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Exchange Rate Pass-through in Papua New Guinea

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Abstract

This paper estimates pass-through from the exchange rate to inflation in Papua New Guinea using 1989-2004 data. Results display sensitivity to how inflation and the exchange rate are measured. Pass-through is found to be higher than previously estimated and evidence is presented that pass-through has increased since the kina was floated. The paper concludes that pass-through to underlying inflation is approximately 50-60 percent and is complete after between four and six quarters. It also finds that exchange rate movements have been the main source of variation in inflation during the sample period.

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Exchange Rate Pass-through in Papua New Guinea*

1. Introduction

How does the value of the kina affect prices in Papua New Guinea (PNG)? Economic theory and descriptive empirics both provide support for thinking that the exchange rate is likely to be one of the principal determinants of inflation.

PNG is a small, open economy with a high marginal propensity to import (Blyth, 1991). A depreciation of the exchange rate can be expected to lead directly to higher prices for imports of both intermediate inputs and final goods. If firms choose to pass the import price increases on to consumers domestic inflation will result. This inflation may in turn stimulate further price changes through 'second round' effects such as increases in inflation-indexed wages or demand shifts resulting from the initial price rises. One of the primary purposes of the 'Hard Kina' policy pursued by PNG from the time of independence until the kina was floated in 1994 was to avoid imported inflation by maintaining the value of the kina (Garnaut and Baxter, 1983).

A comparison of exchange rate movements and inflation rates before and after the floating of the kina in October 1994 illustrates the perceived link. Between the start of 1989 and the end of 1993 the kina depreciated by 16 percent against the United States (US) dollar. Average annual Consumer Price Index (CPI) inflation for this five-year period was 5.2 percent. During the next five years, from 1994-98, the kina depreciated by 53 percent against the US dollar. Average annual inflation for this period was 11.5 percent - double its level before the kina was floated.

Despite the theoretical link between exchange rate movements and inflation outcomes, and the circumstantial evidence supporting this hypothesis,

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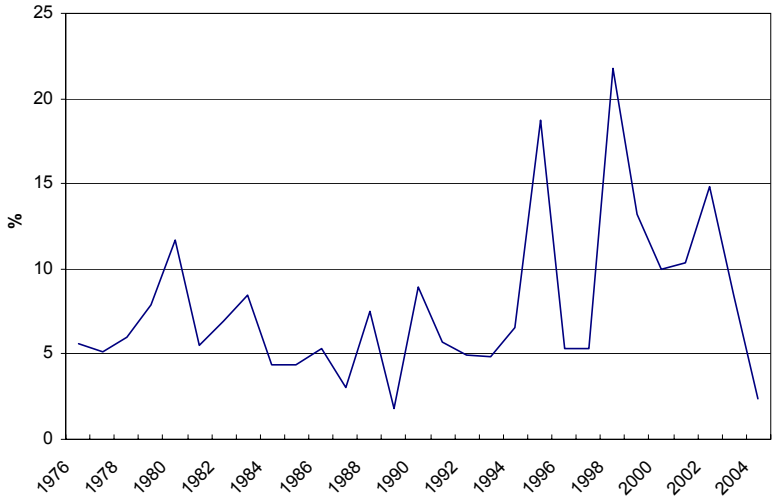
little empirical work has been conducted to quantify the dynamics of the exchange rate-inflation relationship in PNG.

Asafu-Adjaye (1998) and Choudhri and Hakura (2001) both estimate the pass-through[1] of exchange rate movements to inflation to be in the 30-40 percent range. Choudhri and Hakura, who undertake a cross-country analysis, also find that countries with lower average inflation have lower pass-through. However, both papers use datasets primarily covering the period prior to the floating of the kina. Figure 1 shows annual CPI inflation in PNG from 1976-2004. It shows an increase in the average level of inflation after the floating of the kina in 1994. Has exchange rate pass-through increased since the kina was floated?

Figure 1: Annual inflation 1976 - 2004



Source: National Statistical Office (NSO) and Bank of Papua New Guinea (BPNG).

[1] Throughout this paper exchange rate pass-through over K periods is defined to be the cumulative sum of the effects of a 100 percent movement in the exchange rate in period t on estimated inflation in periods t, t+1, …, t+K-1. When the number of periods is not specified, the pass-through referred to is the long run value.

