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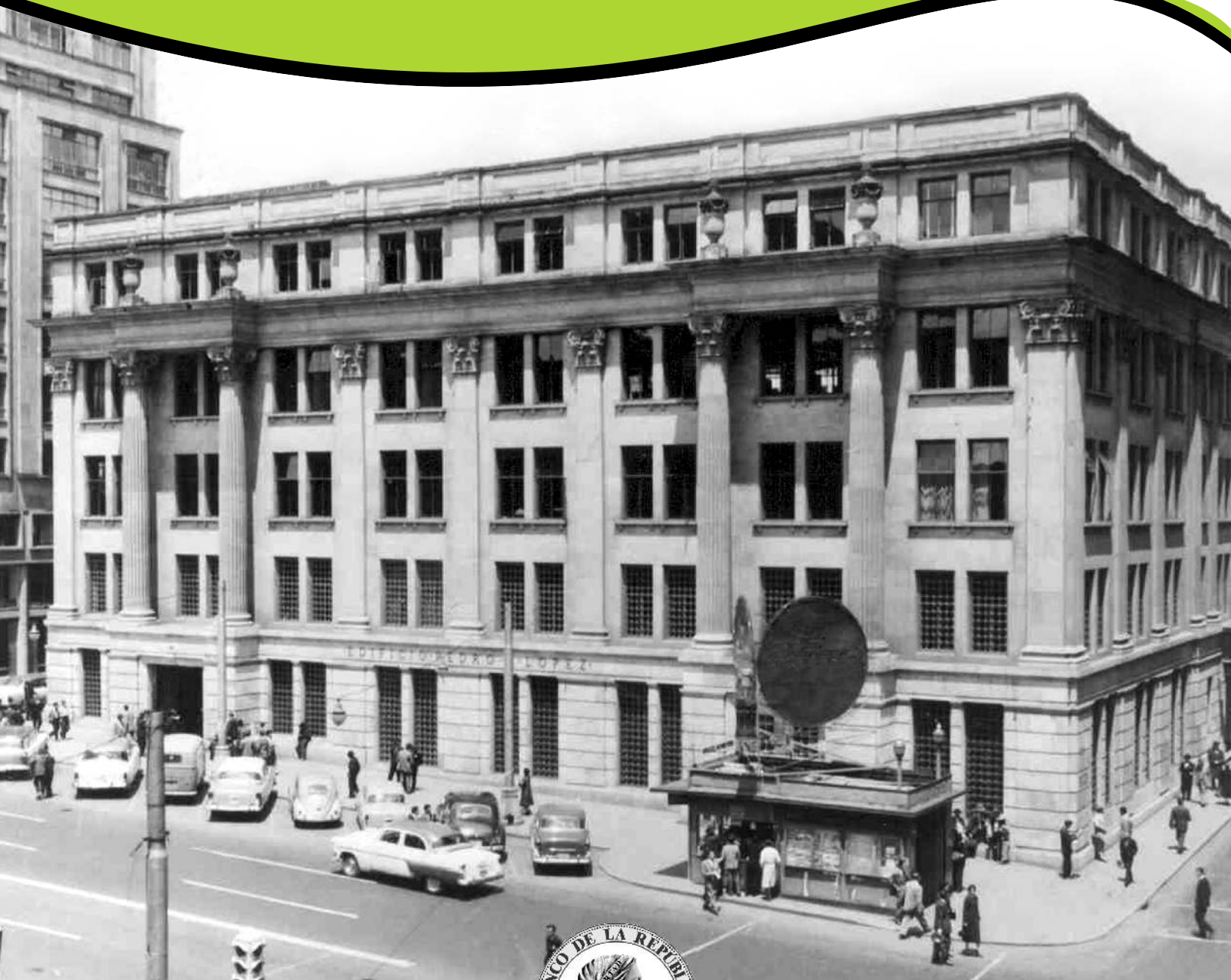
Beyond Bubbles:
The role of asset prices in *early-warning* indicators

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Abstract

Asset prices have recently become a common topic in economic debate. Nevertheless, much time has been spent in determining if they effectively exhibit a bubble component, and not in examining whether asset prices affectively contain relevant information concerning future market developments. This paper is a first effort in Colombia in this direction, aimed towards the construction of $early - warning$ indicators using financial and real variables. Results show evidence to support that there is relevant information embedded in these series, as **all** indicators (except the new housing price indicator) show a significant deviation for the year(s) prior to the 98-99 crisis. Additionally, the exercises here conducted show that the performance of asset price indicators is enhanced by including credit and investment. When the *early-warning* indicators are **on**, the role of the policy maker should be *more* active in the market; not necessarily in terms of altering interest rates, but in communicating with market agents, promoting portfolio and perspective (i.e. short and long-term) diversification and urging financial agents to make the best use of the *tools* that are available to them.

1 Introduction

Asset price bubbles are amongst the most talked-about yet misunderstood topics in economics. Theoretical researchers debate between rational, nonrational or even non-existent bubbles, while empiricists tackle the issue with state-of-the-art econometric tools yielding mixed results.

A bubble is usually defined as the component of asset prices that cannot be accounted for by fundamentals[1]. A rational bubble arises when agents are willing to pay a higher price than the "fundamental price" because they believe that they can sell the asset at an even higher price in the future (Gurkaynak (2005)). A nonrational bubble is defined as a rapid upward price movement, based on exaggerated beliefs about future outcomes (e.g. company earnings or the impact of a new technology), followed by a collapse (Meltzer (2003)).

Some theorists have also developed behavioral models with rational expectations which allow for explaining price behavior without bubble components. In a nut-shell, these models assume expectations are based on *imperfect* knowledge of future fundamentals, so that investors may overestimate potential income flows (i.e. earnings) and hence asset prices. As agents acquire new information, they correct their initial forecasts, altering their investment/consumption decisions and changing asset prices (Meltzer (2003)).

On the empirical side, tests are usually constructed for rational bubbles, given the relative knowledge of researchers on testing the present value model of asset prices. Nonetheless, results vary and there does not appear to be a general consensus regarding a specific empirical test of bubbles. In fact, there is not even a common agreement on the interpretation of a rejection of the no-bubbles hypothesis; while some argue this is proof of the existence of bubbles others attribute this to a failure of the model in another dimension (e.g. misspecified fundamentals). In the end, the choice between bubble solutions and a misspecified model of price behavior remains a matter of belief.

The bottom-line is that even if there is no scientific *proof* of the existence of bubbles, the current volatility in asset prices worldwide has sprang a newfound interest in the subject.

The typical questions found in the literature usually read something like: How should bubbles be measured? Can they be measured? Are they rational or nonrational bubbles? Do bubbles *exist*? Are these the most relevant questions for decision-makers? Probably not. Financial instability usually arises from a combination of economic imbalances and not a single event. That is, large increases in asset prices by themselves do not necessarily lead to widespread instability in the financial system. Rather, an increase in asset prices, rapid credit expansions and high levels of investment, occurring *simultaneously*, could lead to potential problems (Borio and Lowe (2002, 2003)). Thus, the relevant question for policymakers is not whether bubbles *exist*, but rather if the observed behavior in asset prices, along with other financial and real variables, is indicative of possible future imbalances.

In such spirit, we use information on the most relevant asset prices, credit and investment to construct *early-warning* indicators of financial distress, as suggested by Borio and Lowe (2002, 2003). The idea behind these indicators is simply to observe the deviation of each series to its long-term trend, and determine whether imbalances occur after such deviations overcome a specific threshold. Although analyzing the deviation of a variable to its trend is

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[1]Fundamentals are the discounted value of expected future income flows.

by no means revolutionary (the loans to GDP ratio being one of the most common), analyzing real and financial variables *jointly* as early warning indicators of financial distress has only become popular more recently. This is mainly due to the fact that although asset prices have made several appearances on historical accounts of financial instability, their empirical relationship with credit and aggregate demand has been less studied.

