization, the rapid increase in productivity, and the direction of economic policy to promote price stability. For the period of study, the policy generally was characterized by being discretionary during subsequent recessions to crises of 1987, 2000 and 2008, aimed to restore economic activity. The evolution of the main monetary instruments analyzed in this work is shown in Figure 1.

Figure 1. Evolution of monetary variables (loans, interest rates, M1 and prices) from 1992 to 2013



Source Own elaboration with data from the Federal Reserve Bank of St. Louis.

In order to overcome the recessionary environment left by the financial crisis of 1987, the U.S. responds with an "accommodative" monetary policy, the interest rate (three -month T-bills) reached its lowest level in more than three decades to fall to 2.87% in April 1993. Early 1994, thanks to low interest rates and a bank capitalization restoring, credit expansion was started. At the same time, inflation remained under 2.5% annually. It is in this

environment of credit expansion, low interest rates and controlled inflation, which for purposes of this paper, identifies the displacement and overtrading[xiv] of the dot-com bubble as a result of the euphoria generated by the public.[xv]

A similar environment is described after the bursting of the dot-com bubble in 2000 and the terrorist attacks of 2001. Regarding the conduction of economic policy in the United States, an expansionary fiscal and monetary policy was managed. As a result of increased liquidity, interest rates fell substantially from 6.2% in November 2000 to about 1% in June 2003. Additionally, in this environment the biggest tax cut in the last 20 years was carried out, and the conditions generated, again, the feeling of wealth in the public, encouraging over-indebtedness of consumers and investors (Villegas *et al*., 2010). Importantly, these results provide empirical evidence that places the origin of the subprime crisis between 2002 and 2003 when the mutual information between the market and other relevant variables fell to its lowest level prior to the crisis.

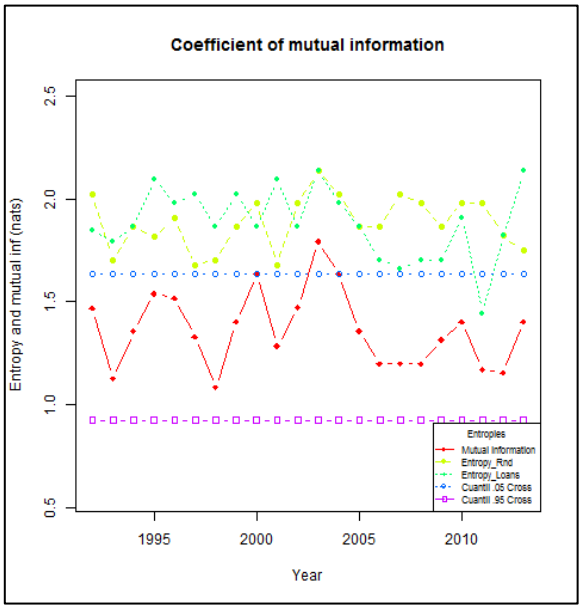
Once a brief description of the economic situation and periods of displacement and overtrading for both bubbles was carried out, we proceed to analyze whether the increases in money supply, the low interest rates, the credit expansion and the low inflation, reflect the decreases of efficiency in the market by using the coefficient of mutual information

To better understand the obtained results, is worth remembering that if some or all of the instruments of monetary policy, discussed here, have an effect on public expectations, these expectations will tend to exacerbate the price of financial assets diminishing the randomness in them. In other words, the asset prices tend to show constant revaluation periods causing a speculative bubble. This behavior should be reflected in a steady decline in the medium and long-term levels of mutual information[xvi].

