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COMMODITY BONDS FOR SMOOTHING THE CONSUMPTION OF PRIMARY COMMODITY EXPORTERS

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I. Introduction

Loans and other investment contracts are widely perceived as legally enforceable in lender countries but not (or not as easily) in debtor countries. In that context, this paper shows how novel financing arrangements using commodity bonds with put options for the seller can be used for stabilization of risks associated with export prices even assuming the complete absence of attachable collateral.

Given the substantial instability in all primary commodity markets, one would expect countries that depend on a single primary export for most of their foreign earnings (for example, Mexico, Nigeria, Zambia, New Guinea and most OPEC countries) to experience especially sharp fluctuations in export earnings and their underlying wealth. To the extent that these fluctuations affect consumption, they are costly; and we would expect such countries to seek ways of managing these fluctuations and reducing their costs.

In many countries the nature of the resource endowment and its comparative advantage rule out production diversification as a significant near-term strategy, and we assume it away here. In addition, we rule out diversification via exchange of equity investments with foreigners. In this paper we consider the cost of export risk and show the potential contribution of commodity bonds in this context. We show that, in theory, appropriate commodity bonds can achieve optimal smoothing of i.i.d. export price disturbances--if that is what countries really want or need.

Commodity bonds are bonds whose terminal value (and perhaps dividend payments) are denominated in units of physical commodity (or the terminal value of

some appropriate futures contract). Thus, a country might issue a bond paying 10 ounces of gold in 10 years' time with a current face value of $3,000 or a bond paying one lot of 10 tonnes of December maturing U.S. futures in cocoa for 10 years with a terminal payment of 25 contracts for a current face value of $350,000. Typically, the buyer has an option to receive the face value or the commodity bundle. That is, the bond usually comes with a call option for the buyer.

Before the second (1979) oil shock awakened the corporate interest in commodity bonds, governments were already using these instruments for various purposes. In 1863 the Confederate States of America issued bonds payable in bales of cotton (O'Hara). The French government used an electricity-indexed bond to compensate for 1945 nationalization of its utilities; and in 1973 "Le Giscard," a $1.5 billion issue with an untimely gold-guaranteed redemption value, was designed to persuade French gold hoarders to deposit their hidden treasure with the government (*New York Times*). The type of internationally-oriented government financing considered here was initiated later in the decade when a Mexican government agency made several bond issues in local currency backed by barrels of crude oil.

Recently, corporations have issued bonds with returns (principal and/or interest) payable in silver (Sunshine Mining); gold (Peggold); oil (Standard Oil Company); coal (Semirara Coal Corporation of the Philippines); and, for small investors requiring guaranteed liquidity of another sort, wine from the French Dordogne (Henry Ryman of the United Kingdom) or port wine (Dourosa Investments, United Kingdom).[1]

In finance literature, studies of the pricing of commodity bonds (Schwartz; Carr) do not distinguish bonds issued by foreign governments from private corporate bond issues—though the recent literature on foreign borrowing recognizes that the distinction is crucial for ordinary bonds (it is also crucial for commodity bonds).

II. Sovereign Borrowing and Default Prevention

The main distinction between corporate and sovereign borrowing, described in masterly fashion by Keynes and incorporated in the seminal work of Eaton and Gersovitz, is that collateral is generally unavailable to creditors of a sovereign borrower since the assets of the latter are located within its borders. Only in exceptional cases can they be attached by lenders in the event of default.

The absence of a final distribution of assets to creditors as seen in domestic bankruptcy also changes the nature of default. It arises in the context of a sequence of strategic moves by creditors and the sovereign debtor who retains (and, in fact, cannot credibly foreswear) the power to make subsequent decisions that affect the interests of creditors.

Here we focus on income-smoothing financial transactions between investors in developed countries (DCs) and a less-developed country (LDC) heavily dependent on a single commodity subject to substantial revenue fluctuations. The default penalty is enforcement of debt seniority clauses in the courts of all potential borrower-lender nations so that a defaulter's foreign investments or servicing of new debt would be subject to seizure. Default means permanent elimination of foreign borrowing or lending opportunities.

III. The Costs of Income Variability

Consider a country that has economically unresponsive production ("zero supply elasticity") and seeks to maximize the expected utility of its representative consumer

$$V_t = E \sum_{t=0}^{\infty} (1+\delta)^{-t} u(c_t) \tag{1}$$

where E is the expectation operator, c_t is consumption in period t, and u is felicity, $u' > 0$, $u'' < 0$. There is no storage. Output and price are each subject to one discrete i.i.d. random disturbance per period.

To dramatize the issues, assume that exports from a single commodity account for 33% of GNP on average, and suppose that the coefficient of variation (CV) of output and price of the commodity are both 30%, and that the correlation between output and price can be ignored. Suppose also that all other income is nonstochastic and that the country optimally shares risks internally. There is, however, no saving or borrowing or other intertemporal income smoothing. Using the standard formulas[2] for the cost of risk, if the coefficient of relative risk aversion is R (defined for one-period variations in consumption), and if the CV of consumption is s, then the annual cost of risk, ρ, is defined implicitly by $u(\bar{c}-\rho) = Eu(c_t)$, where a bar over a variable indicates its expected value, and the relative cost, $\rho/\bar{c}$, is approximately (exactly if utility is quadratic in income per period) $Rs^2/2$. If consumption must be equal to income each year, then $s = 0.33e$ where e is the CV of export revenue (and 0.33 is the average share of exports to GNP). If output and price are independently normally distributed, then $e^2 = 0.19$ (and this will hold approximately even if output and price are not normal). In this case, if R has the not unreasonable value of 2, the cost of risk is approximately 2% of average income, the amount representative consumers would be willing to forego each year in return for a stabilized consumption stream of c.

IV. Consumption Smoothing by Borrowing and Lending

Can a country optimally smooth consumption by borrowing and lending from overseas sources? If the utility function is quadratic, then δ can be interpreted as the rate at which future consumption is discounted; and if this is equal to the rate of interest abroad, r, then the country would have no motive for saving or borrowing other than to smooth consumption. We make this assumption here to focus on the consumption smoothing aspect of international borrowing. We continue to assume that exports are subject to random i.i.d. price disturbances.