However, there have been various attempts in identifying the link between asset prices, financial stability and monetary policy. Some authors argue that a responsible monetary policy leads to low inflation, induces stable asset prices and efficient levels of liquidity, reduces investors' uncertainty (by promoting a sounder macro environment) thus allowing for optimum consumption and investment decisions. On the other hand, some economists have began to realize that financial instability (and large asset price swings) **can** develop in periods of low inflation. A credible monetary policy results in low inflation expectations, meaning it takes longer for higher demand to translate into prices. As agents' expenditure increases, there is a higher demand for loans and banks increase their lending. Debt-financed spending may lead to a faster rise in asset prices, which does not immediately translate to higher inflation. The inverse is also true. There could be high inflation under a stable financial environment. Under this scenario, a rise in interest rates, consistent with the inflation goal, could lead to financial instability by increasing the burden of outstanding floating-rate debt and most importantly creating significant wealth effects through portfolio-valuation losses caused by the fall in the price of tradable assets (this is especially relevant in markets where balance sheets are *marked-to-market*), thus altering investment/consumption decisions. In other words, there is room for important *trade-offs* between monetary and financial stability.

The above does not mean that policymakers are thus left with their hands tied. In the first place, it would be foolish to overlook that asset prices contain a large amount of information from which policymakers can reap incredible benefits[2]. On second place, even if there is no consensus on the exact link between financial and monetary stability there does seem to be a convergence on some of the actions that should be undertaken by policymakers to reduce large asset-price swings. In short, these are aimed towards reducing information asymmetries in the market, promoting the long-term structure of certain specific institutional investors' portfolio (e.g. pension funds) as well as the diversification and sophistication of risk management tools. Additionally, they should promote deeper and wider capital markets to increase the universe of financial assets available to investors and encourage a closer monitoring of financial markets.

Both the retrieval of information embedded in asset prices as well as possible policy actions to help move financial markets into a stronger form of market efficiency (i.e. more shock-resistant) are crucial to policymakers worldwide. This is even more so in a country like Colombia, because emerging markets which are moving towards a model of financial integration are more vulnerable to the adverse effects that speculative capital flows have on the financial cycle. When there are waves of optimism on the real sector, credit grows spectacularly, there is a tendency to overinvest in physical capital, asset prices hike and consumption soars as well. All this factors lead to higher economic growth and a valorization of domestic assets, increasing foreign investors appetite for the latter. This leads to higher capital inflows, which in Colombia are highly (and positively) correlated with credit (see Villar et. al. (2005)),

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[2]Developments in asset prices and credit may have an impact on inflation and are therefore important for central banks when they set interest rates. Additionally, asset prices may be indicative of future developments in output and demand.

thus exacerbating the business cycle. When expectations change (e.g. due to new information on future fundamentals) and agents correct their initial forecasts, the wave of optimism crumbles, imbalances are corrected abruptly and there are perverse effects both on financial markets and the real economy (Collyns and Senhadji (2003)).

This paper is organized as follows. Section 1 presented a quick introduction to the subject at hand and its relevance to policymakers. Section 2 provides an overview of the empirical literature aimed at detecting asset price bubbles, while section 3 presents and overview of the implications of the latter on monetary policy. Empirical exercises with Colombian data on asset prices, credit and investment as *early-warning* indicators are carried out in section 4. Section 5 concludes.

2   Bubbles in the Literature[3]

Econometric tests for identifying bubbles have proven to be fairly ineffective. In principle, such tests are aimed towards rejecting the present value model (or market fundamental model), which is defined as:

$$P_t = \sum_{i=1}^{\infty} \left(\frac{1}{1+r} \right)^i E_t(d_{t+i}) \tag{2.1}$$

where P_t denotes the asset price at time t, r is a one period risk-free market rate and $E_t(d_{t+i})$ is the expected value of future income flows generated by the asset (the market fundamental component)[4].

A rejection of the model in equation (2.1) implies there is an unexplained component of price behavior which could be accounted for by bubbles. Nonetheless, this component can also be attributed to a misspecification of the fundamentals in the model. Hence, the conclusions which can be derived from such tests end up reflecting the personal preferences of the researcher between bubbles and fundamentals-based explanations of price movements.

Even so, many researchers have focused on explaining the dynamics of price behavior and the existence or nonexistence of bubbles with econometric-based tests. Shiller (1981) uses variance bound tests in order to explain the variation in observed prices[5]. These tests are based on the idea that observed prices are formed according to equation (2.1) and that there exists an ex-post rational price which depends on actual income flows (and not expected) of the form:

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[3]The review concerning econometric tests on asset price bubbles is based on a thorough overview of the literature done by Gurkaynak (2005). All the tests covered are related with *rational* bubbles.

[4]In the case where P is the price of stock, d would denote future dividends; in the case where P denotes housing prices d would denote rental flows; whilst in the case where P denotes the price of a bond, d would stand for coupon payments.

[5]The author uses S&P500 annual data for prices and dividends from 1871. This data set is used by most researchers that analyze bubbles in stock prices in the US.

$$P_t^* = \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i d_{t+i} \qquad (2.2)$$

$$where \quad d_{t+i} = [E_t(d_{t+i} + \epsilon_{t+i})] \qquad (2.3)$$

The main assumption is that the variance of P_t^* ($V(P_t^*)$) is greater or at the least equal to that of P_t ($V(P_t)$). This is due to the fact that observed prices (P_t) are based only on expected income flows, while the ex-post rational price (P_t^*) includes the variance that future forecast errors imply[6]. Thus, the test consists of verifying if observed prices effectively have a lower variance than the ex-post rational price. If the variance bound is violated, this is taken as evidence that observed prices do not follow equation (2.1) and so the present value model is rejected[7].

In his empirical application, Shiller (1981) concludes that the high volatility in observed prices (i.e. violation of the variance bound) is due to misspecifications in the general present value model, whereas Tirole (1985) suggests that the variance bound violation may be due to the existence of bubbles. More recently, Cochrane (1992) explicitly tests for bubbles using the variance of the price/dividend ratio[8]. He uses different discount rate models and finds that the variance bound is satisfied for all the different specifications (i.e. no evidence of bubbles).

The author goes one step further and carries out variance decomposition exercises on the price/dividend ratio for each discount rate model. He finds that there *exist* unobserved discount rate processes that explain the variance of the ratio, yet the discount rate *proxies*[9] used in his paper do not satisfy the variance decomposition. Cochrane (1992) then shows that the time-varying discount rate processes needed to explain the variance of the ratio do not require outrageous behavior. Thus, there is no case for bubbles, but rather the challenge of finding successful measures (i.e. *proxies*) of discount rates.

West (1987) introduces a different approach to test for bubble existence, by explicitly putting a bubble in the alternative hypothesis and testing for model specification and the no-bubbles hypothesis sequentially. This method compares two estimates of the impact of income flows on prices, an *actual* and a *constructed* relationship. The latter is defined as:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t(d_{t+i}|\Omega_t) = \bar{\beta} d_t, \qquad (2.4)$$

where[10] $\bar{\beta} = \left(\frac{\frac{\phi}{(1+r)}}{1-\frac{\phi}{(1+r)}}\right)$

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[6]To see this more clearly, note that equation (2.3) implies that actual income flows are equal to expected income flows plus a variable term that captures the unforecastable component of income flows.

[7]The implementation of the test is considerably more complicated than in theory, since the values of d_t out to infinity are unrealized. Generally, the current date is taken as a terminal point in time and the P^* series is constructed recursively using observed values of d_t.

[8]The author utilizes annual data from the New York Stock Exchange for the period 1926-1988.

[9]The author uses the following discount rate models: 1) discount rate = constant, 2) discount rate = reference return plus risk premium, 3) discount rate = return, 4) consumption-based discount rates and 5) the case where no restrictions are placed on discount rates and these are treated as unobserved.

