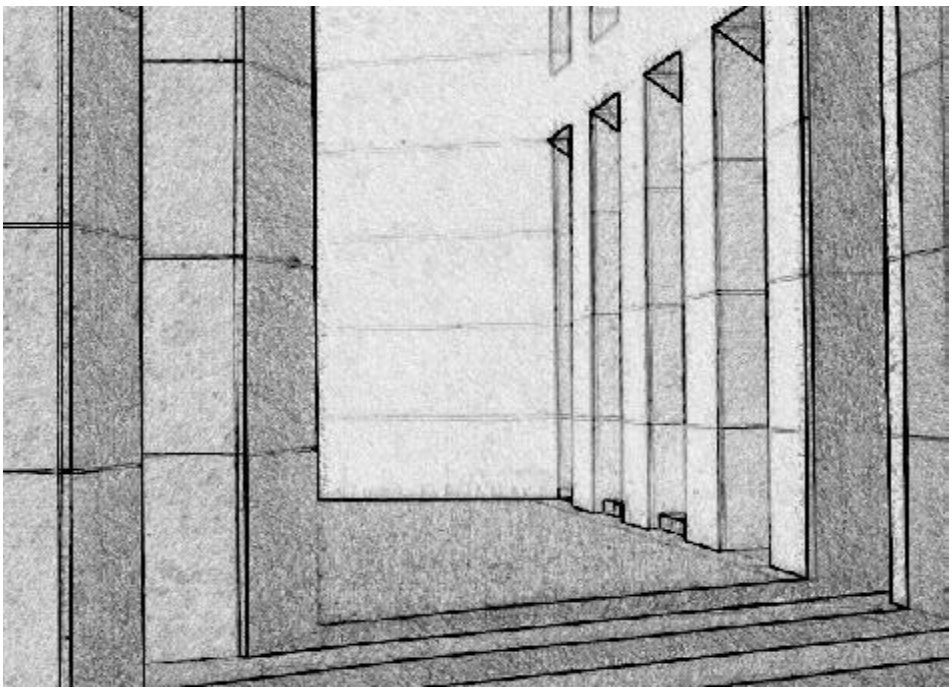

Empirical model of the behavior of the income velocity of money in Colombia, 1982 – 2001

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Ecos de Economía No. 17. Medellín, octubre 2003, pp. 79 - 92

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•***Abstract:*** The study of the income velocity of money is important since monetary factors play a causal role in output fluctuations. The issue of the stability of money demand is critical in assessing the monetary aggregates, M1/M3, usefulness for the formulation of monetary policy. In Colombia, the M1 income velocity of money has been very volatile whereas the M3 velocity has been pretty stable over the last 20 years. Contrary to the assumption underlying the Quantity Theory of Money, the evidence here indicates that the income velocity of money is not constant in Colombia for the 1982 – 2001 period.

The statistical results show that there is a positive relationship between the Colombian inflation rate and the M1 and M3 income velocities of money. A higher rate of inflation will translate into a higher nominal interest rate. The higher the interest rates the higher the opportunity cost of holding money and so the greater the income velocity.

•***Resumen:*** El estudio de la velocidad del dinero es importante porque los factores monetarios juegan un papel fundamental en las fluctuaciones del PIB. La estabilidad de la demanda de dinero es critica en la evaluación de los agregados monetarios, M1 y M3, como instrumentos de formulación de política monetaria.

En Colombia en los últimos veinte años, la velocidad del dinero de M1 ha sido muy volátil mientras que la velocidad del dinero de M3 ha sido estable. En contradicción con la hipótesis fundamental de la Teoría Cuantitativa del Dinero, la evidencia encontrada en este estudio indica que durante el período 1982 – 2001 la velocidad del dinero en Colombia no es constante.

Los resultados estadísticos muestran que hay una relación positiva entre la tasa de inflación Colombiana y las velocidades del dinero de M1 y M3. Un aumento de la tasa de inflación se traducirá en un aumento de la tasa de interés nominal. Entre más altas las tasas de interés, más alto es el costo de oportunidad de tener dinero en efectivo y por ende, la velocidad del dinero será más alta.

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Introducción[1]

This paper attempts to describe the behavior of the income velocity of money in Colombia in the last 20 years. It also tries to determine how well the notion of the Quantity Theory of Money applies to Colombia and tries to relate how several other factors such as the existing dual currency and the adverse social and political conditions might affect the results obtained in the analysis.