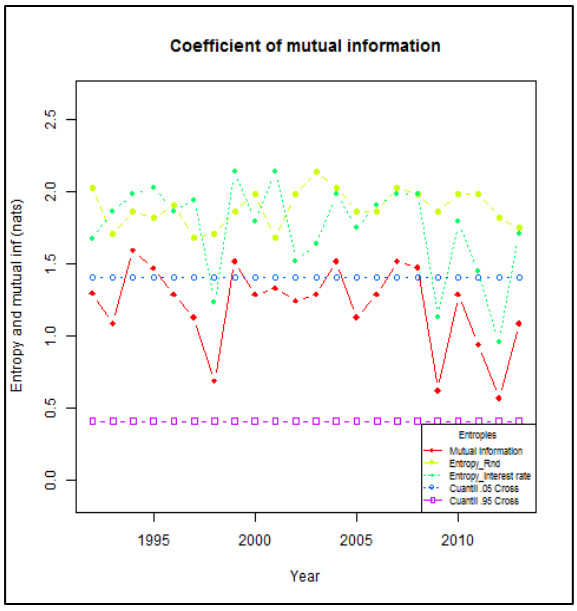
The results for the coefficient of mutual information and confidence intervals obtained, at the 95%, for the variables loans, interest rates, money supply (M1) and inflation, relative to the market return represented by the Dow Jones Industrial Average index are shown in Figure 2. We emphasis on confidence intervals to give the reader a clearer picture of the level of the coefficient of mutual information with respect to its historical values, without making assumptions about the distribution of the coefficient of mutual information of the data or their joint distributions.

Figure 2.Coefficients of mutual information for loans, interest rates, M1 and inflation relative to the stock market

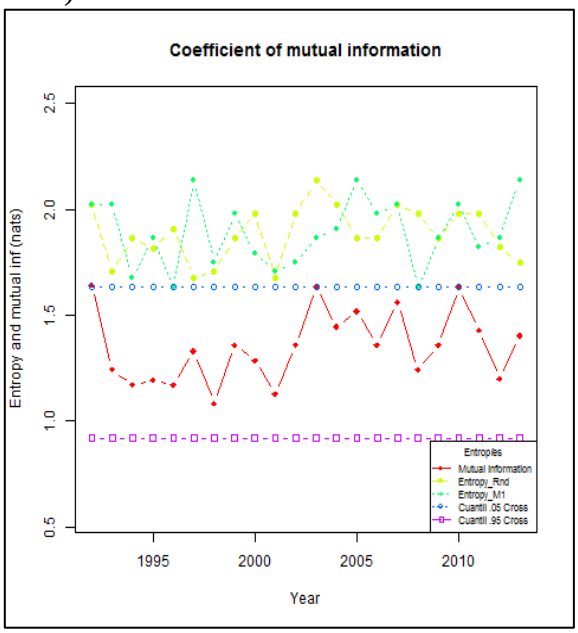
a) Loans.



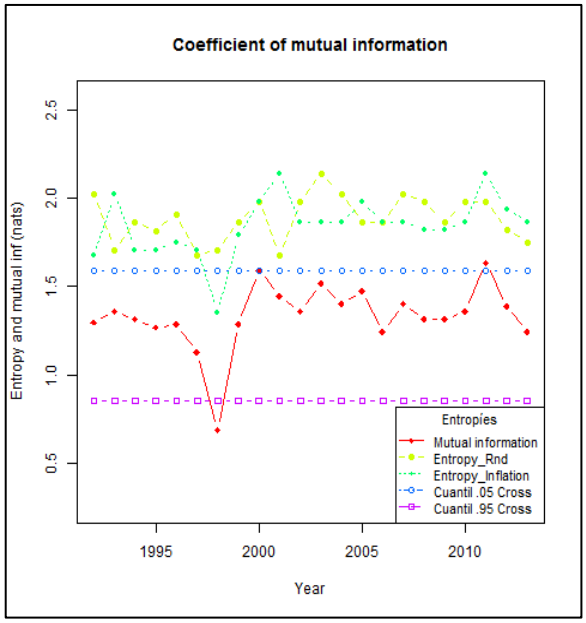
b) Interest rate.



c) M1



d) Inflation



Source: own calculations using data from the Federal Reserve Bank of St. Louis.