[10]See Appendix A for a detailed derivation of this variable.

and the ϕ coefficient is estimated from a prior regression where income flows are assumed to follow a stationary autoregressive process of the form:

$$d_t = \phi d_{t-1} + u_t \tag{2.5}$$

where u_t is a white noise variable. However, the *actual* price does contain a bubble component and can be expressed as:

$$P_t = \beta d_t + B_t \tag{2.6}$$

If there is no bubble in the data, regressing P_t on d_t should give an estimate of β $(\hat{\beta})$ equal to $\bar{\beta}$. If these two differ, it is possible to trace the discrepancy to bubbles or a bad specification of the model. However, the implementation of the test has major inconveniences. First of all, the tests show some inconsistency when a bubble is present (West (1987)) and it rejects the null hypothesis (no bubbles) repeatedly when using small samples (Dezbakhsh and Demirguc-Kunt (1990)). Additionally, there is still the problem of interpreting the rejection of the no-bubbles hypothesis, as it may be due to a misspecification of the model. As mentioned above, it is possible to test between bubbles and model-related issues, but it is still very complicated to test the model's specification for every possible contingency.

Finally, Flood et. al. (1994) stress that even if no misspecifications where found with the existing tests, a rejection of the no-bubbles hypothesis may still be due to factors different from a bubble. For example, the possibility that agents assign a small probability to an event that has a significant impact on asset prices. Their expectations will thus be embedded on prices, independent on the event occurring or not. If it fails to materialize, the observed effect on prices will be very similar to that of a bubble.

Intuitively, the methods described above try to correctly specify the present value model, and if fundamentals cannot explain prices then it must be due to the presence of a bubble (however, as mentioned above, it could also be due to a misspecification of the model).

Integration and cointegration based tests try to address this problem by exploiting the theoretical characteristics of bubbles. Specifically, Diba and Grossman (1988b) rule out the possibility of rational bubbles starting at any given moment in time, thus, if they exist now they must have existed from the first trading day. The authors define the fundamental price as:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r} \right)^i E_t(d_{t+i} + o_t) \tag{2.7}$$

where o_t denotes the fundamentals which cannot be observed by the econometrician[11]. The fact that a bubble cannot *pop* and restart implies that a bubble is generated by a nonstationary process, despite the number of differences applied to the series. Given this, the test is pretty straightforward. In the absence of bubbles, prices should be stationary when differenced the same number of times needed to make income flows stationary. Also, Diba and Grossman

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[11]Additionally, such unobserved variables are assumed to be less nonstationary than income flows. That is, if income flows have to be differenced three times to be stationary, o_t has to be differenced at most three times.

(1988a) observe that equation (2.7) imposes an equilibrium relationship between the two variables, and so assuming there are no bubbles and that o_t is stationary, prices and income flows should be cointegrated.

However, these tests do not come without criticism. First off, the rejection of the no-bubbles hypothesis implies the presence of something non-stationary in price behavior. This does not necessarily imply a bubble, but a violation on the assumptions made on the unobserved fundamentals of the model. On a second note, even when the model does not reject the aforementioned hypothesis, this cannot be taken as proof of the inexistence of bubbles. At the most, it can be said that a bubble generated by an explosive process is not present in the price series. As Evans (1991) points out, it is possible to have a bubble that collapses to a small nonzero value (never actually reaching zero) and then begins increasing again. This special case of a periodically collapsing bubble satisfies the Diba and Grossman (1988b) criticism of bubbles being unable to restart since it actually never *pops*. The author shows that unit root tests have trouble detecting such bubbles because their behavior resembles that of a stationary process.

After Evans (1991) criticism, researchers looked for new and more complex ways to test for periodically collapsing bubbles. Researchers' attention thus turned towards regime switching models, where the expanding and collapsing periods where treated as different regimes. Nonetheless, the exact switching model chosen by the researcher had significant impact on the results[12].

Froot and Obstfeld (1991) propose a different type of bubble phenomenon which they call *intrinsic bubbles*. This term is used because the bubble depends (in a non-linear deterministic way) on fundamentals[13]. The bubble component will, therefore, remain unaltered as long as fundamentals are constant, and will increase or decrease along with the level of income flows. In addition, the intrinsic bubble can cause prices to overreact to changes in fundamentals (i.e. deviate from the fundamental price P_t^f). In this setup, the fundamental price and bubble processes are given by:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r} \right)^i E_t(D_{t+i}) \tag{2.8}$$

$$B_t = \left(\frac{1}{1+r} \right) E_t(B_{t+1}) \tag{2.9}$$

where D_t are the income flows and B_t is the bubble. Froot and Obstfeld (1991) show that a non-linear function of the form:

$$B(D_t) = cD_t^\lambda \qquad c > 0, \lambda > 1 \tag{2.10}$$

satisfies equation (2.9) and implies that the bubble process depends entirely on the level of income flows. The authors assume log income flows follow a random walk with a drift parameter μ and a conditional variance σ^2 such that:

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[12]A striking example is presented by Gurkaynak (2005). Van Norden and Vigfusson (1998) use two different regime switching bubble tests on S&P 500 data and get contrary results on the existence of bubbles.

[13]In their paper, the relationship is between bubbles and the level of dividends.

$$d_t = \mu + d_{t-1} + \zeta_t \qquad (2.11)$$

where d_t are log income flows and ζ_t is a normal random variable with conditional mean zero and variance σ^2. Under this model of behavior for income flows and assuming that D_t is observed at the beginning of the period, the bubble solution $\hat{P}_t$ is given by:

$$\hat{P}_t = P_t^f + B(D_t) = kD_t + cD_t^\lambda \qquad (2.12)$$

where $k = \frac{e^{(\mu+\sigma^2/2)}}{(1+r)-e^{(\mu+\sigma^2/2)}}$ is a constant term[14]. It is clear from equation (2.12) that prices overreact to changes in income flows under the presence of bubbles compared to the 'fundamentals' only solution. In the latter, $\partial P_t^f / \partial D_t = k$ while in the former $\partial P_t / \partial D_t = k + c\lambda D_t^{\lambda-1}$, *with $c > 0$.*

Under the (null) hypothesis of no intrinsic bubbles, the 'bubble' solution is equal to the fundamental price:

$$\hat{P}_t = P_t^f = kD_t, \qquad \frac{P_t}{D_t} = k \qquad (2.13)$$

Equation (2.13) implies both a linear relationship between prices and income flows and a constant price/income flows ratio (i.e. equal to k). It also shows that the latter will be a function of the trend growth and variance parameters (μ and σ^2, respectively) from the model in equation (2.11) as well as of the risk-free interest rate (r).

The introduction of bubbles changes these conditions by imposing a nonlinear relationship between prices and income flows. In this case, the price/income flows ratio can be expressed as:

$$\frac{P_t}{D_t} = k + cD_t^{\lambda-1} + \varepsilon_t \qquad (2.14)$$

where ε_t is a well behaved error term. Henceforth, the test is intuitive, a regression where the price/income flows ratio is the dependent variable is ran against a constant and the income flows variable. If the only significant regressor in the estimation is the constant, this will be indicative of a lack of bubbles in the data. Note that if a non-linear relationship is found between the dependent variable and income flows, this will be taken as evidence of a bubble. However, as Gurkaynak (2005) asserts, this is only because the model is assumed to be linear. What if the *true* relationship is not?

In answering this question, regime switching models got their second chance on tackling the issue of bubbles. Driffill and Sola (1998) characterize the law of motion of income flows in a different way to Froot and Obstfeld (1991) (i.e. they assume a regime switching model for the income flows). The authors find that allowing for both switching fundamentals and bubbles in the model causes the contribution of the latter in explaining the price/income flows ratio to fall dramatically. More importantly, the fit of a model with switching fundamentals and no bubbles is practically the same as the one with intrinsic bubbles and no regime switches.

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[14]See Appendix A for a detailed derivation of this variable.

The bottom line is that there is certainly something non-linear in the data which is not easily attributable to bubbles.

All the tests surveyed above, despite having different econometric techniques, share a common characteristic. They are all, in essence, a test on the present value model against an unidentified alternative (i.e. the bubble). Wu (1997) takes this interpretation of the bubble literally and tries to estimate a series of the bubble component. He estimates the bubble as an unobserved variable in the price generation equation (i.e. everything that is not explained by the market fundamentals; expected income flows) using a Kalman Filter, such as:

$$P_t = \sum_{i=1}^{\infty} \left(\frac{1}{1+r} \right)^i E_t(d_{t+i}) + B_t \tag{2.15}$$

The author finds that the unexplained component effectively explains a large portion of the movement in prices. However, his series of the bubble often takes negative values, which is a violation of one of the few strong theoretical properties of bubbles (i.e. that if one *exists*, it can never be negative)[15]. Therefore, his measure of bubbles must clearly be capturing other components different from a bubble (e.g. a failure of the model due to misspecified fundamentals).

