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Commodity Stabilization Funds

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The optimal rule for deposits in and withdrawals from a commodity stabilization fund: keep the fund small — less than one month's exports. For the windfall gain oil exporters received as a result of the Persian Gulf crisis — about four months of average exports — the optional depletion period is about four years. In the long run, the exporter's fund should be small, significantly less than one month of oil exports.

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This paper — a product of the Debt and International Finance Division, International Economics Department — is part of a larger effort in the Department to contribute to a Bankwide work program on issues related to developing country management of external risk, including currency and exchange rate risk management, currency reserve management, and commodity price risk management. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Sheilah King-Watson, room S8-040, extension 31047 (36 pages). January 1992.

Commodity stabilization funds are hard-currency savings to protect against a fall in income from commodity exports in the presence of borrowing constraints.

Arrau and Claessens develop the optimal rules for deposits in and withdrawals from such a fund by using a benchmark model of precautionary savings with liquidity constraints.

They show that the optimal stabilization fund is small. For the Chilean Copper Stabilization Fund, they show that the actual accumulation of foreign assets has been much larger than the benchmark model requires. Over long periods, the copper fund should contain less than one month's exports.

They also use the model to find the optimal depletion of the windfall gain oil exporters received as a result of the Persian Gulf crisis — amounting to about four months of average exports. They find that such a windfall gain should be depleted in about four years. In the long run, an oil exporter should keep a small fund, significantly less than one month of oil exports. But higher-than-predicted funds can be justified if there are externalities associated with the fund, frictions in the economy, or the borrowing constraint is relaxed.

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1. INTRODUCTION.

Many developing countries have large exposures to commodity price risk because of concentrated export structures. Two methods are available to reduce these large exposures and/or smooth income fluctuations resulting from commodity price movements: 1) self-insure; and 2) transfer risk to international (capital) markets. The first can be achieved in a variety of ways including: (a) diversification of the export structure and, (b) accumulation of foreign assets. The second can be achieved through a combination of borrowing and lending in international capital markets, and through commodity price-linked hedging instruments. In principle, the second method is usually preferred: a developing country does not have a comparative advantage in bearing price risk, while the international (capital) markets at large are better able to do so.

However, developing countries' access to the international capital markets has proven to be far from full. Borrowing from international markets has often proven to be procyclical rather than (the desired) countercyclical. Contingent borrowing facilities (such as the IMF's Compensatory and Contingency Financing Facility (CCFF) and the EC's STABEX) have the disadvantage that they are often only available ex-post. Lack of creditworthiness, in general, tends to restrict the access of developing countries to international capital markets. Access to commodity-linked hedging instruments is, for similar reasons, limited. In addition, for many of the commodities for which developing countries have significant exposure, the markets for long-term hedging instruments are still very limited, e.g., only for metals and energy products is there a fairly complete spectrum of hedging instruments available; long-term markets for tropical commodities are non-existent.[1]

The limited access to international borrowings and the incompleteness of the commodity-linked

[1] In addition, many developing countries hold a large share of world production of some of these commodities and the amounts to be hedged are often very large compared to the size of existing hedging markets (for instance, Mexico's yearly oil exports represent many times the daily turnover on the exchange for oil futures).

hedging markets imply that to some extent developing countries will have to rely on methods of self-insurance. Of these methods, export diversification will often take longer to achieve and may not be the most efficient since it may run counter to the country's comparative advantage. A self-insurance mechanism that may be a relatively efficient alternative is the accumulation of foreign assets by the country to act as a commodity stabilization fund (CSF). A fund like this was established in Chile in 1985. During periods of high commodity prices--and high exports earnings--the country would accumulate foreign assets which it would draw down in periods of low commodity prices. The problem would thus be very similar to that of a liquidity-constrained individual who also has a demand for precautionary savings.

The purpose of this paper is to estimate the processes for income from exports of copper and oil, and to derive the optimal rules for a CSF using as a benchmark Deaton's (1991) precautionary saving model. The problem of designing a CSF is find the optimal rules for deposits and withdrawals given a particular state of nature. The rules will therefore depend on the stochastic characteristics of the income process. Few papers exist on this topic. Hausman and Powell (1991), who assume a random walk process for prices, justify the creation of a fund on adjustment costs in the production process of the commodity. Basch and Engel (1991) combine the predictions of a large-scale copper model with the policy functions derived by Deaton (1991) when income is assumed stationary. Their work differs from ours in that we derive the policy functions in accordance with the income process estimated.

The setup of this paper is as follows. In section two, we determine the stochastic process for income from copper and oil exports. In section three, we present the theoretical model (based on Deaton, 1991) and determine the optimal saving rule given the estimated income process. Our analysis complements Deaton's analysis as we study in-depth a special case--an AR(1) income growth process--which is discussed only briefly by Deaton. In section four, we apply the results to the situation of Chile--and its Copper Stabilization Fund--and derive the optimal drawdown rules for the windfall gain recently received by oil exporters. In section five, we present some possible extensions. The last section contains our conclusions.

2. INCOME FROM EXPORTS OF COPPER AND OIL

2.1 Copper and oil prices

The stochastic process of income from commodity exports depends on the stochastic processes of commodity prices and volumes exported. From the country's point of view, volumes are, however, subject to considerably less uncertainty than commodity prices and, at least in the short run, are more a choice variable. We therefore first model the process of copper and oil prices and then infer the process for income by incorporating the volume component. We then verify that we have appropriately modeled the income process.

We start with stationarity tests on the prices of copper and oil. Table 1 summarizes the result of the tests. Tests are performed on prices in logarithmic-levels and logarithmic first differences, in nominal as well as real terms. To obtain a real price of copper, the monthly dollar copper price (London) for the period 1960-90 is deflated by the US CPI index. For oil prices, we use two nominal prices: the West-Texas Intermediate (WTI) price and the actual price of Mexican oil exports. The former is deflated by the US CPI index and the latter by the price index of imported private consumption goods.[2] Table 1 makes clear that the (log) level of real copper and oil prices are likely better modelled as I(1), i.e., non-stationary processes, and that the logarithmic difference is stationary. Only when 12 lags are introduced in the augmented Dickey-Fuller test is there evidence that the copper price could be stationary and revert to some mean. On the contrary, for the WTI price series, the ADF(12) test even questions stationarity in logarithmic first differences, but the test is probably of too low a power as the series is short (83 observations). From Table 1, and given the time horizon we are interested in and the

[2] We also used the price indexes for total Mexican imports and for imported government consumption goods to deflate the Mexico oil price and found virtually identical results.

difficulties of incorporating autocorrelation of high order in the model, we conclude that the level of prices is best modeled as non-stationary in levels and stationary in first differences.

Next we model the logarithmic first difference of prices. The random walk hypothesis is a logical starting point here. However, Williams and Wright (1991), Deaton and Laroque (1991) and Trivedi (1991) find that typically real commodity price series do not behave like a random walk and that there is more linear and nonlinear dependence in the first difference of prices than is consistent with the random walk hypothesis. Part of this behavior can be explained by the competitive storage model (Williams and Wright, 1991, and Deaton and Laroque, 1991) which indicates that price jumps due to "stock-outs" lead to skewed price distributions and serial dependence. Trivedi (1991) conjectures that more generalized versions of the competitive storage model imply (non-linear) AR processes for commodity prices. Given the application we have in mind, we model the commodity price therefore as an first order autoregressive (AR(1)) process.[3] Consequently, we estimate:

$$(\Delta p_t - \mu_p) = \rho(\Delta p_{t-1} - \mu_p) + \epsilon_t \tag{1}$$

where:

- p_t = the log of the (real or nominal) commodity price,
- ρ = an autoregressive parameter less than 1,
- Δp_t = $p_t - p_{t-1}$,
- μ_p = unconditional mean drift of prices.
- ϵ_t = normal, independent, and identically distributed (i.i.d) error with a zero mean and a variance of σ^2.

Table 2 summarizes the estimation of (1) for the copper and oil price, both in nominal and real terms. The table shows that there is a small (inflationary) drift in the nominal prices and no drift in the real prices. Except for the drift term, deflating has virtually no effect on the other parameter estimates (both the autoregressive term as well as the estimated variance of the error are unaffected). This indicates that

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[3] Using an AR process is consistent with rational expectations (e.g., a no-profits condition in the futures markets) because of the asymmetry introduced by stockouts. Furthermore, using an AR process biases our results towards finding precautionary savings (see footnote 2).

all real price volatility is due to commodity price volatility as the deflators are very smooth.

2.2 Exports Revenues

Although price movements explain most of the unexpected movements of income from exports, a full description of the income process requires us to model the process for the volume exported as well. The volume of exports depend on production as well as on the inventory decisions. In principle, inventories are saving in an asset with return that depends on the price next period (net of any storage cost and depreciation). However, the joint portfolio-saving decision of production, inventories and financial assets is beyond the scope of this paper.[4] We concentrate therefore on the income (foreign exchange) earned from exports and do not make a distinction between production and exports (abstracting thus from domestic consumption).

The simplest way to model the volume of commodity (exported) is to assume a deterministic trend process. Table 3 shows the estimation of such a deterministic trend (using annual data), and Appendix B provides plots of all the series. For Chile, we find that a trend variable can explain 90% of the variance in the volume of copper exports (and 97% of the variance in production) (see also Figure B.2). Only a small part of the variance of volume exported remains unexplained.[5] For Mexico and Venezuela, however, modelling the volume process by a trend only does not seem appropriate. Figures B.4 and B.6 show important structural changes in the volume of oil exported. Large discoveries in Mexico in 1976 led to high volume growth in the following ten years until--in part as a result of fiscal adjustments--exports stagnated in the eighties. For Venezuela, exports in the second half of the seventies declined due to OPEC quota's, but stabilized thereafter at that level.