As it can be seen in Graph 2(a), there is a clear relationship between credit growth and overtrading of the dot-com and subprime bubbles. According to Table 1, there are two periods of loss of efficiency, the first one from 1995 to 1998 in which the mutual information coefficient falls 30%, and the second from 2003 to 2007, period in which the coefficient of information falls 33%.

Table 1. Coefficient of mutual information for loans and stock market.

Year	Loans*	Information coefficient
1995	0.813	1.539
1996	0.693	1.517
1997	0.709	1.330
1998	0.841	1.083
2003	-0.648	1.792
2004	0.312	1.633
2005	1.067	1.358
2006	1.098	1.199
2007	1.602	1.199

Own calculations using data from the Federal Reserve Bank of St. Louis.

* Average monthly rate of change per year.

Another important issue is that the decrease in the rate of credit growth or the negative evolution of the rate itself is reflected in increasing levels of efficiency for two periods, 2001-2003 and 2008-2010. These results are consistent when it is considered that they are following the outbreak of each bubble, so the loan amount is reduced and public expectations are alert after being shaken.

On the other hand, it is particularly interesting the recovery of efficiency between 1998 and 2000. The rate of credit expansion is diminished slightly; however, the credit crisis was not enough to reduce optimism of the public in the pre bubble burst dot-com years. Moreover, when in 2008 the credit expansion decreases more than 50%, the value of the efficiency remains constant, *i.e.*, the market becomes indifferent to the conduction of monetary policy in times of increasing euphoria, which is consistent with the transmission mechanism previously exposed.

The results obtained lead to the conclusion that variations in the amount of credit have a direct effect on the efficiency of financial markets. This conclusion is consistent with the studies from Detken and Smets (2004) who analyze the financial and monetary policy conditions for 38 periods of increasing prices of financial assets in 18 OECD countries. Their findings show strong correlation between the growth of asset prices, real credit and real money growth before and during the rise and growth rates, and decline significantly in the two years following the outbreak of bubble.

It is important to point out that although credit contractions have positive effects, these effects are not enough to reconnect the formation of expectations with market information. This fact provides empirical evidence on the fact that a tight monetary policy cannot return the financial market efficiency, as initially stated in this investigation.

Regarding the interest rate dynamics, it is evident the existence of four periods of loss of efficiency, which are related to reductions in interest rates. Table 2 shows the change in interest rates for the selected periods.

Table 2. Dynamics of the interest rate

Period	T-Bill (annual average)	
	Beginning of period	End of period
1995-1998	5.01%	4.36%
2000-2003	5.37%	0.91%
2008-2009	1.14%	0.14%
2010-2012	0.13%	.08%

Source: own calculations using data from the Federal Reserve Bank of St. Louis.

Table 2 allows us to observe that there is a relationship between loss of efficiency and decreasing interest rates. This is especially true for the period 1995-1998, which corresponds to the overtrading of the dot-com bubble. With regard to the effect on the gestation period of the subprime bubble it is interesting to note that this effect is quantitatively less even though there is a persistent influence of low interest rates on market efficiency, but the effect remains to be the same in period 2000-2003. This finding can be explained by the extremely low interest rates reached at the end of the period with levels of 1% and below. This argument is reinforced for period 2010 to 2012 during which another significant drop in efficiency levels is evident and now with interest rates close to zero.

This situation according to Keynesian analysis, is characteristic of an economy that has fallen into the trap for liquidity, *i.e.*, interest rates have reached a level at which the elasticity of money demand with respect to the interest rate becomes infinitely elastic.

On the other hand, if we consider the consequences of an increase in interest rates, the result of efficiency appears to be marginal, while interest rates increased 48%, the coefficient of information only increases 14% from 2005 to 2006. In brief, unlike the mechanism of bank loans, the interest rate does not seem to be a good tool to regain the levels of efficiency, especially when these have become too low, as the market becomes indifferent to changing interest rates.

