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CURRENCY SUBSTITUTION, DUALITY, AND EXCHANGE RATE INDETERMINACY: AN EMPIRICAL ANALYSIS OF THE VENEZUELAN EXPERIENCE

by

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We develop a currency substitution model to explain the 400 percent depreciation of the free market exchange rate of the Venezuelan bolivar. Applying duality theory, we find that currency substitution is a necessary condition for such a depreciation. Using annual data for 1960-1980, we estimate the elasticity of currency substitution for Venezuela, and we find that this elasticity is significantly greater than one.

Currency Substitution, Duality, and Exchange Rate Indeterminacy: An Empirical Analysis of the Venezuelan Experience

Jaime Marquez*

Board of Governors of the Federal Reserve System

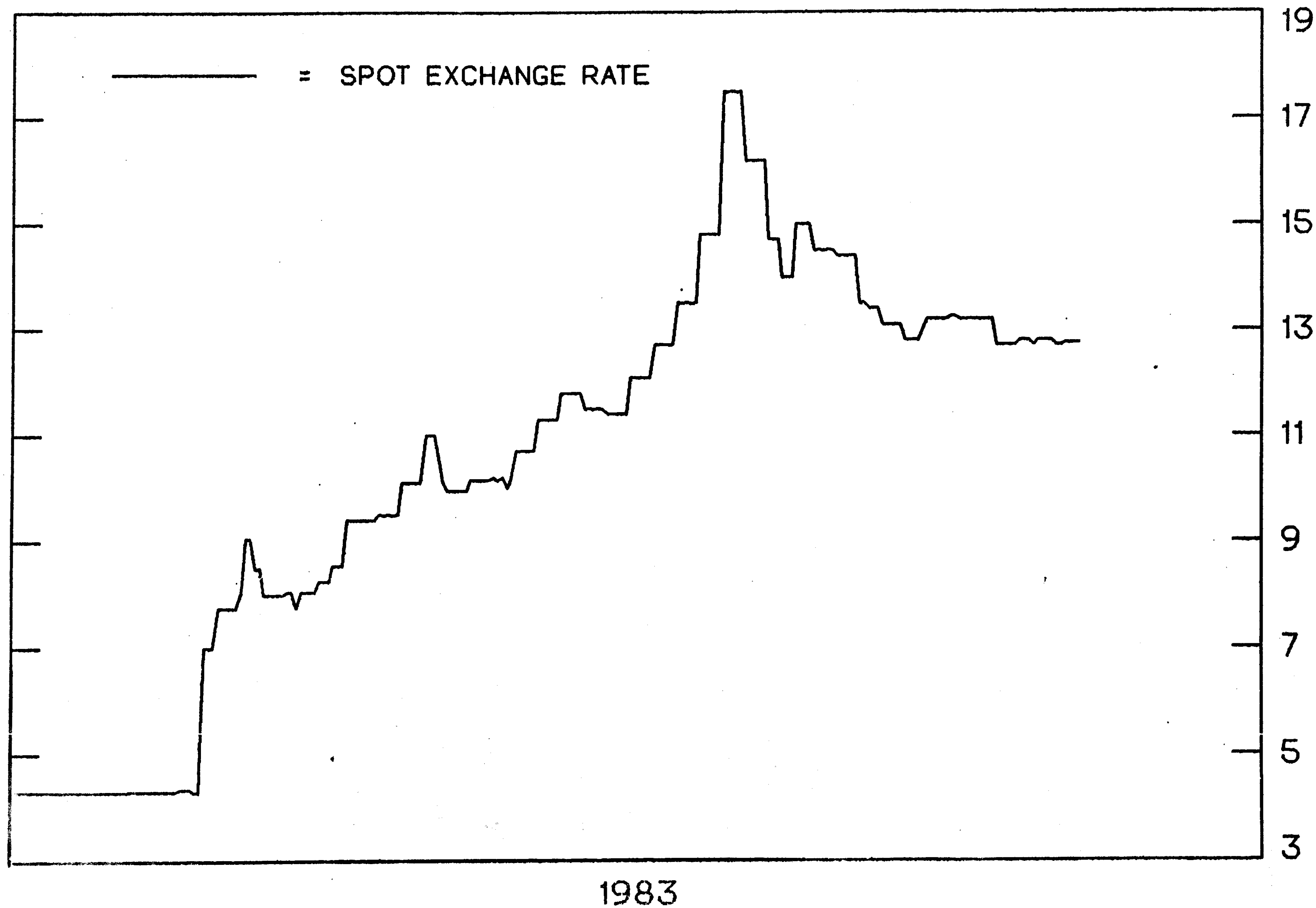
I. INTRODUCTION

The Venezuelan bolivar was pegged to the U.S. dollar for over twenty years until late February of 1983, when the monetary authorities were forced to close the foreign exchange market to prevent a speculative run on the stock of international reserves. The market reopened a week later with an exchange rate system consisting of two controlled exchange rates and a "free" market exchange rate. This last exchange rate depreciated nearly 400 percent in less than 3 months (see Figure 1), a shock greater in magnitude than the oil shock of 1973-74. The basic question we ask in this paper is whether we can find an economic rationale for such a formidable depreciation.[1]

We address this question using a currency substitution model for Venezuela. Currency substitution models have been receiving an increasing amount of attention in the literature because of their implications for both monetary policy and exchange rate behavior in open economies. For example, McKinnon (1982) argues that, because of the existence of currency substitution, the appropriate concept of money supply--and monetary policy--is a global one. Miles (1978, 1981) discusses the implications of currency substitution for the autonomy of monetary policy under flexible exchange rates. Calvo and Rodriguez (1977), Canto and Miles (1983), and Girton and Roper (1981) develop alternative theoretical models to study the implications of different degrees of currency substitution for instability