Since volume variability may influence (offset) price variability, we verified the two-step

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[4] For a model of commodity price determination with storage see Deaton and Laroque (1991) and Williams and Wright (1991). See Choe (1991) for an analysis of the precautionary demand for physical stocks in the presence of consumption or production shocks.

[5] The low Durbin-Watson suggests that the copper exports could be non-stationary.

derivation of the income process by directly estimating an AR(1) process for real (dollar) income using monthly data.[6] The parameter estimates (reported in Table 4) were quite different from those implied by the two-step derivation: the estimate for ρ in case of the real income of copper exports was negative while it was positive for the copper price equation; and Mexico's real income from oil exports resembles a random walk while for the real oil price an AR(1) was appropriate. The reason for these differences is the month-to-month behavior of the volume of exports which exhibits strong negative autocorrelation. We suspect that this is largely the result of seasonality and other (physical) customs related to the shipping of the commodities. We have little reason to believe that next month's volume of exports cannot be predicted accurately by the countries. We consider the volume of exports accordingly not a source of risk and we use the two-step derivation for the income process. Future work should, however, investigate why the month-to-month variability is much higher than that implied by the yearly data.

For Chile, an AR(1) for prices and a trend for volumes provides thus a good explanation for the stochastic process for income from exports. The income process has the same distribution as the price in (1), but with the additional drift term "μ_q" in Table 3 added to the (zero) drift of the real price (μ_p in Table 2). For both oil exporters (where we only have a reasonable process for price fluctuations due to structural breaks in volumes during the sample period) we simply assume a deterministic trend for the future volume of exports.

3. DEATON'S PRECAUTIONARY SAVING MODEL

The benchmark precautionary saving model used here is based on Deaton (1991). He derives the implications for the optimal saving rule under stationary as well as non-stationary income processes. In light of the empirical evidence presented in the previous section, we present an abbreviated version of his model under a non-stationary AR(1) income process (the interested reader is referred to Deaton

[6]Stationarity test were also performed (not reported), which indicated that income is best modelled as I(1).

for a full derivation).

The precautionary savings model is based on the notion that the individual or country faces some constraints on its borrowings which prevent it from smoothing adverse income fluctuations. This is very realistic for many developing countries, including Chile, Mexico and Venezuela. Even though these countries have been receiving some private voluntary capital inflows lately--in particular Mexican private and public companies have gained renewed access to international (bond) markets--most of this renewed access has been project or company specific. There is no indication that the governments of these (and many other) countries are able to use the international capital markets to smooth adverse income shocks.

We assume that the government has an objective function which is a function of a sequence of expenditures--government consumption, provision of public goods, a social program, etc.--to be financed with the income from commodity exports. We assume that all other expenditures, asset accumulation, and policy decisions by the government can be separated from the saving and expenditure decisions related to commodity income.[7] We further assume that the government is risk averse. Because of the volatile income stream from commodity exports and the borrowing constraint, the government has an incentive to set up a fund (CSF) to smooth income fluctuations optimally. Formally, the government maximizes the expected value of a function of the control variable, saving, subject to budget and borrowing constraints.

$$
\begin{aligned}
V_t &= \sum_{i=t}^{\infty} (1+\delta)^{t-i} E[u(G_i)] \\
\text{s.t.} \quad & F_{t+1} = (1+r)(F_t + X_t - G_t) \\
& F_t \geq 0
\end{aligned}
\qquad (2)
$$

where:

[7] Alternatively, we could have assumed that all unexpected deviations of total income can be attri'uted to commodity price (income) fluctuations or that all other expenditures, asset accumulation, and policy decisions of the government can be separated. As a third option, we could have assumed that the government acts benevolently on behalf of the country's risk-adverse citizens who are borrowing constrained themselves.

E = the expectation operator,
u(.) = the objective function, satisfying the usual (concavity) conditions,
G_t = sequence of government expenditures,
X_t = income from exports,
F_t = assets in commodity fund,
δ = rate of time preference,
r = international interest rate.

Because the income process X_t is non-stationary, the model is best normalized by dividing all variables by the income in that period. The lower case letters indicate normalized variables, i.e., $x_{t+1} = X_{t+1}/X_t$; $g_t = G_t/X_t$; and $f_t = F_t/X_t$. By specifying the utility function to display constant relative risk aversion (CRRA) (i.e., $u(g) = g^{1-\alpha}/(1-\alpha)$, where α is the relative risk aversion parameter), the normalized model can be expressed as the solution to the following two equations:

$$g_t^{-\alpha} = \max\left\{ (1+f_t)^{-\alpha}, E_t\left[\frac{(1+r)}{(1+\delta)}\, x_{t+1}^{-\alpha}\, g_{t+1}^{-\alpha}\right]\right\} \tag{3}$$

$$f_{t+1} = \frac{(1+r)(1+f_t-g_t)}{x_{t+1}} \tag{4}$$

Equation 3 is the (modified) Euler equation. Because of the borrowing constraint, the expenditure ratio in the current period has to be less than 1 plus the fund ratio, that is $g_t \leq (1 + f_t)$. If the borrowing constraint is not binding, then g_t is such that the marginal utility today is equal to the expected marginal utility tomorrow appropriately discounted. Because marginal utility is convex, precautionary saving will result and consumption will be less than under perfect certainty. Equation (4) is the law of motion for the fund ratio.

For a given process for x_{t+1}, we can find a policy function p(f, x) which maps the two state variables f_t and x_t into the control variable $g_t = p(f_t, x_t)$. From the previous section, we know that (conditional on information in period t) x_{t+1} is lognormally distributed with conditional distribution $N(\mu(1-\rho)+\rho\log(x_t), \sigma^2)$. Following Deaton (1991), we approximate the normal distribution for $\log(x_{t+1})$

with a ten-value, discrete Markov process.[8] Therefore, we numerically compute ten policy functions, $g = p(f, i)$, $i = 1,\ldots 10$, which map the fund ratio onto the expenditure ratio--given that state "i" was realized. Appendix A describes the steps to obtain the ten policy functions.

Replacing the policy functions in (3) and using (4), the (ten) equilibrium conditions of the model can be written as follows

$$p(f_t, i)^{-\alpha} = \max\left\{(1+f_t)^{-\alpha}, \sum_j \pi_{ij} \frac{(1+r)}{(1+\delta)} x_{t+1}^{-\alpha}\, p\left[\frac{(1+r)(1+f_t-p(f_t,i))}{x_{t+1}}, j\right]^{-\alpha}\right\} \tag{5}$$

where π_{ij} is the probability of state j occurring in the next period given that state i occurred in this period. In this formulation, x_{t+1} takes one of ten discrete values. We checked this approximation to the income process by simulating the discrete process for Chile's copper exports and verified that the simulated series provides estimates for the income process very similar to those of Table 2 and 3 (see further Appendix A).

Figure 1 shows the ten policy functions corresponding to the above income process and parameter values α, δ, and r of 2, 0.08, and 0.04 respectively. We start with $\alpha = 2$ mainly because estimations of the degree of relative risk aversion for the US economy have found the value 2 to be in the lower range. The policy functions are upward sloped, mainly because a higher fund ratio implies higher interest earnings on the foreign assets which allows for a higher expenditure ratio. The policy functions corresponding to good states lie above those corresponding to bad states; because of the positive autocorrelation in the growth of income, a good state indicates a higher likelihood of more good states--and thus a higher (permanent) income--leading to a higher ratio of consumption to assets at hand. A bad

[8] Note that using a (discrete) Markov process allows for easy approximation of other, non-symmetric distributions as long as they are of first autoregressive order.

state, however, results in increased saving in anticipation of likely lower future income growth.[9]

We can see from Figure 1 that this combination of parameters leads to little saving. Savings would only take place if either the worst state or next to worst state is realized and when there is no money in the fund. As soon as the fund reaches 5% of income all policy functions indicate that spending exceeds income (an expenditure ratio greater than 1). In this structure, the fund will be depleted over time.[10] We have also used a very high monthly interest rate and social rate of time preference (4% and 8% respectively) for reasons that will be spelled out below.

It is clear from Figure 1 that higher saving will only result if most of the ten policy functions have an expenditure ratio below one for low fund ratios. We tried several parameter combinations to obtain this. Figure 2 shows the sensitivity of policy functions (for the worst state only) for different values of the CRRA, interest rate and time preference parameters. The figure shows cases of α between 0.5 and 0.8 only, which is very low compared with estimates obtained for the US. For high values of α and reasonable interest rates, we found greater difficulty in obtaining convergence of the numerical algorithm. To understand this, we need to resort to the sufficient condition for the existence of a stationary, stochastic rational expectation equilibrium in this model. As shown by Deaton (1991), this condition for the i.i.d growth case is: $E[(1 + r)/(1 + \delta)\, x^{-\alpha}_{t+1}] < 1$. For simplicity, we will discuss the unconditional version of our AR(1) growth case. Using the approximation $x = \log(1+x)$, taking logs, and using the unconditional lognormal distribution for x_{t+1} (Appendix A), we can express the condition as:

[9] This countercyclical behavior of saving is emphasized by Deaton (1991) who states that this is a counterfactual implication of his model. However, recent (Latin American) experience shows often a consumption boom and a drop in saving in the beginning of recovery (Mexico in 1989 and 1990 is the most recent example).