Gali (2013) offers a different point of view in explaining the low rates of interest in his work noticing that fluctuations in interest rates can encourage further increases in asset prices, so he consider that it can be a positive factor to reduce the interest rates facing to the growth of a bubble.

Regarding the effect of transmission of an increase the money supply, the results show that efficiency losses are consistent with the formation periods of both studied bubbles; this is for the periods 1992-1994, 2000-2001. The same observation is considered in Detken and Smets (2004) who find that real money growth is strong enough before and during the explosive growth in asset prices and with a sharp fall in the next two years of this events. These results are also consistent with Minsky's theory in the sense that an increase in the money supply affects the expectations of the public, who driven by the prospect of plenty lose the ability to properly assess the intrinsic value of financial assets.

It is important to highlight that, from 1998 to 1999, there was a significant recovery in efficiency levels corresponding to the reduction in the money supply. However, again, monetary tightening is not enough to realign the market behavior and prevent the collapse of the bubble in the late 2000s.

Additionally, it is interesting to note that while in times of prosperity a monetary expansion can influence public optimism, in times of uncertainty and economic instability, monetary expansion may become a discretionary measure used to restore stability in the financial system as in 2008- 2010 where efficiency was recovered by increasing the amount of money in circulation. Table 3 shows in detail these results.

Table 3. Coefficient of mutual information between M1 and stock market.

Year	M1*	Information coefficient
1992	9.13	1.64
1993	17.94	1.24
1994	3.51	1.17
1998	-0.57	1.08
1999	-0.17	1.40
2000	-3.14	1.29
2001	0.46	1.13
2008	0.71	1.24
2009	14.47	1.36
2010	4.68	1.63

Own calculations using data from the Federal Reserve Bank of St. Louis. * Annual variation.

In what follows, we will discuss whether or not in practice the paradox of the central bank is confirmed. According to the various theoretical approaches, price stability provides a suitable environment for generating public confidence in the expected return of

assets, thereby facilitating the formation of the bubble. Studies such as those from Bordo and Lane (2013) and Christiano *et al*. (2010) show that inflation is typically low in periods of rapid price increase of financial assets.

For the overtrading of the dot-com bubble, it can be seen a significant drop in efficiency during the period 1993-1998. This trend is consistent with a period of low and stable inflation levels; while prices fell 36%, information ratio fell 49%. Despite inflationary pressures in 2000, from the end of this year and until 2002 it was again observed a return to price stability and a constant loss in the mutual information coefficient, the same relation is found for the years between 2007 and 2009.

According to the obtained results, the price mechanism transmits significant deficiencies in financial markets, which confirms the paradox of the central bank. However, its effect lasts only during the initial stages of the formation of a bubble, as public expectations adapt to price stability. The indicator loses efficiency to give signals in the market and only becomes important when inflationary pressures are observed, as in the case of 2000 and 2007, when the coefficient of information increases significantly with market movements. Table 4 shows the results in detail.

Table 4.Coefficient of mutual information between inflation and stock market.