Figure 1

VENEZUELA SPOT EXCHANGE RATE 1983



of the exchange rate under the rational expectation hypothesis.[2]

The basic message from these analyses is that if two currencies are perfect substitutes for each other, then the exchange rate between them is indeterminate. Consequently, small changes in the expected return to holding one currency will induce swift changes in the composition of the portfolio with a corresponding impact on the exchange rate. Therefore, it would seem that the sharp movements in the exchange rate that were observed in Venezuela would be consistent with an expected depreciation of the venezuelan bolivar provided there existed a substantial degree of currency substitution. Our first purpose in this paper is to determine empirically the degree of currency substitution existing in Venezuela.

The empirical evidence regarding the degree and extent of currency substitution--as shown by Miles (1978), Ortiz (1983), and Daniel and Fried (1983)--has focused on the case where the institutional banking structure allows for the circulation of both domestic and foreign currency. Two of the countries more commonly analyzed are Mexico and Canada, where U.S. dollars have circulated as an additional medium of payments.[3] One question that naturally arises in this context is to what extent the existence of banking regulations are a pre-condition for the existence of currency substitution. In Venezuela, for instance, only domestic currency is allowed to circulate. Therefore an empirical analysis for Venezuela might provide some evidence regarding the need of regulatory constraints for the existence of currency substitution possibilities.

Our second purpose is to apply duality results from production theory in an attempt to formalize the notion of exchange rate instability. One corollary of the analysis we develop is an alternative explanation of exchange rate indeterminacy in the presence of perfect currency substitutability.

Although this issue has received some attention in the literature,[4] the analyses have not been exhaustive. More specifically, we show that the range of fluctuation of the exchange rate depends, to a large extent, on whether perfect currency substitutability is local or global.

We begin our analysis in section II where we develop a model to explain currency substitution relevant for the Venezuelan economy. In section III we apply duality results to derive the conditions leading to exchange rate indeterminacy. In section IV we implement empirically our model and estimate the elasticity of currency substitution using annual data for Venezuela for the period 1960-1980. Finally section V contains our conclusions.

II. A MODEL OF CURRENCY SUBSTITUTION

We will assume an economy where individuals' wealth is mainly made up of "money"[5]. We assume that money can be held in either domestic currency or foreign currency. Since we do not allow for domestic circulation of foreign currency, we need to assume that individuals have foreign currency deposits abroad that can be exchanged for domestic currency and vice-versa. This assumption is consistent with the absence of capitals controls in Venezuela.

Formally, we assume that individuals follow a sequential portfolio decision process, and that the optimal portfolio composition is obtained by minimizing the cost of holding a bundle of domestic and foreign currency subject to a given level of money holdings:[6]

$$\min C/P = (1+i)(M^d/P) + \left((1+i^*)/(1+x)\right)(M^{d*}/P^*), \qquad (1)$$

subject to

$$M/P = A\left(\delta(M^d/P)^{-\rho} + (1-\delta)(M^{d*}/P^*)^{-\rho}\right)^{-1/\rho}, \tag{2}$$

where

C: portfolio holding costs,

i: domestic nominal interest rate,

i*: foreign nominal interest rate,

P: domestic price level,

P*: foreign price level,

x: expected depreciation of the exchange rate,

M^d: nominal money demand for domestic currency,

M^{d*}: nominal money demand for foreign currency,

M: nominal (aggregate) level of money holdings,

δ: distribution parameter, and

ρ: substitution parameter, $\rho \equiv (1-\sigma)/\sigma$.

If we assume purchasing power parity, then we can form the lagrangean as:

$$\Lambda = (1+i)M^d + \left((1+i^*)/(1+x)\right)(eM^{d*}) + \lambda\{M - \left(\delta M^{d^{-\rho}} + (1-\delta)(eM^{d*})^{-\rho}\right)^{-1/\rho}\},$$

where e is the exchange rate (domestic currency/foreign currency). The first-order conditions for the cost minimization problem are:

$$\partial\Lambda/\partial M^d = (1+i) - \lambda(\partial M/\partial M^d) = 0, \tag{3}$$

$$\partial\Lambda/\partial(eM^{d*}) = \left((1+i^*)/(1+x)\right) - \lambda\partial M/\partial(eM^{d*}) = 0, \tag{4}$$

$$\partial\Lambda/\partial\lambda = M - A\left(\delta M^{d^{-\rho}} + (1-\delta)(eM^{d*})^{-\rho}\right)^{-1/\rho} = 0. \qquad (5)$$

Using now equations (3) and (4), we get the optimal currency ratio as:

$$eM^{d*}/M^{d} = \left((1-\delta)/\delta\right)^{\sigma}\left((1+i)(1+x)/(1+i^{*})\right)^{\sigma}, \qquad (6)$$

where $\sigma=(1/1+\rho) > 0$ is the elasticity of substitution between foreign and domestic currency. As $\sigma\to 0$, the two currencies become perfect complements to each other. As $\sigma\to\infty$, the two currencies become perfect substitutes for each other, and as shown in section III, the exchange rate becomes indeterminate.

