Shock exposure: commodity prices and the kina

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Since the kina was floated in 1994, its US dollar value has undergone substantial fluctuations. This paper estimates a model of the determinants of the kina/US dollar exchange rate using quarterly data from 1995 to 2005. The value of the kina is found to be highly dependent on the international price of Papua New Guinea's commodity exports. A 10 per cent increase in commodity prices is estimated to cause the kina to appreciate by 4 per cent immediately and by a further 6 per cent in two quarters' time. No other variable has a robust effect on the value of the kina. These results support the view that Papua New Guinea is highly vulnerable to external commodity price shocks.

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The value of the kina has played a central role in Papua New Guinea's continuing quest for macroeconomic stability. The 'hard kina' policy that provided the framework within which macroeconomic policy operated from 1976 until the kina was floated in 1994 had at its heart the belief that a stable exchange rate was necessary to maintain price stability in Papua New Guinea. Judged in terms of price stability, the policy was successful, with inflation remaining under control throughout the fixed exchange rate period. The high value of the kina that resulted has, however, been blamed for suppressing agricultural export growth and thereby reducing economic growth (NZIER 2006). After the float, depreciation of the kina was widely perceived as contributing to the series of economic crises that Papua New Guinea faced between 1994 and 2002, although the extent to which the depreciation was a cause rather than a symptom of macroeconomic problems is uncertain.[1]

Given the importance of the exchange rate in influencing macroeconomic dynamics in Papua New Guinea, understanding the factors that determine its movements is an important goal for researchers and policymakers. Conventional wisdom holds that the kina is affected primarily by real, rather than financial, developments and that commodity prices, the volume of exports and government expenditure are more important influences on its value

than the interest rate or other financial variables.[2] There has, however, been little empirical analysis testing these views. The most notable exception is Cashin, Cespedes and Sahay (2002), who find evidence of a positive, long-run impact of increases in international commodity prices on the real kina exchange rate. This finding leads the authors to label the kina a 'commodity currency'—a term applied to currencies whose value is influenced by commodity prices. This paper sheds further light on the validity of the conventional wisdom by analysing the determinants of the nominal kina exchange rate, focusing particularly on its relationship to commodity prices.

The effect of changes in commodity prices on the nominal kina/US dollar exchange rate under the floating exchange rate regime is estimated using quarterly data from 1995 to 2005. Commodity prices are measured as an export-weighted average of the real international price of Papua New Guinea's commodity exports. We find that commodity prices have a significant effect on the value of the kina. A 10 per cent increase in commodity prices is estimated to cause the kina to appreciate by approximately 4 per cent in the current quarter and by a further 6 per cent with two quarters' lag. This effect is robust across all specifications estimated and to estimations using data starting in 1998. When commodity prices are decomposed into mineral and non-mineral prices, an increase in non-mineral prices causes the kina to appreciate in the present quarter, while an increase in mineral prices causes an appreciation with two quarters' lag.

No variable other than commodity prices is found to have a robust effect on the exchange rate. There is some evidence that borrowing by the government from the domestic banking system or a decrease in interest rates in Papua New Guinea relative to the United States causes the exchange rate to depreciate, but these findings are sensitive to whether or not these variables are assumed to be stationary. Specifically, the effects are observed if the variables are assumed to be stationary, but not otherwise. We find that the value of the kina is not directly affected by the level of the money supply in Papua New Guinea relative to the United States, the Papua New Guinea fiscal deficit or the volume of commodities exported by Papua New Guinea.

The findings support the classification of the kina as a commodity currency and highlight the vulnerability of Papua New Guinea's economy to external shocks—a vulnerability that raises the question of whether external developments or domestic economic policies are more important in shaping Papua New Guinea's macroeconomic outcomes. Understanding the balance of and interplay between these two influences should be a central objective of policymakers in Papua New Guinea.

A comparison of this paper's results with those of Cashin et al. (2002), who studied the relationship between commodity prices and the real kina exchange rate, and Sampson et al. (2006), who estimated the effect of nominal exchange rate movements on inflation in Papua New Guinea, shows that after a commodity price shock nominal exchange rate movements cause the real exchange rate to overshoot its long-run response. The nominal exchange rate movements, however, induce variations in inflation which return the real exchange rate to its long-run level. This behaviour raises the possibility that the Bank of Papua New Guinea might be able to reduce volatility in domestic prices and the nominal exchange rate by intervening in the foreign exchange market to smooth the adjustment of the real exchange rate to commodity price shocks. A full analysis, however, of the costs and benefits such a policy would entail lies beyond the scope of the present work.

The remainder of this paper is organised as follows. The next section offers some background on the kina and reviews previous literature on determinants of the exchange rate in Papua New Guinea and in other small, open, commodity-dependent economies. The model to be estimated is then described and motivated, followed by a discussion of the data and the estimation methodology. Next, follow two sections presenting the empirical findings: first, using an aggregate commodity price variable, and; second, when commodity prices are decomposed into mineral and non-mineral prices. The final section concludes with a discussion of some policy questions this paper raises and suggestions for future research.

The floating kina

The fixed exchange rate or 'hard kina' policy, adopted when the kina became an independent currency on 1 January 1976, came to an end when the Bank of Papua New Guinea floated the kina on 10 October 1994. Since then, the kina/US dollar exchange rate has been determined by trading between banks (including, at times, the Bank of Papua New Guinea) in the inter-bank foreign exchange market. The exchange rate of the kina with currencies other than the US dollar is then calculated by crossing the kina/US dollar exchange rate with the US dollar exchange rate of those currencies.

Much has been written about the merits, or otherwise, of the hard kina policy and the reasons why it had to be abandoned. The prescient analysis of Garnaut and Baxter (1983) remains the standard reference for understanding the conditions necessary for the policy to succeed. Garnaut (1995) and Chand and Stewart (1997) discuss the causes of its demise, focusing on the fiscal deficits of the early 1990s.