In recent years, Colombia's strong economic performance has given way to slow growth, rising unemployment and a widening of the fiscal and external current accounts due, to a large extent, to the influence of adverse external shocks and the difficult internal security situation.

The study of the income velocity of money is important since monetary factors play a causal role in output fluctuations. Studies[2] have shown that fluctuations in output are observed to be more strongly linked to fluctuations in that part of the money stock consisting of deposits at financial intermediaries than to innovations in the monetary base (the money stock actually controlled by the central bank).

1 This paper was made to obtain the Master of Economics degree at North Carolina State University (USA).

2 Kydland, Finn and Freeman, Scott. Federal Reserve Bank of St. Louis.

The issue of the stability of money demand is critical in assessing the monetary aggregates, M1/M3, usefulness for the formulation of monetary policy. In Colombia, estimates of the demand for financial assets have been used in framing the monetary policy. Particularly, the velocity of circulation of money has played an important role in the determination of the monetary base corridor, which is set annually to support the inflation target. This is very important because of the significant impact that monetary policy has on the performance of the country's economic activity.

The first part of the study explains the concept of the income velocity and its theoretical relationship with the interest rate and the inflation rate. The second part attempts to corroborate the veracity of the Quantity Theory of Money for Colombia.

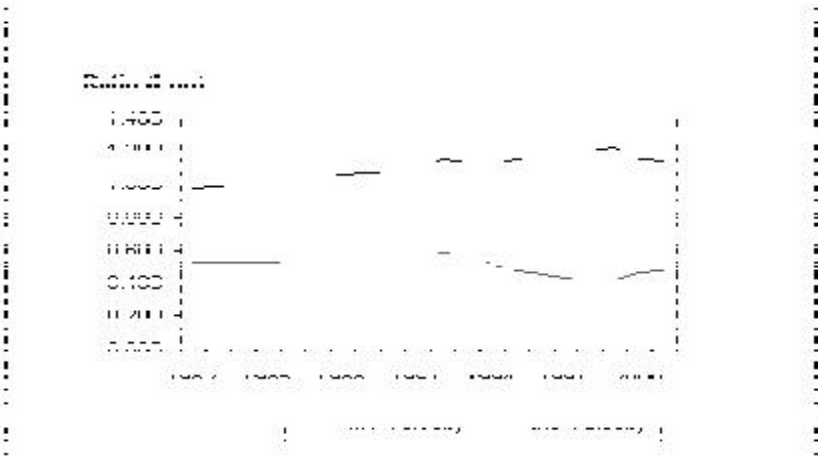
The third part shows a variety of additional econometric results for the M1 and M3 income velocities and other variables that, intuitively, would help explain the velocity's dynamic. Finally, the study outlines the conclusions obtained from the regression analyses and relate them to the other "non-economic" factors that influence the behavior of the Colombian economy.

Theoretical Framework

The income velocity of money measures how often the money stock "turns over" each period. It is defined as the ratio between the nominal GDP and the money stock. Assuming that the volume of transactions (P*Y) is proportional to GDP, if velocity rises, then each peso of the money stock is being used in a greater peso volume of transactions each period.

The monetary aggregate M1 includes currency and balances held in checking accounts while M3 includes M2 (M1 plus saving deposits plus small denomination time deposits), large denomination time deposits and money market mutual funds. In Colombia, the M1 income velocity of money has been very volatile and increasing over the last 20 years. In contrast, the M3 velocity has been pretty stable over the same period (chart #1).

CHART #1
M1 / M3 Velocities 1982 - 2001



Source: data taken from Banco de la República. www.banrep.gov.co

Moreover, in the last two decades, the M1 income velocity has been growing at a rate in the order of 2.6% per year; while the M3 velocity has, on average, been declining at approximately 1.3% per year (Table 1).

Table 1

Dependent Variable	Independent Variable	Coefficient Error	Standard	t-value	R – squared
LnM1V	t	0.02683	0.02760	11.65	0.8828
LnM3V	t	-0.01312	0.00374	-3.51	0.4063

This is concurrent with the theory since the M3 aggregate is a broader measure of the money stock and therefore is less influenced by random shocks to demand for individual components. As a result, movements in the M3 velocity have become more predictable over the last years. Particularly, during the 1990s, advances in technology, the massive use of credit cards and the development of mutual funds have decreased the money demand, M3.

According to the Quantity Theory of Money[3], real money demand is proportional to real income: $M^d / P = kY$, where kY is a function of the real income and the nominal

interest rate, L (Y, i). This assumes that velocity is a constant (1/k) and doesn't depend on income or interest rates.