According to equation (6), an increase in domestic interest rates reduces the attractiveness of holding domestic currency and raises the ratio eM^{d*}/M^{d}. Similarly, an expected depreciation of the domestic currency will increase profit opportunities from holding foreign currency raising the eM^{d*}/M^{d} ratio. Finally, an increase in foreign interest rates will reduce the attractiveness of holding foreign currency and, as a result, will lower the optimal currency ratio. For the purpose of explaining the depreciation of the venezuelan bolivar, the inclusion of interest rates is quite relevant. If individuals expect that a fixed exchange regime will be abandoned at some future date, x>0, then substantial capital gains can be made by borrowing as much money as possible. And what equation (6) says is that the source of borrowing depends on interest rate differentials.

Equation (6) has been used to estimate the elasticity of currency substitution as measured by the parameter σ (Miles 1978, Laney 1980, Ortiz 1983).[7] However, I would argue, that this approach is not entirely correct since equation (6) is not the solution to the system of equations (3) to (5) representing the first-order conditions. In effect, only two of these three equations are used to estimate σ, whereas the equation system that needs to be estimated is:

$$eM^{d*}/M^{d} = \left((1-\delta)/\delta\right)^{\sigma} \left((1+i)(1+x)/(1+i^{*})\right)^{\sigma}, \tag{6}$$

and

$$M = A\left(\delta M^{d^{-(1-\sigma)/\sigma}} + (1-\delta)(eM^{d*})^{-(1-\sigma)/\sigma}\right)^{-\sigma/(1-\sigma)}, \tag{5}$$

and there is absolutely no guarantee that the parameter estimate of σ using only equation (6) will be equal to the parameter estimate of σ using equations (5) and (6).[8]

Perhaps one reason why previous empirical models have used only equation (6) to estimate σ, despite the parameter estimates being at odds with the theory used, is that M is unobservable as it depends on the unknown parameters δ and σ. However, equation (6) is not without problems, especially for developing countries, where the possibility of capital flight creates serious difficulties in obtaining adequate data for M^{d*}. For Venezuela the situation is more complex because, in contrast to the experience of Canada and Mexico, only domestic currency is allowed to circulate as a means of payment.

In this paper we eliminate the second of these problems by using the conditional demand for domestic currency, which is obtainted by solving for eM^{d*} in equation (6) and substituting the result into equation (5):

$$M = A\{\delta {M^d}^{-\rho} + (1-\delta)([(1-\delta)/\delta]^{\sigma} [(1+i)(1+x)/(1+i^*)]^{\sigma} M^d)^{-\rho}\}^{-1/\rho}, \tag{7}$$

and solving for M^d, we get:

$$M^d = \{1+((1-\delta)/\delta)^{\sigma}((1+i)(1+x)/(1+i^*))^{\sigma-1}\}^{\sigma/(1-\sigma)} \delta^{\sigma/(1-\sigma)} (M/A). \tag{8}$$

Equation (8) is the conditional demand for domestic currency, which depends on domestic and foreign interest rates, on the expected rate of depreciation, and on the given aggregate level of money holdings. The main advantages of equation (8) are first, that the parameter σ can be estimated taking into account <u>all</u> the first-order conditions for the portfolio allocation problem, and second, that there is no need to use unreliable data on Venezuelans' holdings of foreign currency abroad. However, we still have the problem that M is unobservable. For the purposes of empirical implementation, we will assume that the aggregate level of money holdings, in nominal terms, is a function of the level of nominal income:

$$M = f(Y). \tag{9}$$

Using this simplifying assumption, we express equation (8) as:

$$M^d = M(i, i^*, x; Y) = M(\underset{\sim}{w}, Y), \tag{10}$$

where $\underset{\sim}{w}' = (i, i^*, x)$. Combining equation (6) with equation (10), we get the conditional demand for foreign currency:

$$M^{d*} = M^*(\underset{\sim}{w}, Y)/e. \tag{11}$$

III. EXCHANGE RATE INDETERMINACY AND DUALITY

It is somewhat surprising that despite the similarity existing between the analysis of currency substitution and the analysis of factor substitution in production theory, almost no attempt has been made to apply duality results to the analysis of currency substitution.[9]

If we substitute the optimal portfolio allocation (equations 10 and 11) into equation (1), then we get the cost function:

$$C = (1+i)M^{d}(\underset{\sim}{w},Y) + \left((1+i^{*})/(1+x)\right)eM^{d*}(\underset{\sim}{w},Y) = C(\underset{\sim}{w},Y). \qquad (12)$$

Using equation (12), we can find the combinations of i, i*, and x for which C is constant, defining in this way an isocost curve. We can also define an isoholdings curve as the set of values of i, i*, and x for which aggregate money holdings, M, are constant. The duality result relevant for our analysis is Shephard's derivative lemma, which implies that the ratio of optimal currency holdings equals the slope of the isocost curve:

$$eM^{d*}/M^{d} = \{\partial C(.)/\partial((1+i^{*})/(1+x))\}/\{\partial C(.)/\partial(1+i)\}. \qquad (13)$$

One corollary of Shephard's lemma is that the curvatures of the isoholdings curve and of the isocost curve are inversely related to each other. Figure 2 depicts the situation where the elasticity of currency substitution is infinite for all possible portfolio allocations, and thus the isoholding curve is perfectly flat. Since the ratio of optimal currency holdings equals the slope of the isocost, it follows that the isocost has a curvature with a 90 degree angle. As a result, for any value of M^{d*}/M^{d}, the exchange rate is indeterminate since any value of e from 0 to ∞ is perfectly consistent with portfolio equilibrium.