[10] Strictly speaking we must also consider the difference between the rate of income growth and the rate of interest as we do below. The statement above is still accurate, however.

$$\alpha^{-1}(r-\delta) + \alpha\frac{\sigma^2}{2(1-\rho^2)} < \mu \tag{6}$$

The left hand side of equation (6) is the expected slope of the expenditure function of the unconstrained problem while the right hand side expression is the expected growth in income. If the former is lower than the latter, an unconstrained government would like to obtain debt and the borrowing constraint would be binding. Note that the expenditure slope (left hand side of equation (6)) comprises two terms. The first term is the life cycle component of savings and is the slope of expenditure in the absence of uncertainty. The term is positive for r > δ and vice-versa. The importance of this term depends on the inverse of the CRRA parameter α (the intertemporal elasticity of substitution in this framework). The second component of the expected slope of expenditure is motivated by precautionary motives. The higher the volatility of income, the higher the precautionary motive implied by the convex nature of the marginal utility of consumption, and the higher the expected slope of expenditure on account of this term.

Because the volatility of income is so large for commodity exporters--as shown above, a value of α as high as 2 generates a large desire for precautionary savings and requires a large differential between the interest rate and time preference parameter to satisfy condition (6). But, the required calibration of the model was not always possible. For reasonable interest rate and time preference values, no convergency of the policy functions resulted for $\alpha = 2$. For instance, in the case of (α, δ, r) = (2, 0.12/12, 0.05/12), even the (annualized) time preference rate which was 7 percentage points higher than the interest rate was not enough to compensate for the desire to raise precautionary savings.

To further evaluate the large uncertainty we observe, consider the following comparison. Deaton (1991) presents a simulation for US quarterly data with an (AR(1)) growth process for income and a CRRA parameter equal to 2. For his simulation, income growth fluctuated between a maximum of 2.5% per annum and a minimum of -0.5%. In the case of copper, (monthly) income growth process fluctuates between -12.0% and 12.7%, a much larger range. The difficulties faced in calibrating the model with

CRRA parameters higher than 1 are therefore predominantly due to the high volatility encountered in commodity prices.[11]

Another compelling reason to use a low α is evidence from Euler estimations for these countries which suggests a lower value than the one typically estimated for the US.[12] The available empirical evidence, combined with the fact that lower values of α still imply large precautionary savings, reinforce the notion that a low value of α is appropriate in this context.[13] The net effect of the high volatility for commodity income and a somewhat lower α can still generate a higher demand for precautionary savings than Deaton's simulations with US data imply.

In the next section we apply the model to the Chilean copper stabilization fund and the recent windfall gain for oil exporters.

4. APPLICATIONS

4.1 Chile's copper stabilization fund

Chile's exports are highly concentrated in copper. Even though, as a result of government policies, Chile has reduced its dependence on copper significantly over the past decade, still more than

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[11] Of course, we are limited by the time-separable utility function we use where high RRA parameters imply low intertemporal elasticity. Obviously, there would be great benefit from disentangling the two parameters as in the non-expected utility framework of Epstein and Zin (1989, 1991), Farmer (1991) and Weil (1991).

[12] Although the empirical evidence is limited in this regard, estimations for Chile and Mexico--in the context of a monetary model--suggest a point estimate for α of 0.63 for Chile and 0.35 for Mexico (Arrau, 1990). These estimates are not very precise--for instance, a value of 1 for Chile could not be ruled out.

[13] In fact, because volatility is so much higher in Latin America than in the US, the low estimate for α could very well be the result of a misspecified model that cannot accommodate such a high volatility, and therefore results in biased estimates for α. Applications of the Euler approach to developing countries with annual data (Ostry and Reinhart, 1991) result in values of α of the order of 2. Because annual data is less volatile than quarterly or monthly data, it seems plausible that the estimate of this parameter might be driven by the volatility of the series employed in the estimations. Applications to Mexico of the more flexible framework of the Epstein-Zin model (Arrau and van Wijnbergen, 1991) show that the RRA parameter is around 1, in concordance with estimations for the US (Epstein and Zin, 1991; Giovaninni and Weil, 1990).

50% of exports comes from this source. Furthermore, since most copper is produced by state-owned mines, it is a very important source of revenue for the Treasury. Volatile copper prices can also affect the competiveness of the rest of the Chilean economy through movements in the real exchange rate.

Chilean authorities have long been aware of the importance of managing this risk. In 1981 they established rules governing the treatment of excess copper revenues. In 1985 they established a Copper Stabilization Fund (CSF) as part of a Structural Adjustment Loan agreement with the World Bank. The first deposit into the CSF was subsequently made in 1987. The rules of the CSF stipulate that deposits (or withdrawals) will be proportional to the excess of the copper price over trigger prices which are established as two bands (narrow and wide) around a reference price. The reference price is set in real terms (adjusted for dollar inflation) and cannot exceed a six year moving average of the spot price. Within the narrow band there would be no deposits or withdrawals; outside the wide band all excess copper revenues would be deposited (if price is above) or withdrawn (if price is below); and in between the two bands 50% of the excess should be deposited (if above) or withdrawn (if below). Furthermore, withdrawals were only to be used for "extraordinary amortizations of public debt".[14] Table 6 presents figures corresponding to two different measures for the fund. The first measure considers as withdrawals only current expenditures, i.e., the subsidy to grape exporters in 1988-89 to cover the damages caused by the US ban on grape exports from Chile in the wake of allegations about cyanide poisoning. The second measure also includes as withdrawals capital expenditures, i.e., repurchases of external debt by the Central Bank in the secondary market.

The CSF has clearly provided a mechanism for avoiding unwanted politically generated pressures

[14] The latter qualification has led to some confusion about the exact nature of the fund--a Treasury fund or part of foreign reserves--and several definitions are used to measure deposits and withdrawals in the fund, including some covering the accounting transactions between the Treasury and the Central Bank (e.g., prepayment of debt by the Treasury to the Central Bank), which consequently shows a very low balance for the fund at the end of 1990. It should also be noted that there is some lack of clarity as to the final purpose of the CSF; official documents indicate its purpose to be "stabilization of fiscal income from copper receipts" as well as "stabilization of the real exchange rate".

to spend funds accumulated during periods of unusually high copper prices. From an economic point of view, however, the mechanics appear (in addition to being confusing) to lack a solid foundation. For instance, the reference price is set without taking into account the underlying process generating copper prices formation. Furthermore, the rules for accumulation and withdrawal do not consider the level of the fund as the model above does.[15]

Two different parameterizations of the benchmark model are used to evaluate the performance of the CSF. In order to make the conclusions more robust, we use the two parameterizations most favorable to saving in Figure 2. As mentioned above, this implies a value for $\alpha = 0.5$, and $\alpha = 0.8$ (Cases 1 and 2 respectively). In both cases, the annualized interest rate is 5%. However, in Case 1, the time preference is assumed to be equal to the monthly interest rate minus 0.05%, which leads to a small desire for life cycle saving. In Case 2, the rate of interest and social time preference are assumed to be equal. It is important to emphasize that the borrowing constraint is never binding in Case 2.[16] This implies that this case can only be valid if one believes that a borrowing constraint does not constitute an essential part of a model for Chile, and its results are biased towards higher savings.

We first discuss the results of Case 1. Figure 3 depicts the ten policy functions for this configuration. The very flat policy functions for modestly-high fund ratios indicate little change in the expenditure ratio as income increases. This is mostly due to the low interest rate assumed, which results in little interest income and thus a low expenditure ratio even for a higher fund ratio. Close to a zero fund ratio, however, the slopes of the policy functions increase sharply as a result of the nonlinearities introduced by the borrowing constraint. Moreover, the five worst states of nature generate saving for all fund ratios, while the five best states of nature generate dissaving for almost all fund ratios. Since

[15]Independently, Basch and Engel (1991) make this point too.

[16]All ten policy functions for Case 2 intersect the vertical axis below 1 and therefore the borrowing constraint is not binding for any.

every state of nature has equal probability of occurrence, we can see from Figure 3 that for high fund ratios the unconditional (average) policy function implies dissaving. The fund ratio can therefore not increase forever but will be mean-reverting.

A typical simulation for 200 periods using these policy functions is shown in Figure 4. We plot the growth factor "x" (plus one for clarity of presentation), the expenditure ratio, and the fund ratio. As can be seen, the fund ratio is stationary, as for high values of the fund, dissaving occurs (unconditionally). For this particular simulation, the average fund ratio is about 0.30 (30% of one month's income).

We repeated the simulation like the one underlying Figure 4 1000 times. Table 5 presents some data based on these 1000 replications. The results show that the average fund ratio is higher, 0.66, with a standard deviation of 1.344. The average fund ratio is misleading, because the fund is bounded below by zero. We therefore also present the median fund ratio, 0.383. The important result to note is that both the mean and median fund ratios are very small, implying less than one month of export income held in foreign assets. So even with a parameter combination that leads to a relatively high desire for precautionary savings and little life cycle saving, the optimal fund is relatively very small.

However, a small fund may still result in large smoothing of income. Table 5 shows the mean and standard deviation of the drift of the expenditure ratio, which can be compared to the parameters of the income process (Table 4). Table 5 shows that the standard deviation of expenditures is 40% less than the standard deviation of income, indicating a considerable degree of smoothing for such a small fund. Table 5 also presents statistics on the marginal propensity to spend (consume) (MPC) out of income from exports (excluding thus, interest income), which is obtained from linear regressions in levels as well as in log differences for every Monte Carlo replication. The regression in levels suggests a MPC equal to one, which is not optimal in our framework. One would expect improvement in results by using a linear specification in levels, since the cointegrated nature of the regression would provide more consistent estimates. However, as the low Durbin-Watson statistic suggests, the borrowing constraint introduces an asymmetry in the errors (consumption is not symmetric) that casts doubt that this is a cointegrated equation. The MPC derived from the regression in log differences (with well-behaved errors) provides the correct answer. The correct marginal propensity to spend out of incremental income is thus about 0.56, not one.