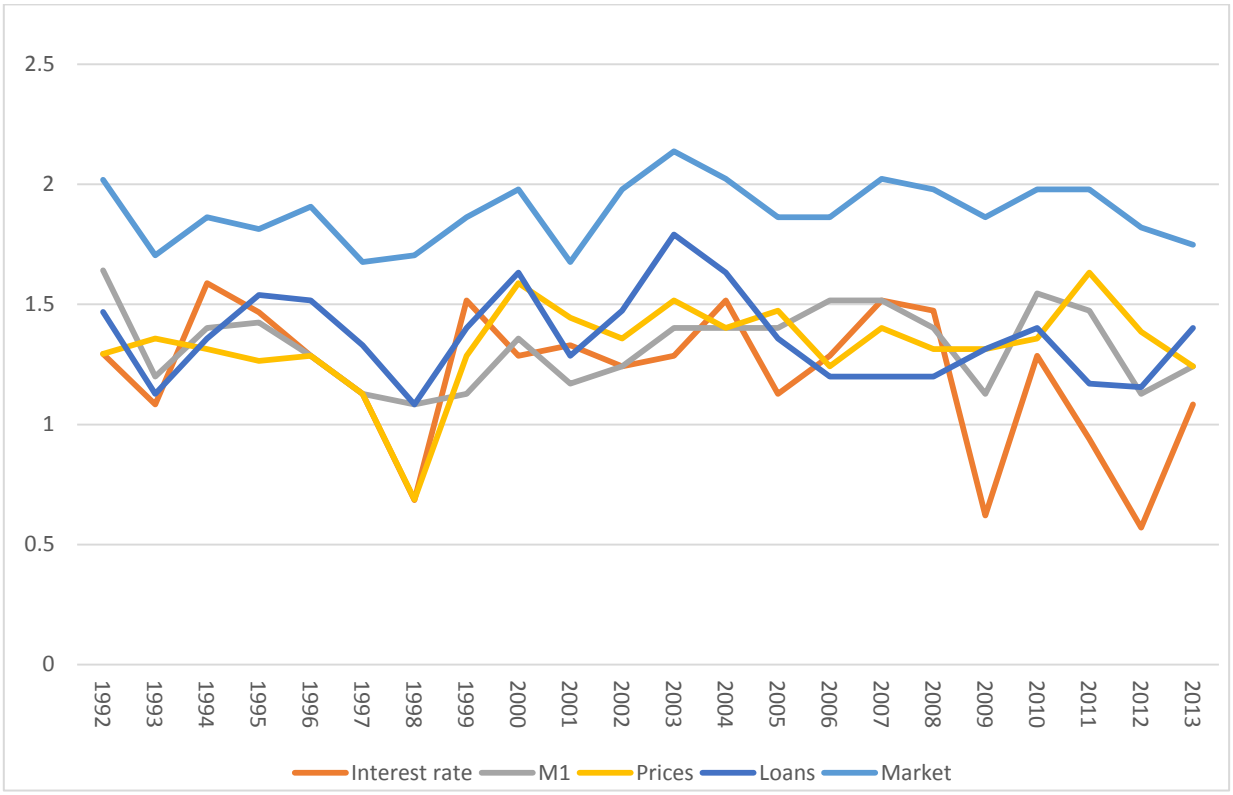
Year	Inflation *	Information coefficient
1993	2.24	1.36
1994	2.39	1.31
1995	2.13	1.27
1996	2.72	1.29
1997	1.38	1.13
1998	1.42	0.69
2000	3.08	1.59
2001	0.91	1.45

2002	2.15	1.36
2007	3.76	1.40
2008	-0.40	1.31
2009	2.28	1.31

Source: own calculations using data from the Federal Reserve Bank of St. Louis.
* Annual variation.

It is now convenient to jointly study all information coefficients obtained for each of the variables. As already was demonstrated, the inefficiency market changes with monetary policy; however, the relationships become complex in varying significantly between periods. As it can be observed the timing between each specified period is different, and the duration and depth of effect is also different. Figure 3 shows these relationships.

Figure 3.Coeficients of mutual information for loans, interest rates, M1mrelative to stock maket prices.



Source: own calculations using data from the Federal Reserve Bank of St. Louis.

As mentioned before, the displacement and overtrading of the first dot-com bubble, occurred between 1992 and 1994. During this period the efficiency loss begins, as provided for in the theory of Minsky with the implementation of a monetary expansion from 1992. Yet in the context of increases of the money in circulation, the so-called paradox of the central bank, according to which price stability leads to distortions in public expectations, is confirmed. This is reflected in the sharp decline of the coefficient of mutual information since 1993. Under the expectation of economic recovery, it begins the decline of interest rates and credit expansion. These events feedback optimism in the public causing the formation of expectations even more disconnected from economic fundamentals. The decrease in the coefficient of information is maintained from 1994 to 1998 for interest rates and from 1995 to 1998 for the credit expansion.