The case portrayed in Figure 2 is a rather extreme case, however, since it is one of global portfolio perfect substitutability, resulting in

Global Perfect Substitutability

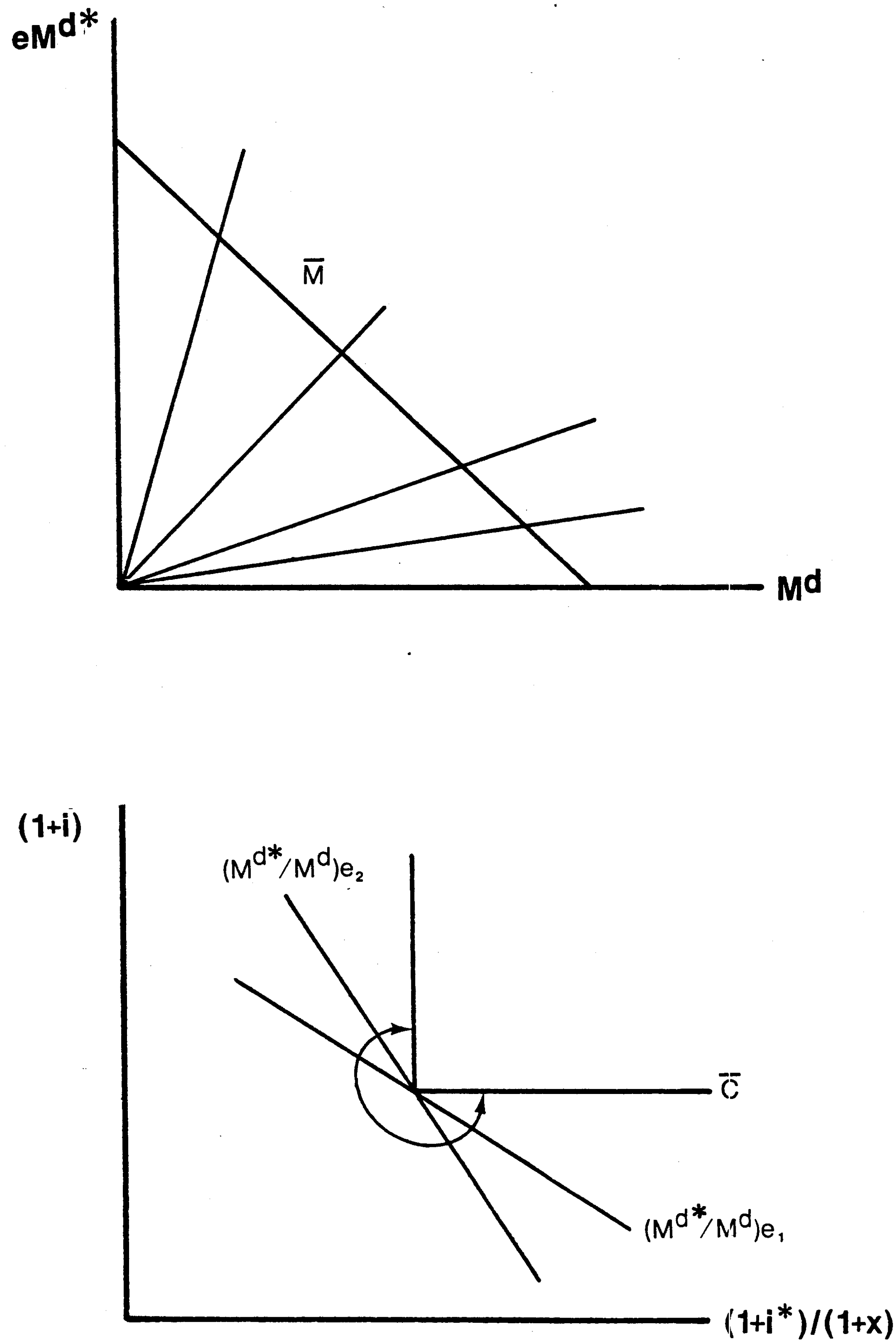


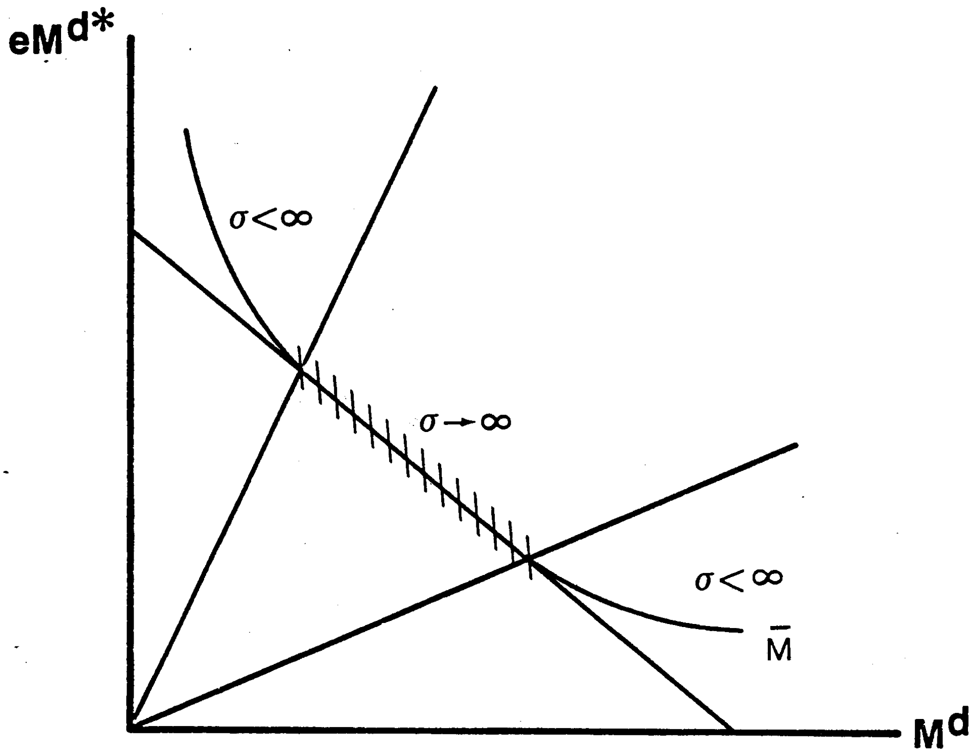
Figure 2

complete indeterminacy of the exchange rate. However, it is possible that perfect asset substitutability might be only a local property--not a global one--of the isoholdings curve. The local perfect substitutability case is portrayed in Figure 3. The existence of a flat zone in the isoholdings curve induces a kink in the isocost curve. At the kink, the exchange rate will also be indeterminate, but now the range of indetermination is bounded away from both zero and infinity. Given that movements in the exchange rate of the most important currencies have been bounded, the notion of local perfect substitutability has some appeal, at least from an empirical standpoint.

How do these duality results relate to the original question of this paper, namely, is there a plausible explanation for the sharp depreciation of the exchange rate in Venezuela during 1983? These duality results suggest that an expected devaluation of the venezuelan bolivar will not by itself generate an increase in foreign currency holdings. It is the combined effect of a high elasticity of substitution between foreign and domestic currency coupled with an expected depreciation of the bolivar that leads to an increase in foreign currency holdings. To see this, suppose that the initial portfolio equilibrium is given by point A in Figure 4. If the domestic currency is expected to depreciate ($x>0$), then the opportunity cost of holding foreign currency decreases and induces an increase in the demand for foreign currency from point A to point B. From the figure we can readily see that the increase in foreign currency holding is greater the larger is the elasticity of substitution.

Although we do not present any formal test to show that $x>0$, the evidence from table 1 suggests that indeed venezuelans expected a devaluation of the bolivar. In particular, table 1 shows that the amount of liabilities of U.S. banks to venezuelan residents were in the order of \$4