Finally, we apply the model to Chile using the actual copper price realized since 1987. We first classify the actual prices between September 1987 and December 1990 to one of the ten states of nature (details in Appendix A). Using the appropriate policy function, we then compute the optimal fund ratio. This is done for both cases described above. For Case 1, Figure 5 shows the evolution of actual income growth x (plus one for clarity of presentation), and the optimal fund and expenditure ratios for every month. Based on this analysis, the fund should optimally have amounted to about 20% of one month's worth of export income at the end of 1990. Case 2 is depicted in Figure 6. As noted above, this parameter combination implies that the borrowing constraint is irrelevant because of the absence of the desire to borrow for life cycle motives and because of the high level of desire to save for precautionary motives. Consequently, in Case 2 the fund is never depleted completely during the period 1987-1990. Even in this high-savings, no-borrowing desire case, the fund should have reached a level equivalent to only 2.2 times monthly exports at the end of 1990.

Table 6 compares the actual deposits, according to the two definitions of the fund spelled out above, and the two simulation cases. As we can see, the stock of the fund was between \$2.4 and \$1.9 billion by 1990, depending on the assumptions made about capitalization of interest (zero and 2% quarterly respectively). These levels correspond to about six to seven times the average monthly income in the last quarter of 1990 (and about 25% of annual total exports). The third and fourth columns are computed by applying the derived optimal monthly saving ratio to the <u>actual</u> monthly exports from October 1987 to December 1990, and then cumulating the monthly saving for each quarter. By using actual monthly exports, we prevent the high month-to-month variability in the volume of exports (which we kept as certain in the theoretical model) from influencing the differences between the optimal fund and the actual fund.

For Case 1, the model suggests that the fund should optimally have been between $60 and $70 million dollars at the end of 1990 (20% to 22% of monthly income). However, the actual fund was six to seven times monthly exports, or more than thirty times as large as predicted by the benchmark model under Case 1.[17] Even in Case 2 (the non-borrowing constrained benchmark), the actual fund was only three times as large as desired (between $580 and $640 million). Clearly, from the point of desired consumption smoothing, there has been a substantial overaccumulation of foreign assets in the CSF through the end of 1990.[18]

The optimal level at the end of 1990 does not necessarily represent the optimal long run fund level. Equation (4) can be rewritten, by substituting the expected growth rate for income $(1+\mu)$ for x_{t+1} and setting f_{t+1} equal to f_t, as one of two conditions that define the stochastic, stationary steady state.

$$g = 1 - \frac{f(\mu - r)}{1+r} \qquad (7)$$

The second condition for the steady state is the (unconditional) policy function, $p(f) = \Sigma_i\, 0.1 * p(f, i)$, the state weighted average of the equation (5) policy functions. Figure 7 plots these two functions for the parameters of Case 1. The intersection of the two functions represents the steady state value of f. In Case 1, the steady state ratio of f is about 0.30--close to the median value in our earlier Monte Carlo

[17]This differs from Basch and Engel (1991) who--assuming stationary prices--find that the fund should have been between $835 and $1649 million at the end of 1990 (in constant 1989 dollars).

[18]There may be one caveat to this observation. Foreign exchange reserves are not held for precautionary reasons only: for example, transaction demand (to cover imports) also gives rise to demand for reserves. If, during the period that the Chilean authorities accumulated a too large CSF, other demand was reduced, then the overaccumulation would have been less. However, then the CSF needs to be defined differently.

simulations (Table 5). Note that the stationary stochastic steady state for f is stable as the slope of p(f) is higher than the slope of (7). Therefore for f values higher than 0.30, the unconditional policy function implies an expenditure ratio higher than the one compatible with a stationary f and the fund would be run down (in an expected value sense). For values of f lower than the equilibrium value, the opposite is true and the fund increases (in an expected value sense).

For Case 2 (not shown), the state steady ratio of the fund is much larger, about 16, confirming the higher desire for savings under this set of parameters.

4.2 The 1990-91 oil windfall gain

The increase in oil prices from August 1990 to January 1991 due to the Gulf Crisis represented a windfall gain for oil exporters. The income gain for a typical oil exporter can be approximated as being equal to four months of normal exports (for example, in the case of Mexico, prices were on average 80% higher than in the previous year during roughly five months). Both Mexico and Venezuela did not spend the windfall, but invested it (Mexico used part of it to retire public debt and Venezuela established an oil stabilization fund (along the lines of the Chilean CSF)). The question arises, how much of the windfall should be invested and how it should be spent over time. As we showed in the previous section, the optimal fund size for copper amounts to only about 0.2 months of imports. The oil windfall is much more than that: four months. This does not mean, however, that it would be optimal to deplete the fund quickly.

Questions regarding the optimal speed at which to deplete a windfall gain of this magnitude can be determined using the benchmark model, given the estimates for the Mexico oil income process. In accordance with the results of section 2, the real price is held constant. Since, as was shown earlier, it is not clear what is the volume drift for Mexico (and Venezuela), we solve the ten policy functions assuming $\mu = 0.003$, or 0.3% export volume increase per month. We use values for other parameters as follows: $\alpha = 0.5$, $\delta = 0.08/12$, $r = 0.05/12$ and the estimates $\rho = 0.48$ and $\sigma^2 = 0.005723$ from

Table 2. Note that because σ^2 and ρ are both larger than those for copper, the unconditional variance of income from oil exports is even larger than from copper exports. To partially offset the resulting higher desire to save for precautionary motives and to obtain convergence of the algorithm, we use an annualized time preference of 8%.

The exercise uses the unconditional average of the ten policy functions--instead of using Monte Carlo simulations, so the results should be interpreted in an expected value sense. Figure 8 shows the optimal, unconditional expenditure ratio, g = p(f), and the relation (7). Starting from a fund ratio of four, the optimal policy is to run the fund down by consuming (in an expected sense) along the function g=p(f), using equation (4), until the fund ratio reaches its long-run level of about 0.10. The exercise leads to the following results. In the first year, the fund ratio is reduced from 4 to 2.13 months of exports. In the next two years the fund ratio is further reduced to about 0.33 at the end of the third year and in year four to about 0.13. Therefore, the optimal policy is to run the windfall gain down slowly: a windfall gain worth four months of exports should be run down over a period of about 48 months.

5. EXTENSIONS

A straightforward extension of the model is to consider the interaction which may exist between commodity price movements and interest rate movements. If interest rates are stochastic, then the optimal saving rule will depend on the variance of interest rate movements and the covariance between interest rates and prices. The effect of a stochastic r is best demonstrated by looking at the sufficient condition for the existence of an equilibrium. Equation (8) shows the condition (which replaces equation (6)) when the growth process for income is independent, identically distributed:

$$\alpha^{-1}\left(r-\delta+\frac{\sigma_r^2}{2}\right)+\alpha\frac{\sigma_x^2}{2}<\mu+\sigma_{r,x} \tag{8}$$

where r stands now for the expected interest rate, σ^2_r for the variance of r, σ^2_x for the variance of log(x), and $\sigma^2_{r,x}$ for the covariance between log(x) and r. The existence condition can, in a heuristic way, show the effect of introducing stochastic interest rates. If $\sigma^2_{r,x}$ is positive, then introducing a stochastic interest rate is similar to increasing the slope of the income path, since an income shock is to some extent exacerbated by an interest earnings shock (and vice-versa for a negative covariance). Interest rate volatility per se (the term σ^2_r on the left hand side) acts as an increase in the interest rate which is likely to generate more saving. However, empirically, this modification of the model is not likely to be significant. For the period 1975-90, for instance, using the US T-bill rate and the logarithmic difference in copper prices, σ^2_r is about 1.08×10^{-5} and $\sigma^2_{r,x}$ is about 1.7×10^{-6}.

We have shown in the previous section that a well designed and well managed commodity stabilization fund will lead to a reasonable amount of smoothing of short-term income fluctuations. How does this smoothing compare to the results of using other risk management measures? Short-term market-based, commodity risk management instruments--futures and options--are one of the possibilities here. Margin requirements assure that credit risk is not an issue, and, in principle, make these instruments available to (entities in) all countries at low costs. Through simulations, Claessens and Varangis (1991) found that oil futures could remove up to 85% of price risk for periods one to two months ahead. For longer periods, these instruments still reduced uncertainty by up to 81%. Similar results were found for coffee (approximately 70% risk reduction) and can be found for hedging many other commodities with market-based instruments. As a short-term hedging tool, market-based instruments could thus perform equally well or better than a CSF in removing short-period volatility at lower costs. Especially in the presence of spikes and fatter tails in the commodity price distribution it may be even more efficient to hedge using market-based instruments (especially designed to remove the effects of spikes, such as options) instead of holding low-yielding assets in reserves. It is surprising that to date so few developing countries have used these instruments.

Because these hedging instruments have short maturities, they will provide--even with rolling over of the hedges--limited hedging value over longer periods.[19] Longer-dated instruments would thus be desirable. The market for longer-term commodity hedging instruments is thin, however, and, so far, less available (or only on unattractive terms) to many developing countries due to institutional, creditworthiness, and other constraints.[20] It would appear, therefore, that the best strategy to follow for a commodity-dependent country would be to remove as much short-period commodity price risk as possible through short-dated instruments as well as--to the extent possible--use longer-term hedging tools. The CSF mechanism can be used for smoothing any remaining longer-period risk.