But it's silly to think about constant velocity in the real world. Contrary to the assumption underlying the Quantity Theory of Money, changes in the interest rate, i, will affect velocity. Note that this is a special (simplified) form:

V: $\mathbf{V} = P*Y / M$, $\mathbf{V} = Y / (M/P) = Y / L (Y, i)$

$(M/P)^d = L (Y, i) = Y*i^{-a}$

$V = Y / Y* i^{-a}$, $V = i^a$

This suggests that there is positive relationship between the income velocity of money and the interest rate.

Due to the lack of data available for Colombia, this paper assumes that the Fisher effect is true ($i = r + n^e$), where i represents the nominal (actual) interest rate, r is the real interest rate and n^e is the expected rate of inflation and uses the actual inflation rate as a measure of the cost of holding money.

***Econometric models*[4]**

In econometric theory, the notion of a stationary process has always played an important role in the analysis of time series. A series that is strongly dependent is not reliable for regression analysis because under strong dependence, the classical OLS estimators are not valid.

In order to test the reliability of the models, unit root tests with linear trend (n = 20) were conducted on the series used in the models. Failure to include a time trend, if it belongs, will likely make the estimate of the first-order autocorrelation term larger than it might otherwise be.

The hypothesis to be tested is: H_o: $\rho_1 = 1$, H_1: $\rho_1 < 1$. A simple rule of thumb [5] was applied: if $\rho_1 > 0.9$, then it might be concluded that the distribution of the series is strongly dependent, I (1).

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3 Bernanke, Ben and Abel, Andrew. Macroeconomics, fourth edition. 2001. Page 257.

4 All data series for Colombia were obtained from Colombia's Central Bank website: Banco de la República, http://www.banrep.gov.co. The 3-month Treasury Constant Maturity rate was downloaded from the Federal Reserve Bank of St.Louis, Economic Research: http://research.stlouisfed.org/fred2/

5 Thanks to the advice of Matt Holt. Professor of Econometrics at NC State University.

The variables are defined as follows: $LnM1V_t$ is the log of the M1 income velocity of money, $LnM3V_t$ is the log of the M3 income velocity of money and $LnColinfrate_t$ is the log of the inflation rate in Colombia.

Summary results are given below:

$LnM1V_t$: $\rho_1 = 0.73842$, reject H_o

$LnM3V_t$: $\rho_1 = 0.81216$, reject H_o

$LnColinfrate_t$: $\rho_1 = 0.89746$, reject H_o

Based on these outcomes, it seems reasonable to conclude that, under the null hypothesis, there is no evidence in favor of a unit root in any of the three variables. That is, the estimated first-order autocorrelation coefficient (ρ_1) is reasonably far from one, thus these three series are integrated of order zero, I (0).

In order to determine how well the notion of the Quantity Theory of Money applies to Colombia, the following multiple regression equations were estimated:

(1) $LnM1V = \delta_0 + \delta_1 * LnColinfrate + \delta_2 * t + \varepsilon_t$

(2) $LnM3V = \lambda_0 + \lambda_1 * LnColinfrate + \lambda_2 * t + \lambda_t$

Statistic results are shown in table 2.

Table 2.
Dependent Variable: LnM1V

Variable	DF	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	1	1.87894	0.12774	14.71	0.0001
LnColinfrate	1	0.10469	0.03707	2.82	0.0117
t	1	0.03108	0.00247	12.59	0.0001
	R-squared: 0.9203		Adj R-sq: 0.9109	n = 20	

Dependent Variable: LnM3V

Variable	DF	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	1	0.83796	0.22183	3.78	0.0015
LnColinfrate	1	0.14112	0.06438	2.19	0.0426
t	1	-0.00739	0.00429	-1.72	0.1029
	R-squared: 0.5371		Adj R-sq: 0.4827	n = 20	

Unit root tests (n = 20) were also conducted on the residuals obtained from the regressions. For equation (1), Ut: $\rho_1 = 0.27970$ and for equation (2), Ut: $\rho_1 = 0.75192$.

Since the first-order autocorrelation terms are significantly far from one, the residuals of the estimated models in (1) and (2) are also weakly dependent or integrated of order zero, I (0).

Hence, it can be said that the Colombian inflation rate (used as a measure of the cost of holding money) considerably helps explain the behavior of the M1 and the M3 income velocities.

For equations (1) and (2), the M1 and the M3 income velocities show positive and statistically significant elasticities with respect to the Colombian inflation rate. Therefore, a one-percent increase in the Colombian inflation rate will cause a 0.10% increase in the M1 income velocity and a 0.14% increase in the M3 income velocity of money.