Empirical research has not only focused on econometric tests. Other studies have used rational expectations general equilibrium models (McGrattan and Prescott (2003)) in order to explain possible price behavior. Nonetheless, such models are not devoid of criticism. Mainly, because they do not converge to a unique stationary equilibrium or dynamic equilibrium path. In fact, the bubble solutions (when prices do not converge to finite values) arise among the plausible multiple equilibria these models have. As Meltzer (2003) notes, such solutions may be due to the specific assumptions made in the model[16] and additionally, they do not necessarily imply the existence of a bubble (i.e. all explosive movements are not bubbles)[17].

The state of the art in empirical tests has yet to deliver a useful asset price model that separates the various components that drive price behavior (Meltzer (2003)). Essentially, all models fail because expectations are not observable, so assumptions must be made concerning how they are measured. Ultimately, this means that the so-called fundamental value is based on beliefs rather than on data.

3 Implications of Bubbles on Monetary Policy

3.1 To intervene or not to intervene

Although there seems to be an agreement regarding the relevance that asset price developments have over financial stability and economic growth, the debate concerning the optimum intervention of economic authorities to prevent strong swings in these prices prevails.

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[15]See Diba and Grossman (1988b) for an analytical derivation of this property.

[16]For example, assuming there does not exists an infinitely lived rational policymaker.

[17]Meltzer (2003) provides the case of Germany's hyperinflation (1920-1923) as an example. The Reichsbank allowed monetary acceleration and it was hence rational for agents to expect price acceleration as a response to higher liquidity. This is a typical case of price explosion that does not imply a bubble.

One branch of the literature supports the hypothesis that expansive policies may compensate the recessive effects of large swings in asset prices. As Meltzer (2003) notes, asset price declines need not be followed by output or consumption recessions. By analyzing several bubble episodes, the author states that the different effects that high asset prices have on an economy are explained by the policy actions implemented by the relevant authorities. Moreover, Cecchetti et. al. (2003) suggest that even though asset prices should not belong to the objective function of the Central Bank, misalignments in these prices must be taken into account. The main reason is that asset price bubbles lead to increases in real output and inflation, followed by sharp falls. The authors suggest these effects can be offset with modest movements on the interest rates by policymakers. Nevertheless, they clarify that the decision of reacting to asset price changes should be dependent on the context on which these occur, and not be a mechanical and symmetric response[18].

Given that monetary authorities act mainly by altering a short-term interest rate that directly affects the interbank overnight rate, this literature distinguishes three channels by which monetary policy can affect asset valuations[19]. First, changes in interest rates may affect individual expectations about future behavior of economic growth. Second, monetary policy affects agents' set of discount factors. Finally, they may induce portfolio shifts that affect assets' relative prices[20].

On the other hand, a branch of the literature states that central banks should not react to changes in asset prices. They support their position by arguing that it would be harmful for economic stability to introduce such a volatile indicator into policy decisions. Additionally, asset prices cannot be determined scientifically: as Trichet (2003) argues, *what matters is not only the asset price level per se, or the pace of its change, but also its deviation from a highly hypothetical fundamental value, which is hard to determine.*

Another important argument to remain extremely cautious about monetary policy intervention is moral hazard problems: if individuals expect intervention they may take riskier projects in order to magnify their expected returns because they internalize that their losses are limited.

Moreover, Goodfriend (2003) advices that monetary policy should not react directly to asset prices because there can be no theoretical presumption on the correlation between interest rates and equity price movements, and hence on the overall *effectiveness* of the intervention.

3.2 What can Monetary Authorities do?

Although the debate concerning intervention seems endless, there are certain points in which researchers and academics have reached an agreement. For instance, there is consensus regarding the reasons that explain the abnormal behavior of asset prices in the last years. Three facts can be clearly distinguished. First, agents have increased their interest in short-term results. This has magnified price volatility by amplifying the impact of any new information. Second, markets have developed mimetic or herding behavior. That is, agents prefer to be

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[18]This decision should contemplate all relevant asset prices, which in their paper include equity and housing prices.

[19]These channels are exposed in further detail by Trichet (2003).

[20]There are other indirect channels such as wealth effects in investment and consumption that may affect prices via households intertemporal smoothing behavior.

wrong along with everybody else rather than taking the risk of being right alone. This type of conduct leads to massive earnings or losses. Finally, converging risk management techniques have led to contemporaneous homogeneous responses by different market players, increasing the size of trading volumes and magnifying initial shocks.

The above implies that monetary authorities must safeguard financial stability by promoting diversity in financial markets, which in turn may prevent asset price swings. In order to achieve this objective, monetary policy should focus on *i)* strengthening market transparency, *ii)* preserving the long term perspective of some investors (e.g. pension funds), and *iii)* promoting the diversification of risk management tools of financial institutions.

Market transparency reduces the mimetic behavior of agents in the market. By reducing incomplete information and uncertainty it gives confidence to investors regarding their own decisions. In this way, an agent would no longer prefer to follow bigger participants, rather than carry on his own analysis, if he believes that all market participants have access to the same information. Additionally, transparency enables better differentiation of a borrower's creditworthiness[21].

Furthermore, when economic authorities preserve the long-term perspective of pension funds and insurance companies they compensate for the "short-termism" of other agents, thus reducing the impact of new information in the price formation process. Lastly, diversifying the risk management tools of financial institutions, so that they include more than the massively adopted Value-at-Risk (VaR) measure, can help reduce the mimetic behavior observed in markets. Authorities must promote the use of *stress testing* techniques by all financial institutions, because their results are inherently more diversified than those of the VaR approach[22], as well as advancing towards more sophisticated risk-measures, such as Expected Shortfall (ES), Extreme Value Theory (EVT) and Spectral Risk Measures (SRM)[23].

Monetary authorities may also openly promote the deepening of existing capital markets and the creation of new ones. For example, in Colombia few firms are listed in the Colombian Stock Exchange[24], and even fewer issue corporate bonds as means of obtaining financial resources. Policy maker's must strive to create the necessary conditions (i.e. a sound macroeconomic environment, low and stable interest rates, low inflation, quicker and more reliable information systems, efficient legal systems, tax incentives) for firms to effectively consider exploring these new markets. The former would allow for a larger universe of financial assets available to investors, thus reducing the high concentration and homogeneity present today in local investors' portfolios, which increases systemic risk.

Other policies that authorities may apply to promote financial diversity are[25]:

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[21]As Trichet (2003) mentions, this may prevent that when one big firm has difficulties all the other firms that belong to that specific sector face credit restrictions.

[22]This is simply due to the way in which a *stress test* is conducted. Each institution, by endogenously choosing the *shocks* for the stress test, is revealing its individual perception of an exceptional event in a given market or over a given portfolio of assets. This alone implies a diversity not found in the VaR analysis, where the parameters used are usually calibrated with similar data sets (Trichet (2003)).

[23]An intuitive and practical exposition of these risk measures can be found in Dowd (2005).

[24]As of July 2006, there are 8980 listed firms of a total of over 20,000 firms who actively report their balance sheet to the relevant authorities.

[25]These policies are part of President Bush's 10 Point plan on financial disclosure. For more information see Kroszner (2003).

- Require companies to disclose periodical information necessary to assess a company's value (that does not compromise competitive secrets). The periodicity of the disclosures could vary depending on the market.

- Each investor should have prompt access to critical information.

- Chief Executive Officers who clearly abused their power should lose their right to serve in any corporate leadership position.

- Enhancing the accountability of corporate leaders to restore trust in the system.

