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Managing Financial Risks in Papua New Guinea

An Optimal External Debt Portfolio

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and
Ying Qian

Commodity-linked bonds issued with payments linked to the prices of oil and cocoa could significantly improve Papua New Guinea's risk management.

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This paper -- a product of the International Trade Division, International Economics Department — is part of PRE's research on the use by developing countries of financial instruments linked to commodity prices. Copies are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Julie Carroll, room S7-069, extension 33715 (30 pages, with tables).

Papua New Guinea is vulnerable to instability and uncertainty associated with fluctuating commodity prices. This is because its GDP, export earnings, and government revenues depend largely on sales of a small set of primary commodities whose prices fluctuate substantially on the international market. Papua New Guinea is also exposed to fluctuating exchange rates. The degree of exposure depends heavily on (1) how the currency composition of net export earnings match the currency composition of net liabilities and (2) how changes in commodity prices affect exchange rates.

Based on these criteria, Coleman and Qian show that Papua New Guinea's assets and liabilities may be poorly balanced for debt servicing. Thus, it could benefit substantially from active risk management, especially through better selection of the financial instruments in its debt portfolio.

Coleman and Qian present a model and estimate of an optimal debt portfolio that allows for the use of commodity-linked bonds and conventional debt denominated in different currencies. They judge 'he hedging effectiveness of this portfolio by now much the variance of expected real imports is reduced.

The results indicate that commodity-linked bonds could play an important role in Papua New Guinea's risk management strategy. The proportion of commodity-linked bonds in the optimal debt portfolio ranges from 20 percent to 45 percent for real interest rates of 8 percent to 1 percent. They show that commodity bonds issued with payments linked to the prices of oil and cocoa could substantially lower the variability of expected future imports.

Their results also show that Papua New Guinea's external debt structure is not well balanced to hedge the foreign exchange risk from the existing composition of non-U.S. dollar-denominated liabilities. The debt portfolio contains an excess of Japanese yen- and Deutschemark-denominated liabilities, while liabilities denominated in British pounds are substantially underrepresented.

Managing Financial Risks in Papua New Guinea:
Optimal External Debt Portfolio

by

Jonathan R. Coleman and Ying Qian

Table of Contents

1. Introduction 1

2. Commodity Price Risks 2

3. Foreign Rate Risks 5

4. Theory 7

5. Estimation 13

6. Results 18

7. Conclusions 23

Appendix I 25

Appendix II 27

References 30

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1. Introduction

Throughout the 1980s, Papua New Guinea (PNG) increasingly turned to external borrowing to finance its current account deficits. As shown in Table 1, PNG indebtedness increased more than four-fold between 1980 and 1989. In contrast, the increase in debt has not been matched by increases in GDP and export earnings, which depend, to a large extent, on sales of a small set of agricultural and mineral commodities. Moreover, given the large fluctuations in primary commodity prices on the international market during the 1980s, the foreign exchange earnings of PNG from exports have tended to be unstable (Table 1).

Table 1. Measures of Indebtedness of Papua New Guinea, 1980-89 (Million US Dollars)

	1980	1983	1986	1987	1988	1989
Total Debt Stock (TDS)	720	1,860	2,420	2,700	2,270	2,450
Total Debt Service	150	290	495	510	540	530
Gross National Product (GDP)	2,460	2,220	2,450	2,940	3,320	3,650
Export Earnings (EE)	1,090	950	1,190	1,400	1,720	1,670
Current Account Balance	-310	-380	-100	-370	-160	-200
TDS/GDP (%)	29	84	99	81	68	67
TDS/EE (%)	66	196	203	192	132	147

Source: World Debt Tables 1989-90, The World Bank.

In addition to the instability associated with fluctuating commodity prices, PNG faces additional financial risks associated with sharp movements of exchange rates. This is because a large proportion of its external debt is denominated in non-US dollar currencies and because significant movements of the US dollar vis-a-vis other major currencies in excess of interest differentials have taken place in recent years. Thus the currency valuation effect (i.e., unanticipated deviations from interest rate parity - see section III) on PNG's external debt is considerable. The fluctuations in the level of US dollar measured debt stock are likely to continue, given that the volatility of cross-currency exchange rates is not expected to decline and that the level of new borrowing by PNG in non-US dollar currencies will remain high, given the current pattern of international capital availability.

This paper has three major objectives. The first is to analyze the two financial risks faced by PNG--exchange rate and commodity price risks--and to assess to what extent these risks create serious problems in terms of external debt management. Given that there may be scope to manage these risks better by re-shaping the debt portfolio to include commodity-linked bonds and by altering the currency composition of conventional debt, the second objective of this paper is to present a rational expectations model--extending Myers and Thompson (1989)--which solves for the optimal debt portfolio (including conventional debt denominated in different currencies and commodity-linked bonds). The third objective of the paper is to compare the optimal debt portfolio (derived from the model) with the actual debt portfolio of PNG, and, on the basis of this comparison, to make some broad suggestions as to how the current debt structure might be altered in order to manage commodity price and exchange rate risks more effectively.

The paper is organized into the following sections. The risk exposure to commodity price fluctuations and to exchange rate movements is discussed in sections 2 and 3, respectively. In section 4, a rational expectations model is presented which can be used to solve for the optimal portfolio of external debt; and in section 5, the estimation procedure is discussed, and in section 6 the results from estimating the model are reported and discussed. Finally, in section 7, some conclusions are drawn.

2. Commodity Price Risks

In recent years copper, gold, coffee, logs and palm oil have accounted for over 80% of total export revenues in PNG. Furthermore, the contribution of these five major export commodities to total export earnings has been increasing over time (see Table 2). This dependence on the price and volume performance of a small set of commodities is likely to continue into the 1990s. For instance, the current mineral and petroleum expansion and exploration programs will further increase the dependence of PNG on copper, gold, and crude oil exports[1].

Table 2. Contribution of Major Primary Commodity Exports to Total Export Earnings, PNG, 1985-1992.

Commodity	1985	1986	1987	1988	1989	1990[1]	1991[1]	1992[1]
					Percent			
Minerals	46.5	60.9	67.7	70.6	69.0	65.5	64.1	64.7
Gold	25.4	40.2	41.5	36.4	25.1	31.2	34.3	40.1
Copper	21.1	20.7	20.2	34.2	43.9	34.3	29.8	24.6
Nonminerals	53.5	39.1	38.3	29.4	31.0	34.5	35.9	35.3
Cocoa	7.5	6.3	5.3	3.5	3.8	3.2	2.6	2.6
Coffee	13.4	15.4	16.5	9.4	10.9	9.2	7.2	6.9
Copra	5.1	2.0	1.0	1.3	1.4	1.5	1.4	1.2
Logs	7.7	5.7	6.9	7.6	6.6	8.9	10.1	9.6
Palm Oil	7.5	3.9	2.8	1.7	3.1	4.3	5.4	5.6
Other	12.3	5.8	5.8	5.9	5.2	7.4	12.2	9.4

Source: Based on Table II in Annex VII of IMF Report on PNG, March 1990.
1/ Projected.