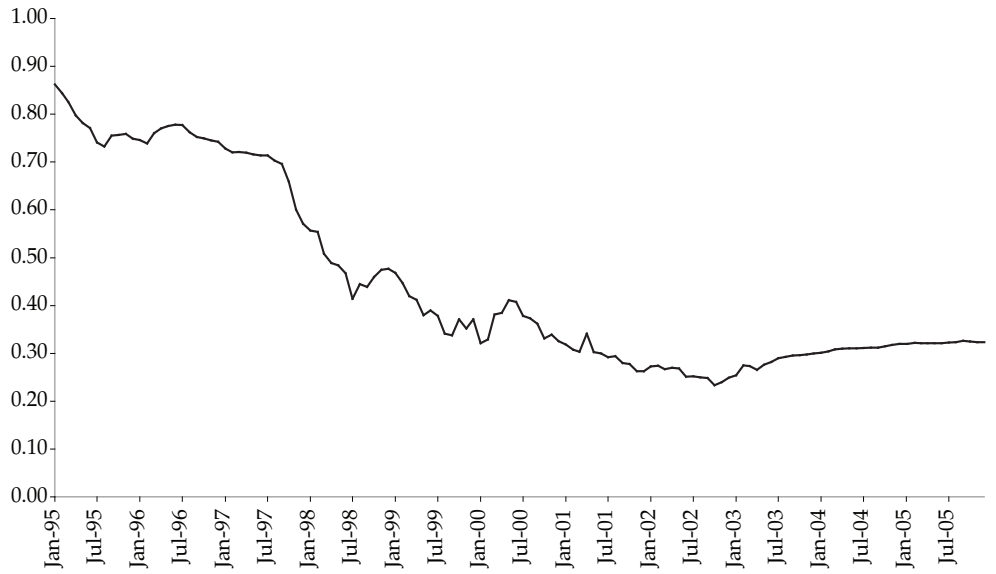
There is also a substantial literature devoted to discussing whether the kina should remain a floating currency. King and Sugden (1997) favour a freely floating kina on the grounds that a fixed exchange rate could damage the competitiveness of Papua New Guinea's exports by preventing any depreciation of the kina. Duncan and Xu (2000), however, argue that Papua New Guinea should adopt the Australian dollar to reduce the scope for monetary policy mismanagement by the Government of Papua New Guinea. They further argue that Australia and Papua New Guinea constitute an optimal currency area, based on evidence in Xu (1999) that the two countries suffer from common shocks. de Brouwer (2000), who endorses the idea, reviews the arguments for and against Pacific island countries, including Papua New Guinea, adopting the Australian dollar. In contrast, Bowman (2004) suggests that Pacific island countries should consider replacing their national currencies with the US dollar because their exchange rates are more strongly correlated with the value of the US dollar than with the Australian dollar and the importance of Australia as a trading partner for Pacific island countries is declining.

This paper differs from the literature on the optimal choice of exchange rate regime for Papua New Guinea by taking the floating exchange rate as given and investigating empirically the causes of changes in the value of the kina. The kina/US dollar exchange rate from 1995 to 2005 is considered (Figure 1). The most striking features of the graph are the downward trend in the kina until late 2002 and the appreciation of the kina thereafter. Between the end of 1994 and October 2002, the kina depreciated by 72 per cent from US$0.85 to US$0.23, but by the end of 2005 the kina had appreciated back to US$0.32.

Even during the period when the kina was trending downwards, however, its behaviour varied greatly. After a sharp decline in the first six months of 1995, the kina remained broadly stable until the second half of 1997, when it began a rapid depreciation that took it from US$0.70 in September 1997 to US$0.41 in July 1998. The kina then appreciated slightly to end 1998 at US$0.48, before beginning the gradual depreciation that, although punctuated by occasional periods of appreciation, continued until late 2002. It would be a mistake, therefore, to view Figure 1 as showing simply a depreciation followed by an appreciation. The dynamics of the changes in the value of the kina are much richer than this simple characterisation suggests. What is the explanation for these changes?

There is a substantial body of work showing that positive terms-of-trade shocks cause exchange rate appreciations in small, open, primary commodity-dependent economies. Gruen and Wilkinson (1994) and Gruen and Kortian (1996) find a link between the terms of trade and the real Australian dollar/US dollar exchange rate. Chen and Rogoff (2003) present evidence that in Australia, Canada and New Zealand the price of commodity exports has a significant influence on the real US dollar exchange rate, while Chen (2004) finds a strong effect of commodity prices on the nominal exchange rates of Australia and New Zealand, but not of Canada. Cashin et al. (2002) consider a sample of 58 primary commodity-dependent countries including Papua New Guinea and, for each country, test whether there is a long-run relationship

Figure 1 **Kina/US dollar exchange rate, 1995-2005**



Source: Bank of Papua New Guinea

between the real international price of its commodity exports and its real effective exchange rate. Using monthly data from 1980 to 2002, they find evidence of a co-integrating relationship for 22 of the countries. For Papua New Guinea, they find not only evidence of co-integration between commodity prices and the real exchange rate but that causality runs from commodity prices to the exchange rate. Their estimates imply that a 10 per cent increase in commodity prices leads to a 4 per cent long-run appreciation of the real kina exchange rate.

Other work on exchange rate determinants in Papua New Guinea has also focused on the real exchange rate; perhaps because it may vary even if the nominal exchange rate is fixed and, until recently, insufficient time has passed since the float to permit a detailed analysis of the determinants of the post-float kina. Chowdhury (1999) estimates a real exchange rate model using annual data from 1970 to 1994, but his findings lack robustness across alternative definitions of the real exchange rate and the small size of the data set (25 observations) means his results should be interpreted with caution. Duncan et al. (1998:65) argue, based on 1983–96 data, that 'market forces consistent with purchasing power parity (PPP) operate in Papua New Guinea'. The authors also claim that there is a link between fiscal policy and the exchange rate in Papua New Guinea, but they fail to provide rigorous empirical evidence in support of this assertion.

In contrast to these studies this paper considers the nominal exchange rate. It estimates the causes of movements in the nominal kina/US dollar exchange rate from 1995 to 2005. Only the US dollar exchange rate is considered because, as explained above, the exchange rate of the kina with currencies other than the US dollar is partially determined by developments in international currency markets. For instance, a depreciation of the kina against the Australian dollar could be caused either by a depreciation of the kina against the US dollar or an appreciation of the Australian dollar against the US dollar (or a combination of the two). Working only with the US dollar exchange rate avoids the need to model behaviour in foreign exchange markets outside Papua New Guinea.[3]

Exchange rate models

Despite the vast amount of work undertaken on the economics of exchange rates during the past 30 years, and the multitude of competing models that have been postulated, no consensus has emerged on how to explain the behaviour of exchange rates. Instead, the success of different models has varied greatly across time and currency pairs, and in-sample fit has not been matched by forecasting success (Meese and Rogoff 1983; Cheung et al. 2005). Against this backdrop, this paper does not attempt estimation of a theoretically based exchange rate model, preferring instead to estimate a reduced-form equation formed as a combination of variables selected either for their prominence in the exchange rate literature or because they are often cited as important influences on the value of the kina.[4]

Motivated by the empirical success of the terms of trade in explaining the exchange rate in other small, open, primary commodity-dependent economies, and by the findings of Cashin et al. (2002) discussed above, the primary focus of this paper is on the relationship between commodity prices and the exchange rate. Following Chen and Rogoff (2003), Chen (2004) and Cashin et al. (2002), the international price of commodity exports is used as an explanatory variable in preference to the terms of trade. This has

two advantages. First, the terms of trade are likely to be endogenous to the exchange rate so that their inclusion could result in inconsistent parameter estimates, whereas, being a price taker on world markets is the defining characteristic of a small economy. Second, there is no import price index available to calculate the terms of trade for Papua New Guinea.