Regarding the evolution of the subprime bubble, again, low levels of inflation and monetary expansion are present during displacement and overtrading. The effect of these variables on market efficiency is observed in 2001 and 2002, respectively. But now their influence is much less marked, the monetary instrument now transmits greater inefficiencies to the market is the credit expansion, which causes a significant and sustained decrease in the coefficient of information from 2003 to 2007. Strong effect on loans and the marginal effect of interest rates in the period 2000-2003 can be explained by the low interest rates[xvii].

5. Conclusions

The empirical results confirm that monetary policy can lead to significant deficiencies in the functioning of financial markets. The process begins, as described by Minsky, under the implementation of an expansionary monetary policy that generates public expectations of economic prosperity. At the same time, it is confirmed with empirical evidence that low levels of inflation affect economic growth exacerbated the increase asset prices, as predicted by the paradox of the central bank.

Also, it was shown that public optimism is fed back by other routes of transmission. This is understood as the management of interest rates and credit expansion, which are present at different times. These mechanisms vary considerably at each moment of time, so when the monetary authorities pretend control the exacerbated atmosphere, what Keynes called the animal spirits, it is not sufficient to apply restrictive monetary measures, as promoted classical quantity theory, to recover efficiency without generating costs.

Regarding the effect of credit growth, this is a characteristic of the overtrading of the dot-com and subprime bubbles. Inefficiencies in the market caused by this instrument are of considerable importance and even if the authorities try to restrain the growth rate of bank credits to burst the bubble, and the market efficiency increases only marginally or remains practically indifferent. In this sense, the conclusion outlined here differs from other research such as Christiano *et al*. (2008) arguing that a monetary policy that reacts to credit growth and inflation control can reduce the likelihood of forming or bursting of the speculative bubble.

Moreover, the consequences of a decline in interest rates can be divided in two categories. First, in order to maintains a credible management policy of Central Bank, changes in interest rates are an important factor in the process of bubble formation. Other possibility is that interest rates drop to levels close to zero, thus the market falls into the trap liquidity and becomes indifferent to changing interest rates.

Finally, it was shown that the coefficient of mutual information adequately represent the variations in the efficiency of a financial market, even in stages where an incipient drop of this indicator can provide alarm signals. In this sense, the coefficient of mutual information is a measure for the evolution of market behavior. Needless to say, it

remains for future research to establish a range of scores to assess the average behavior of the market.

Bibliography

Alvarez-Ramirez, J., E. Rodriguez y J. Alvarez (2012). A Multiscale Entropy Approach for Market Efficiency. *International Review of Financial Analysis*, Vol. 21, pp. 64-69.

Adam, M. C. and A. Szafar (1992). Speculative Bubbles and Financial Markets. *Oxford Economic Papers*, Vol. 44, No. 4, pp. 626-640.

Borio, C. and P. Lowe (2002). Asset prices, financial and monetary stability: exploring the nexus. BIS, working papers no. 114, July.

Bordo, M. D. and J. Landon-Lane (2013). Does expansionary monetary policy cause asset price booms; some historical and empirical evidence. National bureau of economic research October 2013 Working Paper 19585 http://www.nber.org/papers/w19585.

Campbell, J. Y. and T. Vuolteenaho (2004). Inflation Illusion and Stock Prices, *The American Economic Review*, Vol. 94, No. 2, pp. 19-23.

Christiano, L., C. L. Ilut, R. Motto, M. Rostagno (2010). Monetary policy and stock market booms. National bureau of economic research, Working Paper 16402. September 2010. http://www.nber.org/papers/w16402.

Cruz-Aké, S., R. S. García Ruiz y F. Venegas-Martínez (2014). Una medición no lineal de la dependencia de la inflación sobre el tipo de cambio nominal (pass-through). *El Trimestre Económico*, por aparecer.