Then the optimally "smoothed" consumption of a borrower committed to borrowing and lending only for smoothing and to meeting his interest payment obligations is (Newbery and Stiglitz, pp. 201 and 202) $c_t = E_t(c_{t+1}) = \bar{y} - rL_t$. Under the scheme accumulated debt, L, follows a discrete random walk with increment equal to the difference between income y_t and its mean, $\bar{y}$. For permanent operation, there must be no limit on L. But in finite time, L will pass the value at which repudiation becomes more attractive than continued interest payments, even if all borrowing and lending opportunities are then cut off.[3] Thus, competitive lenders will not make unlimited loans. Any feasible loans would offer at best only suboptimal and/or impermanent smoothing.

The nature of the evolution of general obligation loan contracts for sovereign borrowers is a currently active research area.[4] At this stage it seems clear that consumption smoothing by sovereign borrowers using conventional borrowing and lending is infeasible if the contract is not renegotiated. If so the quest for a better instrument makes sense. Accordingly we now turn our attention to c-bonds.

V. Commodity Bonds Issued by Sovereign Borrowers

To simplify the discussion, assume that the c-bond under discussion is a zero-coupon bond with payment upon maturity consisting only of a completely specified commodity bundle. We assume the purchaser (lender) is competitive and market risk-neutral with respect to this bond (see O'Hara for analysis of the demand side of the market for c-bonds under other assumptions). As above, assume initially that all contracts are always honored.

Under these assumptions, if the country issues c-bonds (which in this model need only be one-period bonds) and if these can be issued (and indefinitely re-issued) at the present value of the expected price for next period, then their risk-reducing properties in the steady state are exactly the same as those of an optimal forward or futures hedge at the same price. Newbery and Stiglitz (p. 186) show that, in the case of stationary, uncorrelated output and price disturbances, the ratio of income variance with and without optimal forward hedging, is roughly $1/(1 + k^2)$, where k is the ratio of the CVs of price and output. In our numerical example above, k equals 1. If there is no other means of consumption smoothing by lending and borrowing, then c-bonds will halve the steady state costs of the risk—to 1% of GNP in our example. If the CV of income were the same, but only price were stochastic, then c-bonds eliminate risk, worth 2% of GNP.

Assume, henceforth, that no other borrowing is possible and that all income variation is due to price. Then with credible commitment, complete smoothing is achieved by selling c-bonds for the whole (deterministic) output. The country then has constant income and consumption and delivers all output of random value to the lender.

But is the commitment to deliver credible? Is the commodity bond contract subgame perfect? Note first that the lender's obligation within the contract is fulfilled

at the start of the deal, by making the loan. Only the borrower has an unfulfilled obligation after the initial loan. The borrower's motivation to fulfill her part of the contract depends on her expectations of continued lending conditional on her current behavior. If her behavior complies with equilibrium expectations of the lender, then she can expect the competitive lenders to be willing to conform to the equilibrium in the future as they have proved to currently.

So within the contract period, only the sovereign borrower has any obligation, so she alone can default. The incentive for her to default is state-dependent. This case with pure price uncertainty is illustrated in Figure 1, in which the world spot price P_t is on the horizontal axis and the exporter's contract payment per unit committed are shown on the vertical axis. If all sales are spot, then payment per unit and P_t are related by the 45° line OA.

The simple (non-contingent) commodity bond can be considered as a combination of a one-period loan and a forward contract of the same duration. Under a *forward* contract, the borrower's incentive to default is the difference between the spot price at maturity, P_t, and the forward price to be paid on delivery. The latter equals the expected price $\overline{P}$ as of the signing of the contract, under the assumptions of risk neutrality, competitive buyers, and credible seller commitment to deliver. The short-run temptation to default (to be weighed against any effects on future smoothing opportunities) is $P_t - \overline{P}$; the higher the spot price, the greater the temptation. The short-run default incentive of the buyer of the contract (the "long" side) is, symmetrically, $\overline{P} - P_t$.

In a commodity bond contract, the borrower incurs at the outset a repayment obligation of $\overline{P}$ per unit of exports (from a loan of $\overline{P}/(1 + r)$ per unit in the previous period) in addition to the delivery obligation. This adds the amount of the loan repayment under compliance, $\overline{P}$, to the short-run incentive to default. The temptation to default is thus P_t.

This default temptation at time t must be balanced against the opportunity cost of defaulting. The cost is the loss of expected future consumption smoothing given no default at time t. If the price distribution is such that P is always less than this opportunity cost, there is no default problem, and borrower commitment to repay in all states is credible. If not, then potential lenders, foreseeing the possibility of default, realize the above contract will yield an expected loss, and do not buy the bond.

The credibility of a no-default commitment depends upon the parameters of the model. Consider the simple example of pure price uncertainty with $\bar{y}$ and $\bar{P}$ normalized at unit, and $y_t = \bar{y}(1+v_t)$. The probability density for the multiplicative disturbances v is i.i.d. with mean of zero and variance of σ^2, so that the coefficient of variation of price, and of income is σ. The annual current cost of risk in this case is $R\sigma^2/2$ with present value $R\sigma^2/2r$.

Consider the stochastic steady state in which a fraction α of output, $0 < \alpha < 1$, is covered each period by commodity bonds. Each period a fraction α of output is delivered in payment of the previous loan and a new loan of $\alpha/(1 + r)$ is received. Given a price draw of $(1 + v_t)$, consumption is $[(1 - \alpha)(1 + v_t) + \alpha/(1 + r)]$ if the old contract is fulfilled. The contract is rationally honored if the current temptation to default, $\alpha[1 + v - 1/(1 + r)]$, is less than the present value of the extra risk cost incurred, $(1 - (1 - \alpha)^2)R\sigma^2$, that is, if

$$1+v-1/(1+r) < (2-\alpha)R\sigma^2/(2r)$$

VI. Optimal Dynamic Smoothing Strategies

Default Constraint Nonbinding

In section V above, we concentrated on the stochastic steady state. From an initial uncovered situation, the availability of commodity bonds adds to the short-run resources represented by initial income y_0.