But are there other factors that influence the behavior of the income velocity of money in Colombia? On the one hand, the following equations were estimated:

(3) $LnM1V_t = \delta_3 + \delta_4 * LnUSint_t + \delta_5 * t + \varepsilon_t$

(4) $LnM1V_t = \lambda_3 + \lambda_4 * LnUSint + \lambda_5 * LnColinfrate_t + \lambda_6 * t + V_t x\ \lambda_t$

(5) $LnM3V_t = \delta_6 + \delta_7 * LnUSint_t + \delta_8 * t\ \varepsilon_t$

(6) $LnM3V_t = \lambda_7 + \lambda_8 * LnUSint + \lambda_9 * LnColinfrate_t + \lambda_{10} * t + V_t$

The variables are defined as follows: $LnM1V_t$, LnM3V and LnColinfrate are defined as before, $LnUSint_t$ is the log of the US short term interest rate (3-Month Treasury Constant Maturity Rate), t is a simple time trend and ε_t, vt are the error terms. Summary statistics are given in table 3.

Based on these results, it seems reasonable to conclude that, the M3 income velocity has a negative elasticity with respect to the US short-term interest rate whereas the elasticity of the M1 velocity with respect to the US short-term interest rate is not significant (instead, the trend term appears to have substantial explanatory power). Therefore, a one percent increase in the US interest rate will cause a 0.22% decrease in the M3 velocity.

In addition, in the short run, there're many other disturbances in the Colombian economy such as a not fully developed financial system and the relatively small size of the market that might have a greater influence on the money demand.

Table 3

Dependent Variable	Independent Variable	Coefficient	Standard Error	t-value	R – squared
LnM1V	LnUSint	-0.05361	0.05646	-0.95	0.8887
	t	0.02454	0.00334	7.35	
	LnUSint	-0.01683	0.05119	-0.33	0.9208
	LnColinfrate	0.10101	0.03970	2.54	
	t	0.03021	0.00366	8.25	
LnM3V	LnUSint	-0.22425	0.07668	-2.92	0.6050
	t	-0.02269	0.00453	-5.00	
	LnUSint	-0.18786	0.07583	-2.48	0.6655
	LnColinfrate	-0.09997	0.05881	1.70	
	t	-0.01708	0.00542	-3.15	

Nevertheless, we would expect that a higher US interest rate will make deposits in dollars more attractive to Colombians (since the rate of return on deposits in dollars will be higher) and so the nominal money demand for pesos will be decreased and the income velocity increased.

In contrast, once the log of the Colombian inflation rate is added to the model, the explanatory power of the log of the US short-term interest rate remains insignificant for the M1 velocity -equation (4)- and holds significant for the M3 velocity -equation (6).

The US interest rate seems to be more associated with the broader measure of the money stock, M3, than with M1. This is, the opportunity cost of saving money in term deposits versus holding American dollars. In fact, since M1 is a narrower measure of the money stock, the M1 velocity tends to be more influenced by temporary shocks. In synthesis, the US short-term interest rate does not help explain the behavior of the M1 velocity but it does help explain the performance of the M3 income velocity.

On the other hand, countries are interdependent: the expansions and recessions occurred in one country are transmitted to the others through commercial flows and variations in the interest rates of an important country immediately affect the exchange rates of other countries (Dornbusch and Fischer, 1994). Thus, it is expected to find a relationship between the exchange rate and the domestic money demand.

Furthermore, "when…depreciation is anticipated, there is a tendency among owners of money to spend it speedily…the result being to raise prices by increasing the transactions velocity" (Irving Fisher, 1911).

Specifically, in order to arrive at conclusions about the influence of the international flow of capital on the Colombian economy, regressions of the income velocities against the nominal exchange rate and the real exchange rate were calculated.

The rate of change of the nominal exchange rate was defined as the percentage change of the exchange rate (pesos per dollar) from year to year. In theory, the rate of change of the real exchange rate can be expressed as: $\Delta e/e = \Delta e_{nom}/e_{nom} + \Delta P/P - \Delta P_{for}/P_{for}$, where $\Delta e_{nom}/e_{nom}$ is the rate of change of the nominal exchange rate, $\Delta P/P$ is the percentage change in the domestic price level or the domestic rate of inflation and $\Delta P_{for}/P_{for}$ is the percentage change in the foreign price level or the foreign rate of inflation[6].