Moreover, there is consensus over the idea that asset prices offer useful information to monetary authorities in the short-run (Goodfriend (2003)), especially because they have important consequences over financial markets. This idea is central to the core of this paper, because it implies that observing financial series may give policy makers vital information regarding the future development of certain segments (or in some cases the whole) of the financial system. This means that a central bank **should** use the information that these variables contain in order to ensure and promote the stability of financial markets. In the next section, indicators that may exploit such information and make it useful for political purposes are presented.

4 Empirical Exercises

4.1 What can be done

Given the aforementioned problems with empirical tests on the existence of asset price bubbles discussed in Section 2, this paper takes a different direction when tackling the issue at hand. Following the spirit of Borio and Lowe (2002, 2003), the central question in this analysis is not whether bubbles exist or not, but rather how much information can be derived from asset prices and other real and financial variables concerning financial instability[26]. From a policymaker's perspective, this is probably the relevant issue anyway; even if the bubble question is interesting in its own right, knowing what *combination* of events in the real and financial sectors increase the probability of possible risks materializing is even more so.

Historical experience has taught us that financial distress generally arises as a *combination* of economic imbalances which unwind simultaneously. In this sense, hikes and declines in asset prices, along with rapid credit expansion[27] and - in some cases - above-average capital accumulation, rather than any of these alone, are the most common symptoms of such scenarios. Accordingly, they are an indication of an increase in the likelihood of possible imbalances.

Therefore, in what follows we seek to construct what can be called an *Early-Warning Financial Imbalance Indicator* using *ex ante* Colombian data on credit, investment and asset

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[26]This approach was first proposed by Kaminsky and Reinhart (1999).

[27]Much debate exists concerning the criteria that defines adverse credit growth. In this paper, when we refer to *rapid* credit growth we do not think of a higher equilibrium growth level, but rather an expansion related to increased market liquidity, a relaxation in risk assessment and monitoring standards, and indebtment decisions above actual repayment capacities. Hilbers et. al. (2005) identify an expansion above 20% in real terms as worrying for countries with low credit to GDP ratios (i.e. below 30%). Credit in Colombia grew 26.5% in real terms during 2006, and the credit/GDP ratio was slightly above 30% for the first time in over 5 years.

prices[28]. To build this indicator, we utilize quarterly data that covers the period between December 1994 and December 2006[29]. The idea behind these indicators is to measure the deviation of each variable from its long-term trend, and then determine if an imbalance was effectively observed after such deviations overcome a specific threshold value[30]. If the above occurs, then the deviations of the variables from their long-run tendencies (which we refer to as the *gap* in what follows) can be seen as an *ex ante* indicator of possible financial distress.

The above implies that our indicators focus on cumulative processes, as suggested by Borio and Lowe (2002, 2003), since a large *gap* can develop through either one year of very rapid growth in the relevant variable, or as the result of a number of years of above trend growth. We also follow the authors in that we consider *joint* indicators, to see which combination of real and financial variables provide the most useful signals. Finally, we take into consideration different forecast horizons to recognize the difficulty of predicting the exact time of a financial imbalance.

Before explaining the way in which the indicators were constructed and the variables used, a simple caveat concerning the threshold values is necessary. Although highly sophisticated methods could have been used in order to determine the optimal threshold values, the approach followed here is a *parsimony-criteria*. This is done for two reasons. First of all, because it is significantly easier to calculate. Secondly, because we are interested in constructing an *ex ante* indicator for policymakers which provides them with the largest amount of useful information possible. We believe this information set includes different *early-warning* scenarios under a relevant range of threshold values, rather than under one value alone. The criteria used, therefore, is simply to observe for each individual *gap* the threshold value(s) that is/(are) only exceeded during times of financial instability.

4.2 Calculating the Early-Warning Indicators

Following Borio and Lowe (2002, 2003) we calculate the ratio of loans[31] to gross domestic product (GDP)[32], as well as the ratio of investments to GDP[33]. Additionally, we use three asset price indexes: the general equity index, the new housing price index and an aggregate price index (IGBC, IPVN for their Spanish initials and API, respectively)[34].

Afterwards, we employ a Hodrick and Prescott filter to obtain the long-run trend of these

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[28]Intuitively, we want to calculate the various indicators using only information that would have been available to the policymaker when determining whether or not a "boom" existed.

[29]The information was obtained from the Superintendencia Financiera (Financial Superintendency), DANE (Department of National Statistics), DNP (Department of National Planning) and the Bolsa de Valores de Colombia (Colombian Stock Exchange). The Superintendencia Financiera is in charge of financial regulation and supervision in Colombia.

[30]Following Borio and Lowe (2002, 2003), we utilize various threshold levels in our indicators. The idea is to try and find the threshold value that best identifies actual imbalance periods whilst minimizing the number of *false alarms* i.e. the number of wrongly predicted crises.

[31]The loan series includes mortgage, consumer and commercial loans.

[32]This ratio is also suggested by Kaminsky and Reinhart (1999), Gourinchas et. al. (2001), and Sopanha (2006), among others.

[33]All the variables here used are in real terms.

[34]IGBC is constructed by the Bolsa de Valores de Colombia (www.bvc.com.co) and IPVN is constructed by DNP (www.dnp.gov.co). Appendix B carefully explains the construction of the aggregate price index, calculated at Banco de la República (Central Bank of Colombia).

variables[35]. Subsequently, we calculate the deviation of each series with respect to its trend. We shall from this point on refer to these deviations as the *credit gap*, *investment gap*, *equity gap*, *housing gap* and *API gap*. Figure 1 plots the percentage *gap* for each of the series considered[36, 37]. The shaded region corresponds to the crisis period (i.e. 98-99).

4.3   Results

As Figure 1 reveals, the credit, investment, equity and API *gap* present high deviations from their long-term trend for the year prior to and/or during the financial crisis of 1998-1999[38]. However, the same is not true for the *housing gap* which does not show a high *gap* for the year before or during the crisis, but rather 3 years earlier (i.e. 1995). This could mean one of two things. Either that housing prices are not a good *early-warning* indicator, or on the contrary, they are the best *early-warning* indicator, because they predict the imbalance first.

Additionally, it is interesting to note that the *credit gap*, *equity gap* and *API gap* showed somewhat similar deviations during the pre-crisis period and the first quarter of 2006. However, they diverge significantly starting the second quarter and up until the end of the year, with the loans to GDP ratio registering its highest deviations (over 10%) with respect to its trend, while both equity prices and the API presented important reductions in theirs (around 20 percentage points). This is not surprising if one keeps in mind that credit grew over 20% in real terms during 2006 (GDP grew 6.8%), a level that has already began to worry supervisory authorities as well as the Central Bank. This has led to important monetary measures to slow-down the rapid credit expansion (interest rate hikes, marginal reserve requirements, among others) and the implementation of a new credit-risk model to enhance the current risk measures[39]. The fall in the API and equity prices is explained by the high volatility experienced in local markets during the second quarter of 2006, which increased certain investors' risk aversion and adversely affected their portfolio position in these assets (e.g. pension funds, stock brokers, investment funds, among others).

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[35]The filter assumes that the tendency of a series (i.e the long-term component) is determined by technological changes, demographic changes, factor productivity, etc. Thus, variations in the aggregate demand explain the short-run behavior of the series. Therefore, a series can be seen as a combination of two components: the long-term supply component or tendency and the short-term demand component, also called cycle. Under this approach, any series (x_t) can be written as the sum of a trend (g_t) and a cyclical component (c_t):

$$x_t = g_t + c_t, t = 1, ..., T$$

The authors find the long-term component of a series by minimizing the following expression:

$$\sum_{t=1}^{T}(x_t - g_t^2) + \lambda \sum_{t=1}^{T}[(g_{t+1} - g_t) - (g_t - g_{t-1})]^2$$

[36]A *gap* of 1.2 implies a deviation of 20% between the series and its trend. In other words, the series' value is 20% greater than the long-run trend value.

[37]Appendix C includes the graphs for each analyzed series along with the long-term component.

[38]This crisis was the must pronounced *shock* the Colombian economy has suffered in the last century, and is actually the only crisis in our data set.