Let us now assume that the sovereign starts with no savings, but that she can save overseas in the countries that host the international lenders. We assume that these lender countries collectively enforce financial contracts within their borders. In particular, they cooperatively enforce claims by foreigners on domestic assets, and senior claims of domestic lenders on sovereign borrowers are enforced with respect to all inflows from sovereign borrowers, including savings deposits as well as loan repayments.[5] Then if so, one description of the optimal infinite horizon smoothing plan for implementation in period 0, given current income, y_0 (assumed for this exposition to be entirely from export of one commodity at price p), and the discount rate equal to the interest rate is as follows: Invest βy_0, where $\beta \equiv 1/(1+r)$, overseas for a certain periodic rate of return of r, issue a c-bond to cover all output, with current sale price $\beta\bar{y}$, and consume $r\beta y_0 + \beta\bar{y}$ in each period 0, 1, 2,.... Full consumption smoothing is immediately achieved forever.

The opportunities for legally protected overseas investment at the (certain) market interest rate and for sale of c-bonds at unbiased prices are all the financial facilities needed for this plan. Furthermore, note that, if the initial income, y_0, is invested where it can be collateralized for the c-bond loan (for example in the lending country), the default constraint is relaxed relative to the comparative static analysis above that assumed all income was from sales of c-bonds and none of the current

income in the period in which c-bonds were introduced was saved. So, even if full c-bond coverage seemed infeasible in that analysis, the above strategy may work.

If one ignores transactions costs, as we do here, a number of different combinations of contracts could replicate the above arrangement, given the assumption of a nonbinding default constraint. One example is a short forward contract plus a loan on the anticipated proceeds of the contract. Several commentators have inferred that a combination of a futures contract and a loan would also be equivalent. If one takes seriously the assumption of one discrete decision instant before the later maturity date, then they *are* equivalent if the loan is adjusted to cover initial margins. But in a more general context the futures contract is marked to market as price varies over the time between commitment and maturity, and this leads to additional uncertain increases or decreases in credit requirements on the part of the hedger. In practice this can result in serious complications, especially if trading is obstructed by price move limits for significant periods, and/or interest rates move substantially and are not themselves hedged.

If the default constraint binds on hedging with commodity bonds or forward contracts, the full smoothing described above is infeasible. The alternative of using futures markets is precluded because the variation margin requirements that make default unattractive cannot be met by a liquidity-starved borrower. Nor will the margin calls be loaned by a third party lender because of the induced incentive of the borrower to default on those loans.

Default Constraint Binding

If the default constraint binds, the immediate transition to permanent full consumption smoothing is precluded. What is the optimal consumption smoothing contract is in such cases? Here we follow the analysis of the characteristics of an optimal smoothing arrangement by Worrall (and noting also Kletzer), and then show how it can be

replicated by existing financial instruments. Suppose the export price in any period t can take one of S values corresponding to S states of the world, $p_t(s) = p(s)$, $s = 1, 2, \ldots, S$, $p(1) < p(2) < \ldots p(S)$, and associated with these values, the income of the country, valued at the spot price, is $y(s) = p(s)\,\bar{q}$, where $\bar{q}$ is the fixed output, all exported. The optimal contingent borrowing contract is a level of borrowing, b, and a schedule for repayment in the next period, $M_{t,s} \equiv M(y_t - m_t, p_{t+1}(s))$, contingent on the price realization $p_{t+1}(s)$ which maximizes the borrower's utility subject to his not wishing to default. If the optimal value function is V, then V is the solution to the problem

$$V(y_t - m_t) = \text{Max}\; u(y_t - m_t + b_t) + E\left[V(y(s) - M_{t,s})\right]/(1+r) \tag{2}$$

where y_t and m_t are the levels of income at current price p_t and debt repayment in the current period t, and consumption $c_t = y_t + b_t - m_t$. This is to be maximized by choosing $[b_t, M_{t,s}]$ subject to the constraint that the borrower does not wish to default in any state s, and consequently forego any future lending or borrowing opportunities:

$$V(y_s - M_{t,s}) \geq u(y(s)) + E[u(y)]/r, \quad s = 1, 2, \ldots, S \tag{3}$$

and subject to the zero profit constraint which, for risk-neutral lenders, is

$$-b_t + \beta\; E\,[M_{t,s}] = 0. \tag{4}$$

From the envelope condition, $u'(y_t - m_t + b_t) = V'(y_t - m_t)$, $V(\bullet)$ is strictly concave, implying existence of a unique optimum. The first-order conditions from this constrained maximization problem are

$$u'(c_t) = (1 + \mu_s)\,V'(y(s) - M_{t,s}), \qquad s = 1, 2, \ldots, S \tag{5}$$

where μ_s is proportional to the multiplier on the default constraint in state s, which will be zero if the constraint does not bind.

It is possible to show (Worrall, pp. 5-6, Results 1-3) that, if the default constraint binds when the scheme is implemented in period t, with current repayment obligation m_t, then the optimal loan has a contingent repayment schedule that sets a floor on net income in the next period, $(y(s) - M_{t,s})$, equal to current net income, $(y_t - m_t)$, with repayment at higher income satisfying $V[y(s) - M_{t,s}] = u(y(s)) + E[u(y)]/r$. Consumption $(y(s) + b_{t+1} - M_{t,s})$ is nondecreasing in net income, $y(s)$.

Assuming the default constraint precludes complete smoothing, this optimal scheme could be operated using c-bonds as follows: In period t the lender issues to the borrower a loan b_t with repayment obligation $P_t^* \bar{q}$ and a put option to cover fixed output $\bar{q}$ with strike price P_t^* equal to

$$P_t^* = (y_t - m_t + b_t/\beta + Z_t)/\bar{q} \tag{6}$$

where the option premium, Z_t, is determined by the zero-profit condition for the writer of the put

$$(y_t - m_t + b_t/\beta)/\bar{q} = E\left\{\min\ \left[p_{t+1}, (y_t - m_t + b_t/\beta + Z_t)/\bar{q}\right]\right\}, \tag{7}$$

and b_t is the solution to the borrower's optimization problem given the associated values of P_t^* and Z_t from (6) and (7).