Figure 1 shows the annual percentage change in export unit values of the five major commodity exports of PNG. The coefficients of variation[2] (CV) of these export unit values between 1977 and 1988

[1]PNG's first oil project is likely come on stream in the second half of 1992, with a production profile that is heavily front-end loaded.

[2]The standard deviation as a proportion of the mean.

are: copper 42%, gold 50%, cocoa 37%, coffee 34% and logs 25%. Unstable export prices have resulted in unstable export revenues, which recorded a CV in excess of 27% during the 1980s. This indicates a high degree of instability, even among developing countries, and presents a significant problem in debt servicing, as well as affecting PNG's ability to secure additional loans.

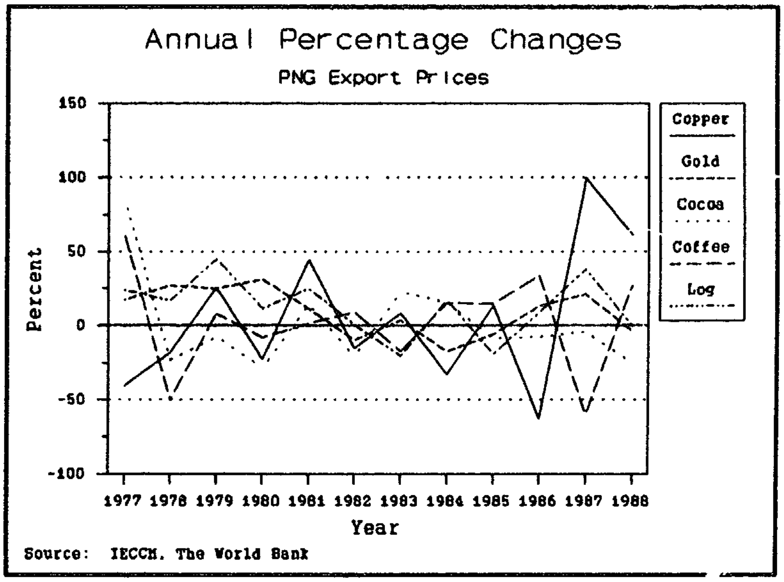

Figure 1

While the export performance of the country depends on the price and volume of a small set of commodities, the mix of imports has been more diversified and the unit values of imports have been relatively more stable.

Various instruments have been used by countries attempting to manage commodity price risk. Among these are: (a) buffer stock schemes, commodity stabilization fund schemes and macroeconomic policies; (b) financial market instruments such as futures, forwards, options, swaps and commodity bonds; and (c) international commodity agreements and compensatory financing schemes. PNG has extensively used instruments listed under (a) and (c) above to manage its risk exposure, with moderate success[3]. Claessens and Coleman (1991) report that the financial market instruments listed in (b) above have not been used in PNG.

[3] The Minerals Resources Stabilization Fund (MRSF) was established in 1975 to prevent unstable mineral-based tax revenues from causing instability in the rest of the economy. However, Claessens and Coleman (1991) show that the coefficient of variation of out-flows from this fund is only slightly lower than the coefficient of variation of its in-flows, indicating only moderate effectiveness in stabilization. PNG operated commodity price stabilization funds for its major agricultural export commodities (i.e., coffee, cocoa, copra and oil palm). These funds were successful for many years and often cited as models of how effective a well managed scheme can be in risk management. However, with the sharp fall in the prices of these commodities in recent years these funds became depleted and new approaches to commodity price risk management for agriculture are being sought. PNG was a member of the International Coffee Organization.

Among the financial instruments associated with primary commodities listed above, commodity-linked bonds have substantial potential for PNG which relies on commodity export revenues to meet its debt obligations. Commodity-linked bonds differ from conventional bonds in that coupon and/or principal payments are linked to a given quantity of a commodity. For example, a gold-denominated commodity bond might require coupons payments to be made annually, equivalent to the value of a pre-specified quantity of gold, with the price set at some average daily price over the preceding 12 months. A decline in the price of gold leads to lower coupon payments and vice versa, with the result that debt servicing requirements are better matched with the ability to pay.

3. Foreign Exchange Risks.

In addition to commodity price risks, PNG is vulnerable to risks associated with exchange rate fluctuations[4]. The degree of exposure to exchange risk depends, to a large extent, on (i) the matching of the currency composition of net export earnings with the currency composition of net liabilities, and (ii) the effects on exchange rates of changes in commodity prices. Based on these criteria, Claessens et al (1989) showed that the assets and liabilities for debt servicing in PNG were potentially poorly balanced.

An appreciation of the Kina vis-a-vis the currency of a country with which PNG has negative trade balance causes PNG goods to become more expensive. This can lead to a decline in the export revenues from this country. However, if PNG borrows from this country, then debt servicing requirements also fall with a depreciation, so that the overall impact of an exchange rate change may be diminished. For this reason, Claessens et al argued that PNG should secure conventional loans

[4]Movements in cross-currency exchange rates can be expected to compensate for nominal interest rate differentials (uncovered interest rate parity), except for risk premia (ex-ante devations from uncovered interest rate parity). However, ex-post, deviations from uncovered interest rate parity are unobserved. Therefore, active currency management should be employed to reduce risks of ex-post deviations through optimal currency composition. In the model, all variables (denominated in nominal US dollars) are deflated by PNG's import price index (based on US dollars). Thus the model measures the currency valuation effect in terms of units of imports.

denominated in the currency of those countries with which it has a positive trade balance. As well, it should try to borrow from countries whose currencies move positively with the prices of the major exports of PNG. Perhaps after PNG starts exporting oil it should obtain loans from those countries whose currency value is positively linked to the price of oil, such as the United Kingdom since it exports oil. As the price of oil increases, the pound sterling tends to get stronger, leading to higher debt obligations in terms of PNG's currency (Kina). However, as a result of higher oil prices, revenues from oil exports also rise, allowing the higher debt repayments to be met. In contrast, lower oil prices tend to strengthen the Yen, leading to higher debt repayment, which must be met by lower oil export revenues, making the Yen a poor currency in which to borrow.

As demonstrated in Table 3, the trade pattern and currency debt composition of PNG are not well matched in terms of hedging risk. The most striking imbalance is in the shares of the United States. If the US dollar appreciates, PNG's debt repayments will be higher without any significant offsetting effect of increased foreign exchange earnings from additional sales of exports to the United States.