To fix ideas concerning the theoretical relationship between the terms of trade and the nominal exchange rate, consider the following 'sticky-price' variant of the exchange rate model presented in Cashin et al. (2002). The world consists of two economies: home and foreign. Home is a small, open economy that produces two goods: a primary commodity and a non-tradable good. The primary commodity can be traded without cost across countries. Both goods are produced under perfect competition using constant returns-to-scale technologies with labour as the only factor of production. Let y_C be home production of the primary commodity. Then:

$$y_C = a_C L_C \tag{1}$$

in which L_C is labour used in commodity production and a_C measures labour productivity in the commodity sector. Similarly, if y_N is home non-tradable production, then:

$$y_N = a_N L_N. \tag{2}$$

Labour is assumed to be perfectly mobile across sectors within a country, but immobile across countries. Using Equations 1 and 2, producer profit maximisation together with equalisation of wages across sectors requires:

$$p_N = \frac{a_C}{a_N} p_C \tag{3}$$

in which pJ, $J=I$ and C denotes the price of good J. Now let S denote the exchange rate, written as the foreign currency price of the home currency so that an increase in S denotes an appreciation of the home currency. Free trade in the primary commodity ensures:

$$p_C^* = p_C S. \tag{4}$$

Combining Equations 3 and 4 then gives

$$S = \frac{a_C}{a_N} \frac{p_C^*}{p_N}. \tag{5}$$

Under the assumption that the price of the non-tradable good is 'sticky'—meaning that it does not respond to changes in the foreign price of the primary commodity—it follows that a rise in international commodity prices must lead to an appreciation of the home nominal exchange rate to ensure that the law of one price given in Equation 4 always holds. Note that no assumptions about the structure of the foreign economy or the nature of consumer demand are required to obtain this result. Moreover, even if non-tradable goods prices are not sticky, an analogous relation between the foreign price of the primary commodity and the real exchange rate can still be derived.[5]

In addition to commodity prices, the baseline equation estimated below will also include as explanatory variables the inter-country interest rate differential and a fiscal variable. The interest rate differential

is at the heart of asset pricing-based exchange rate models that make use of the uncovered interest parity condition.[6] With capital mobility between countries, a rise in the domestic interest rate is expected to lead to an inflow of capital and cause the domestic currency to appreciate. If foreign and domestic assets are perfect substitutes, the domestic currency will appreciate to the point where the difference between foreign and domestic interest rates is exactly offset by expected future exchange rate movements. The sensitivity of the kina exchange rate to interest rates is an important factor that the Bank of Papua New Guinea should consider when assessing the impact of changes in monetary policy. On the fiscal side, Garnaut (1995) and Chand and Stewart (1997) argued that a loss of fiscal control in the early 1990s was the principal reason why the hard kina policy had to be abandoned. Subsequent depreciations of the kina have also been linked informally to fiscal deficits.

Therefore, the baseline equation used in this paper is:

$$s_t = \alpha + \beta_0 t + \beta_1 (i_t - i_t^*) + \beta_2 g_t + B(L)z_t + \varepsilon_t \quad (6)$$

in which s is the logarithm of the nominal kina/US dollar exchange rate, i is the nominal interest rate in Papua New Guinea, i* is the nominal interest rate in the United States, g is a measure of the fiscal position of the PNG government, z is the logarithm of the real US dollar price of Papua New Guinea's commodity exports, B(L) is a polynomial in the lag operator, ε is an error term and t indexes the period.

Data and estimation methodology

The model is estimated using quarterly data from the first quarter (Q1) of 1995 to the fourth quarter (Q4) of 2005. Full details of the definition and source of each of the variables used are given in the Appendix.

Commodity prices are measured using an index of the real international price of Papua New Guinea's commodity exports. To construct the commodity price variable, the international US dollar price of each of Papua New Guinea's 11 largest commodity exports is deflated using the US Consumer Price Index (CPI) to obtain real prices. The geometrically weighted average of the real international prices is then calculated. The weight given to each commodity is the average of its annual shares from 1995 to 2004 of the value of Papua New Guinea's exports of the 11 commodities.[7] Weights are given to each of the commodities (Table 1).

The fiscal position is measured in two ways: first, by the net credit to government from the banking system as a percentage of gross domestic product (GDP). Net credit to government measures the stock of government borrowing from commercial banks and the Bank of Papua New Guinea. It is a determinant of broad money, M3, and changes in net credit to government measure the extent to which financing of the fiscal deficit leads to money creation. Second, the fiscal position is measured by the fiscal deficit as a percentage of GDP. The fiscal deficit differs from changes to net credit to government because of government borrowing from the non-bank private sector and from foreign sources.

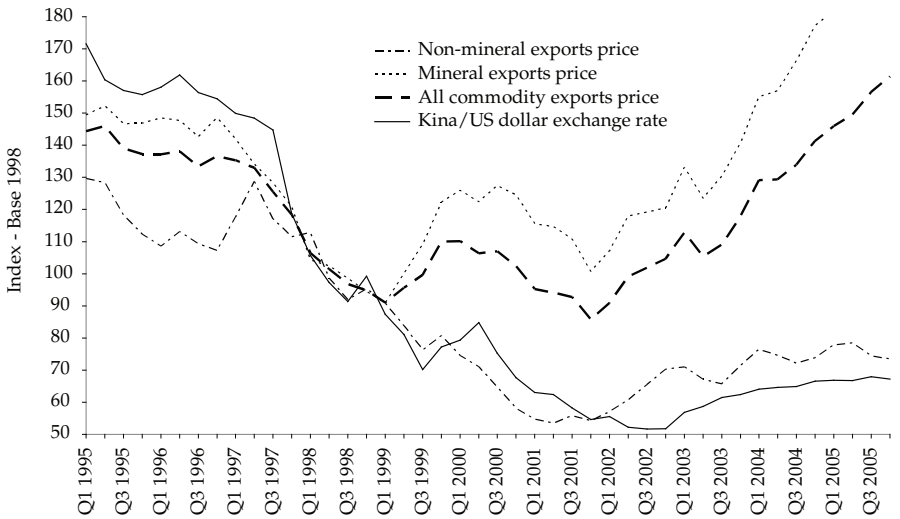
Interest rates are measured as the nominal interest rate per annum on six-month government securities. The exchange rate is the kina/US dollar exchange rate. An increase in the exchange rate corresponds

Table 1 **Commodity price index weights**

Commodity	Weight (%)
Cocoa	2.4
Coffee	6.7
Tea	0.3
Copra	0.8
Copra oil	1.2
Palm oil	5.9
Rubber	0.1
Forest products	8.3
Crude oil	27.1
Gold	32.3
Copper	14.8
Non-mineral (aggregate)	**25.8**
Mineral (aggregate)	**74.2**

Notes: Each commodity's weight is given by the average of its annual shares from 1995 to 2004 of Papua New Guinea's exports of the 11 commodities shown. The export volume index is also constructed using these weights.
Source: Authors' calculations.