In period $t + 1$, the maximum repayment is $b_t/\beta + Z_t = m^*$, where m^* solves (3) with equality, for s = S. If the realized state s in that period is such that $p_{t+1} \leq P_t^*$ and the option is exercised by delivery of $\bar{q}$ or equivalent trades, the borrower receives the option return less repayments, $P_t^* \bar{q} - b_t/\beta - Z_t = y_t - m_t$. The lender is paid a net sum of $m_{t+1} = M_{t,s} = y(s) - y_t + m_t$, which may be negative. The sovereign borrower's income net of repayments is the same as last year, i.e., $y_{t+1} - m_{t+1} = y_t - m_t$. The smoothing arrangements of period t, $[b_t, P_t^*\ Z_t]$, are then replicated in period $t + 1$.

If, however, $p_{t+1} > P_t^*$, then the borrower repays the lender m^*, sells $\bar{q}$ on the market, and retains net income $\bar{q}\, p_{t+1} - m^* = y_{t+1} - m^* > y_t$. Then the procedure is repeated for period $t + 1$ and the new amount borrowed, b_{t+1}, is, in this case, less than b_t, but the strike price is higher to raise minimum net income to $(y_{t+1} - m^*)$.

An instrument that can achieve this optimal smoothing is a zero-coupon, one-period (c-bond payable in dollars or in a specified commodity bundle, at the sellers option. This instrument can be constructed as a package of a loan of b_t with a repayment obligation of m^* covered by a put written by the buyer (lender) to the seller (borrower) at strike price P_t^*. In the initial period price $P_0 = P_i$, the repayment obligation in period 1 under this arrangement is illustrated in Figure 2. Note that the maximum temptation to default is limited to m^*, the maximum value under which the default constraint (3) holds. Income net of repayments in period 1 is smooth at the period 0 level, for $P_t \leq P_t^*$ is illustrated in Figure 3. For $P_t > P_t^*$ net income is greater, to satisfy the default constraint.

This instrument contrasts with the typical c-bond package which contains a *call* option for the lender, rather than a *put* option for the borrower. Such a package would seem to tempt default at high prices. The default problem also precludes full coverage by forward contracts, which could otherwise be used to achieve full smoothing form the initial period.

In later periods, at higher prices, b may be negative and m may also change sign. When that happens, the "borrower" in effect buys insurance to smooth future income.

If the default constraint is initially binding, the process thus evolves as follows. In the initial period (call it period 0), assuming no prior obligations, $m_0 = 0$, and $y_0 = p_0 \bar{q}$. Consumption is raised by c-bond sales to $y_0 + b_0$. In period 1, if the state is j, $1 \leq j \leq S$, then $y_1 = y(j) = p(j)\bar{q}$, and $m_1 = M(y_0, p(j))$, so that consumption is $c_1 = y_1 + b_1 - m_1 \geq c_0$. Consumption never falls. It remains constant at the initial level until the

first period t' in which $P_t > P_0^*$, at which time it rises to a new level $P_{t'}^* - m^*$. It stays at this level until a price higher than $P_{t'}^*$ is reached, when it rises again, and so on. Assuming the maximum price $p(S)$ has positive probability, in finite time (period w), it occurs, and $c_{w+i} < p(S)\bar{q}$ is constant for $i = 0, 1, 2, 3. \ldots$ (A longer maturity offers no additional advantage in our model). Consumption paths for sequences of price realizations are illustrated in Figure 4. Note that even if the default constraint binds, the initial smoothing transaction may involve a payment by, rather than to, the exporter if the program starts with price around the mean. Credible commitment by the recipients of such payment is crucial in this arrangement.

Before closing this section, we note that the theory used here assumes that sovereign defaults are penalized by withdrawal of all lending and borrowing opportunities. But the historical record (Lindert and Morton; Eichengreen) does not clearly show the expected differentiation, in availability of loans and their terms, between countries that have defaulted several times and those that have never done so. On the other hand, despite the apparently lenient treatment of sovereign defaulters, the overall ex post rate of return has substantially exceeded the return on lending within the creditor countries themselves (Lindert and Morton). Borrowers often appear to make net repayments in circumstances where it is difficult to demonstrate that their efforts are in their own self-interest, even where the latter is recognized as extending well beyond stabilization.[6] Resolution of these puzzles is currently an active area of empirical investigation.

VII. Conclusions

Consumption smoothing could in principle be quite valuable to many countries in the absence of any other risk-reducing strategies. Commodity bonds (c-bonds) can achieve optimal consumption smoothing in the face of random export prices for commodity-dependent countries that cannot offer credible collateral for foreign loans,

dominating other international arrangements such as international buffer funds or attempts to create longer term futures markets.[7]

Depending on initial conditions, the smoothing may be immediately complete, and use a straight c-bond, or it might involve a nondecreasing consumption path, which becomes constant if and when the highest income level is attained. In the latter case the bond could be constructed as a conventional loan with fixed repayment obligation and an attached put for the seller. This type of c-bond contrasts with the observed forms, which generally give the *buyer* a choice of forms of payment received from the seller. The consumption-smoothing achieved reduces downside exposure of the seller, while leaving him a sufficiently large share of high realizations that he is not tempted to default.

Though we have shown this only in the case of pure price uncertainty with i.i.d. disturbances (and, hence, no interperiod storage), availability of a constant risk-free rate of return and market risk neutrality of lenders, our results suggest further investigation of the smoothing possibilities of these instruments in more general circumstances. If prices follow a random walk, it is easy to show that bond-option packages like those discussed here can smooth producers over a one-period production commitment under a default constraint. (Of course, eventual perfect smoothing is not feasible in such circumstances.) In a model with storage, prices tend frequently to be highly correlated over short intervals. Nevertheless, the price process is stationary, though complicated.[8] The optimal smoothing contract in such a model is an interesting topic for further investigation.