Table 3. Comparison of Shares of Key Currencies in PNG Public and Publicly Guaranteed Debt with Shares of Total Exports by Major Export Destination 1982-87

Country	1982	1983	1984	1985	1986	1987
		Percent Export Earnings				
Australia	8.4	7.5	8.4	10.3	4.8	8.0
Germany, F.R.	26.9	25.7	21.3	30.0	34.4	27.2
Japan	34.0	35.3	29.3	22.5	25.6	28.5
United Kingdom	5.8	5.8	11.3	7.5	4.5	4.7
United States	1.8	2.2	2.7	3.9	3.3	2.1
Total	76.9	76.5	73.0	74.2	72.6	70.5
		Percent Debt shares				
Australia						
Germany, F.R.	3.1	1.9	1.9	2.1	2.3	2.3
Japan	3.4	3.0	8.1	12.9	14.5	16.2
Switzerland	3.4	2.5	4.2	7.2	9.4	10.3
United Kingdom	2.4	1.7	1.2	1.2	1.8	2.0
United States	40.6	47.1	45.1	38.9	35.6	28.6
Total	52.9	56.2	60.5	62.3	63.6	59.4

Source: World Bank Debt Reporting Service; Papua New Guinea Opportunities and Challenges for Accelerated Development, World Bank Report No. 7707 PNG, April 1990.

4. Theory

The model used to determine an optimal hedging strategy for PNG is that of aggregate consumer portfolio choice for a given output. It is an adaptation of the model presented by Myers and Thompson (1989). In conformity with the model, PNG is a small open economy with all its external debt issued by the government. The government has a utility function, $u(m_t)$, where m_t is the real value of imports of goods and services in period t. The utility function is assumed to satisfy the Von Neuman-Morgenstern axioms, as well as $u'(m_t) \geq 0$ and $u''(m_t) \leq 0$.

In the absence of borrowing, the current account must balance in each period, with the value of exports equal to the value of imports and debt servicing requirements. However, the government can borrow externally by taking out a conventional loan at a real rate of interest r. In addition, the government can borrow by issuing commodity bonds which mature in one period and require a payment at the beginning of the next period equal to the price in the next period of the commodity to which the bond is linked. Given these conditions, the government faces a budget constraint given by:

$$m_t+(1+r)(e_t'd_{t-1}^*+d_{t-1}^{us})+p_t'b_{t-1}\leq x_t+(e_t'd_t^*+d_t^{us})+w_t'b_t \qquad (1)$$

where: m_t = real value of imports,
r = real interest rate[5],
e_t = column vector of exchange rates of non-US dollar denominated debt in units of real US dollars per other currency, $(e_{1t}, e_{2t}, \ldots, e_{mt})'$,
d_t^* = column vector of conventional debt of each (non-US) currency, $(d_{1t}, d_{2t}, \ldots, d_{mt})'$,
d_t^{us} = conventional debt denominated in real US dollars,
p_t = column vector of real prices of the underlying commodities, $(p_{1t}, p_{2t}, \ldots, p_{nt})'$,
b_t = column vector of the quantity of bonds sold which are denominated in physical units of the commodity, $(b_{1t}, b_{2t}, \ldots, b_{nt})'$,
x_t = real value of exports, and
w_t = column vector of real prices of the commodity bonds, $(w_{1t}, w_{2t}, \ldots, w_{nt})'$.

Equation (1) can be rearranged as:

$$m_t+(1+r)d_{t-1}^{us}+[(1+r)e_t',p_t']\begin{bmatrix}d_{t-1}^*\\ b_{t-1}\end{bmatrix} \leq x_t+d_t^{us}+[e_t',w_t']\begin{bmatrix}d_t^*\\ b_t\end{bmatrix} \qquad (2)$$

or,

$$m_t+(1+r)d_{t-1}^{us}+p_t^{*\prime}b_{t-1}^*\leq x_t+d_t^{us}+w_t^{*\prime}b_t^* \qquad (3)$$

where: $p_t^* = [(1+r)e_t', p_t']'$

[5]The model proposed here assumes uncovered interest parity holds. Covered interest parity is not assumed because long term (i.e., more than a year) forward exchange markets do not exist.

$b^*_t = [d'^*_{t-1}, b'_{t-1}]'$, and

$w^*_t = [e'_t, w'_t]'$.

The government also faces transversaiity conditions[6]:

$$\lim_{t\to\infty}(1+r)^{-t}d_t^{us}=\lim_{t\to\infty}(1+r)^{-t}w_t^{*\prime}b_t^*=0 \tag{4}$$

The agent's problem is to choose a portfolio of commodity-linked bonds and conventional debt in different currencies to maximize the expected life-time utility function (5):

$$E_0\sum_{t=0}^{\infty}\beta^t u(m_t) \tag{5}$$

subject to (1) and (4), where β^t is the subjective discount rate.

The associated Euler equations are:

$$u'(m_t)-\beta(1+r)E_t u'(m_{t+1})=0 \tag{6}$$

$$u'(m_t)w_t^*-\beta E_t(u'(m_{t+1})p_{t+1}^*)=0 \tag{7}$$

Solving this maximization problem requires that strict assumptions be placed on the form of the utility function, as well as on the probability distributions of prices and exports. Taking the approach of Myers and Thompson, a solution can be found by using the permanent income theory of consumption. The optimal import path can be defined as[7]:

[6]This condition ensures that borrowing will not increase the present value of net wealth. This condition is used also in Appendix I.

[7]A derivation and discussion of this equation is given in Appendix I.

$$m_t=\frac{r}{1+r}[\sum_{i=0}^{\infty}(1+r)^{-i}E_t(x_{t+i})-p_t^{*\prime}b_{t-1}^{*}-(1+r)d_{t-1}^{us}] \tag{8}$$

The equation 8 is not a decision rule because the $E_t(x_{t+i})$ terms cannot be observed. To retrieve it, $E_t(x_{t+i})$ can be expressed as a function of variables which the government can observe in period t. One procedure is to set up a vector y_t in which the first element is x_t. That is, $y_t = (x_t, p_t^*, s_t)'$, where p_t is a vector of commodity prices, and s_t is the set of other state variables useful for predicting future exports. The vector y_t is assumed to follow the autoregressive process:

$$A(L)y_t=\epsilon_t \tag{9}$$

where A(L) is a matrix polynomial in the lag operator and ϵ_t is a zero mean, serially uncorrelated error vector, with covariance matrix Ω. The optimal projection of the future income stream through exports can be defined as (see Hansen and Sargent (1980)):

$$\sum_{i=0}^{\infty}(1+r)^{-i}E_t(x_{t+i})=\gamma' y_t+B(L)y_{t-1}, \tag{10}$$

with,

$$\gamma'=\phi A(\frac{1}{1+r})^{-1}, \tag{11}$$

and,

$$B(L)=\phi A(\frac{1}{1+r})^{-1}[\sum_{j=1}^{q-1}[\sum_{k=j+1}^{q}(1+r)^{j-k}A_k]L^{j-1}] \tag{12}$$

where: ϕ = a row vector with a one in the first column and zeros elsewhere.