Figure 2 **Commodity prices and the exchange rate, 1995 Q1– 2005 Q3**



Source: Authors' calculations.

to an appreciation of the kina. Net credit to government, the exchange rate and the interest rates are end-of-quarter values.

Estimating Equation 6 in the form given above will lead to spurious regression results if any of the included variables are non-stationary. It is possible to test for stationarity using unit root tests. The augmented Dickey-Fuller test indicates that the exchange rate, commodity prices, the interest rate differential and net credit to government are I(1) processes, while the fiscal deficit is I(0). As Chen and Rogoff (2003) argue, however, the low power of existing unit root tests means that testing for stationarity using fewer than 100 observations is not meaningful. The data set used in this paper contains only 44 observations. Therefore, to avoid any risk of spurious inference, the first differences of all variables are used. The baseline specification is:

$$\Delta s_t = \beta_0 + \beta_1 \Delta(i_t - i_t^*) + \beta_2 \Delta g_t + B(L)\Delta z_t + u_t \quad (7)$$

in which $u_t = \varepsilon_t - \varepsilon_t\text{-}1$. To test the robustness of the results to the alternative hypothesis that the interest rate differential and the fiscal variables are I(0), the model is also estimated with these variables in levels.

The model is estimated by ordinary least squares (OLS) and by two-stage least squares (2SLS). In the 2SLS estimations, the interest rate differential and the fiscal variables are treated as endogenous and their lagged values are used as instruments.

Empirical results

Visual inspection of movements in commodity prices and the kina exchange rate during the 1995–2005 sample period suggests a correlation between the two (Figure 2). Does this relationship survive more rigorous empirical scrutiny? When Equation 7 is estimated by OLS, with the price of Papua New Guinea's commodity exports as the only independent variable, commodity prices have a highly significant effect on the exchange rate (Table 2: column a). If four lags of commodity prices are included, a 1 per cent increase in commodity prices in a given quarter is estimated to cause a 0.47 per cent appreciation of the exchange rate in that quarter and a further 0.58 per cent appreciation in two quarters' time. The other lags of the commodity price variable are insignificant. The finding that changes in commodity prices affect the exchange rate in the current quarter and with two quarters' lag, but not at other lags, is robust to varying the number of lags included and to controlling for a range of additional independent variables. From this point on, only the results obtained from estimating the model including just the first two lags are reported.

The link between commodity prices and the exchange rate could result from omitted variable bias if commodity prices are correlated with other variables that affect the value of the kina. Including the first differences of the interest rate differential and net credit to government in the estimation does not substantially affect the estimated impact of changes in commodity prices and neither the interest rate differential nor net credit to government is significant (Table 2: column b). Similar results are obtained when the fiscal deficit is used instead of net credit to government (Table 2: column c).

The evidence presented above indicates that commodity prices are a significant determinant of the kina/US dollar exchange rate. Do exogenous shocks to the supply of export commodities also affect the exchange rate? The most substantial supply shock during the sample period was the

Table 2 **OLS estimation results with the interest rate differential and net credit to government in first differences**

	(a)		(b)	(c)	(d)	(e)	(f)
Δ Commodity price	0.47[c] (0.11)	Δ Commodity price	0.43[c] (0.10)	0.43[c] (0.10)	0.41[c] (0.12)	0.34[c] (0.12)	0.41[c] (0.11)
Δ Commodity price (lag 1)	0.016 (0.17)	Δ Commodity price (lag 1)	–0.049 (0.16)	0.022 (0.16)	–0.017 (0.15)	–0.039 (0.14)	–0.030 (0.17)
Δ Commodity price (lag 2)	0.58[b] (0.21)	Δ Commodity price (lag 2)	0.53[b] (0.20)	0.50[b] (0.19)	0.56[c] (0.19)	0.52[b] (0.20)	0.63[b] (0.23)
Δ Commodity price (lag 3)	–0.11 (0.22)	Δ Interest rate differential	–0.20 (0.38)	–0.11 (0.36)	–0.098 (0.39)	–0.073 (0.35)	0.41 (0.25)
Δ Commodity price (lag 4)	0.065 (0.20)	Δ Net credit to government	–0.51 (0.62)		–0.38 (0.61)	–0.32 (0.55)	0.26 (0.41)
		Δ Fiscal deficit		–0.051 (0.092)			
		Southern Oscillation Index			0.00097 (0.00087)		
		Ok Tedi closed				–0.050[a] (0.027)	
Constant	–0.025[c] (0.0063)	Constant	–0.024[c] (0.0072)	–0.023[c] (0.0067)	–0.022[c] (0.0079)	–0.019[b] (0.0078)	–0.022 (0.00980
R^2	0.39		0.38	0.37	0.39	0.41	0.36
N	39		41	41	41	41	29
Sample	1995 Q1–2005 Q4		1995 Q1–2005 Q4	1995 Q1–2005 Q4	1995 Q1–2005 Q4	1995 Q1–2005 Q4	1998 Q1–2005 Q4

[a] significant at the 10 per cent level
[b] significant at the 5 per cent level
[c] significant at the 1 per cent level

Notes: The dependent variable is the first difference of the kina/US dollar exchange rate. Newey-West heteroscedasticity and autocorrelation consistent standard errors are in parentheses.
Source: Authors'calculations.

El Niño-induced drought of 1997–98. The drought led to low water levels in the Fly River, which forced the temporary closure of the Ok Tedi mine, Papua New Guinea's largest source of export revenue. In column d (Table 2), Equation 7 is estimated including the Southern Oscillation Index[8] as an independent variable. The Southern Oscillation Index variable is insignificant and its inclusion has negligible impact on the estimated coefficients of the other variables. Column e (Table 2) includes a dummy variable for those quarters when Ok Tedi was closed at the start of the quarter due to the drought.[9] The Ok Tedi dummy has a negative coefficient with a p-value of 0.07, while the effects of other variables are similar to before. The results suggest that during each quarter in which Ok Tedi was closed, the kina/US dollar exchange rate depreciated by 5 per cent more than it would otherwise have done.