[39]The new model is called SARC (for its spanish initials) and is currently operating only for commercial loans. The idea is to extend it to consumption loans by 2008. The central idea behind the model is for banks to have higher provisioning levels during the ascending part of the economic cycle so as to create a reserve fund for the "bad" times. More on this model can be found at www.superfinanciera.gov.co

Figure 1: *Deviation from the analyzed series to their long-term trend (Gap)*
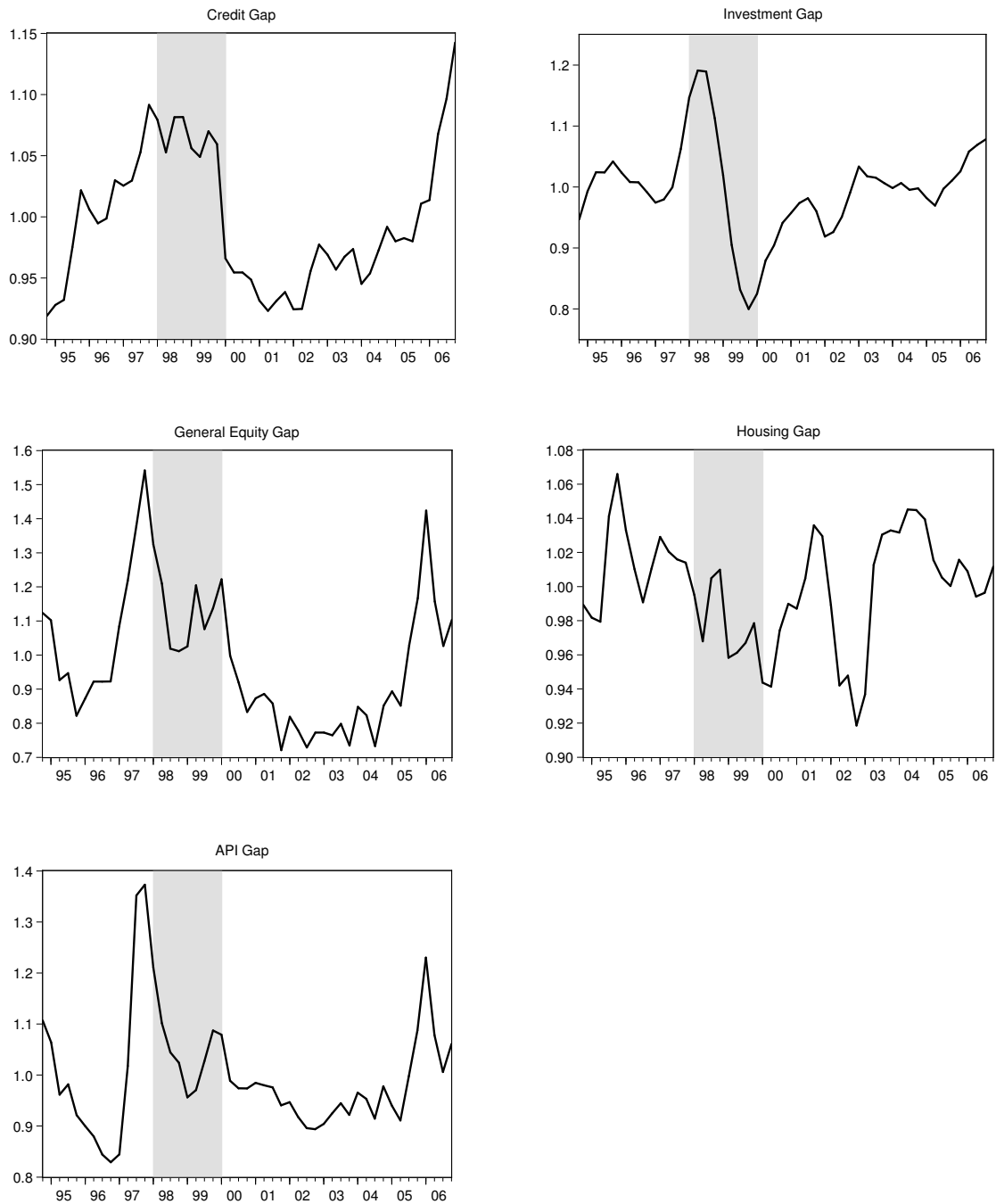
The *indicators* that we intend to build must give an alert signal when the estimated gaps overcome certain threshold values. In this way, we use a trial-and-error methodology to verify the efficiency of these indicators by checking whether they were able to predict the 1998-1999 economic crisis, how many *false alarms* are detected and whether each indicator identifies a financial imbalance as of December 2006. Obviously, the information may vary depending on the threshold values that are chosen. We construct information tables for the alert signals that the various indicators give for different threshold values and time horizons, we also use *combinations* of indicators. Results are presented in Figure 2.

In the tables presented, an imbalance is defined as a period in which two or more quarters present deviations above the chosen threshold level[40] at the respective time horizon. A 1 year horizon means that the predictive capacity of the indicator is validated **only** if the threshold is surpassed the year immediately prior to the crisis; a 2 year horizon means it is validated if the threshold is surpassed either the year before or two years before, and so on. For the *joint* indicators, **all** the chosen variables must surpass the given threshold level in order for the signal to be **on**.

The results from the individual indicators show no apparent surprises. All indicators correctly predict the 98-99 crisis at all horizons for the threshold values chosen, except housing prices. The latter only identifies the crisis when a 3 year horizon is considered. Additionally, only the credit indicator identifies an imbalance *today*, for all threshold values and horizons. The investment, equity and API indicators identify it as well, but only with the lowest threshold values considered. However, the equity and API indicators both give *false signals* when such a threshold is chosen, which is certainly not a desired feature in these type of indicators.

The fact that both the API and equity indicators *fail* to predict an imbalance as of December 2006 is directly related to the volatility period during the second quarter of 2006, which reduced the deviation of each series to its respective trend[41]. However, it is interesting to note that the deviations present during the latter half of 2005 and the first quarter of 2006 did effectively reflect a possible imbalance in those markets; one which corrected abruptly before the end of the first semester.

The *joint* indicators give diverse results. Not surprisingly, when an indicator involves housing prices (Credit-Investment-Equity-Housing), it does not predict a financial imbalance *today* and only correctly predicts the 98-99 crisis when a 3 year horizon is chosen. The second *joint* indicator (Credit-Investment-Equity), correctly predicts the crisis period for the threshold values and horizons considered. Moreover, including real variables along with equity prices eliminates the *false alarms* present when the latter was taken individually. Whether the indicator predicts an imbalance *today* remains a matter of choice between the two sets of threshold values, and given uncertainty as to whether the next years will effectively feature a financial imbalance, a definite choice cannot be made between the two. The same conclusion holds for the Credit-Investment-API indicator, which is expected given the relative importance of equity price movements in the behavior of this index.

Overall, a definite conclusion cannot be made as to which indicator is *best*. However, there is enough evidence in these indicators regarding the information that financial prices

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[40]This is done in order to eliminate possible "noisy-signals" which arise due to high volatilities under very specific conjunctures in the market.

[41]Assuming that the deviation would have continued to increase had there been no such volatility in the market.

Figure 2: Early-Warning Indicators

Housing Gap				
Threshold Value		Horizon		
		1 year	2 years	3 years
4	N. of correctly predicted	0	0	1
	N. of false alarms	2	2	0
	Predicts imbalance today	No	No	No
5	N. of correctly predicted	0	0	0
	N. of false alarms	0	0	0
	Predicts imbalance today	No	No	No
6	N. of correctly predicted	0	0	0
	N. of false alarms	0	0	0
	Predicts imbalance today	No	No	No

Credit Gap				
Threshold Value		Horizon		
		1 year	2 years	3 years
4	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	Yes	Yes	Yes
6	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	Yes	Yes	Yes
7	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	Yes	Yes	Yes

Investment Gap				
Threshold Value		Horizon		
		1 year	2 years	3 years
5	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	Yes	Yes	Yes
9	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	No	No	No
10	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	No	No	No

- The threshold values are expressed as *percentage* deviations from the trend.
- The horizon is the number of years, prior to the imbalance period, considered to test the predictive power of the indicator.
- An indicator is **on** if the deviation form the trend is above the chosen threshold level for two or more consecutive quarters at the respective horizon.