Substituting (10) into (8) gives the operational decision rule:

$$m_t = \frac{r}{1+r}[\gamma' y_t + B(L)y_{t-1} - p_t^{*'} b_{t-1}^{*} - (1+r)d_{t-1}^{us}] \tag{13}$$

with imports as a function of observable variables. However, while this formula gives the optimal level of imports and therefore the optimal level of debt, it does not provide the optimal portfolio of conventional and commodity-linked debt.

To obtain the optimal debt portfolio further derivations are needed. Rearranging the Euler equations (6) and (7), and assuming that the expected real return on holding bonds is equal to the real interest rate; gives:

$$E_t[u'(m_{t+1})(w_t^{*'} - \frac{p_{t+1}^{*'}}{1+r})] = 0 \tag{14}$$

$$E_t(w_t^{*'} - \frac{p_{t+1}^{*'}}{1+r}) = 0 \tag{15}$$

Which implies:

$$COV(u'(m_{t+1}), p_{t+1}^{*'}) = 0 \tag{16}$$

In order to calculate this covariance matrix, it is necessary to obtain an expression for $u'(m_{t+1})$. Following Myers and Thompson, a linear approximation of the first derivative of the utility function gives,

$$COV(m_{t+1}, p_{t+1}^{*'}) = 0 \tag{17}$$

Leading (13) one period and computing the relevant covariance (17) gives:

$$COV((\frac{r}{1+r}(\gamma' y_{t+1} + B(L)y_t - p_{t+1}^{*'} b_t^* - (1+r)d_t^*)), p_{t+1}^{*'}) = 0 \tag{18}$$

Recognizing that $B(L)y_t$ is known at time t, the covariance expression is:

$$COV((\gamma' y_{t+1} - p_{t+1}^{*'} b_t^*), p_{t+1}^*) = 0 \tag{19}$$

Rearranging (19) gives[8]:

$$\Omega_{p^* y^*} \gamma - \Omega_{p^* p^*} b_t^* = 0 \tag{20}$$

Where: Ω_{p^*y} = covariance operation between vector p^* and y, and
$\Omega_{p^*p^*}$ = covariance operation between elements in the p^* vector.

Solving for b_t^* gives:

$$b_t^* = \Omega_{p^* p^*}^{-1} \Omega_{p^* y} \gamma \tag{21}$$

While the optimal portfolios have been computed, it is important to determine whether the variance of real imports is reduced in order to evaluate the hedging effectiveness of commodity-linked bonds and conventional debt in different currencies. Leading (13) one period, the conditional variance of m_{t+1} at time t gives:

$$\begin{aligned} VAR(m_{t+1}) &= (\frac{r}{1+r})^2 (VAR(\gamma' y_{t+1}) + VAR(p_{t+1}^{*'} b_t^*) \\ &\quad -2COV(\gamma' y_{t+1}, p_{t+1}^{*'} b_t^*)) \\ &= (\frac{r}{1+r})^2 (\gamma' \Omega_{yy} \gamma + b_t^{*'} \Omega_{p^* p^*} b_t^* - 2 b_t^{*'} \Omega_{p^* y} \gamma) \end{aligned} \tag{22}$$

Rearranging (20):

[8]For simplicity, subscript t+1 has been dropped.

$$\begin{aligned}\Omega_{p^*y}\gamma &= \Omega_{p^*p^*}b_t^* \\ b_t^{*\prime}\Omega_{p^*y}\gamma &= b_t^{*\prime}\Omega_{p^*p^*}b_t^*\end{aligned} \tag{23}$$

Substituting (23) into (22):

$$\begin{aligned}VAR(m_{t+1}) &= \left(\frac{r}{1+r}\right)^2(\gamma'\Omega_{yy}\gamma + b_t^{*\prime}\Omega_{p^*p^*}b_t^* - 2b_t^{*\prime}\Omega_{p^*y}\gamma) \\ &= \left(\frac{r}{1+r}\right)^2(\gamma'\Omega_{yy}\gamma - b_t^{*\prime}\Omega_{p^*p^*}b_t^*)\end{aligned} \tag{24}$$

Both the terms in the lower expression of (24) are in quadratic form, and, by definition, non-negative. Therefore, if there are no commodity bonds or non-US dollar, denominated debt available (i.e., b^* is zero), then the variance of m_{t+1} is simply the first item in the expression. If commodity bonds and non-US dollar debt are determined by equation (21) and some of the elements in b^* are non-zero, then the second term in (24) is positive. Thus the conditional variance of m_{t+1} is always smaller.

5. Estimation

Estimation of the optimal portfolio model is directly related to the vector auto-regressive process $A(L)y_t = \epsilon_t$. The VAR process predicts future export revenues, commodity prices, and foreign exchange rates. More importantly, the conditional covariance matrix, Ω, of the error term ϵ_t, provides Ω_{py} and Ω_{pp}. Further, the parameter vector, γ, can be derived from coefficients of the VAR system as shown in (11). In Table 4 the index of variable names assigned in the model is presented, and in Table 5 the VAR regression results are shown. Only OLS results are presented[9]. Table 6 presents the estimated covariance matrix Ω of the VAR system.

[9]The diagnostics for the SUR estimates (e.g., R-squared and Durbin-Watson statistics) are not reported by SAS for the individual equations in the VAR system.

Table 4. Index of Variable Names

Mnemonic	Variable
XT	Total exports per capita (constant 1980 US$)
CP	Price of copper (constant 1980 US$ per metric ton)
GD	Price of gold (constant 1980 US$ per metric ton)
CC	Price of cocoa (constant 1980 US$ per metric ton)
CF	Price of coffee (constant 1980 US$ per metric ton)
LG	Price of logs (constant 1980 US$ per cubic meter)
OL	Price of crude oil (constant 1980 US$ per barrel)
SF	Exchange rate (constant 1980 US$ per Swiss Franc)
DM	Exchange rate (constant 1980 US$ per Deutsche Mark)
BP	Exchange rate (constant 1980 US$ per British Pound)
JY	Exchange rate (constant 1980 US$ per Japanese Yen)
**L&	Lags of the variable ** in the order of &

The stationarity of variables in levels was tested using the standard set of unit root tests. Using the Dickey-Fuller and Augmented Dickey-Fuller tests, the unit root hypothesis for CP, GD, CC, CF, BP, and DM (see Table 4 for definitions) was rejected at the 95% level. However, the test statistics for SF, XT, LG were close to the critical values, and, in the cases of OL and JY, the null hypothesis was rejected. However, using the Durbin-Watson tests of Sargan and Bhargava, the unit root null hypothesis was rejected. Therefore, all variables were assumed to be stationary.