Whether the type of smoothing discussed here is what commodity exporters want or need is another question. But continued access to the benefit of income-smoothing is often identified as a major inducement for honoring loan contracts originally motivated by other objectives such as economic development (Eaton, Gersovitz, and Stiglitz), though the observed procyclical nature of much borrowing

raises questions about the smoothing objective (Gersovitz; see also Fishlow). Integration of this analysis with the extensive literature on swaps, renegotiation, and related matters is an obvious extension of this approach.

FOOTNOTES

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[1]See *World Business Weekly* (pp. 50 and 51) for silver and coal, *Wall Street Journal* for Standard Oil's first successful and second unsuccessful offering, Priovolos for gold, and *The Economist* for wine. The port contract is a pure zero coupon commodity bond; other contracts contain options to redeem at monetary face value.

[2]If consumption c is a random variable with coefficient of variation s,

$u(E(c)-\rho)=Eu(c)$. Expand both sides in a Taylor series:

$u(E(c))-\rho u'(E(c))\approx u(E(c))+0.5s^2E(c)u''(E(c))$ or $\rho/E(c)\approx 0.5s^2R$.

[3]If only borrowing opportunities are lost, but the country may invest the payments it saves overseas at the same interest rate, it can actually achieve exactly the same consumption stream for periods beyond $t+k$ as if it did not default (or never borrowed at all); see Bulow and Rogoff (1988). The partial smoothing is like that achieved by commodity storage (Wright and Williams).

[4]See Eaton, Gersovitz, and Stiglitz for a recent survey. See also Kletzer and Bulow and Rogoff (1987). Alternative instruments are reviewed in Lessard.

[5]Both types of enforcement together support the dynamic smoothing contracts that follow. Bulow and Rogoff (1989) show that if the former type alone is effective, the smoothing strategies formulated below do not work.

[6]There is a large literature following the pioneering work of Feder and Just on *estimation* (as distinct from *explanation*) of debt-service behavior.

[7]See Finger and de Rosa for a cautionary analysis of the Compensatory Finance Facility of the International Monetary Fund. They find that, on average, it did not even stabilize the annual export incomes of participants.

[8]See Wright and Williams 1982 for steady-state price distributions in a model of storage with rational expectations, and Williams and Wright (forthcoming) for details of price behavior with storage.

REFERENCES

Bulow, Jeremy, and Kenneth Rogoff. "A Constant Recontracting Model of Sovereign Debt." *Journal of Political Economy*. 97 No. 1 (February 1988): 155-178.

_____. "Sovereign Debt: Is to Forgive to Forget?" *Amer. Econ. Rev.* 79 No. 1 (March 1989):43-50.

Carr, Peter. "A Note on the Pricing of Commodity-Linked Bonds." *J. Finance* 42(1987):1071-76.

Eaton, Jonathan, and Mark Gersovitz. "Debt with Potential Repudiation: Theoretical and Empirical Analysis." *Rev. Econ. Stud.* 48(1981):289-309.

Eaton, Jonathan, Mark Gersovitz, and Joseph E. Stiglitz. "The Pure Theory of Country Risk." *European Econ. Rev.* 30(1986): 481-513.

Eichengreen, Barry. "Til Debt Do Us Part: The U. S. Capital Market and Foreign Lending: 1920-1955." NBER Working Paper No. 2394, Oct. 1987.

Feder, G., and Just, R. "A Study of Debt Servicing Capacity Applying Logit Analysis." *J. Develop. Econ.* 17(1977):25-32.

Finger, J. M., and Dean A. DeRosa. "The Compensatory Finance Facility and Export Instability." *J. World Trade Law* 14(19[illegible]):14-22.

Fishlow, A. "Lessons of the 1880's for the 1980's." University of California, Berkeley, Dep. Econ. Work. Pap. No. 8724, 26 Jan. 1987.

Gersovitz, Mark. "Banks' International Lending Decisions: What We Know and Implications for Future Research." *International Debt and the Developing Countries*, ed. Gordon W. Smith and John T. Cuddington, Washington D. C.: The World Bank, 1985.

Keynes, J. M. "Foreign Investment and National Advantage." *The Nation and the Athenæum*, August 9, 1924.

Kletzer, Kenneth M. "Sovereign Debt Renegotiation Under Asymmetric Information." Yale University Economic Growth Center, Discussion Paper No. 555, June 1988.

Lessard, Donald R. "Recapitalizing Third-World Debt: Toward a New Vision of Commercial Financing for Less-Developed Countries." *Midland Corporate Finance J.* 5(1987):6-21.

Lindert, Peter H., and Peter J. Morton. "How Sovereign Debt Has Worked." Institute of Government Affairs Research Program in Applied Macroeconomics and Macro Policy Work. Pap. Ser. No. 45, University of California, Davis, Aug. 1987.

Newbery, D. M. G., and J. E. Stiglitz. *The Theory of Commodity Price Stabilization.* Oxford, England: Oxford University Press, 1981.

O'Hara, Maureen. "Commodity Bonds and Consumption Risks." *J. Finan.* 39(1984):193-206.

Priovolos, Theophilos. "An Overview of Commodity Bonds: A Balance Sheet Management Instrument." Washington D.C.: World Bank, 1987.

Schwartz, Eduardo S. "The Pricing of Commodity-Linked Bonds." *J. Finan.* 37(1982):525-41.

Williams, Jeffrey C. and Wright, Brian D. "Storage and Commodity Markets." New York, N.Y.: Cambridge University Press, (forthcoming).

Worrall, T. "Debt with Potential Repudiation: Short-Run and Long-Run Contracts." University of Reading Disc. Pap. in Econ., Ser. A, No. 186, 1987.

Wright, Brian D., and Jeffrey C. Williams. "The Economic Role of Commodity Storage." *Econ. J.* 92(September 1982):596-614.

Wright, Brian D., and David M. Newbery. "Financial Instruments for Consumption Smoothing by Commodity-Dependent Exporters" *American Journal of Agricultural Economics* Vol. 71, no. 2, May 1989.