6. CONCLUSIONS

This paper concludes that given actual commodity price processes observed, and assuming reasonable values for other parameters, a risk-averse, credit-constrained country would only wish to maintain a relatively small CSF, amounting possibly to only a fraction of one month's export income. Using Deaton's (1991) precautionary saving model with liquidity constraints, we found that the Chilean Copper Stabilization Fund should have held only about 20% of monthly income from copper exports at the end of 1990--far less than the actual level of six to seven times monthly income held at that time. Even if Chile is assumed not to be a credit-constrained, the fund should only have been about two times the monthly exports at the end of 1990. The opportunity cost of maintaining such large liquid foreign reserves to smooth adverse income shocks is too high, even granting a high degree of risk aversion.

How can we explain CSFs as large as the Chilean case? One, seemingly rational explanation, could be that the fund provides positive externalities, such as an increase in overall confidence, which justifies keeping a large amount of low-yielding assets even when one is credit-constrained. Part of this

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[19]The problem with rolling-over coverage based on short-term maturing instruments is that this usually implies a large exposure in these instruments. This can imply large margin calls and/or large option premiums, making the instruments less attractive for foreign-exchange constrained countries.

[20]Instruments such as commodity swaps involve credit risks, compete with other credits to the borrower, and may thus not be available to the country on attractive terms.

improved confidence could come from a stabilization of the real exchange rate, which may benefit other sectors of the economy when there are costs of adjustment. Basch and Engel (1991) explore this notion by introducing frictions in adjusting government programs. Other possible benefits of holding a CSF include reduction in (a) the public pressures to quickly spend windfall income gains, (b) spending which either takes on a life of its own and cannot be reversed, and (c) spending which is inefficient. These are, however, more politically-oriented explanations and have little appeal from an economic point of view.

The benchmark model was also used to compute the optimal depletion rule for a typical oil exporter that received a windfall gain of about four times its monthly export revenues during five months of high oil prices as occurred during the Gulf crisis. The paper show that the typical oil exporter should take about four years to deplete this large a windfall gain.

Our paper complements Deaton (1991) by providing an in-depth study of the AR(1) growth process for income. We show that, even for risk aversion parameters less than 1, the much higher volatility encountered in the income processes of developing countries compared to developed countries (because of depending on volatile commodity prices) implies high levels of precautionary savings.

Finally, future work which deals with the use of self-insurance schemes such as commodity stabilization funds should take into account the existence of commodity-linked contingent instruments and present an integrated analysis, given the possible substitutability and complementarity between the two. Especially the benefits of market-based instruments designed to remove the effects of spikes in commodity prices, such as options, needs to be explored. Further analysis of the volume and the price components of income risk is another fruitful research avenue.

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Appendix A: Computation of policy functions

The first step is to compute the 10-point discrete Markov approximation to the continuous, autoregressive process for $\log(x_{t+1})$. If $\log(x_{t+1})$ is distributed conditional on the information in period t as $N(\mu(1 - \rho) + \rho \log(x_t), \sigma^2)$, then $\log(x_{t+1})$ is unconditionally distributed as $N(\mu, \sigma^2/(1 - \rho^2))$.

To approximate the unconditional distribution, we follow Deaton (1991) and Tauchen (1986). First divide the real line **R** in 10 segments of equal area under the unconditional density so that every segment of the distribution has a one tenth probability of occurrence. Let $a_1,\ldots,a_9$ be the nine values that divide the 10 segments (from left to right) and let $a_0 = -\infty$ and $a_{10} = \infty$. Every segment of the distribution of log(x) is now represented by its within-interval mean $z_1,\ldots,z_{10}$. (For the case of copper income distribution $z_1 = -0.120$ and $z_{10} = 0.127$).

Because the process is positively autocorrelated, given a value z_i in the previous period, it will be more likely that this period realization will be close to z_i. This can be represented by the Markov transition matrix with typical element $\pi_{i,j}$, which stands for the probability of state j, given that state i occurred last period. Unlike Deaton (1991), and more along the lines of Tauchen (1986), we approximate this transition matrix by computing

$$\pi_{i,j} = \Pr\left[a_j \geq \log(x_{t+1}) \geq a_{j-1} \mid \log(x_t) = z_i\right]$$

We use thus the <u>conditional</u> distribution of $\log(x_{t+1})$, and the transition probabilities which can easily be computed numerically.

We verify the accuracy of the discrete approximation by simulation. We simulate the income process using the parameterization for Chile: $(\mu, \sigma^2, \rho) = (0.0032, 0.004436, 0.32)$. The drift $\mu = \mu_p + \mu_q$ is obtained from the first regressions in Table 2 and 3 respectively (the estimate of μ_p in Table 2 is taken as zero) and the other two parameters come from the first regression in Table 2. We simulate 1000 replications of 370 observations each and estimate the autoregressive process for income from these 1000 replications. Table A1 compares the values from the actual regressions with the average estimates from the Monte Carlo replications. We can see that our approximation to the true process is very accurate as true and simulated estimates are very close.

Table A1: Simulation of income process:

$$\Delta X_t = \mu(1 - \rho) + \rho \, \Delta X_{t-1} + \epsilon_t,$$

ϵ_t is $N(0, \sigma^2)$

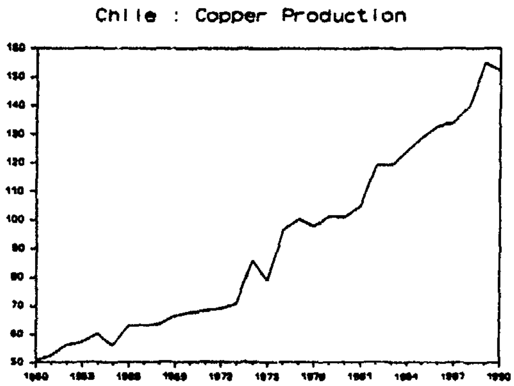
	True Parameters	Mean Simulation	Standard dev. Simulation
$\mu(1-\rho)$	0.00218	0.00214	0.00332
ρ	0.320	0.306	0.0599
σ^2	0.004436	0.004277	0.00027
R^2	-	0.0956	0.0301
D.W.	-	1.99	0.0326

Note: True parameters come from the first equation in Tables 2 and 3 ($\mu = \mu_p + \mu_q$). Columns 2 and 3 come from OLS estimations of 370 Monte Carlo simulations each, replicated 1000 times. For each estimated parameter and statistic we present the mean and the standard deviation of the 1000 replications.

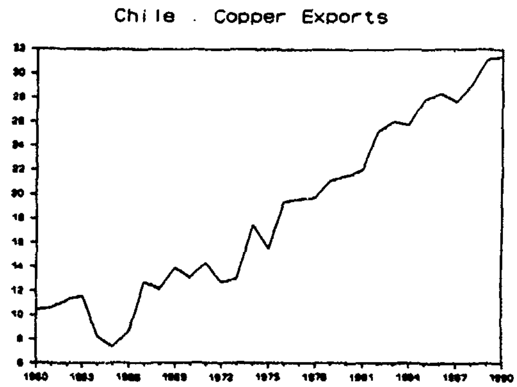
For the simulations underlying Figures 5 and 6 and Table 6, we first classify the actual realization of the logarithmic difference of real copper prices between September 1987 and December 1990 (adding the drift $\mu = 0.0032$) to one of the ten intervals of the unconditional distribution.

The ten policy functions are computed by iterating equation (5) in the text, which as discussed by Deaton (1991), are contraction mappings for some sets of parameters.

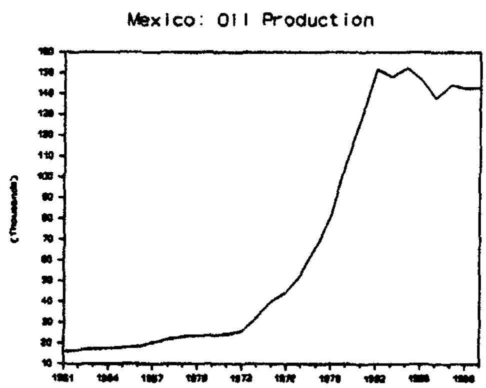
Appendix B: **Commodity Production and Exports for Chile, Mexico and Venezuela (volumes)**



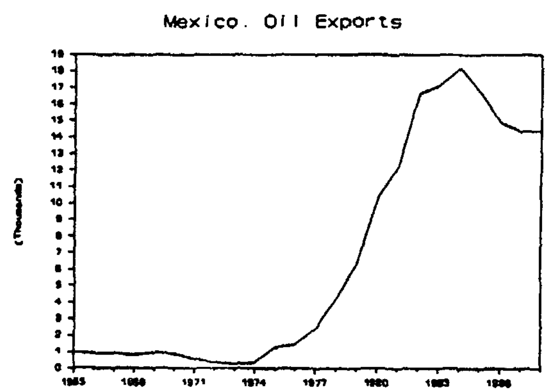
(index, 1977=100)



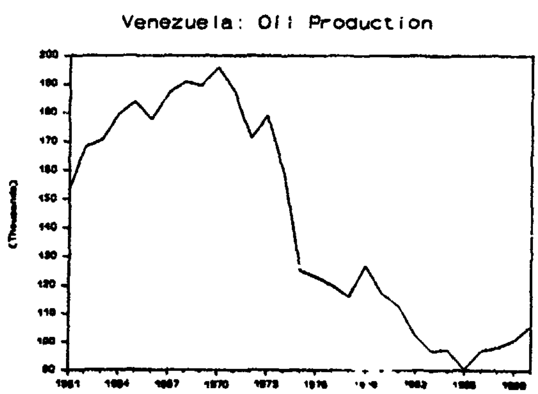
(million pounds)



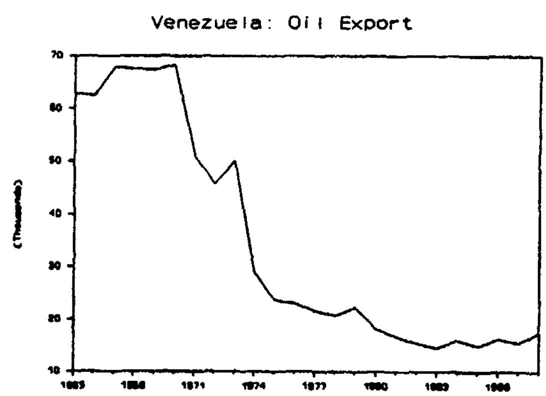
(KL oil equivalent)



(KT oil equivalent)



(KT oil equivalent)



(KT oil equivalent)

Source and Notes: See Table 3.