In order to specify the VAR equations, the SAS STEPWISE procedure was applied which searches for the best fitting model, allowing for degrees of freedom considerations. It was assumed that exchange rates affect commodity prices, but not vice versa, except for the price of crude oil.

Table 5. Estimation Results (t-values given in parenthesis).

Total Exports Per Capita

XT = 108.6 + 0.50 XTL1 - 0.035 CFL3 + 2.75 JYL2 + 1.00 LGL2 - 1.70 OLL1
(4.34) (7.666) (-14.82) (10.15) (3.919) (-4.969)

$R^2 = 0.99$ DW = 2.34

Price of Copper

CP = 1431.3 + 0.193 CPL1 + 0.610 CFL3 - 34.0 SFL3 - 17.89 LL2 + 0.215 CPL3
(3.77) (2.28) (11.99) (-6.81) (-2.14) (3.322)

$R^2 = 0.99$ DW = 1.93

Price of Gold

GD = 16903 - 0.16 GDL1 - 2.84 CCL1 + 0.72 CFL1 + 32.12 JYL1
(10.92) (-1.70) (-10.65) (5.63) (3.58)

$R^2 = 0.98$ DW = 3.01

Price of Cocoa

CC = 2878 + 0.45 CCL1 - 8.82 XTL3 + 0.122 GDL1 - 25.09 LGL1 + 19.06 OLL3
(13.29) (13.52) (-21.00) (8.23) (-16.11) (6.77)

$R^2 = 0.99$ DW = 2.44

Price of Coffee

CF = -14232 - 0.09 CFL1 + 0.688 CPL2 + 0.919 GDL3 + 1.09 CCL2 + 58.44 SFL2
(-4.07) (-0.50) (4.05) (6.19) (6.69) (2.59)

$R^2 = 0.94$ DW = 1.62

Price of Logs

LG = 37.27 - 0.195 LGL1 + 0.009 GDL1 - 1.03 SFL1 - 1.60 OLL1 + 0.008 CCL2
(1.90) (-2.21) (7.33) (-5.88) (-10.08) (2.70)

$R^2 = 0.99$ DW = 1.46

Price of Oil

OL = 21.07 + 0.716 OLL1 - 0.551 OLL3
(1.89) (2.57) (-1.59)

$R^2 = 0.55$ DW = 2.72

Table 5. Continued.

Swiss Franc/US Dollar Exchange Rate

SF = 38.70 - 1.02 SFL2 + 0.959 DML1 - 0.765 OLL2
(3.51) (-3.81) (3.70) (-1.83)

R^2 = 0.82 DW = 2.45

Deutsche Mark/US Dollar Exchange Rate

DM = -22.04 - 2.44 DML1 + 0.918 BPL1 + 1.24 JYL1 - 0.402 BPL2 + 0.659 JYL2
(-1.49) (-2.31) (2.80) (3.25) (-2.39) (1.99)

R^2 = 0.94 DW = 2.99

British Pound/US Dollar Exchange Rate

BP = -156.6 + 1.15 BPL1 + 2.70 JYL1 + 0.364 OLL1 - 3.61 SFL1 + 1.78 OLL2 + 2.56 JYL2
(-2.22) (7.38) (3.67) (0.51) (-3.33) (2.32) (3.43)

R^2 = 0.99 DW = 2.77

Japanese Yen/US Dollar Exchange Rate

JY = 88.4 + 0.709 JYL1 - 0.895 DML2 - 0.99 OLL2
(3.25) (3.63) (-4.38) (-2.30)

R^2 = 0.90 DW = 2.67

Table 6. Covariance Matrix of Residuals from the Vector Autoregression Model

	XTR	CPR	GDR	CCR	CFR	LGR	OLR	SFR	DMR	BPR	JYR
XTR	7.17	-66.52	-110.33	-1.80	-245.44	-1.33	-1.13	1.31	3.40	-0.38	3.08
CPR	-66.52	6447.07	5992.51	222.75	3104.22	31.30	26.09	67.57	7.98	95.43	-47.34
GDR	-110.33	5992.51	26245.50	-932.91	14229.90	-2.66	-387.23	408.00	188.21	291.47	107.64
CCR	-1.80	222.75	-932.91	400.52	-1975.60	-6.07	87.14	-20.60	-14.86	-42.66	-52.20
CFR	-245.44	3104.22	14229.90	-1975.60	26851.10	109.68	-577.23	221.72	-43.65	188.47	171.50
LGR	-1.33	31.30	-2.66	-6.07	109.68	1.65	-3.17	1.42	-1.10	0.93	2.28
OLR	-1.13	26.09	-387.23	87.14	-577.23	-3.17	30.13	-13.94	-4.64	-10.35	-19.02
SFR	1.31	67.57	408.00	-20.60	221.72	1.42	-13.94	15.89	5.23	6.59	10.92
DMR	3.40	7.98	188.21	-14.86	-43.65	-1.10	-4.64	5.23	4.76	4.07	4.24
BPR	-0.38	95.43	291.47	-42.66	188.47	0.93	-10.35	6.59	4.07	9.45	8.01
JYR	3.08	-47.34	107.64	-52.20	171.50	2.28	-19.02	10.92	4.24	8.01	16.55

Note: **R is the residual of variable ** from the VAR system.

The seemingly uncorrelated regression (SUR) estimator was used to estimate the VAR system. Having obtained the coefficient matrix A(L) and covariance matrix, the optimal quantity of commodity-linked bonds and the optimal foreign currency compositions were computed using formula (21). According to the theoretical model reported in section IV, it is possible for the elements in the solution vector b^* to be positive or negative. Positive values of either commodity-linked bonds or foreign exchanges indicate borrowing in these instruments (i.e., commodity-linked bonds and conventional debt denominated in the particular currency). Negative values of commodity-linked bonds or foreign exchanges indicate lending. However, it is highly unlikely that PNG be a lender in international financial market given its foreign exchange shortage, and so the maximization problem was altered by adding a non-negativity constraint, $b \geq 0$.