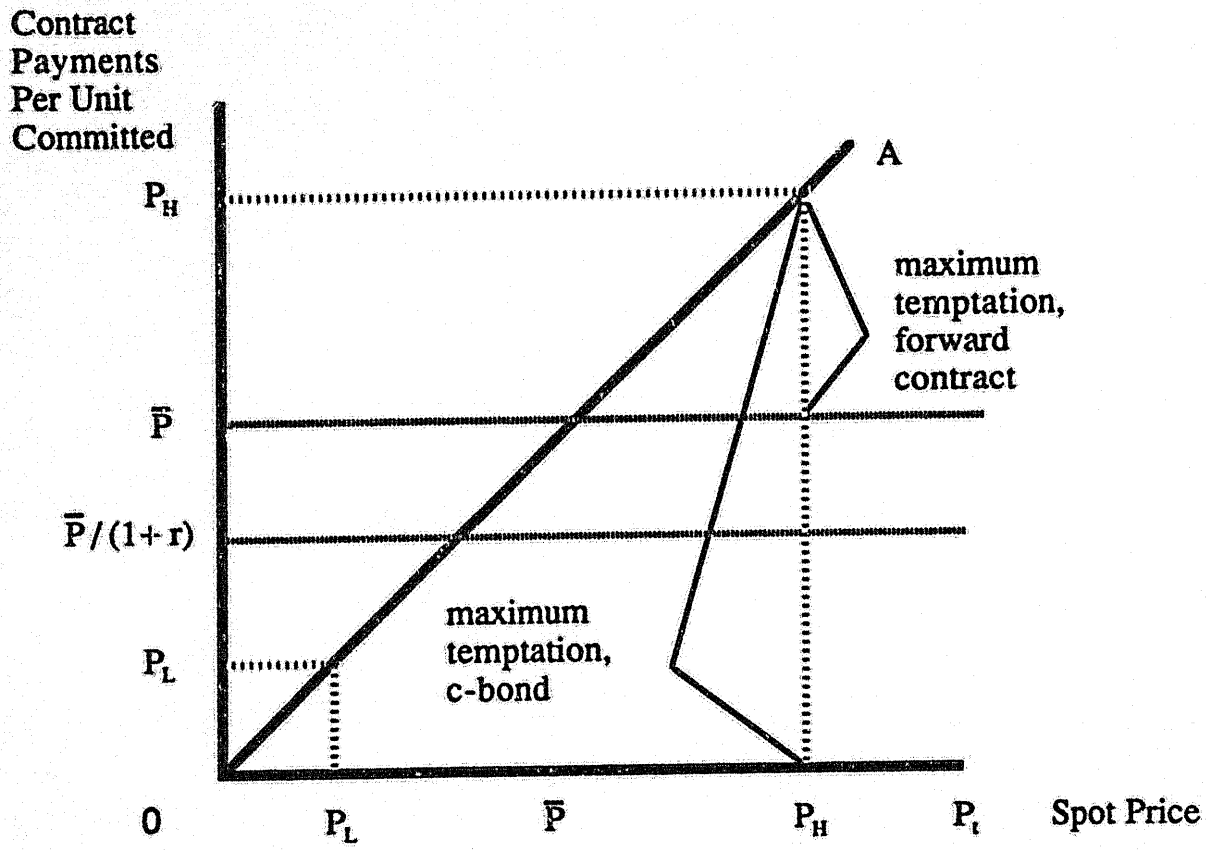


Figure 1

Default Incentives:

Simple Commodity Bond vs. Forward Contract

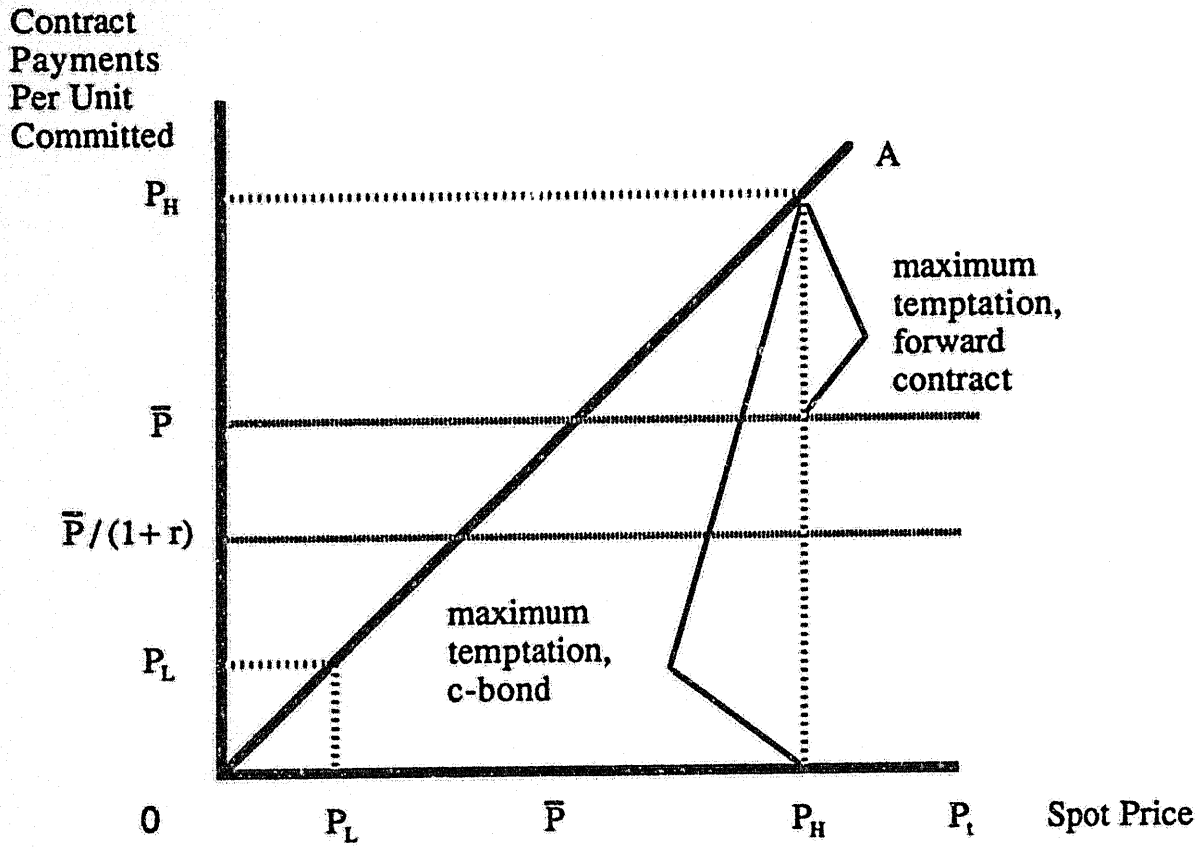


Figure 1

Default Incentives:

Simple Commodity Bond vs. Forward Contract

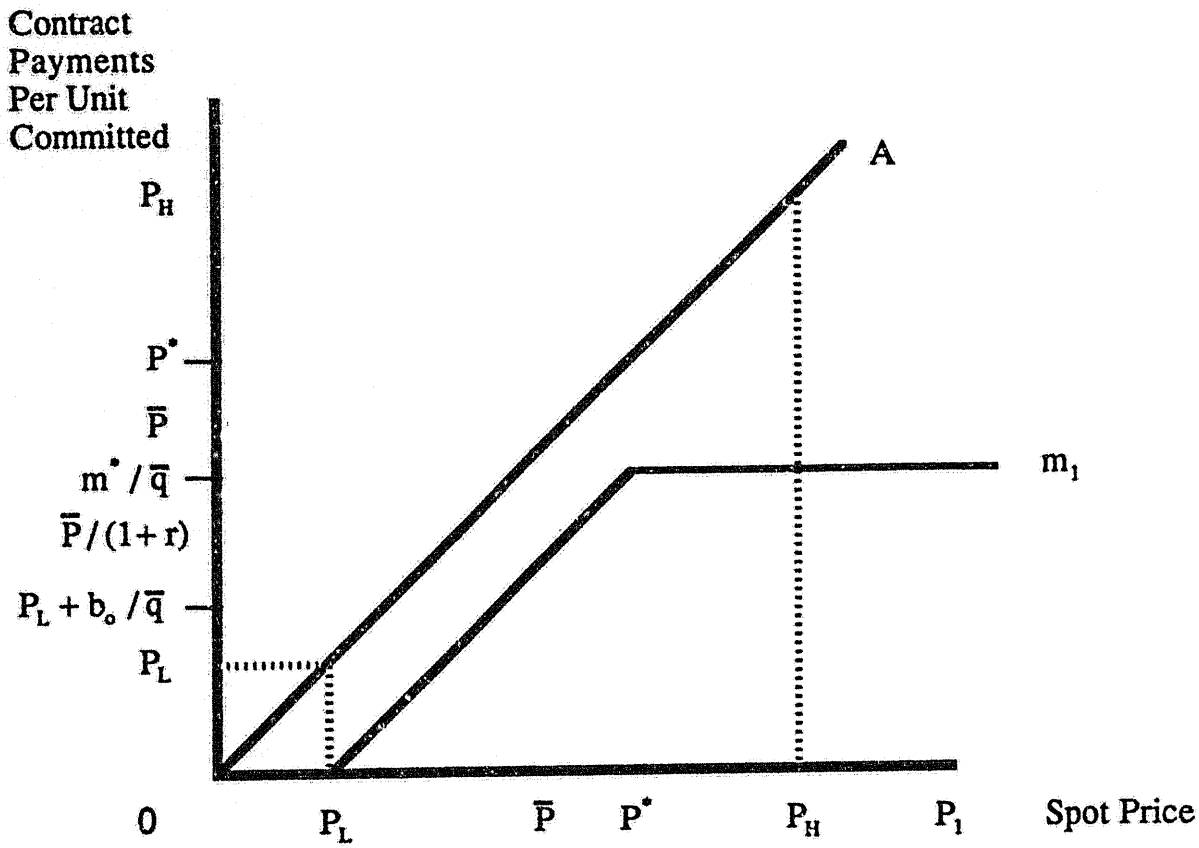


Figure 2

Initial Repayment Schedule for Optimal c-bond

$(P_0 = P_L)$

P^*	Strike price
$m^* / \bar{q}$	Max. repayment per unit
$b_o / \bar{q}$	Bond price per unit of commodity