For our purposes, the rate of change of the real exchange rate, $\Delta e/e$, equals the rate of change of the nominal exchange rate in Colombia (pesos per dollar) plus the US inflation rate[7] minus the Colombian inflation rate.

In Colombia over the last 20 years, the rate of change of the nominal exchange rate has been decreasing at a rate of approximately 0.78% per year and the rate of change of the real exchange rate has, on average, been declining at approximately 1.29% per year.

Regression models of the following form were estimated:

(7) $LnM1V_t = \alpha_o + \alpha_1 * dexcrate_t + \alpha_2 * t + \eta_t$, (8) $LnM1V_t = \delta_o + \delta_1 * drexcrate_t + \delta_2 * t + \varepsilon_t$, where $LnM1V_t$ is defined as before, $dexcrate_t$ is defined as the rate of change of the nominal exchange rate, $drexcrate_t$ represents the rate of change of the real exchange rate, t is the time trend and η_t, ε_t are the error terms. (9) $LnM3V_t = \gamma_o + \gamma_1 * dexcrate_t + \gamma_2 * t + \upsilon_t$, and (10) $LnM3V_t = \gamma_o + \gamma_1 * drexcrate_t + \gamma_2 * t + \tau_t$, where $LnM3V_t$, $dexcrate_t$, $drexcrate_t$ and t are defined as before and υ_t, τ_t are the error or disturbance terms.

Regression estimation results are as follows:

(7) $LnM1V = 2.23127 + 0.00007952 * dexcrate + 0.02689 * t$, $R^2 = 0.8829$

(0.0627) (0.0019) (0.0028)

6 Andrew, Abel and Bernanke, Ben. Macroeconomics, fourth edition. 2001. Page 476.

7 Series downloaded from the Federal Reserve Bank of St.Louis, Economic Research: http://research.stlouisfed.org/fred2/

(8) LnM1V = 2.11656 + 0.00229*drexcrate + 0.02979*t, R^2 = 0.8957
(0.0852) (0.0015) (0.0030)

(9) LnM3V = 1.39392 – 0.00272*dexcrate – 0.01526*t, R^2 = 0.4321
(0.0995) (0.0031) (0.0044)

(10) LnM3V = 1.22715 + 0.00174*$drexcrate_t$ – 0.01087*t, R^2 = 0.4205
(0.1448) (0.0026) (0.0051)

It is important to report these interesting findings. The output shows that the simple trend term has substantial explanatory power in each of the above regressions (its t-values are highly significant).

On one hand, the coefficients (semi-elasticities) of the rate of change of the nominal exchange rate with respect to the income velocities of money, M1V and M3V are insignificant at any significance level (the p-values are very high).

Although, it was expected that an anticipated increase in the rate of change of the nominal exchange rate (a nominal depreciation) will cause a decrease in the demand for pesos and consequently, an increase in the income velocity of money.

On the other hand, the coefficients on the M1 and M3 income velocities with respect to the terms of trade (δ_1 and γ_1 from equation (8) and (10)) were also found insignificant at any level.

In reality, prices are sticky in the short run and therefore, the rate of change of the nominal exchange rate is correlated with the rate of change of the real exchange rate. In addition, the influence of the dollars repatriated to Colombia as a result of the illicit drug business, the existent "black market" of dollars and the persistent speculation have been causing important distortions in the determination of the value of the foreign currency.

Lastly, as mentioned before, the monetary aggregate M3 represents a broader measure of the money stock and is a more stable variable thus, additional regression equations were estimated in order to further explain the behavior of the M3 income velocity of money.

Specifically, a combination of the US interest rate and the US inflation rate was introduced: (11) $LnM3V_t = \beta o + \beta_1 LnUSint_t + \beta_2 LnUSinfrate_t + \beta_3 *t + U_t$ where $LnM3V_t$ represents the log of the M3 income velocity; $LnUSint_t$ is the log of the US short term interest rate (3-Month Treasury Constant Maturity Rate); $LnUSinfrate_t$ is the log of the US inflation rate (CPI for all urban consumers: all items, seasonally adjusted); t is a simple time trend and U_t is the error term. Summary statistics are shown in table 4.

Table 4.