Local Perfect Substitutability



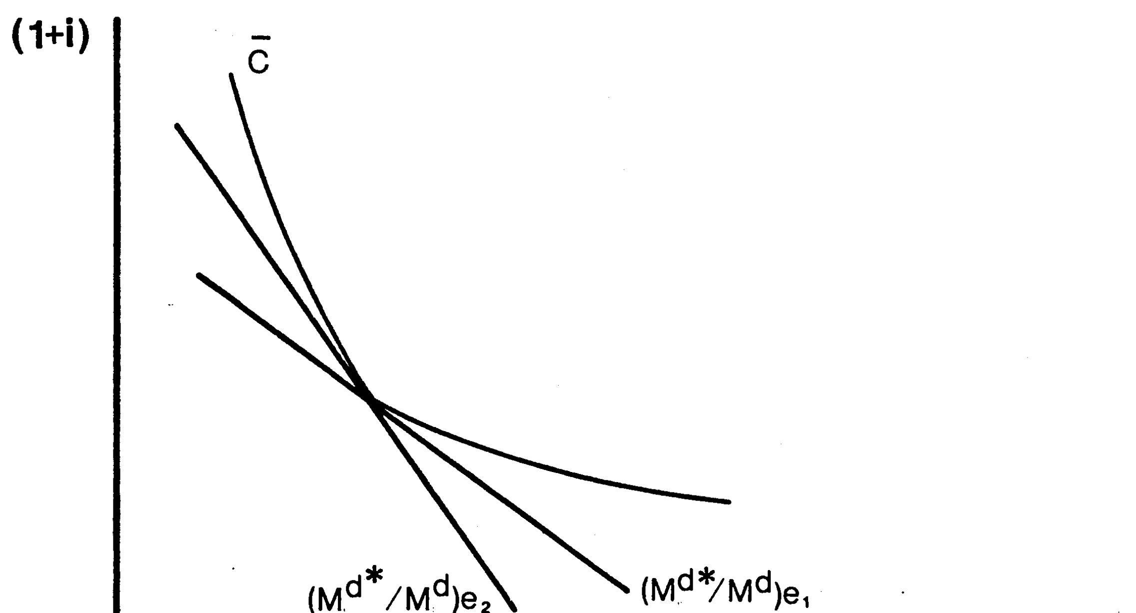


Figure 3

Effect of Expected Devaluation on Currency Composition

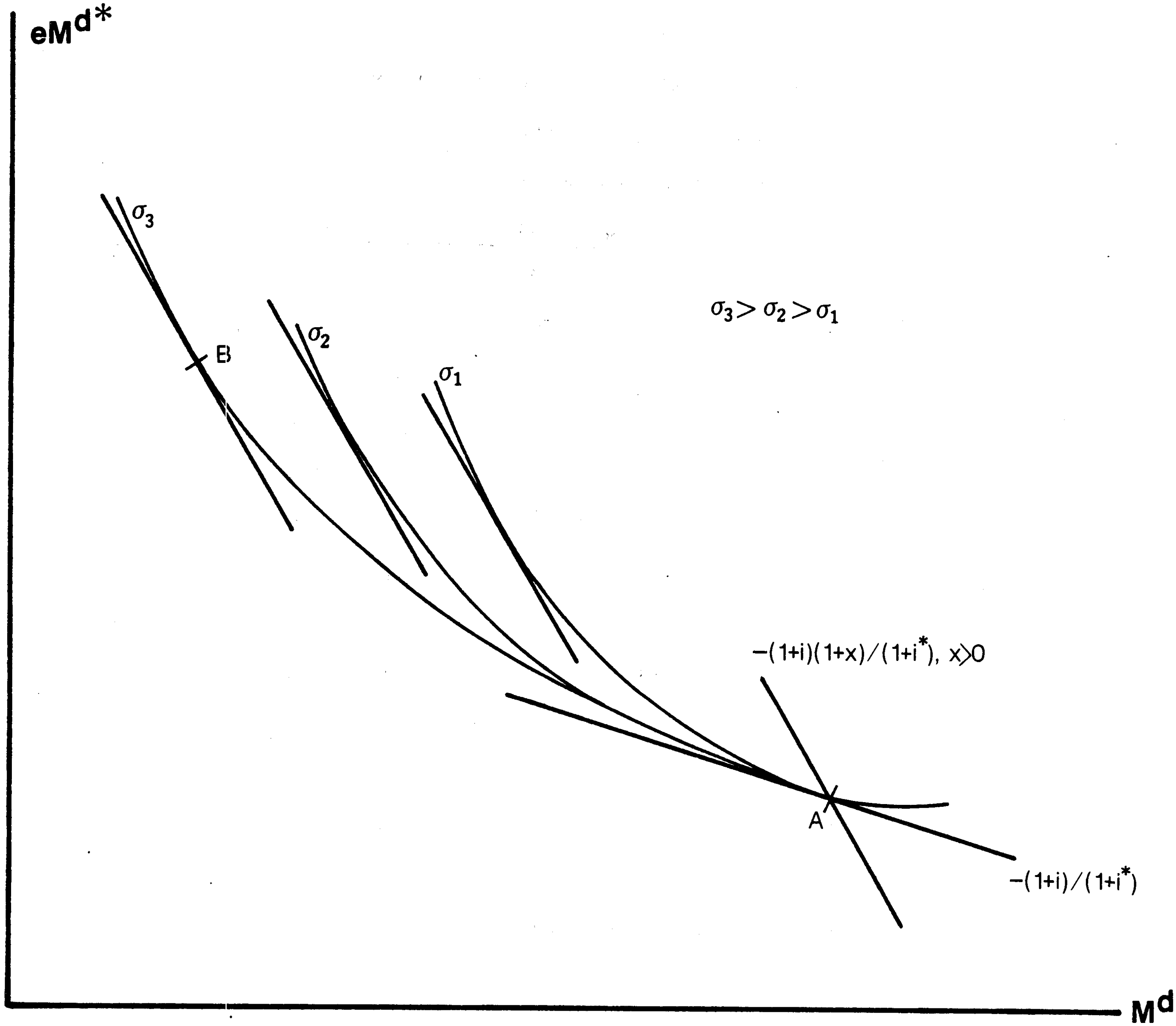


Figure 4

Table 1

Liabilities of U.S. Banks to Venezuelan Residents

Payables in U.S. dollars

(U.S.$ billion, end of period)

	1979	1980	1981	1982	1983	1984
January				4.6	7.7	9.3
February				4.6	7.7	9.4
March				5.1	8.2	
April				8.2	8.5	
May				9.4	8.6	
June				9.3	8.6	
July				9.1	7.7	
August				9.2	8.6	
September				8.6	8.4	
October				8.8	8.2	
November				8.3	8.0	
December	4.2	3.2	4.2	8.4	8.6	

Source: Federal Reserve Bulletin, several issues.

billion between 1979 until 1981. However, these liabilities more than doubled from a level of \$4.6 billion in February of 1982 to a level of \$9.4 billion in May of 1982, and have remained in the \$8 billion range since then.[10]

Thus this evidence is consistent with the hypothesis that venezuelans expected a devaluation as it became apparent that the government, with a level of international reserves of \$12 billion, facing a decline in international oil prices, and not being able to service its short term external obligations, would stop selling foreign exchange at the prevailing exchange rate at some point in the near future.

IV. EMPIRICAL IMPLEMENTATION