Table 1: Integration tests for real commodity prices. Are the series stationary?

	DF		ADF(4)		ADF(12)		
	C	CT	C	CT	C	CT	# obs
Real Copper Price							
log level	NO	NO	NO	NO	NO	YES(*)	372
log. diff.	YES	YES	YES	YES	YES	YES	371
Real Oil Price West-Texas Interm.							
log level	NO	NO	NO	NO	NO	NO	83
log. diff.	YES	YES	YES	YES	NO	NO	82
Real Oil Price for Mexico							
log level	NO	NO	NO	NO	NO	NO	132
log. diff.	YES	YES	YES	YES	YES	YES	131

Note: Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests at 5% critical value. Applied to the log of the level of prices and logarithmic difference of prices. The nominal copper (1960.01-1990.12) and the West-Texas intermediate oil price (1984.01-1990.12) are deflated by the US CPI. An index of imported private consumption goods is used to deflate the oil price for Mexico (1980.01-1990.12). 'C' means that only the constant is included in the test; 'CT' means constant as well as trend are included in the test. The critical values for the tests come from Mackinnon (1990). (*) Reject at 10% critical value.
Sources: Banco de Mexico, "Indicadores Economicos"; IMF, International Financial Statistics data base.

Table 2: Estimation of commodity price processes

$$\Delta \log(p_t) = \mu_p(1 - \rho) + \rho \Delta \log(p_{t-1}) + \epsilon_t$$

ϵ_t is $N(0, \sigma^2)$

	$\mu_p (1 - \rho)$	ρ	R^2 (σ^2)	DW
Real copper price	-0.00057	0.320	0.10	1.88
	(-0.17)	(6.47)	(0.004436)	
Nominal copper price	0.00222	0.317	0.10	1.88
	(0.64)	(6.41)	(0.004417)	
Real oil price WTI	-0.00367	0.356	0.12	1.82
	(-0.35)	(3.34)	(0.008841)	
Nominal oil price WTI	-0.00160	0.364	0.13	1.82
	(-0.15)	(3.42)	(0.008980)	
Real oil price Mexico	-0.00323	0.483	0.23	1.78
	(-0.48)	(6.11)	(0.005723)	
Nominal oil price Mexico	-0.00188	0.493	0.23	1.79
	(-0.28)	(6.26)	(0.005727)	

Note: t-statistics in parentheses.
Source: IMF-International Financial Statistics data set; Banco de Mexico, "Indicadores Economicos". WTI stands for the West Texas Intermediate price. Deflator is the US CPI index except for Mexico where the deflator is an index of the unit value of imported private consumption goods.

Table 3: Estimation of deterministic trend for volume of commodity
$Log(Q_t) = \text{intercept} + \mu_q t + \epsilon_t$

Volume Index	Intercept	μ_q	R^2	DW
Chile				
Copper produced	3.844	0.00318	0.97	1.31
1960-90	(191)	(34.9)		
Copper exported	2.111	0.00371	0.91	1.01
1960-90	(43.5)	(16.9)		
Mexico				
Fuel produced	9.268	0.00835	0.93	0.15
1961-89	(99.1)	(18.4)		
Fuel exported	9.196	0.00897	0.91	0.13
1965-88	(86.9)	(14.5)		
Venezuela				
Fuel produced	12.251	-0.00280	0.78	0.33
1961-89	(252)	(-9.9)		
Fuel exported	12.259	-0.00287	0.71	0.31
1965-88	(216)	(-7.3)		

Note: t-statistics in parentheses.
Sources: Mexico and Venezuela: International Economics Department, The World Bank, Energy data set. Production and export index is in terms of kilo tons (KT) oil equivalent. Chile: Banco Central de Chile "Indicadores economicos y sociales 1960-88", and "Monthly Bouletin". Production index for copper is 100 for 1977. Volume of copper exports is derived by dividing the nominal dollar amount of copper exports (in millions) by the London Metal Exchange copper price (cents/pound).

Table 4: Direct Estimation of Income Process

$$\Delta \log(X_t) = \mu_x(1 - \rho) + \rho \, \Delta \log(X_{t-1}) + \epsilon_t$$
$$\epsilon_t \text{ is } N(0, \sigma^2)$$

	$\mu_x (1 - \rho)$	ρ	R^2 (σ^2)	DW
Real copper exports	-0.00016	-0.598	0.36	2.06
	(0.01)	(8.42)	(0.0655)	
Nominal copper exports	0.01043	-0.597	0.36	2.05
	(0.46)	(8.40)	(0.0655)	
Real oil exports Mexico	0.00195	-0.108	0.01	1.98
	(0.12)	(1.23)	(0.0320)	
Nominal oil exports Mexico	0.00509	-0.102	0.01	1.98
	(0.32)	(1.15)	(0.0321)	

Note: t-statistics in parentheses.
Source: Dollar copper exports values come from IMF, International Financial Statistics. Oil exports values come from Banco de Mexico, "Indicadores Economicos". Deflator is the US CPI index for copper and an index of the unit value of imported private consumption goods for Mexico.

Table 5: Simulation of Full Model for Chile, Case 1

	Mean Simulation	Standard dev. Simulation
Fund ratio (f)	0.657 (0.383[a])	1.344
Δ log (G)	0.0015	0.0028
s. d. Δ log (G)	0.0402	0.00173
M.P.C in level	1.000	0.00672
- Durbin-Watson	1.46	0.189
M.P.C in log diff.	0.559	0.0146
- Durbin-Watson	2.01	0.0540

Note: Mean and standard deviation of 1000 replications of the simulated model with 200 observations in each replication. M.P.C. is the marginal propensity to consume (spend) out of income from exports. It is obtained by a linear OLS regression between the simulated expenditure sequence and income sequence. In the first case the regression is in levels and in the second in growth innovations (log differences). In both cases we report below the M.P.C the Durbin-Watson statistic from the OLS regression.
(a) median (midpoint)

Table 6: Comparison of actual and optimum quarterly deposits in Copper Stabilization Fund for Chile (millions of US dollars)

	Deposits Net of Expenditure Withdrawals (grape crisis)[c]	Deposits Net of Expenditure + Capital[d] Withdrawals	Model Case 1	Model Case 2
1987.IV	26.36	26.36	-2.37	21.76
1988.I	125.43	125.34	21.45	51.24
1988.II	146.95	146.95	-1.71	33.34
1988.III	140.77	140.77	2.63	37.01
1988.IV	82.85	-87.15	-28.65	13.90
1989.I	467.51	467.51	18.11	58.24
1989.II	112.17	112.17	34.31	73.06
1989.III	219.93	219.93	-24.91	26.72
1989.IV	40.40	-53.16	33.92	82.41
1990.I	263.34	263.34	-10.46	25.50
1990.II	79.65	79.65	3.32	49.81
1990.III	229.32	229.32	-18.77	27.08
1990.IV	239.76	239.76	36.07	76.56
Fund 1[a]	2174.4	1910.9	62.9	576.60
Fund 2[a]	2419.7	2119.3	69.1	643.40
Fund 1/Exp[b]. (months)	6.7	6.0	0.20	1.8
Fund 2/Exp[b]. (months)	7.6	6.6	0.22	2.0

Notes: a: Fund 1 is the stock of assets at the end of the period without interest capitalizations. Fund 2 uses a quarterly nominal interest of 2%.

b: The average monthly copper exports in the last quarter of 1990 were US$320 million.

c: Funds were used to smooth out the effects of the grape crisis by allowing exporters to purchase debt instruments in the secondary market and then resell them to the Central Bank at a price close to par.

d: The government repurchased external debt of the Central Bank (in the amount of $252.3 million). Other "accounting" transactions between the Treasury and the Central Bank are not considered. Source: Fund figures: Ministry of Finance; Copper exports: Central Bank, "Monthly Bouletin"

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Figure 1: Policy Functions, g = p(f), for a given state