Dependent Variable: LnM3V

Variable	DF	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	1	1.67832	0.11978	14.01	0.0001
LnUSint	1	-0.31024	0.05433	-5.71	0.0001
LnUSinfrate	1	0.21710	0.04611	4.71	0.0002
T	1	-0.01945	0.00310	-6.27	0.0001

R-squared: 0.8344 Adj R-sq: 0.8034 n = 20

As previously mentioned, the notion of a stationary process plays an important role in the analysis of time series. In order to test the reliability of this model, Dickey-Fuller unit root tests with linear trend (n = 20) were conducted: H_o: $\theta = 0$, where $\theta = \rho_1 - 1$; H_1: $\theta < 0$.

Summary results are given below:

$LnM3V_t$: $t_\theta = (0.81216 - 1) / 0.13393 = -1.40$, fail to reject H_o at any level.

$LnUSint_t$: $t_\theta = (0.49511 - 1) / 0.21090 = -2.39$, fail to reject H_o at any level.

$LnUSinfrate_t$: $t_\theta = (0.27781 - 1) / 0.23036 = -3.13$, fail to reject H_o at any level.

U_t: $t_\theta = (-0.07028 - 1) / 0.21913 = -4.88$, reject H_o at any significance level.

Under the null hypothesis, there is strong evidence in favor of a unit root in all three variables[8]. That is, all series in the model are integrated of order one, I (1). But there's no evidence in favor of a unit root in the residuals, given that the null was rejected and the estimated ρ_1 is not so far from zero. Then the residuals of the estimated model in (11) are weakly dependent or integrated of order zero, I (0).

Therefore, it is reasonable to conclude that the variables in equation (11) are cointegrated and so the OLS coefficient estimators will be consistent and asymptotically efficient. Also, this model is a more consistent approximation to the long-term relationships between the variables and there might be a non-linear relationship between the M3 velocity and the US interest and inflation rates.

8 The asymptotic critical values for unit root tests with time trend were obtained from Woolridge, Jeffrey: Introductory Econometrics.

From the regression results, both variables met the 0.05 significance level for entry into the model and the adjusted R-square turned out to be quite good. A linear time trend was included since all variables showed a trending pattern in the sample period. The simple trend term appears to have substantial explanatory power in the above regression equation.

The output shows that the elasticity of the M3 velocity with respect to the US interest rate is negative and very strong. A 1% increase in the US short-term interest rate will cause a 0.31% decrease in the M3 velocity.

Although, in theory, the higher the interest rate the higher the opportunity cost of holding money and consequently, the money demand, M3, will be decreased and the velocity increased (since velocity and money demand are inversely related).

Additionally, the elasticity of the M3 velocity with respect to the US inflation rate turns out to be positive and significant. A 1% increase in the US inflation rate will increase M3 velocity, approximately, in 0.22%.

Assuming that the Fisher effect holds, a higher rate of inflation in the US will mean a higher nominal interest rate in the US. The higher the interest rate the higher the opportunity cost of holding pesos and consequently, the money demand, M3, will be decreased and the Colombian's income velocity increased.

Conclusions

In Colombia, the M1 income velocity of money has been very volatile whereas the M3 velocity has been pretty stable over the last 20 years. The evidence here indicates that the income velocity of money is not constant in Colombia for the 1982 – 2001 period.

The statistical results show that there is a positive relationship between the Colombian inflation rate and the M1 and M3 income velocities of money. A higher rate of inflation will translate into a higher nominal interest rate. The higher the interest rates the higher the opportunity cost of holding money and so the greater the income velocity.

In this context, in the last decade, the influence of the short-term interest rates on income velocity has been increased as a consequence of the reduced attractiveness of M3, mainly because of the effects of new financial regulations, advances in technology, the massive use of credit cards and the development of mutual funds.

On the one hand, the data suggests that the US short-term interest rate does not help explain the behavior of the M1 velocity but it does help explain the performance of the M3 income velocity of money.

On the other hand, while some of the results obtained from the regressions seem to follow the economic theory others do not. These findings can be explained by the fact that Colombia has been the world's foremost producer and exporter of cocaine since the 1970s. While the drug money may provide much needed influxes of capital to the economy, experts now agree that over time the money can devastate legitimate business and long term development. In the long run, the drug money creates systems that are outside the formal channels.[9]

Finally, the particular dynamic of the Colombian economy i.e. the distortions created by a variety of other factors such as the influence of the drug business, difficult social and political conditions, poverty, weak institutions, a long history of armed conflict and corruption introduce significant disturbances in the outcomes derived from the regressions. Specifically, in the regressions of the velocities against the US short-term interest rates, there's confusion about the negative sign of the coefficient and, surprisingly, the influences of the rate of change of the exchange rate and the terms of trade in the M1 and M3 income velocities are very ambiguous.

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