Central to our explanation of the large depreciation of the bolivar in the free market is the existence of a very large elasticity of substitution between domestic and foreign currencies. Our purpose in this section is to estimate the value of the elasticity of currency substitution using annual data for Venezuela for alternative monetary aggregates covering the period 1960-1980.

We begin by adding an error term to the equation representing optimal holdings of domestic currency, equation (10):

$$M_t^d = M(w_t, Y_t) + u_t, \tag{14}$$

where $u_t \sim N(0, \sigma_u^2)$, with

$$E(u_{t-k} \cdot u_{t-k-s}) = \begin{cases} \eta \text{ for } s=1, \ k \geqslant 0 \\ 0 \text{ for } s>1, \ k \geqslant 0. \end{cases}$$

In addition, we assume that actual money holdings, m_t^d, adjust to optimal money holdings, M_t^d, following a partial adjustment process:[11]

$$m_t^d = \prod_{j=0}^{\infty} \left(M(\underset{\sim}{w}_{t-j}, Y_{t-j})^{\psi(1-\psi)^j}\right) + u_t, \tag{15}$$

which yields the following expression:

$$m_t^d = M(\underset{\sim}{w}_t, Y_t)^{\psi} (m_{t-1}^d)^{1-\psi} + (u_t - (1-\psi)u_{t-1}), \tag{16}$$

where ψ is the speed of adjustment. Substituting equation (8) into equation (16), we get:[12]

$$m_t^d = \{1+[(1-\delta)/\delta]^{\sigma}[(1+i)(1+x)/(1+i^*)]^{\sigma-1}\}^{\psi\sigma/(1-\sigma)} \delta^{\psi\sigma/(1-\sigma)} Y^{\psi/\mu} \cdot k {m_{t-1}^d}^{1-\psi} + v_t, \tag{17}$$

where $f(y) = \alpha Y^{1/\mu}$,

$k = (\alpha/A)^{\psi}$,

$v_t = u_t - (1-\psi)u_{t-1}$.