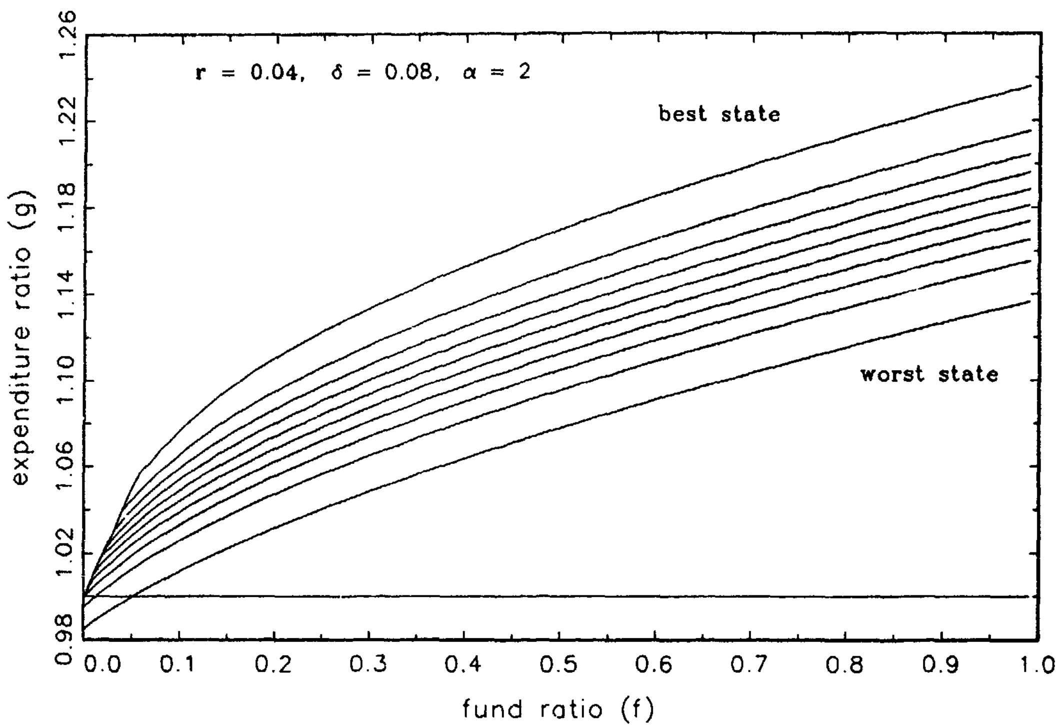

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Figure 2:
Sensitivity of Policy Functions (worst state only)

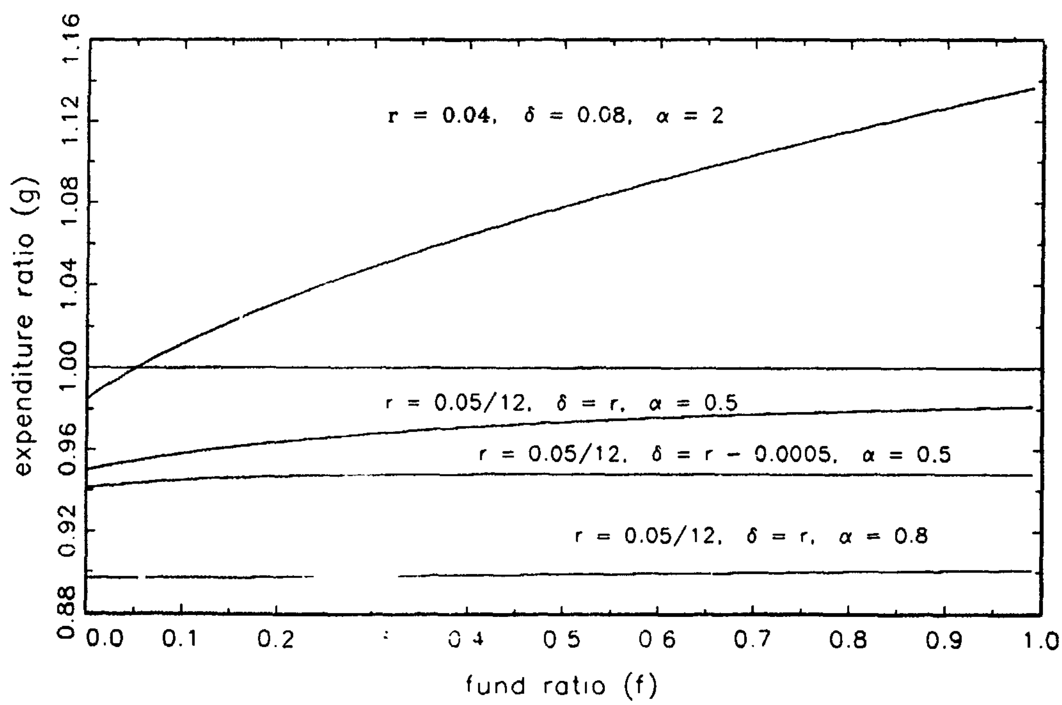

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Figure 3: Policy functions base simuiation case

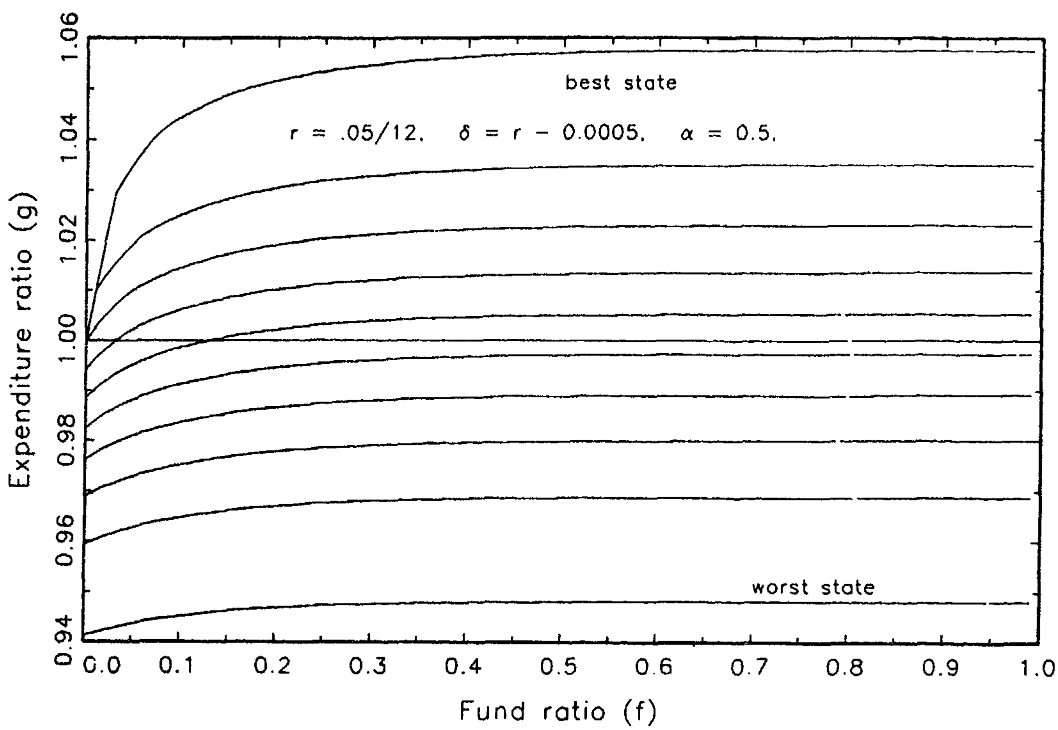

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Figure 4: Typical simulation for Chile

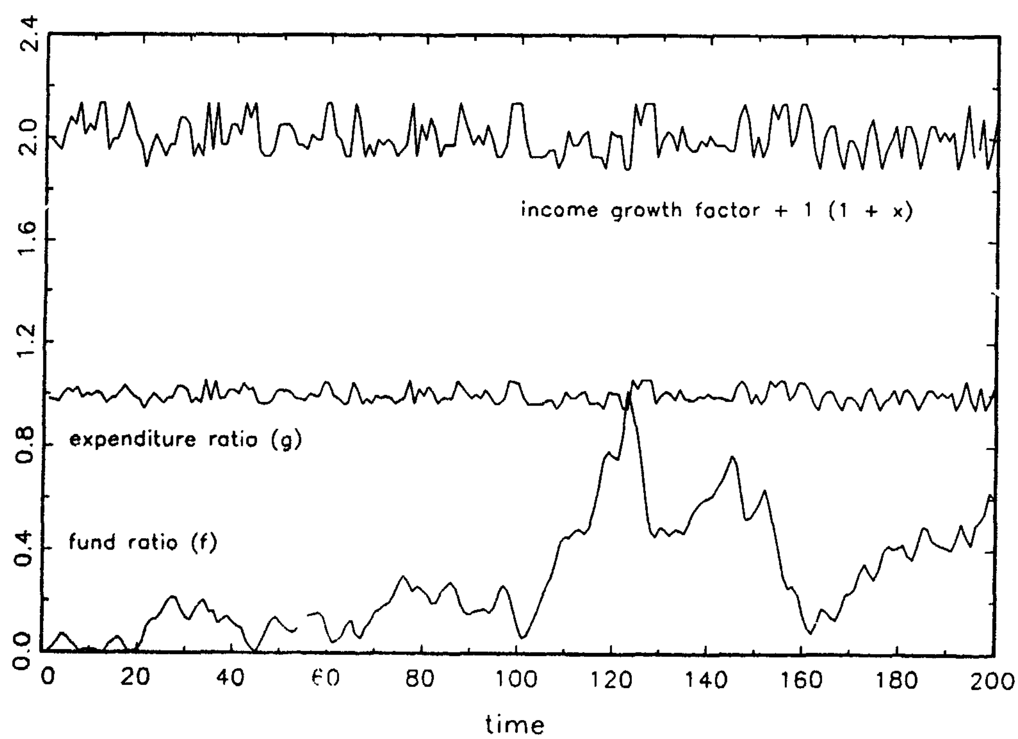

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Figure 5:
Actual Simulation for Chile: 1987–1990, Case 1