The non-negativity constraint on commodity-linked bonds greatly complicated the maximization problem (the Euler equations in particular), which made empirical estimation difficult[10]. However, an iterative method was used imposing non-negativity, without formally incorporating the $b \geq 0$ requirement

[10]A non-linear programming package (e.g., GAMS) can be used to solve this maximization problem with a non-negative constraint. However, the solution tends to be highly unstable.

into the mathematical formulation. This method was as follows. If, after the first round of calculation, any of the commodity-linked bonds were found to be negative in the optimal solution, they were dropped from the instrument list, and the re-defined maximization problem on the remaining instruments was re-solved. If more commodity-linked bonds on the remaining instrument list were found to be negative in the second round solution, they were also eliminated and the previously discarded commodity-linked bonds in the first round were reinstated in the model. Iterations were repeated until all the commodity-linked bonds remaining in the model were positive[11].

Although the financial instrument list changed in the iterative process, the VAR system specification as shown in Table 5 did not need to change. The autoregressive process defined by (9), allowed the unused commodity-linked bonds (i.e., the ones dropped from the list) to be treated as exogenous, and included as state variables s_t in y_t. However, the matrices $\Omega_{p^e y}$ and $\Omega_{p^e p^e}$ derived from the VAR covariance matrix presented in Table 6 were re-specified according to which commodity-linked bonds were set to zero. The rows and columns of $\Omega_{p^e p^e}$ and $\Omega_{p^e y}$ corresponding to the dropped financial instruments were set at zero. In order to avoid singularity while inverting the matrix $\Omega_{p^e p^e}$, the diagonal elements were set to one before inverting this matrix and to zero afterwards.

6. Results

The model was solved for 1988. Conventional debt in US dollars was derived from the budget constraint (1), assuming no commodity-linked bonds were issued in 1987. Table 7 presents the estimation results of the optimal portfolio model. All naming conventions follow the description in Table 4. Results are presented for different real interest rates because the model does not have the feature of hedging against interest rate risk, and because the real interest rate was assumed to be equal to the

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[11]This approach is capable of producing an infinite loop in calculations. Fortunately, in the model tested for PNG, the infinite loop did not appear, and the final solution was quickly located.

subjective discount rate. The last two columns in Table 7 show the total commodity-linked bonds and the total external debt (including commodity-linked bonds and conventional debt).

The total imports, exports, and debt stock per capita for 1988 are also listed in Table 7. Only cocoa- and crude oil-linked bonds are found in the optimal portfolio. According to the results, PNG should sell an amount of cocoa-linked bonds ranging from $54 to $84 per capita (in constant 1980 US dollars) depending on the real interest rate. Further, a large share of the external financing should be obtained though sales of the crude oil-linked bond. The per capita value of oil-linked bond ranges from $103 to $260 in constant 1980 US dollars.

Table 7. Optimal Portfolio of External Debt Per Capita (1988)(Constant 1980 US$)

Interest Rate	Cocoa Bonds	Oil Bonds	Swiss Franc	Deutsche Mark	British Pounds	Japanese Yen	US Dollar	Total C.Bonds	Total Debt
0.01	84.40	260.57	5.82	-1.86	151.59	14.06	261.00	344.97	775.58
0.02	82.49	247.77	1.46	-0.33	134.64	3.02	314.38	330.26	783.43
0.03	79.60	230.74	-2.91	0.84	115.03	-6.08	374.04	310.34	791.26
0.04	75.78	209.84	-7.14	1.57	93.34	-14.95	439.21	285.62	797.65
0.05	71.10	185.70	-11.11	1.85	70.30	-21.04	507.96	256.80	804.76
0.06	65.75	159.20	-14.68	1.66	46.78	-24.85	578.01	224.95	811.87
0.07	59.93	131.38	-17.77	1.06	23.66	-26.34	647.07	191.31	818.99
0.08	53.87	103.28	-20.32	0.93	1.72	-25.60	713.05	157.15	826.93

Debt Stock Per Capita (1987)	711.20
Total Imports Per Capita (1988)	436.00
Total Exports Per Capita (1988)	378.00

The foreign currency composition of the optimal debt portfolio is also presented in Table 7. At low real interest rates, the optimal portfolio does not contain liabilities denominated in Japanese Yen and Swiss Francs, but includes liabilities denominated in British Pounds. This supports the argument made earlier that PNG should denominate its liabilities in currencies (e.g., British Pounds) positively correlated with its assets (e.g., oil revenues). The negative signs for Japanese Yen and Swiss Francs suggest that PNG should hold assets denominated in these currencies in its optimal portfolio, by holding foreign exchange earnings from exporting to these countries. The Deutsche Mark does not play a significant role in the optimal portfolio. At high interest rates, total borrowing of non-US, dollar denominated debt declines, because the willingness to borrow declines. For example, conventional debt denominated in British Pounds become less important in the optimal portfolio at high interest rates.

Table 8. Optimal Composition of Total External Debt (percent)

Interest Rate (1)	Commodity Bonds (2)	Conventional Debt (3)	Combined SF/DM/JY[1/] (4)	British Pounds (5)	US Dollars (6)	Total Debt (7)
0.01	44.48	55.52	2.32	19.55	33.65	100.00
0.02	42.16	57.84	0.53	17.19	40.13	100.00
0.03	39.22	60.78	-1.03	14.54	47.27	100.00
0.04	35.81	64.19	-2.57	11.70	55.06	100.00
0.05	31.91	68.09	-3.77	8.74	63.12	100.00
0.06	27.71	72.29	-4.66	5.76	71.19	100.00
0.07	23.36	76.64	-5.26	2.89	79.01	100.00
0.08	19.00	81.00	-5.44	0.21	86.23	100.00

[1/] Combined percent of Swiss Francs, Deutsche Marks and Japanese Yen.

For clarity, Table 8 presents the composition of the optimal portfolio in terms of total external debt. The second column of Table 8 shows that the share of the commodity-linked bonds ranges from 19% to 45% as the real interest rate declines. This emphasizes the important role that commodity-linked bonds can play in the external finance of PNG. The third column gives the percentage for total net conventional debt. The fourth column gives the percentage of debt made up of Swiss Francs, Deutsche Marks and Japanese Yen and shows that these currencies are not important to the external debt portfolio. The British Pound's share is important when real interest rates are low. The proportion of US dollar denominated conventional debt is large when the real interest rate is high. However, this does not mean that US dollar denominated debt is the best liability to hedge risks. Rather, it shows that as the real interest rate increases, the hedging effectiveness of other instruments decreases because borrowing declines, while at the same time, the total debt stock carried over from last period becomes larger. As a result, the proportion of US dollar denominated conventional debt in the optimal portfolio model has to increase in order to satisfy the binding budget constraint (1).