The statistical properties of v_t are:

(1) $E(v_t) = 0$,

(2) $E(v_t^2) = \sigma_u^2[1+(1-\psi)^2] - 2(1-\psi)E(u_t u_{t-1})$,

(3) $E(v_t v_{t-1}) = E(u_t u_{t-1}) - (1-\psi)\sigma_u^2 + (1-\psi)^2 E(u_{t-1}u_{t-2}) = \eta(1+(1-\psi)^2) - (1-\psi)\sigma_u^2$.

Therefore, a sufficient condition for serial independence in v_t is: $\eta = [\sigma_u^2(1-\psi)]/[(1+(1-\psi)^2]$.

The parameters of equation (17) are estimated using a Davidon-Fletcher-Powell nonlinear estimation algorithm. We find that the parameter estimates are sensitive to the starting values. One possible reason for this instability is the presence of exponents of the form $\sigma/(1-\sigma)$, which when coupled with the possibility of σ being equal to one during the optimization routine, induce a discontinuity in the sum of squared residuals (at $\sigma=1$). As a result of this parameter sensitivity, we estimate equation (17) using the value of σ that minimizes the sum of squared residuals. The parameter estimates corresponding to equation (17) are shown in table 2 for alternative definitions of the money stock.

The estimate of the long run elasticity of substitution, σ, equals 6.0 for M1, 8.5 for M2, and 7.4 for M3. All of the elasticities are significantly greater than one. Our parameter estimates are robust to the definition of the monetary aggregate and although the estimates of σ are less than infinite (perfect substitutability case), they point to the existence of a significant elasticity of substitution. One implication of our empirical results for σ is that banking regulations preventing the circulation of more than one currency (domestic versus foreign) have not dampened currency substitution, at least in Venezuela.

The parameter μ represents the inverse of the long run income elasticity of money holdings and its estimated value ranges from 0.76 to 0.96, implying an income elasticity ranging from 1.31 to 1.04 (Cardozo 1983 obtains similar results for Brazil). The estimate of the (constant) speed of adjustment, ψ, ranges from 0.28 to 0.45 which implies an estimated mean lag of adjustment ranging from 5 to 10 months.

We have also tested the hypothesis that the error term possesses the statistical properties assumed in classical estimation. In particular, the

Table 2
Parameter Estimates For Conditional Money Demand
Alternative Definitions of Aggregate Money
Venezuela: 1960-1980
(Numbers in parenthese are t-statistics)

	M1	M2	M3
σ	6.038	8.521	7.409
	(2.1)	(3.9)	(7.4)
μ	0.956	0.763	0.871
	(5.4)	(15.4)	(7.5)
k	1.109	1.095	1.132
	(20.1)	(29.5)	(27.)
ψ	0.279	0.446	0.297
	(1.7)	(3.9)	(2.5)
δ	0.900	0.900	0.900
	(n.a.)	(n.a.)	(n.a.)
$\bar{R}^2$	0.99	0.99	0.99
D.W.	1.56	1.83	1.27
h	0.668	0.442	1.926
Jarque-Bera	4.637	2.571	0.892
ARCH	0.019	-0.051	-0.095
	(0.08)	(-0.21)	(-0.39)

h-statistic for serial correlation in the error process is 0.67 for M1, 0.44 for M2, and 1.96 for M3. Of these statistics, only the value for M3 is above the critical value (1.645) for which the hypothesis of positive serial correlation cannot be rejected. Second, we cannot reject the hypothesis that the error term is homoskedastic, as indicated by the ARCH value.[13] Finally, the Jarque-Bera statistic (see Jarque and Bera 1980) indicates that we cannot reject the hypothesis of a normal distribution for the error process for any of the monetary measures considered here. All in all, we cannot reject the assumptions made for the error term in classical regression analysis.

Although our parameter estimates are robust to alternative measures of money, we do not hesitate in pointing out the preliminary nature of our results. We have used rather strong assumptions in our analysis such as purchasing power parity, the aggregation of variables across individuals, and especially the aggregation with respect to expectations. In particular, we have assumed that the distribution of expectations of depreciation across individuals is concentrated at $x = (e_t - e_{t-1})/e_{t-1} \simeq 0$ since $e_t \simeq e_{t-1}$ over the last twenty years.

V. CONCLUSIONS

The main purpose of this paper has been to provide an economic rationale for the 400% depreciation of the bolivar exchange rate that occurred between March and August of 1983. We approach this question using a currency substitution model which, when coupled with duality results from production theory, implied that a necessary condition for the observed exchange rate instability is the existence of a large elasticity of substitution in currency holding.

The empirical results yield a statistically significant elasticity of currency substitution estimate ranging from 6 to 8. This empirical evidence lends support to the hypothesis that the sharp depreciation of the venezuelan bolivar in 1983 was the result of an expected depreciation of the bolivar, probably arising out of declining nominal oil prices and international reserves below Venezuela's short term external obligations, given the significant extent of currency substitution.