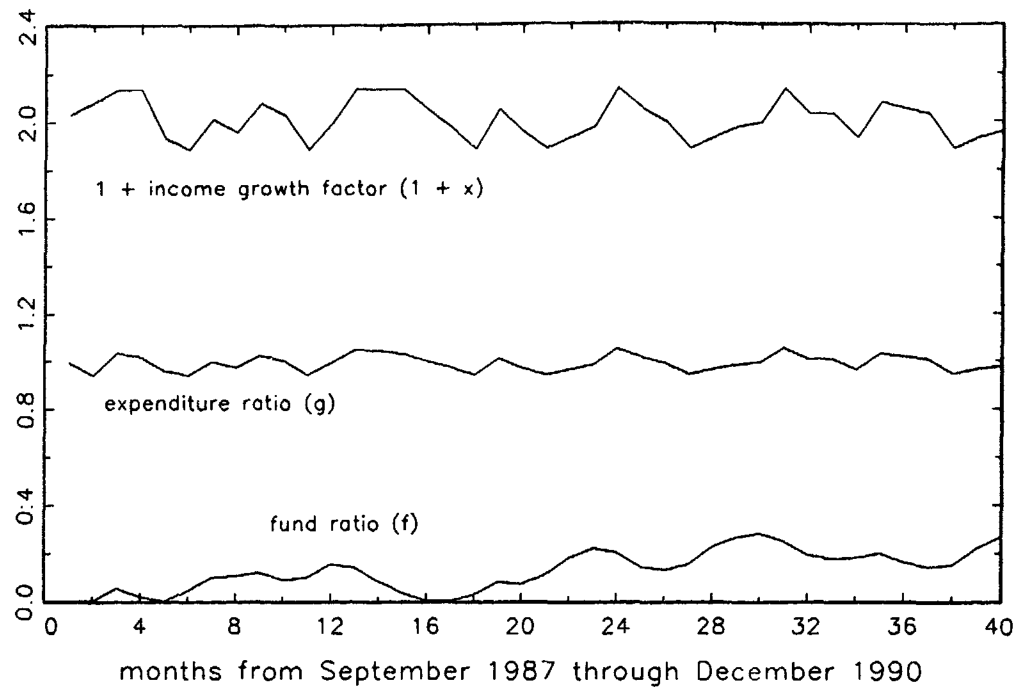

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Figure 6:
Actual Simulation for Chile: 1987–1990, Case 2

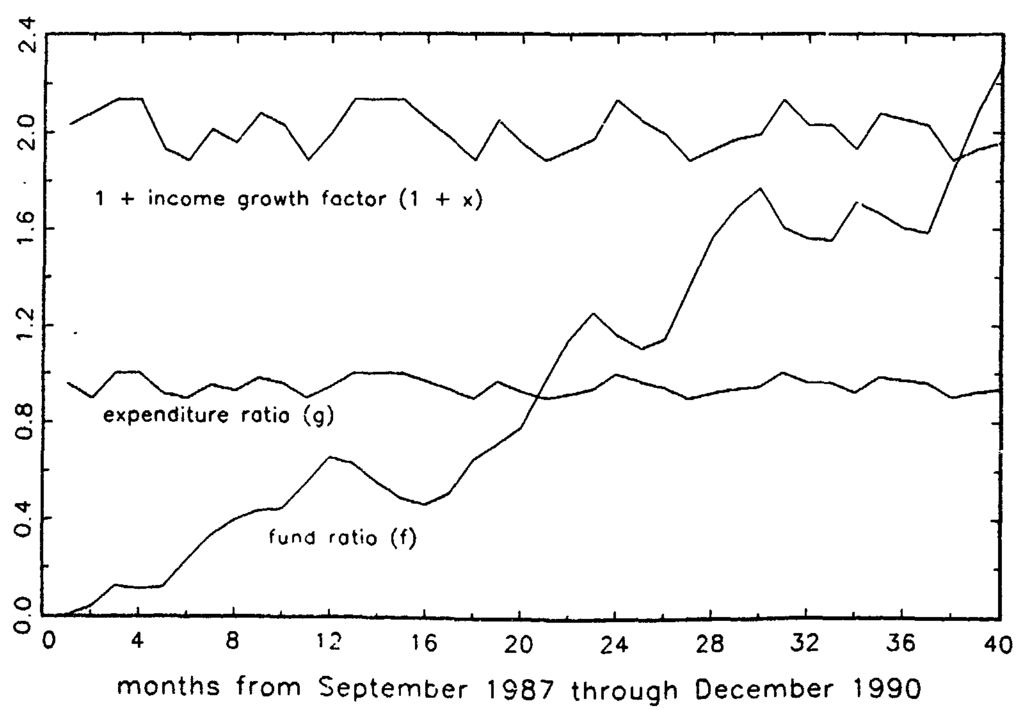

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Figure 7: Long–Run Fund Level for Chile, Case 1

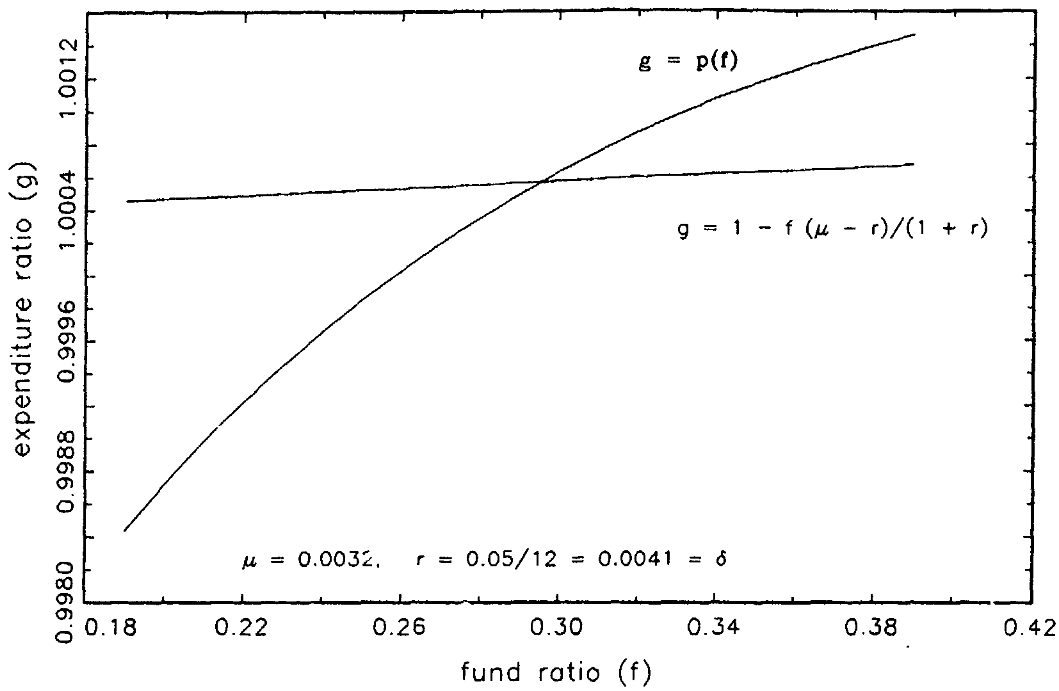

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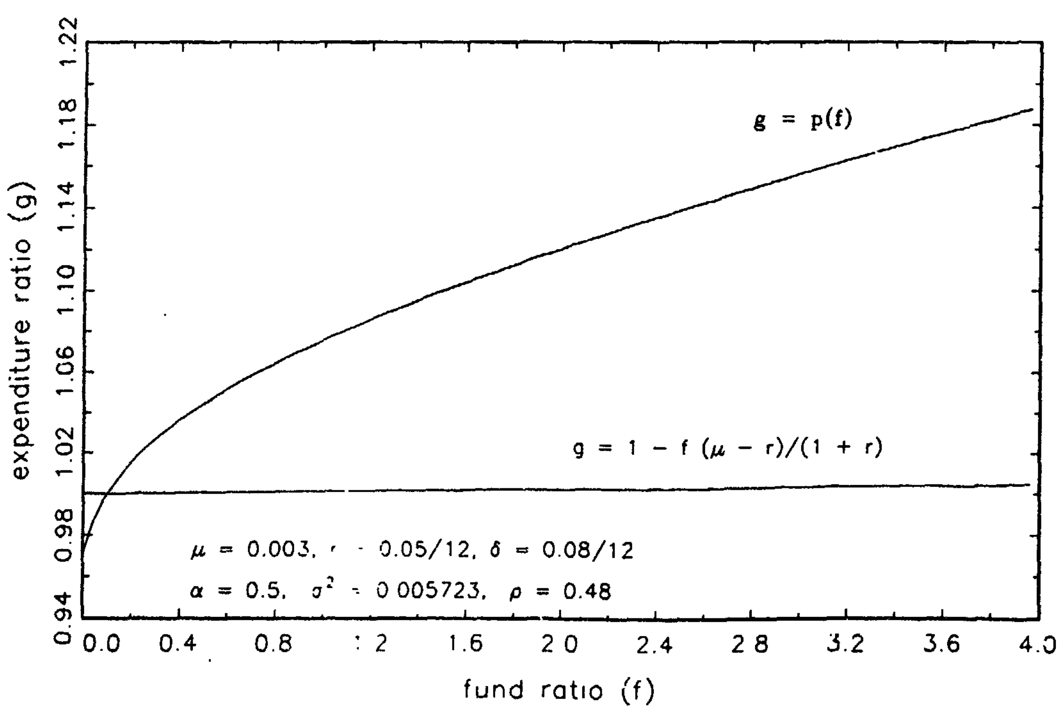
Figure 8:
Depletion Rule of the oil Windfall Gain for Mexico



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