Delgado-Selley O. (2011). La hipótesis de la inestabilidad financiera y la crisis de 2007-2009. *Economía Teoría y Práctica*, Vol. 34. No.1, 9-41.

Dow, C. Sheila (2007). Endogenous Money: Structuralist. "A HandBook of Alternative Monetary Economics". C3. Edward Elgar Publiching.

Detken, C. and F. Smets (2004). Asset price booms and monetary policy. European Central Bank, Working paper series no.364 may (2004). http://www.ecb.int or from the Social Science Research Network electronic library at http://ssrn.com/abstract_id=533122.

Fama, E. F. (1965). Random walks in stock market prices. *Financial Analysts Journal*, pp. 55–59. Reprinted in 1995 as Random Walks in Stock Market Prices, *Financial Analysts Journal*, Vol. 51, No. 1, pp. 75–80.

Fama, E. F. (1970), Efficient capital markets: A review of theory and empirical work, *The Journal of Finance*, Vol. 25, No. 2, pp. 383–417.

Galí, J. (2013). Monetary policy and rational asset price bubbles. National bureau of economic research, working paper 18806, february 2013. http://www.nber.org/papers/w18806

García-Kobeh, A., J. P. Graf-Noriega, G. Hernández-Chávez y R. Paniagua-Ruiz (1990). Economía monetaria de producción y circuito. *Economía Teoría y Práctica*, No 1. No. 1, pp. 149-170.

Gilchrist, S., and M. Saito (2006). Expectations, asset prices, and monetary policy: the role of learning. National bureau of economic research, Working Paper 12442 August 2006. http://www.nber.org/papers/w12442

Gordon, M. (1982). The investment, financing, and valuation of the corporation. Greenwood Publishing Group, Incorporated, 1982.

Greenspan, A. (2004). Innovations and Issues in Monetary Policy: The Last Fifteen Years Risk and Uncertainty In Monetary Policy. *The American Economic Review* vol. 94, No. 2, pp. 33-40.

Karatzas, I. and S. E. Shreve (1991). "Methods of Mathematical Finance". Springer 1991.

Kindleberger, C. P. (2005). "Manias, panics and crashes. A History of Financial Crises". (1978); 3ª ed.,Wiley. New Jersey (2005).

Minsky, H. P. (1992). The Financial instability hypothesis. *The Jerome Levy Economics Institute*, working paper no. 74. (May 1992). Available at SSRN: http://ssrn.com/abstract=161024

Mishkin, F. S. (2011). How Should Central Banks Respond to Asset-Price Bubbles? The 'Lean' versus 'Clean' Debate After the GFC Reserve Bank of Australia, *Journal RBA Bulletin*, junio 2011.

Lavoie, M. (2007). "A Hand Book of Alternative Monetary Economics". C2 Endogenous Money: Acommodationist. Edward Elgar Publishing.

Ludwig, K. K. (2006). Insider Trading rules and price formation in security markets. An entropy analisis of strategic trading. *International Journal of Theoretical and Applied Finance*, Vol. 9, No. 8, pp. 1215-1243

Pincus, S. M. (1991). Approximate entropy as a measure of system complexity. *Proceedings of the National Academy of Sciences*.

Risso, W. A. (2008). The US Housing Bubble and the Informational Efficiency. Available at SSRN: http://ssrn.com/abstract=1259427

Shiller, R. J. (1981). Do stock prices move too much to be justified by subsequent changes in dividends? *American Economic Review*, vol. 71, pp. 421–436.

Trichet, J. C. (2005). Asset price bubbles and monetary policy. Speech by President of the ECB. 8 June 2005, Singapore.

Villegas, E., A. Acosta y R. Cayaffa (2010). La crisis hipotecaria estadounidense: origen y evolución. *Cuadernos Latinoamericanos,* Año 21. pp. 49-68

Wang Gang-Jin, Xie Chi, Han Feng (2012). Multi-Scale Approximate Entropy Analysis of Foreign Exchange Markets Efficiency. *Systems Engineering Procedia* vol. 3, 201-208.