Equity Gap				
Threshold Value		Horizon		
		1 year	2 years	3 years
10	N. of correctly predicted	1	1	1
	N. of false alarms	1	1	1
	Predicts imbalance today	Yes	Yes	Yes
20	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	No	No	No
30	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	No	No	No

Aggregate Price Index (API)				
Threshold Value		Horizon		
		1 year	2 years	3 years
5	N. of correctly predicted	1	1	1
	N. of false alarms	1	1	1
	Predicts imbalance today	Yes	Yes	Yes
15	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	No	No	No
25	N. of correctly predicted	1	1	1
	N. of false alarms	0	0	0
	Predicts imbalance today	No	No	No

Joint Indicator (Credit-Investment-Equity-Housing)							
Threshold Value					Horizon		
Credit	Invest.	Equity	Housing		1 year	2 years	3 years
4	5	30	4	N. of correctly predicted	0	0	1
				N. of false alarms	0	0	0
				Predicts imbalance today	No	No	No
4	10	30	4	N. of correctly predicted	0	0	1
				N. of false alarms	0	0	0
				Predicts imbalance today	No	No	No

- The threshold values are expressed as *percentage* deviations from the trend.
- The horizon is the number of years, prior to the imbalance period, considered to test the predictive power of the indicator.
- An indicator is **on** if the deviation form the trend is above the chosen threshold level for two or more consecutive quarters at the respective horizon.

Joint Indicator (Credit-Investment-Equity)						
Threshold Value				Horizon		
Credit	Invest.	Equity		1 year	2 years	3 years
4	5	30	N. of correctly predicted	1	1	1
			N. of false alarms	0	0	0
			Predicts imbalance today	No	No	No
4	5	10	N. of correctly predicted	1	1	1
			N. of false alarms	0	0	0
			Predicts imbalance today	Yes	Yes	Yes

Joint Indicator (Credit-Investment-API)						
Threshold Value				Horizon		
Credit	Invest.	API		1 year	2 years	3 years
4	5	15	N. of correctly predicted	1	1	1
			N. of false alarms	0	0	0
			Predicts imbalance today	No	No	No
4	5	5	N. of correctly predicted	1	1	1
			N. of false alarms	0	0	0
			Predicts imbalance today	Yes	Yes	Yes
4	10	5	N. of correctly predicted	1	1	1
			N. of false alarms	0	0	0
			Predicts imbalance today	No	No	No

- The threshold values are expressed as *percentage* deviations from the trend.
- The horizon is the number of years, prior to the imbalance period, considered to test the predictive power of the indicator.
- An indicator is **on** if the deviation form the trend is above the chosen threshold level for two or more consecutive quarters at the respective horizon.

(at least equity prices), among with other key variables, have in identifying possible future imbalances (i.e. almost all indicators were **on** before the 98-99 crisis). Preliminary results tend to favor both the Credit indicator and the *joint* indicators Credit-Investment-Equity and Credit-Investment-API, as they all correctly predict the crisis period and make no *false alarms*. The strong appeal of the latter lies in that they take into account financial and real variables and theoretically include more market information. The future behavior of the market (i.e. the occurrence or not of a financial imbalance) will more specifically tell us which threshold values work *best*; However, note that the realization of a future imbalance will make a strong case for the Credit indicator, since it is the only *early-warning* signal that is **on** regardless of the threshold value chosen. In this more than in any other case, only time will tell.

5   Concluding Remarks

Asset prices have recently began to experience an academic *boom*, by becoming a common topic in economic debate. However, much time has been spent in determining whether asset prices effectively exhibit a bubble component, a question which although being theoretically appealing deviates from the policy makers needs. For the latter, the fact that asset prices may contain relevant information concerning future market developments is central, and should therefore be exploited.

This paper is a first effort in this direction, aimed towards the construction of *early-warning* indicators using financial (including asset prices) and real variables, both individually and *jointly*. Results show evidence to support that there is relevant information embedded in these series, as **all** indicators (except the new housing price indicator) reveal a significant deviation for the year(s) prior to the 98-99 crisis (i.e. they are **on**). Additionally, the exercises here conducted show that the performance of asset price indicators is enhanced by including credit and investment, thus considering a wider range of market information. A definite conclusion regarding the *best* indicator (along with the *best* forecast horizon and threshold level) will unfortunately depend on future market events. They will be the ultimate judge on the predictive power of each indicator.

In terms of policy action, these indicators serve two purposes. Firstly, the individual indicators help identify specific markets where signs of possible imbalances are present. Secondly, the *joint* indicators help to identify specific moments when the promotion of a sounder financial system is **most necessary** (although by no means unique). When the *early-warning* indicators are **on**, the role of the policy maker should be *more* active in the market. Not necessarily in the traditional sense (i.e. altering interest rates), but in communicating with market participants, promoting portfolio diversification, preserving the long-term perspective of institutional investors (e.g. pension funds) and urging financial agents to make the best use of the information (i.e. credit data bases and/or firms balance sheets) and risk management tools that are available to them[42].

However, as mentioned above, these actions should not be the sole responsibility of the *imbalance* periods, and should be regularly practiced by local authorities (i.e. prudential

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[42] An excellent review of the prudential and supervisory measures that can and have been used by policy-makers worldwide to undermine possible future financial imbalances is found in Hilbers et. al. (2005).

regulation). Additionally, promoting the creation and deepening of capital markets to increase portfolio diversification is a task that must not be left aside, because the future development of a more shock-resistant financial system will largely depend on the level of maturity of the system as a whole.

In this respect, the Banco de la República has done an immense effort, by openly collaborating with the Superintendencia Financiera in the sophistication and implementation of risk management tools to better face market, credit and liquidity risk. Additionally, by emphasizing in its periodical publications the need to advance in better credit-information data bases for the financial system, alerting banks to keep a close watch on the level of non-performing loans and analyzing asset prices in an effort to identify possible imbalances.

Future research in this field is more than necessary, especially since this is only a first approach to obtaining all the relevant information for policy makers from asset prices. A possible next step would be to follow Coudert and Gex (2006) in utilizing risk aversion indicators (which are constructed using principal component analysis on financial price series) to anticipate financial imbalances[43]. The important issue at hand is that all such efforts, no matter how sophisticated or practical, by being aimed towards granting monetary authorities new tools to prevent pronounced periods of recession, are welcome.

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[43]The authors use probability models to test this hypothesis.

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A   Appendix: Calculating $\bar{\beta}$ and k

In Section 3 of this paper a solution for P_t^f is given for the case where income flows are explicitly modelled:

$$P_t^f = \bar{\beta}d_t; \qquad where \qquad \bar{\beta} = \left(\frac{\frac{\phi}{(1+r)}}{1 - \frac{\phi}{(1+r)}} \right) \tag{A.1}$$

$$P_t^f = kD_t; \qquad where \qquad k = \frac{e^{(\mu+\sigma^2/2)}}{(1+r) - e^{(\mu+\sigma^2/2)}} \tag{A.2}$$

In the first case, income flows are modelled as $d_t = \phi d_{t-1} + u_t$. In the second case *log* income flows are assumed to follow a random walk process with drift of the form $d_t = \mu + d_{t-1} + \zeta_t$.

In this appendix, the solutions given in equations (A.1) and (A.2) are explained in detail.

A.1   Calculating $\bar{\beta}$

To obtain $\bar{\beta}$ simply remember that the fundamental price is expressed as:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r} \right)^i E_t(d_{t+i}|\Omega_t) \tag{A.3}$$

d_{t+i} cannot be observed at time t, but d_t is. Solving d_{t+i} recursively yields:

$$d_{t+i} = \phi d_{t+i-1} + u_{t+i} \tag{A.4}$$

$$= \phi^2 d_{t+i-2} + \phi u_{t+i-1} + u_{t+i} \tag{A.5}$$

$$\vdots \tag{A.6}$$

$$= \phi^i d_t + \sum_{j=0}^{i} \phi^j u_{t+i-j} \tag{A.7}$$

Recall that u_t is a white noise variable (i.e. $N(0,\sigma^2)$) and that the expected value $(E_t[\cdot])$ is a linear operator, such that
$E_t[\sum_{j=0}^{\infty} u_{t+i-j}] = \sum_{j=0}^{\infty} E_t[u_{t+i-j}] = 0$.