DATA APPENDIX

M_t^d = M1, M2, M3 in nominal terms; source: Banco Central de Venezuela

i = interest rate of commercial active banks in Caracas;
source: Banco Central de Venezuela

i^* = U.S. Treasury bill rate; source: IMF

e = exchange rate (bolivars/dollars);
source: Banco Central de Venezuela

Y = nominal GDP; source: Banco Central de Venezuela

ENDNOTES

[*] I have benefited from comments by Eric Bond, Peter B. Clark, Neil Ericsson, Dale Henderson, Dave Howard, Karen Johnson, Karen Lewis, Marc Miles, and Ken Rogoff. Andrew Atkeson provided invaluable research assistance. An earlier version of this paper was presented at the Tenth Annual Meeting of The Eastern Economic Association, March 16, 1984. Any remaining errors are my own. This paper represents the views of the author and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or other members of its staff.

[1] An even greater depreciation (900 percent) took place in Argentina's black market during 1975 (Calvo and Rodriguez 1977).

[2] On the other hand, Cuddington (1983) argues that, for all practical purposes, currency substitution models have nothing new to offer in the way of understanding interest and exchange rate behavior since these models are already embedded into more general portfolio models. Nevertheless, Brillembourg and Schadler (1979) implement empirically a portfolio model to explain exchange rate behavior for the eight most important currencies; they find that currency substitutability is a significant phenomenom that needs to be taken into account in explaining exchange rate behavior. For an earlier introduction of the issue of currency substitutability, see Marwah (1969).

[3] Other empirical analyses focus on the role of currency substitutability on the behavior of the exchange rate for the major currencies. For instance, see Brillembourg and Schadler (1979), Britain (1981), Miles (1981), McKinnon (1982), Goldstein and Haynes (1984). However, these studies analyze exchange rate behavior for countries with a flexible exchange rate system, whereas one of the interesting aspects of the Venezuelan case is the existence of currency substitution in a fixed exchange rate system. In addition to providing a rationale for the depreciation of the Venezuelan bolivar, a currency substitution model for Venezuela might be useful in addressing issues such as the timing of a devaluation and the development of speculative runs on the stock of foreign exchange (Flood and Garber 1981, and Blanco and Garber 1983). Similarly, one of the essential features of the balance-of-payment-crises models developed by Krugman (1979) and Obstfeld (1984) is the specification of the money demand function, which can be derived within the framework of analysis of currency substitution models.

[4] See in particular the analyses developed by Canto and Miles (1983), Girton and Roper (1981), Cuddington (1983), and Calvo and Rodriguez (1977).

[5] The real capital stock should also be considered part of wealth, but we have left it out for simplifying purposes.

[6] There is not a single--and universally accepted-- definition of money (see Osborne 1984 for a survey). Each monetary instrument has a number of attributes that complicates the process of aggregating various instruments into a single monetary aggregate. In aggregating linearly (adding) different monetary instruments, we make the assumption that individuals are

perfectly indifferent with respect to each and every attribute of each monetary instrument. In this paper we assume that there is an aggregate of money holdings depending on the different monetary instruments:

$$M = M(M_1^d, \ldots, M_n^d, M_1^{d*}, \ldots, M_m^{d*}),$$

where M : monetary aggregate,
M_i^d: ith domestic monetary instrument,
M_i^{d*}: ith foreign monetary instrument.

Assuming weak separability between domestic and foreign instruments, we get:

$$M = M(M^d(M_1^d, \ldots, M_n^d), M^{d*}(M_1^{d*}, \ldots, M_m^{d*})).$$

If we now assume (1) perfect substitutability among the arguments of domestic and foreign money aggregates, and (2) strong separability between M^d and M^{d*}, then we get equation (2). Notice that as a result of our aggregational assumptions, the term currency does not refer exclusively to coins, bills and demand deposits, but might encompass other monetary instruments as well, such as saving deposits.

[7] In solving the portfolio allocation problem, Miles (1978) and Ortiz (1983) maximize the production of money services, equation (2), subject to a liquidity constraint. Their solution to this problem seems, however, inconsistent with their assumption that the level of money services is given. In effect, they endogenize the variable that is assumed exogenous. Furthermore, although their first-order conditions are the same for a maximum or a minimum, their empirical implementation is faulty since not all of the constraints have been taken into account.

[8] The main consequence of not using all of the first-order conditions is that the marginal cost of holding money is left unspecified for a given level of money holdings. I am grateful to Eric Bond for bringing this point to my attention.

[9] An exception is Barnett (1980), who examines the issue of constructing monetary aggregates recognizing that different monetary instruments need not be perfect substitutes for each other.

[10] Furthermore, this sizeable capital flight probably underestimates the actual capital flight since foreign currency could be deposited outside the U.S., and even if deposited in the U.S., it need not be registered as a liability to venezuelans if they declare their residence to be outside Venezuela.

[11] One clear limitation of this assumption is that the speed of adjustment is the same for all explanatory variables.

[12] If we were to estimate υ using the demand for money in real terms, we would have to transform nominal income and lagged nominal holdings into real terms. This would entail multiplying the deterministic part of equation (17) by a factor of the form $P(t-1)P^{(\psi/\mu)-1}$, P being the GDP deflator, and the error term by a factor of (1/P). However, notice that the

error term would become heteroskedastic.

[13] To obtain the ARCH value, regress the estimated residuals on the squared estimated residuals lagged one period. If the coefficient for this last variable is not significantly different from zero, then we cannot reject the hypothesis of a homoskedastic error term. The value shown in table 2 is the coefficient of the squared residuals lagged one period, and the number in parentheses is the t-statistic.

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