Estimating Equation 2 with a sample starting in the first quarter of 1998 makes little difference to the results (Table 2: column f). Net credit to government and the interest rate differential remain insignificant and the estimated commodity price effects are similar to before. This confirms that the results were not driven by events immediately after the float in 1995–97, during which the kina suffered a substantial depreciation (Figure 1).

The results obtained from estimating the model under the plausible alternative assumption that the interest rate differential and fiscal variables are stationary are reported (Table 3). The commodity price effects are broadly unchanged, but the interest rate differential and net credit to government are now significant (Table 3 column a). A 1 percentage point increase in the interest rate differential is linked to a 0.31 per cent appreciation of the kina, while a 1 percentage point increase in the ratio of net credit to government to GDP is associated with a 1.1 per cent depreciation of the kina.

As net credit to government is one of the determinants of broad money, M3, this finding is suggestive of a possible link between the money supply and the exchange rate. When the broad money supply differential is included, however, instead of net credit to government, it is insignificant, while the coefficients of other variables are unaffected (column b). The money supply differential remains insignificant if its first difference is used, if net credit to government is not included in the estimation or if it is defined using M1 instead of M3. When the Ok Tedi dummy is included, it is no longer significant, but the other results are similar (column c). If the fiscal deficit is included in place of net credit to government, not only is it insignificant, the interest rate differential ceases to be significant (column d).

The results in Table 3 show that the estimated effect of commodity prices on the exchange rate is robust to alternative assumptions regarding the data-generating processes for the interest rate differential and the fiscal variables. They also provide some evidence of correlation between the interest rate differential and net credit to government and the exchange rate, conditional on the assumption that the two explanatory variables are stationary. If this assumption is valid, these findings support the view that net credit to government—and not the fiscal deficit—is the variable to focus on when analysing the effect of fiscal behaviour on the exchange rate in Papua New Guinea.

The next scenario considered is whether the estimation results are biased because of endogeneity of the independent variables. Although international commodity prices are exogenous to Papua New Guinea, the interest rate differential and the fiscal variables can be affected by changes in

Table 3 **OLS estimation results with the interest rate differential and net credit to government in levels**

	(a)	(b)	(c)	(d)
Δ Commodity price	0.44[c]	0.46[c]	0.37[c]	0.43[c]
	(0.11)	(0.12)	(0.13)	(0.11)
Δ Commodity price (lag 1)	–0.023	–0.012	–0.036	0.073
	(0.15)	(0.17)	(0.15)	(0.17)
Δ Commodity price (lag 2)	0.55[c]	0.58[c]	0.54[c]	0.52[c]
	(0.17)	(0.19)	(0.18)	(0.16)
Interest rate differential	0.31[b]	0.35[a]	0.27[b]	0.19
	(0.14)	(0.18)	(0.13)	(0.12)
Net credit to government	–1.1[a]	–1.3[a]	–1.0[a]	
	(0.56)	(0.72)	(0.59)	
Broad money supply differential		0.044		
		(0.075)		
Ok Tedi closed			–0.038	
			(0.024)	
Fiscal deficit				–0.17
				(0.16)
Constant	0.054	0.10	0.051	–0.040[c]
	(0.048)	(0.11)	(0.052)	(0.012)
R^2	0.45	0.46	0.47	0.40
N	41	41	41	41

[a] significant at the 10 per cent level
[b] significant at the 5 per cent level
[c] significant at the 1 per cent level

Notes: The dependent variable is the first difference of the kina/US dollar exchange rate. Newey-West heteroscedasticity and autocorrelation consistent standard errors are in parentheses. Sample: 1995 Q1 to 2005 Q4.
Source: Authors' calculations

the exchange rate.[10] To investigate this possibility, the model is estimated by 2SLS using as instruments the first lag of the interest rate differential and net credit to government, which are assumed not to affect the current period exchange rate directly. A necessary condition for the lagged variables to be valid instruments is that the error terms are serially uncorrelated. When the heteroscedasticity robust version of Durbin's alternative test is applied to the residuals from the equations estimated above, evidence of negative third-order serial correlation is found. The null hypothesis, however, of no serial correlation is accepted if the first three lag differences of the exchange rate are included as regressors and, consequently, they are used as independent variables in the 2SLS regressions.[11]

Table 4 shows the results from 2SLS estimation with the interest rate differential and net credit to government in levels. Panel B shows the first-stage regression results, which indicate that the lagged values are strong instruments for the endogenous variables.

In the 2SLS results (panel A), commodity prices are significant in the current quarter and with two quarters' lag and the estimated elasticities of 0.48 and 0.67, respectively, are slightly higher than the elasticities estimated using OLS. The estimated impacts of the interest rate differential and net credit to government are approximately twice as large as in the OLS results; however, their estimated standard errors have increased by similar proportions and, consequently, the interest rate differential is not significant and net credit to government is only marginally significant. When a test for endogeneity of the interest rate differential and net credit to government is performed the null hypothesis that they are exogenous is accepted (panel A).

Estimating alternative specifications of Equation 7 using 2SLS gives results that are broadly similar to those shown in Tables 2 and 3, but with larger standard errors. There is strong evidence of an effect of current and twice-lagged commodity prices on the exchange rate and some evidence that net credit to government affects the exchange rate when in level form. The interest rate differential, the fiscal deficit and the money supply differential variables are never significant. Overall, the 2SLS results are consistent with the OLS results.

Mineral and non-mineral prices

An unexpected implication of the results above is that commodity prices affect the value of the kina in the current quarter and with two quarters' lag, but not with a one-quarter lag. This section attempts to explain this phenomenon by analysing the differing impacts of mineral and non-mineral commodity prices on the exchange rate.

The commodity price index is a weighted average of mineral and non-mineral price indices, in which the mineral price index has a weight of 0.742 and the non-mineral price index has a weight of 0.258 (Table 1). Therefore, the use of a single composite commodity price index assumes that changes in mineral prices have a 2.9 times (2.9 = 0.742/0.258) larger effect on the kina/US dollar exchange rate than changes in non-mineral prices and that changes in mineral and non-mineral prices affect the exchange rate at the same lags.