Comparison of T ıbles 3 and 8 shows that there are significant differences between the optimal debt portfolio derived from the model and the one held by PNG in the late 1980s. For example, the actual combined share of Swiss Francs, Deutsche Marks, and Japanese Yen in the debt portfolio was between 20% and 30%. In the optimal portfolio, their combined share is negative for almost all levels of the real interest rate. As shown in Table 3, the British Pound's share was only 2% in 1987, while in the optimal debt portfolio (Table 8) the share is almost 20% at low real interest rates. US dollar denominated debt shares in the optimal portfolio are consistent with the actual levels at moderate levels of real interest rates. As mentioned earlier, commodity-linked bonds are absent from the actual portfolio, while the optimal portfolio calls for a share of between 20% and 45% in these instruments.

To evaluate the hedging effectiveness of the optimal portfolio, it is necessary to examine the impact in reducing the variance of imports. Table 9 presents the calculation of variances of the expected future imports per capita for PNG under different real interest rates. These were derived using equation (24).

Table 9. Variance of Expected Future Imports.

r (1)	Total (2)	Reduction (3)	Net (4)	Percent (5)
0.01	4461.20	2849.13	1612.07	63.86
0.02	4380.07	2705.71	1674.36	61.18
0.03	4163.81	2467.84	1695.97	59.27
0.04	3822.15	2150.69	1671.46	56.27
0.05	3380.76	1780.52	1600.24	52.67
0.06	2877.50	1390.61	1486.89	48.33
0.07	2355.51	1015.02	1340.49	43.09
0.08	1855.47	682.54	1172.93	36.79

The second column in the table relates to the first term in (24), that is, the variance of expected imports without external financing. The third column relates to the second term in (24), which can be interpreted as the contribution of optimally structured external financing to reducing the variance of expected future imports. The fourth column shows the variance of expect future imports that cannot be reduced through external financing. The fifth column is the ratio between columns three and two measuring the hedging effectiveness in relative terms.

The results from Table 9 show that the optimal portfolio of external debt can reduce future uncertainty substantially. Between 40% to 60% of total variance of expect future imports can be reduced by external financing, including commodity-linked bonds and conventional debt (under various levels of the real interest rate). This is equivalent to a 20% to 40% reduction in terms of standard errors or confidence intervals. The hedging effectiveness of all instruments other than conventional debt denominated in US dollar is sensitive to the real interest rate assumptions. In particular, this can be seen from column 5 in Table 9. The ratio which measures the hedging effectiveness falls by one-third when the real interest rate increases from 1% to 8%. The deterioration of the hedging effectiveness of the optimal portfolio coincides with the results reported in Table 8, which shows that the share of US dollar denominated conventional debt is more than doubled as the real interest rate changes from 1% to 8%. Because higher real interest rates lower the importance of non-US, dollar denominated conventional debt, and since the US dollar denominated conventional debt does not make any contribution to reducing future uncertainty (i.e., through reducing the variance), it is expected that hedging effectiveness is less at higher real interest rates.

A final issue concerns the robustness of the model's optimal portfolio solution to changing assumptions and model specification. By using the VAR approach which is equivalent to estimating the reduced form of a structural model, assumptions about model structure are irrelevant.

7. Conclusions

As stated in the introductory section, the objectives of the study were (i) to assess the nature and extent of financial risks facing PNG associated with fluctuating commodity prices and exchange rates, (ii) to present a model solving for the optimal debt portfolio of PNG, allowing for the use of commodity-linked bonds and conventional debt denominated in different currencies, and (iii) to compare the optimal debt portfolio derived from the model with the portfolio currently held by PNG, and, on the basis of this comparison, to suggest changes in the existing debt structure.

The analysis showed that commodity price and exchange rate risks faced by PNG are considerable. The major primary commodities of PNG -- copper, gold, cocoa, coffee, logs, and palm oil -- contributed almost 90% of total export earnings in 1988, and the coefficients of variation for the prices of these commodities ranged from 25% for logs to 50% for gold. Overall, export revenues have been highly unstable, recording a CV of 27% for the 1980s. Analysis of PNG's trading patterns and currency combination in the debt portfolio showed that these were not well matched. Further, the value of debt when denominated in US dollars was vulnerable to movements in cross-currency exchange rates, and the currency valuation effects were considerable.

The hedging effectiveness of the optimal portfolio was judged by the reduction in the variance of expected future real imports. The model indicated that commodity-linked bonds can play a very important role in the overall risk management strategy of PNG. The proportion of commodity-linked bonds in the optimal debt portfolio ranged from 20% to 45%, for real interest rates going from 8% to 1%. It was shown that bonds issued with payments linked to the prices of oil and cocoa would substantially lower the variability of expected future imports.

The model also showed that PNG's external debt structure is not well balanced to hedge the foreign exchange risk resulting from the existing composition of non-US dollar denominated liabilities. In particular, the actual debt portfolio contains an excess of Japanese Yen and Deutsche Mark denominated liabilities, while British Pounds are substantially under-represented in the portfolio. As a corollary to this statement, this finding indicates that PNG should re-shape its debt portfolio by borrowing a relatively higher proportion of British Pounds and less Japanese Yen and Deutsche Marks.

Appendix I - Explanation of Equation 8

Rewrite the binding budget constraint:

$$m_t = x_t - (1+r)d_{t-1} - p_t' b_{t-1} + d_t + w_t' b_t \tag{A1.1}$$

Lead (1) one period, multiply both side by 1/(1+r) and take the expectation:

$$\frac{1}{1+r} E_t m_{t+1} = \frac{1}{1+r}(E_t x_{t+1} - (1+r)d_t - E_t p_{t+1}' b_t + E_t d_{t+1} + E_t w_{t+1}' b_{t+1}) \tag{A1.2}$$

Assuming:

$$\begin{gathered} E_t[w_{t+i} - \frac{p_{t+i+1}}{1+r}] = 0 \\ E_t[e_{t+i} - \frac{e_{t+i+1}}{1+r}] = 0 \\ i = 0, 1, \ldots, \infty \end{gathered} \tag{A1.3}$$

and summing (A1.1) and (A1.2) gives,

$$m_t + \frac{1}{1+r} E_t m_{t+1} = x_t + \frac{1}{1+r} E_t x_{t+1} - (1+r)d_{t-1} - p_t' b_{t-1} + \frac{1}{1+r} E_t d_{t+1} + \frac{1}{1+r} E_t w_{t+1}' b_{t+1} \tag{A1.4}$$

Leading (A1.1) two periods, multiplying both sides by $1/(1+r)^2$, taking expectation, and adding (A1.3) gives,

$$\begin{gathered} m_t + \frac{1}{1+r} E_t m_{t+1} + \frac{1}{(1+r)^2} E_t m_{t+2} = \\ x_t + \frac{1}{1+r} E_t x_{t+1} + \frac{1}{(1+r)^2} E_t x_{t+2} - (1+r)d_{t-1} - p_t b_{t-1} + \frac{1}{(1+r)^2} E_t d_{t+2} + \frac{1}{(1+r)^2} E_t w_{t+2} b_{t+2} \end{gathered} \tag{A1.5}$$