Using the result in equation (A.7), one can rewrite equation (A.3) as:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t(\phi^i d_t + \sum_{j=0}^{i} \phi^j u_{t+i-j}) \tag{A.8}$$

$$= \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i \phi^i d_t \tag{A.9}$$

$$= \sum_{i=0}^{\infty} \left(\frac{1}{1+r}\right)^{i+1} \phi^{i+i} d_t \tag{A.10}$$

$$= dt\left(\frac{\phi}{1+r}\right) \sum_{i=0}^{\infty} \left(\frac{\phi}{1+r}\right)^i \tag{A.11}$$

$$= dt\left(\frac{\frac{\phi}{1+r}}{1 - \frac{\phi}{(1+r)}}\right) \tag{A.12}$$

$$= d_t\bar{\beta} \tag{A.13}$$

Note that the sum converges as long as $\phi < 1 + r$.

A.2   Calculating k

Obtaining the k parameter is very similar to calculating $\bar{\beta}$. The only significant difference lies in dealing with an exponential function. To start off, recall that the fundamental price is defined as:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t(D_{t+i}) \tag{A.14}$$

Since log income flows (d_t) are assumed to follow a random walk process such that $d_t = \mu + d_{t-1} + \zeta_t$, equation (A.14) can be written as:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t(e^{d_{t+i}}) \tag{A.15}$$

As in the prior case, d_{t+i} cannot be observed at time t, yet d_t is. So once again solving recursively for d_{t+i} one obtains:

$$d_{t+i} = \mu + d_{t+i-1} + \zeta_{t+i} \tag{A.16}$$

$$= \mu + \mu + d_{t+i-2} + \zeta_{t+i-1} + \zeta_{t+i} \tag{A.17}$$

$$\vdots \tag{A.18}$$

$$= i\mu + d_t + \sum_{j=0}^{i} \zeta_{t+i-j} \tag{A.19}$$

So that equation (A.15) can be expressed as:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t(e^{i\mu + d_t + \sum_{j=0}^{i} \zeta_{t+i-j}}) \tag{A.20}$$

$$= \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i E_t(e^{i\mu + d_t + X}) \tag{A.21}$$

where $X = \sum_{j=0}^{i} \zeta_{t+i-j}$. Note that X is normal because it is the sum of normal variables (ζ_t is a white noise variable $N(0, \sigma^2)$).

The log-normal distribution has the property that $E_t[e^X]$, where X is a normal variable with mean ν and variance σ^2 is $e^{\nu + \sigma^2/2}$. Since the mean of each ζ_t is equal to 0, the mean of X will be equal to 0 as well (i.e. $\nu = 0$). Given this, the variance of X will simply be the sum of the variances of ζ_t;

$$\sigma_X^2 = var(\sum_{j=0}^{i} \zeta_{t+i-j}) = \sum_{j=0}^{i} var(\zeta_{t+i-j}) = i\sigma^2$$

$$\text{and } E_t(e^X) \text{ will be;}$$

$$E_t(e^X) = e^{\nu_X + \sigma_X^2/2} = e^{i\sigma^2/2}$$

Using the above result, equation (A.21) can be expressed in the following way:

$$P_t^f = \sum_{i=1}^{\infty} \left(\frac{1}{1+r}\right)^i e^{i\mu + d_t} e^{i\sigma^2/2} \tag{A.22}$$

$$= D_t \sum_{i=1}^{\infty} \left(\frac{e^{\mu + \sigma^2/2}}{1+r}\right)^i \tag{A.23}$$

$$= D_t \sum_{i=0}^{\infty} \left(\frac{e^{\mu + \sigma^2/2}}{1+r}\right)^{i+1} \tag{A.24}$$

$$= D_t \left(\frac{e^{\mu + \sigma^2/2}}{1+r}\right) \sum_{i=0}^{\infty} \left(\frac{e^{\mu + \sigma^2/2}}{1+r}\right)^i \tag{A.25}$$

$$= D_t \left(\frac{\frac{e^{\mu + \sigma^2/2}}{(1+r)}}{1 - \frac{e^{\mu + \sigma^2/2}}{(1+r)}}\right) \tag{A.26}$$

$$= D_t \left(\frac{e^{\mu + \sigma^2/2}}{(1+r) - e^{\mu + \sigma^2/2}}\right) \tag{A.27}$$

$$= kD_t \tag{A.28}$$

The sum converges as long as $r > \mu + \sigma^2/2$.

B Appendix: Calculating the Aggregate Price Index

The Aggregate Price Index (API) mentioned in Section 4 of this paper is a "new" series that has only recently began to be calculated by the Financial Stability Department of the Banco de la República (Central Bank of Colombia). This Appendix describes the methodology and assumptions used in the construction of this index.

The API, in its shortest form, can be written as:

$$API_t = API_{cs,t}\,\phi_1 + API_{hh,t}\,\phi_2 + API_{fs,t}\,\phi_3 \quad ; \quad \sum_{i=1}^{3}\phi_i = 1 \qquad (B.1)$$

where API_{cs}, API_{hh} and API_{fs} refer to the aggregate price index of the private Corporate Sector, Households and the Financial Sector. ϕ is the weight given to each sector and is determined by the relative participation of each sectors' assets on total assets. The API for each sector is defined as:

$$API_{cs,t} = IPEN_t\,\delta_{fa,t} + IGBC_t\,\delta_{eq,t} + IPTES_t\,\delta_{gb,t} \quad ; \quad \delta_{fa} + \delta_{eq} + \delta_{gb} = 1 \quad (B.2)$$
$$API_{hh,t} = IPVN_t\,\beta_{fa,t} + IGBC_t\,\beta_{eq,t} + IPTES_t\,\beta_{gb,t} \quad ; \quad \beta_{fa} + \beta_{eq} + \beta_{gb} = 1 \quad (B.3)$$
$$API_{fs,t} = IPEN_t\,\zeta_{fa,t} + IGBC_t\,\zeta_{eq,t} + IPTES_t\,\zeta_{gb,t} \quad ; \quad \zeta_{fa} + \zeta_{eq} + \zeta_{gb} = 1 \quad (B.4)$$

where IPEN is an index of new commercial, office and warehouse constructions calculated by DANE (Department of National Statistics) and IPVN is an index of new residential housing prices calculated by DNP (Department of National Planning). Both these indexes are used as the price of fixed assets. IGBC is the general equity price index calculated by the Bolsa de Valores de Colombia (Colombian Stock Exchange) and IPTES is a price index for government bonds calculated at Banco de la República[44]. The choice of simplifying each sector's assets to these three types is based on actual price information availability (e.g. there is not a decent price series for corporate bonds) and the fact that they represent a significant portion of each sectors' assets[45]. All series used in the construction of these indexes are in real terms.

δ_{fa}, δ_{eq} and δ_{gb} represent the relative weights given to fixed assets, equity and government bonds, respectively, for the corporate sector. The β weights for households' API and the ζ weights for the financial sector's API are interpreted accordingly. Each weight is given by the relative importance of each type of asset in the total assets of each economic sector.

The index was calculated on a monthly basis for the period 1994:1-2006:12. For the purposes of this paper, the index was used on a quarterly basis, where each quarter corresponds to the average of the three relevant months.

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[44]The specific index used in this paper is for inflation-linked government bonds (called TES UVR).

[45]This is especially true for the financial sector and households, where these three assets represent more than 60% of total assets. In the corporate sector their participation falls close to 30%.

C   Appendix: Analyzed Series and Their Long-Term Trend

Loans to GDP ratio

Investment to GDP ratio

General Equity Index

New Housing Price Index

Aggregate Price Index