The share of minerals in Papua New Guinea's commodity exports could, however, overstate the importance of mineral exports relative to non-mineral commodity exports in the Papua New Guinea foreign exchange market. Bank of Papua New Guinea data on the foreign exchange market show that

Table 4 **Two-stage least squares estimation results**

	Panel A: 2SLS results
Δ Commodity price	0.48[b]
	(0.19)
Δ Commodity price (lag 1)	–0.11
	(0.20)
Δ Commodity price (lag 2)	0.67[c]
	(0.20)
Interest rate differential	0.52
	(0.32)
Net credit to government	–2.4[a]
	(1.3)
Δ Exchange rate (lag 1)	0.037
	(0.13)
Δ Exchange rate (lag 2)	–0.12
	(0.11)
Δ Exchange rate (lag 3)	–0.25[b]
	(0.12)
Constant	0.16
	(0.099)
Endogenous regressors	No
(p-value)	(0.27)
N	40

	Panel B: first-stage regressions	
Dependent variable	Interest rate differential	Net credit to government
Δ Commodity price	–0.048	–0.020
	(0.10)	(0.046)
Δ Commodity price (lag 1)	–0.061	–0.084
	(0.10)	(0.063)
Δ Commodity price (lag 2)	–0.060	0.032
	(0.094)	(0.044)
Interest rate differential (lag 1)	0.79[c]	0.076
	(0.085)	(0.051)
Net credit to government (lag 1)	0.58b	0.55[c]
	(0.27)	(0.17)
Δ Exchange rate (lag 1)	–0.071	–0.0061
	(0.067)	(0.054)
Δ Exchange rate (lag 2)	0.024	–0.029
	(0.069)	(0.031)
Δ Exchange rate (lag 3)	–0.088	0.030
	(0.071)	(0.032)
Constant	–0.041[a]	0.036[b]
	(0.024)	(0.015)
Under identified (p-value)	No	No
	(0.00)	(0.00)
R^2	0.84	0.54
N	40	40

[a] significant at the 10 per cent level
[b] significant at the 5 per cent level
[c] significant at the 1 per cent level

Notes: The dependent variable in the second stage is the first difference of the kina/US dollar exchange rate. Heteroscedasticity robust standard errors are in parentheses. Sample: 1995 Q1 to 2005 Q4. 'Endogenous regressors' reports the results of a robust test, based on Sargan-Hansen statistics, of the null hypothesis that the interest rate differential and net credit to government are exogenous. 'Under identified' reports the results of a robust F-test of the joint significance of the two instrumental variables: the lagged interest rate differential and lagged net credit to government.

Source: Authors' calculations.

from 2003 to 2005, on average, 74 per cent of foreign exchange inflows were from the commodity export sector. Of these, 56 per cent were from the mineral export sector and 44 per cent from the non-mineral commodity export sector. Thus, foreign exchange inflows from the mineral sector were only 1.3 times larger than those from the non-mineral commodity export sector. The discrepancy between this number and the 2.9 times difference in export shares probably results from the widespread use by mineral-sector companies of offshore foreign currency accounts to store export receipts. In 2003 and 2004, the kina value of mineral exports was more than twice as large as the kina value of foreign exchange inflows from the mineral sector. In comparison, the difference between the kina value of non-mineral commodity exports and foreign exchange inflows from the non-mineral commodity export sector was less than 10 per cent.

In addition, if the form of export contracts differs across sectors there could be a corresponding difference in the responsiveness of the exchange rate to price movements. For instance, widespread use of forward contracts might be expected to dampen and slow the effect of price changes on the exchange rate.

To test the relative sensitivity of the exchange rate to mineral and non-mineral price movements, Equation 8 is estimated:

$$\Delta s_t = \beta_0 + \beta_1 (i_t - i_t^*) + \beta_2 g_t + C(L) \Delta x_t + D(L)\Delta v_t + \varepsilon_t \quad (8)$$

in which x is the logarithm of the real US dollar denominated price of Papua New Guinea's non-mineral commodity exports, v is the logarithm of the real US dollar denominated price of Papua New Guinea's mineral exports and C(L) and D(L) are lag polynomials.

The results from estimating Equation 8 including two lags of both commodity price variables are shown (Table 5). The non-mineral price has a significant impact only on the exchange rate for the current quarter, while the mineral price variable is marginally significant for the current quarter, but highly significant when lagged twice. Otherwise, the results are consistent with those in Tables 2–4 and are similar for OLS (column a) and 2SLS (column b) estimations. Including higher lags of the commodity price variables, or using the interest rate and net credit to government in first difference form, does not change these findings. Therefore, the puzzling timing of the effect of commodity price changes on the exchange rate is a consequence of non-mineral prices affecting the exchange rate immediately, while mineral prices affect the exchange rate most strongly at two quarters' lag.

The elasticity of the exchange rate with respect to mineral prices is estimated to be greater than the elasticity with respect to non-mineral prices. The coefficients, however, are not estimated with sufficient precision to reject either the hypothesis that current-period non-mineral prices and twice-lagged mineral prices have the same impact on the exchange rate, or the hypothesis that the mineral prices effect is 2.9 times larger. The question of whether the relative export shares are an accurate indicator of the relative impact of mineral and non-mineral prices on the exchange rate therefore remains unresolved.

The strong effect of commodity prices on the exchange rate raises the question of whether a change in the volume of commodity exports has a similar effect. To test this possibility, a commodity exports volume variable was constructed using the same weights and methodology used

Table 5 **Estimation results including separate mineral and non-mineral export prices and volume of commodity exports**

	(a)	(b)		(c)	(d)
Estimation method	OLS	2SLS		OLS	2SLS
Δ Non-mineral price	0.33[a]	0.28[a]	Δ Commodity price	0.35[c]	0.30
	(0.18)	(0.14)		(0.12)	(0.36)
Δ Non-mineral price (lag 1)	–0.00064	–0.037	Δ Commodity price (lag 1)	0.032	–0.043
	(0.16)	(0.19)		(0.16)	(0.26)
Δ Non-mineral price (lag 2)	0.043	0.074	Δ Commodity price (lag 2)	0.58[c]	0.70[c]
	(0.15)	(0.19)		(0.17)	(0.25)
Δ Mineral price	0.24	0.30[a]	Interest rate differential	0.31[b]	0.58
	(0.15)	(0.16)		(0.13)	(0.41)
Δ Mineral price (lag 1)	–0.053	–0.093	Net credit to government	–1.2[b]	–3.0[a]
	(0.12)	(0.14)		(0.52)	(1.8)
Δ Mineral price (lag 2)	0.49[c]	0.53[c]	Δ Commodity volume	0.12[a]	0.23
	(0.14)	(0.16)		(0.061)	(0.34)
Interest rate differential	0.31[a]	0.43			
	(0.16)	(0.26)			
Net credit to government	–0.91	–1.8[a]			
	(0.56)	(1.1)			
Constant	0.036	0.11	Constant	0.063	0.20
	(0.047)	(0.086)		(0.046)	(0.14)
R^2	0.52		R^2	0.49	
N	41	40	N	41	40
Endogenous regressors (p-value)		No (0.31)	Endogenous regressors (p-value)		No (0.29)