[i] The fundamental value or intrinsic value of an asset, according to Shiller (2001), can be defined as the real value of future expected dividends discounted at a constant interest rate.

[ii] The definition of the speculative bubble phenomenon involves an additional difficulty to distinguish, according to Le Roy (2004), two categories, rational and irrational. Generally speaking, a rational bubble refers to growth that goes according with the evolution of interest rates. The label of irrationality is identified with the existence of agents who trade assets for reasons that cannot be modeled. These agents are called "noise traders" and they do not have any behavior that could be described as rational, are those that tend to exacerbate tensions in the investing public.

[iii] As an example it may be mentioned the Fed model, which relates asset prices with inflation. The mechanism is explained by the competition between bonds and equities in the investment portfolios of families. The yield of a bond is affected for the general level of prices. In response, the stock performance should also be enhanced, otherwise stock will be abandoned the portfolio (Campbell and Vuolteenaho, 2004).

[iv] This view of the Austrian school goes back to Hayek, Mises and Robbins. Under this approach an exacerbated growth in asset prices can generate a bubble if the "accommodative" monetary policy allows bank credit to increase the boom (Bordo, 2013).

[v] Jean-Claude Trichet, President of the European Central Bank (ECB), said in lecture to Singapor monetary authorities in 2005 that the paradox of credibility of the central bank is one of the main challenges to be faced by the monetary authorities in the XXI century. Basically, this problem is that the credibility gained by the monetary authorities in controlling price generates pressures in the prices of financial assets making vulnerable the financial system.

[vi] Delgado (2009) argues that in a context of monetary economy the variables that are affected by the expectations are financial variables, such as: the market value of capital assets, the prices of financial assets and the expected behavior with respect to the structure of obligations of employers and bankers.

[vii] For more details, see Minsky (1992).

[viii] Among the first studies in post Keynesian monetary economics are the work of Kaldor (1970) and Moore (1982) arguing that the money supply of high expansive power and money should be considered as endogenous and demand determined. They argued that the central bank has no direct control over the money supply and cannot exercise many restrictions on bank reserves.

[ix] Under the scheme proposed by the post Keynesian "horizontalist" vision, money supply is completely elastic, *i.e*., the banks have the ability to meet all requested appropriations to the level of the interest rate and, therefore, variations in demand money do not affect the interest rate. Thus, the money supply in the economy is determined by demand and not under the autonomy of the Central Bank.

[x] Both schemes the "horizontalist" and "structuralist" agree in indicating that the central authority has a very limited ability to effectively control money supply within an economy. Dow (2007) states that the failure of the authorities to control the money supply became evident during the eighties and establishes that central banks have the tools to directly control either the volume of money supply or the credit.

[xi] Irving Fisher proposed his very well known quantity equation, whose representation is $MV = pQ$. In this model the money supply (M) is treated as a controlled exogenous variable and subject to discretionary changes by the monetary authority.

[xii] This theory defines the maximum data compression and the maximum transmission rate of data transmitted without error.

[xiii] Ludwig (2006) states that the degree of uncertainty of a random variable is quantified by a measure which is known as entropy, and Pincus (1991) proposed the method of approximate entropy based on information theory as a useful measure of the stability of system.

[xiv] Kindelberg (1998) refers to the stages that characterize a bubble, the displacement as an exogenous shock to the macroeconomic system, which gives rise to optimistic expectations of the public. If this period extends,

it is followed the overtrading. At that moment speculation about the increase in asset prices starts, overestimating the potential returns.

[xv] Greenspan (2004) coincides in indicating that employers were reacting in such a way that they perceived a high potential in the rates of return on new technologies. This encouraged the expectation of gain among the investing public.

[xvi] The unit of measure for the rate of information is expressed in "nats" because we are using the natural logarithm in coding.

[xvii] In December 2003, the three-month treasury-bill rate reached the level of 0.90%, the lowest level since 1960.