If this operation is repeated an infinite number of times, and the transversality conditions are assumed then,

$$\sum_{i=0}^{\infty}(1+r)^{-i}E_t m_{t+i}=\sum_{i=0}^{\infty}(1+r)^{-i}E_t x_{t+i}-(1+r)d_{t-1}-p_t'b_{t-1} \qquad \text{(A1.6)}$$

Assume the permanent income hypothesis:

$$m_t=E_t m_{t+1}=E_t m_{t+2}=\ldots=E_t m_{t+i}=E_t m_{t+i+1}=\ldots \qquad \text{(A1.7)}$$
$$i=0,1,\ldots,\infty$$

So the optimal import path can be found:

$$m_t=\frac{r}{1+r}[\sum_{i=0}^{\infty}(1+r)^{-i}E_t x_{t+i}-(1+r)d_{t-1}-p_t'b_{t-1}] \qquad \text{(A1.7)}$$

Appendix II - Explanation of Equation 23

Redefine $y_t = (x_t, p_t')$, thus the set of other state variables s_t is null. Rewrite (21) as follows[12]:

$$
\begin{aligned}
b_t &= \Omega_{pp}^{-1}\Omega_{py}\gamma \\
&= \Omega_{pp}^{-1}[V_{px}, \Omega_{pp}]\gamma \\
&= [\Omega_{pp}^{-1}V_{px}, I]\gamma \\
&= [\beta, I]\gamma
\end{aligned}
\qquad \text{(A2.1)}
$$

where V_{px} is the column vector of covariance between the unexpected export earnings x and the unexpected vector of prices p; I is the identity matrix; and, β is equivalent to the OLS regression coefficients of residuals of x on residuals of p' given as[13]:

$$
\begin{aligned}
x_R &= \beta' p_R \\
&= \beta_1 p_{R1} + \beta_2 p_{R2} + \ldots + \beta_n p_{Rn}
\end{aligned}
\qquad \text{(A2.2)}
$$

where x_R and $p_R = (p_{R1}, p_{R2}, \ldots, p_{Rn})'$ are the residuals from the VAR system (9), which are unexpected shocks in export earnings, commodity prices, and foreign exchange rates. Each element in the coefficient vector β indicates the amount of instantaneous hedge with commodity bonds or non-US, dollar-denominated conventional debt in response to unexpected shocks in commodity prices and foreign exchange rates. Because an unexpected change in price p_i by an amount p_{Ri} (where i is a commodity or foreign currency), results in a change in unexpected export earnings, x_R, by $\beta_i p_{Ri}$, it is possible to hedge the risk exposure of β_i amount of debt that is linked to p_i which experiences such an unexpected shock.

One can find similar formulations such as β as the parameter estimates of a simple OLS

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12 For simplicity, the superscript * has been dropped since there is no essential difference in commodity prices and foreign exchange rates in the theoretical optimal portfolio model.

13 The VAR system acts like a filter.

regression in other optimal portfolio literature[14]. However, as suggested by (A2.1), to derive the final composition of debt, β has to be adjusted by the vector of γ, which is defined in (11).

Rewrite (11) as follows:

$$R_t\left(\sum_{i=0}^{\infty}(1+r)^{-i}E_t(x_{t+i})\right)=R_t(\gamma' y_t+B(L)y_{t-1})=R_t\gamma' y_t \tag{A2.3}$$

where R_t is the "unexpected at time t" operator. $R_t\gamma' y_t$ can be further written as:[15]

$$R_t\gamma' y_t=\gamma' y_{Rt}=\gamma_x x_R+\gamma_{p1}p_{R1}+\ldots+\gamma_{pn}p_{Rn} \tag{A2.4}$$

Where $y_{Rt} = (x_{Rt}, p_{Rt})'$, and $\gamma=(\gamma_x, \gamma_{p1}, \gamma_{p2}, \ldots, \gamma_{pn})'$ which can be considered as a vector of multipliers of unexpected shocks x_R, and p_R, to the permanent income of export earnings. Thus, as given by (A2.1), the quantity of commodity bonds b_{it}, which are linked to price p_{it} is:

$$b_{it}=\gamma_x\beta_i+\gamma_{p_i} \qquad i=1,\ldots,n \tag{A2.5}$$

b_{it} has an interesting interpretation. Starting from (A2.2), the unexpected shock p_{Ri} on price p_i can be hedged instantaneously by the amount of p_i-linked debt, β_i, because of the unexpected export earnings $\beta_i p_{ri}$ on x. However, shocks p_{Ri} and $\beta_i p_{Ri}$ continue to spill over into the permanent income of export earnings through the vector of γ. Thus, according to (A2.4), the permanent income of export earnings is changed by $\gamma_x\beta_i p_{Ri}+\gamma_i p_{Ri}$. So the amount of price p_i-linked debt which can be optimally hedged against the unexpected price shock p_{Ri} is $\gamma_x\beta_i+\gamma_i$.

Some implications can be derived through a decomposition of equation (22). First, it reveals the theoretical connections between the infinite horizon/rational expectations approach to the treatment

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14 See Kroner and Claessens (1990)

15 For simplicity, subscript t has been dropped in last part of the expression.

of optimal debt portfolio analysis, and mean-variance type approaches. Second, it provides econometric guidelines and insights into the empirical estimation process. For example, equation (A2.2) can be estimated by OLS regression. However, if multicollinearity exists among price residuals p_{R1}, p_{R2}, ... , p_{Rn}, which are most likely among groups of primary commodity prices or foreign exchange rates, the efficiency of estimating instantaneous amount of debts β_1, β_2, ... , β_n would be undermined, and the result for each individual β_i could be highly unstable. Therefore, the optimal composition of the debt portfolio could vary greatly for small changes in the model's assumptions and input. On the other hand, if some prices have been dropped to avoid the collinearity, the efficiency of estimating the remaining instantaneous debt is greatly improved without greatly reducing hedging effectiveness. Third, the vector multiplier γ shows that the effect on permanent export earnings of unexpected shocks in primary commodity prices or foreign exchange rates, determines the optimal hedging strategy, not the instantaneous one. Intuitively, a positive shock in commodity price p_i will most likely bring a positive instantaneous rise in unexpected export earnings. But its effect on permanent export earnings are uncertain. It is possible for a positive shock in p_i to induce a decline in permanent export earnings (e.g., the case of "Dutch" disease). Thus the p_i-linked debt has no effectiveness in hedging permanent export earnings.

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