[a] significant at the 10 per cent level
[b] significant at the 5 per cent level
[c] significant at the 1 per cent level

Notes: The dependent variable is the first difference of the kina/US dollar exchange rate. OLS estimates have Newey-West heteroscedasticity and autocorrelation consistent standard errors in parentheses. 2SLS estimates have heteroscedasticity robust standard errors in parentheses. The 2SLS regressions in columns b and d include the first three lags of the dependent variable as additional regressors. In columns b and d, the interest rate differential and net credit to government are treated as endogenous and their lagged values are used as instruments. In column d, ΔCommodity volume is also treated as endogenous and its lagged value is used as an instrument. Sample: 1995 Q1 to 2005 Q4. 'Endogenous regressors' reports the results of a robust test, based on Sargan-Hansen statistics, of the null hypothesis that the instrumented variables are exogenous.
Source: Authors' calculations.

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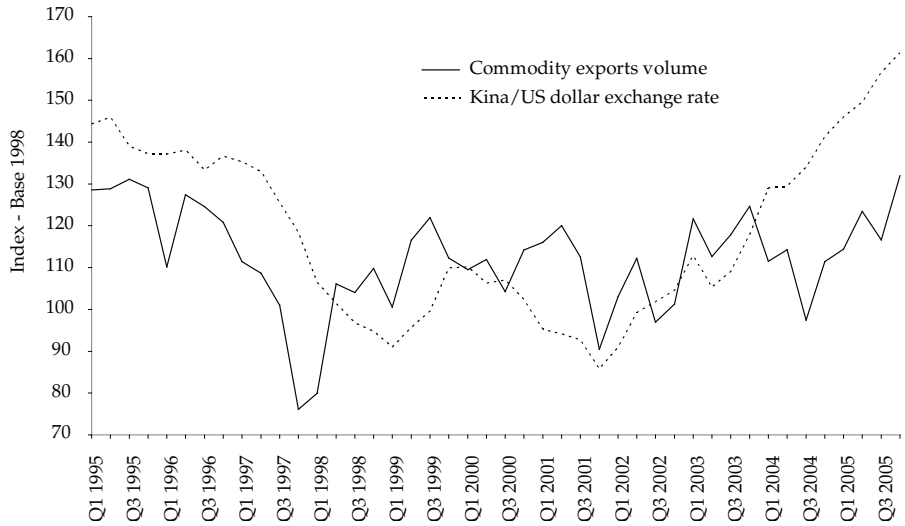
to compute the commodity price variable (Figure 3). When the model is estimated by OLS with the first difference of the logarithm of commodity volume as an explanatory variable, the estimated effects of other variables are unchanged and commodity volume is positive and significant (Table 5: column c). The volume of exports is, however, likely to be endogenous to the exchange rate. For example, a depreciation of the exchange rate will, *ceteris paribus*, raise the kina price of exports, which could lead to higher export volumes if producers supply more at the higher price, or lower export volumes if producers expect the depreciation to continue and consequently hold back supplies. When the equation is re-estimated by 2SLS—using lagged values as instruments for commodity exports volume, the interest rate differential and net credit to government—commodity volume is no longer significant (column d) and the first-stage results show that an increase in commodity prices causes higher commodity export volumes. Therefore, there is little empirical support for the idea that the volume of exports affects the exchange rate.

Conclusion

This analysis provides further evidence supporting the view that the kina is a commodity currency—a finding with important implications for how macroeconomic developments in Papua New Guinea should be understood and for policymaking in the country.

The dependence of the exchange rate on commodity prices highlights the vulnerability of the Papua New Guinea economy to external shocks—a vulnerability that is heightened by the positive impact of commodity prices on government tax

Figure 3 **Commodity exports volume and the exchange rate, 1995Q1–2005Q3**



Source: Authors' calculations.

revenues and export earnings. This exposure raises a number of issues worthy of further consideration. First, the Somare government and the Bank of Papua New Guinea have frequently been credited with restoring macroeconomic stability after the 2002 election. An alternative hypothesis would be that they have simply been the beneficiaries of a fortuitous rise in commodity prices. Between the end of 1999 and the end of 2001, the price of Papua New Guinea's commodity exports fell 22 per cent and the kina depreciated by 29 per cent against the US dollar. In the next four years, commodity prices rose by 88 per cent and the kina appreciated by 23 per cent. Understanding better the relative roles of macroeconomic policy and external shocks in shaping Papua New Guinea's macroeconomic behaviour is an important area for future work.

Second, is the current level of commodity price vulnerability desirable and, if not, what steps can be taken to reduce it? Answering this question will require an assessment of the optimal trade-off between exploiting Papua New Guinea's comparative advantage by promoting primary commodity exports and reducing exposure to external shocks by seeking a more diversified economic base. It is also likely that there is heterogeneity in costs and benefits across commodities. Desirable characteristics include: low price volatility; facilitating technology diffusion into Papua New Guinea and the establishment of domestic upstream and downstream industries; and high levels of job creation.

Understanding the behaviour of the exchange rate is also an essential part of the Bank of Papua New Guinea's quest for price stability. For instance, the *Monetary Policy Statement January 2005* (Bank of Papua New Guinea 2005:2) says, 'Maintaining price stability in a small open economy like Papua New Guinea requires amongst other things, relative stability in the exchange rate.' Sampson et al. (2006) document the close relationship between the exchange rate and inflation in Papua New Guinea, suggesting that this view is well founded. Therefore, the results above imply that movements in commodity prices, through their effect on the exchange rate, have the potential to disrupt price stability and that commodity prices should be an important factor influencing the Bank of Papua New Guinea's monetary policy decisions. If movements in commodity prices are judged to pose a threat to price stability, an offsetting monetary policy response could be required.

In this regard, it is interesting to compare this study's finding that a 10 per cent increase in commodity prices leads to a cumulative 10 per cent appreciation of the nominal exchange rate with the estimate of Cashin et al. (2002) that a 10 per cent increase in commodity prices leads to a 4 per cent appreciation of the real kina exchange rate in the long run. These two results can be reconciled by noting that Sampson et al. (2006) conclude that long-run pass-through from the exchange rate to inflation in Papua New Guinea is 50–60 per cent. Based on this estimate, a 10 per cent exchange rate appreciation will cause a 5–6 per cent fall in inflation—meaning that the real exchange rate will appreciate by 4–5 per cent in the long run.[12] The consistency of these three sets of results is reassuring. Moreover, taken together, they suggest that the Bank of Papua New Guinea might be able to reduce domestic price and nominal exchange rate volatility by intervening in the foreign exchange market to dampen the response of the nominal exchange rate to commodity price shocks.[13] Such a policy has potential drawbacks: not all exchange rate movements are caused by changes in commodity prices; identifying when the real exchange rate is overshooting is easier *ex post facto* than in real time; and not all foreign

exchange market interventions have the desired outcome.[14] It is, however, far from clear that these costs outweigh the possible benefits of lower price and exchange rate volatility; a full analysis of the trade-offs involved would be useful.