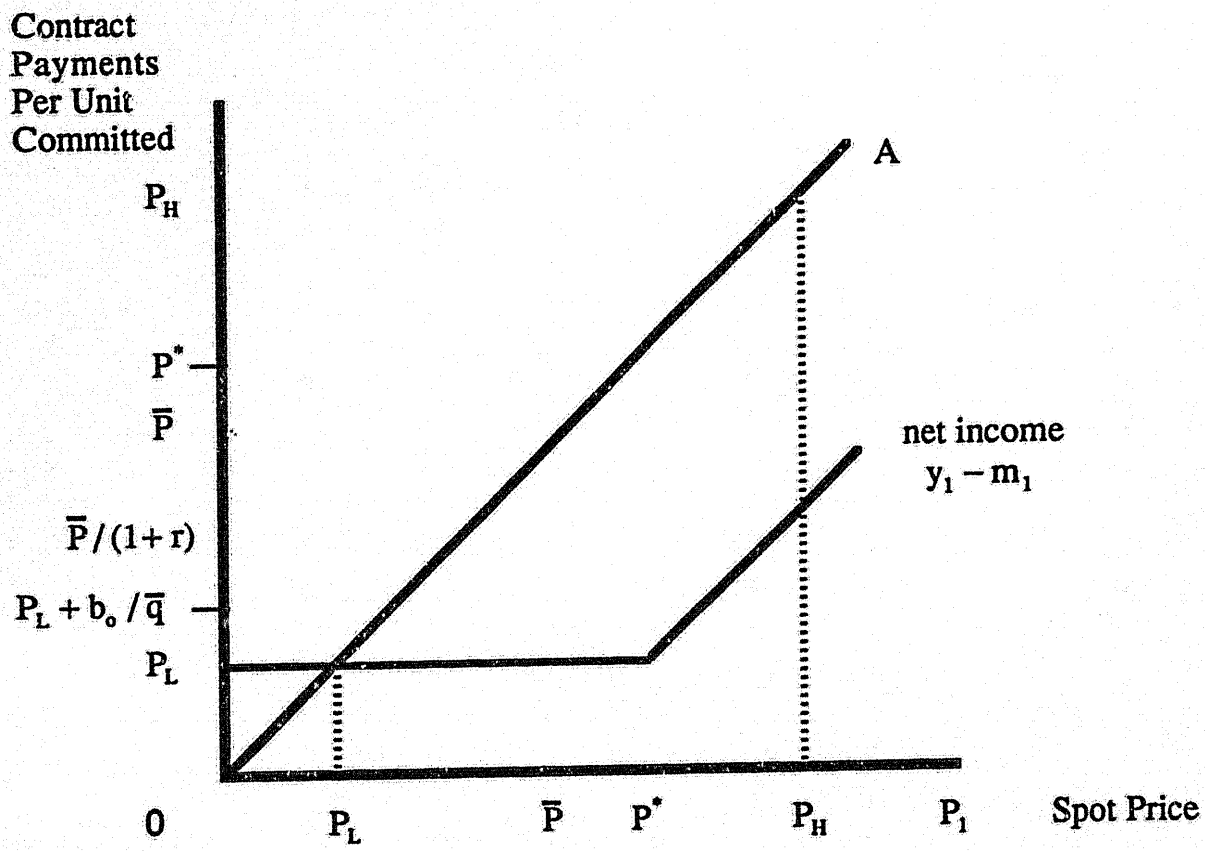


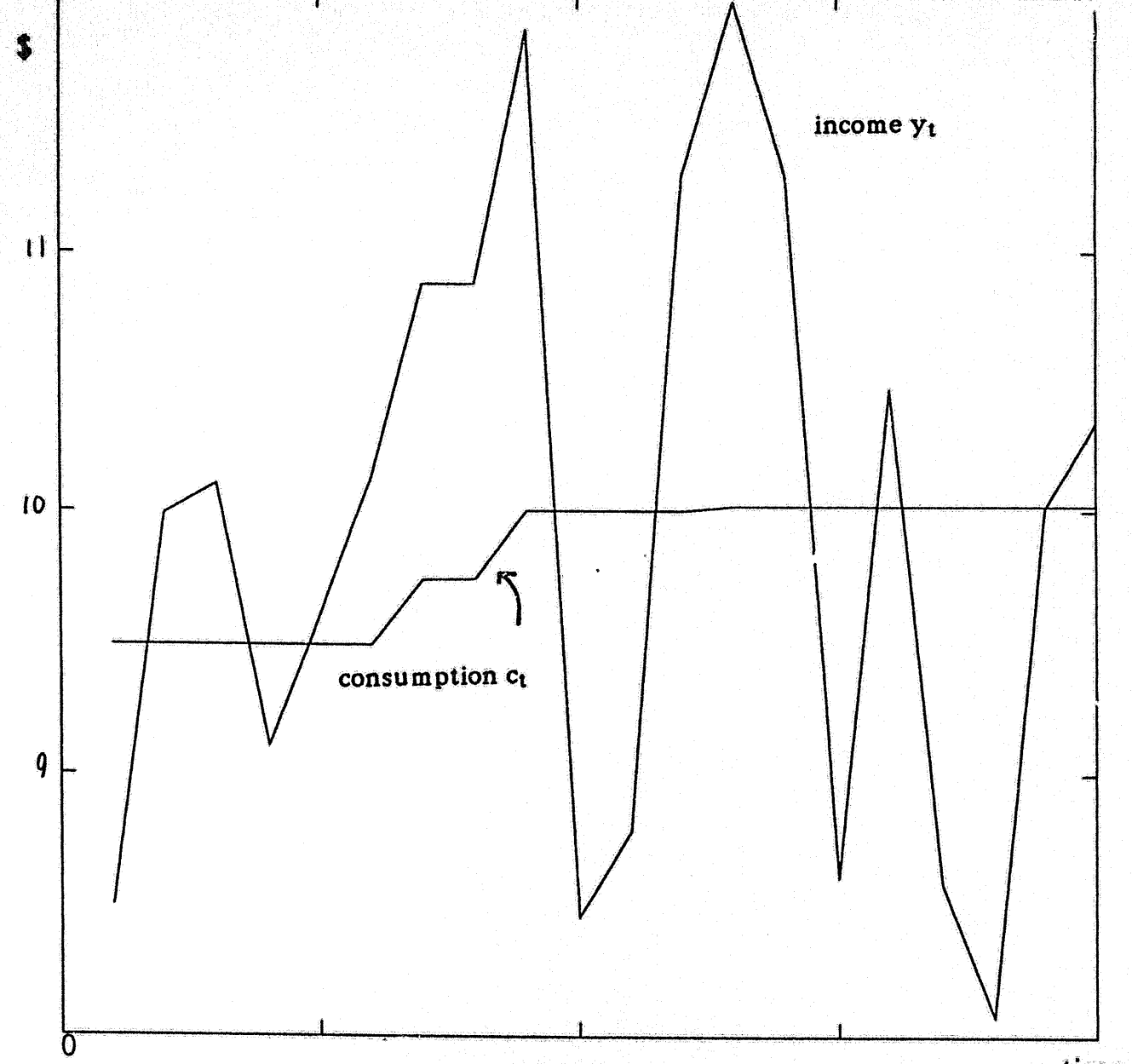
Figure 3

Net Income in Period 1 under Optimal Smoothing Plan

$(P_0 = P_L)$

P^* Strike price

$b_o/\bar{q}$ Bond price per unit of commodity



Uniform Price Distributio
Range 8 to12

Interest Rate r = 0.15

Constant Relative Risk
Aversion R = 0.9

Initial Income y_0 = 8.5

Figure 4