This paper advances our understanding of the determinants of the value of the kina but further work is clearly required. The relationships between the interest rate differential and net credit to government and the exchange rate need to be clarified. This is likely to require research on whether or not these variables are stationary—something that will become possible when longer time series are available. Alternative estimation methodologies, particularly those based on co-integration techniques, should also be considered. Work on the real exchange rate and the applicability of models of purchasing power parity in Papua New Guinea would be interesting. In addition, note that this paper has not considered the effect on the kina of the Bank of Papua New Guinea's foreign exchange market interventions. Research on the effectiveness and importance of these interventions would be very valuable. Finally, it is important to remember that perhaps the most notable features of results from empirical studies of other currencies have been their lack of robustness and their forecasting failures. Once more data are available it will be necessary to evaluate whether the link between commodity prices and the kina experiences these difficulties.

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The views expressed in this article are those of the authors and do not represent the position of the Bank of Papua New Guinea.

Notes

1 Chand and Stewart (1997) analyse the 1994 exchange rate crisis; Manning (1998) discusses the kina depreciation of 1997–98.

2 See, for instance, ANZ (2005) and Bank of Papua New Guinea (2005).

3 As of 31 December 2005, no offshore trading in the kina had been reported.

4 Chen (2004) takes a similar approach to estimating whether commodity prices affect the nominal exchange rates of Australia, Canada and New Zealand. He takes four canonical exchange rate models and augments each of them with a commodity price variable.

5 See Cashin et al. (2002) for details.

6 See, for instance, Dornbusch (1976) and Frankel (1979) for a sticky-price monetary model.

7 Exports of these 11 commodities made up more than 90 per cent of Papua New Guinea's total exports in each year from 1995 to 2004.

8 The Southern Oscillation Index measures differences in the air pressure between Tahiti and Darwin. Sustained negative values of the Southern Oscillation Index often indicate El Niño episodes.

9 Namely: 1997 Q3, 1997 Q4 and 1998 Q1.

10 For instance, a depreciation of the kina can lead to a rise in interest rates to support the kina and to an increase in the kina value of the government's foreign currency denominated debt, which could necessitate an increase in domestic government borrowing.

11 When the model is estimated including lags of the dependent variable, only the third lag is significant. Including the third lag of the exchange rate in the specifications

estimated in Tables 2 and 3 causes only minor changes to the results. The interest rate differential ceases to be significant in any of the equations estimated in Table 3, as does the Ok Tedi dummy in column e of Table 2. Most importantly, the estimated commodity price effects are essentially unchanged.

[12] It should also be pointed out that while this paper works with the kina/US dollar exchange rate, Cashin et al. (2002) and Sampson et al. (2006) use trade-weighted effective kina exchange rates.

[13] Although Papua New Guinea has had a floating exchange rate since 1994, the Bank of Papua New Guinea has a policy of intervening in the foreign exchange market to 'smoothen volatility in the exchange rate where necessary' (Bank of Papua New Guinea 2005:16). It does not, however, aim explicitly to ensure a smooth adjustment of the real exchange rate to commodity price movements.

[14] In addition, such a policy can be effective only if there is some endogeneity of the estimates reported above to the Bank of Papua New Guinea's exchange rate policy. For instance, if pass-through from the exchange rate to inflation is always 60 per cent, a 4 per cent real exchange rate appreciation will necessarily require a 10 per cent nominal exchange rate appreciation. If, however, the degree of pass-through is endogenous to the policy regime, it could be possible to obtain a 4 per cent real exchange rate appreciation despite having a nominal exchange rate movement below 10 per cent. Consideration of the likely effect of a change in policy on the extent of pass-through from commodity price shocks to the real exchange rate and from the nominal exchange rate to inflation should be central to any analysis of the desirability of smoothing real exchange rate adjustment to commodity price shocks. See Choudhri and Hakura (2001) for cross-country evidence that low average inflation is associated with low pass-through from the exchange rate to inflation, and Sampson et al. (2006) for evidence that pass-through from the exchange rate to inflation in Papua New Guinea has risen since the floating of the kina.

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Appendix: data definitions and sources

Exchange rate: End of quarter nominal kina/US dollar exchange rate; source: Bank of Papua New Guinea.
Commodity prices: Quarterly average international US dollar prices; source: International Monetary Fund's International Financial Statistics (IMF IFS). Series: cocoa, 65276R.ZZFM44; coconut oil, 56674AIZZF; coffee, 38676EBZZF; copper, 11276C.ZZF; copra, 56676AGZZF; gold, 11276KRZZF; palm oil, 54876DGZZF; petroleum, 00176AAZZF; rubber, 54876L.ZZF; tea, 11276S.ZZF; timber, 54876VXZZF.
Export data: Annual value of exports and volume of exports by commodity; source: Bank of Papua New Guinea.
Net credit to government: End of quarter net credit to the Government of Papua New Guinea from the domestic banking system; source: Bank of Papua New Guinea.

Fiscal deficit: Quarterly Papua New Guinea government budget deficit; source: Bank of Papua New Guinea.
Nominal GDP: Quarterly GDP data are not available for Papua New Guinea, therefore, quarterly estimates are interpolated from the annual data. Annual data source: Papua New Guinea National Statistical Office for years up to and including 2002 and Papua New Guinea Department of Treasury's *2006 National Budget* thereafter.
Interest rates: End of quarter nominal interest rate per annum on six-month government security (182-day Treasury Bill for Papua New Guinea, six-month Treasury Bill for United States); source: Papua New Guinea data from the Bank of Papua New Guinea, US data from the US Federal Reserve.
Southern Oscillation Index: Quarterly average Troup Southern Oscillation Index; source: Australian Bureau of Meteorology.
Money supply: End of quarter M1 or M3. Money supply differential is calculated as the difference between the logarithm of the Papua New Guinea money supply and the logarithm of the US money supply. Source: Papua New Guinea data from Bank of Papua New Guinea; US data from IMF IFS.
Foreign exchange market turnover: Annual inflows of foreign exchange to Papua New Guinea by sector; source: Bank of Papua New Guinea.