This paper uses 1989-2004 data to investigate the dynamics of pass-through in PNG under a floating exchange rate. A simple pass-through model is estimated in which inflation is postulated to be a function of exchange rate movements, past inflation outcomes, foreign inflation and the output gap. Estimated pass-through dynamics are sensitive to how inflation and the exchange rate are measured, but pass-through is generally found to be in the 50-60 percent range and to take between four and six quarters. The results also confirm that exchange rate movements have been the principal determinant of inflation during the sample period. When the model is estimated using data from before the kina was floated pass-through is only 25 percent and is complete after three quarters.

Modeling exchange rate pass-through is an integral part of developing an understanding of macroeconomic behaviour in PNG. It establishes a relationship between two of the main macroeconomic variables. The magnitude and timing of exchange rate pass-through also has important policy implications for the Bank of PNG (BPNG), which is mandated to maintain price stability. The findings presented in this paper could form the basis for an improvement to the current inflation-forecasting model to be used in the monetary policy formulation process.

In addition, the relatively high level of estimated pass-through, combined with the dominance of exchange rate movements in causing inflation, raises an issue that would become important were PNG to consider adopting an explicit inflation-targeting framework for monetary policy. Is the impact of monetary policy induced interest rate changes on the determinants of inflation sufficient for BPNG to be able to combat the inflationary effects of shocks to a freely floating exchange rate and maintain a credible inflation targeting regime? Attempts to answer this question should bear in mind that the results suggest that if a low inflation environment can be achieved pass-through may decline from its current levels.

The remainder of the paper is organised as follows. Section 2 discusses the measurement of inflation in PNG. Section 3 reviews previous work on the exchange rate-inflation relationship in PNG, presents the model to be estimated and defines the variables used. Section 4 presents the results obtained when the basic model is estimated, while section 5 considers the effect of using alternative proxies for domestic demand. Section 6 analyses whether pass-through has changed since the kina was floated and section 7 concludes.

2. Measuring Inflation in PNG

Measurement of inflation in PNG faces three principal difficulties. Two of these are country specific, while the other is of more general concern.

Firstly, there is the lack of alternative measures of inflation. The only domestic inflation measure in PNG is the CPI,[2] published quarterly by the National Statistical Office (NSO) since the December quarter of 1975. There is no measure of producer prices, import prices, retail prices or non-tradable prices and no measure of consumer prices to compare with the figures published by the NSO.

Secondly, there are the limitations of the CPI. The basket of goods whose prices are included in the CPI is based on a survey of the consumption patterns of wage-earning urban households in 1975-76. The limited coverage of this survey, and, more importantly, the failure to update the consumption basket in the last thirty years, means that the CPI basket is not an accurate reflection of current expenditure patterns. Both the items included[3] and the weights given to different areas of expenditure are out of date and even in 1975-76 did not represent the consumption of the urban poor and rural households.[4]

[2] BPNG publishes a quarterly Export Price Index, but this is not suitable as a measure of domestic inflation.
[3] For instance, the price of cinema admission makes up 0.96 percent of the CPI basket, even though there are currently no cinemas in PNG. When calculating the CPI the NSO assumes the price of cinema admission remains constant.
[4] For further details see Box 1.2 in World Bank (1999).

The first two difficulties result from the failure of successive governments to devote sufficient resources to the collection of the data necessary to make informed policy decisions. The third is a problem faced by statisticians in all countries: how can the underlying rate of inflation be inferred from published inflation figures? No consensus exists on the theoretical definition of underlying inflation (Roberts, 2005). Heuristically, it is generally taken to be the medium-term trend in inflation, but this understanding admits multiple modeling frameworks. Roberts presents a model in which the underlying rate of inflation is the systematic component of aggregate inflation:

$$\Pi_{it} = \Pi_t^U + \varepsilon_{it} \qquad (1)$$

where:

Π_{it} is the inflation rate of item *i* in period *t*;

Π_t^U is underlying inflation; and

ε_{it} is a stochastic shock specific to item *i*.

Alternatively, underlying inflation may be viewed as the residual when seasonal effects, temporary economic shocks and stochastic variations are removed from observed headline inflation:

$$\Pi_t^U = \Pi_t - S_t - N_t - U_t \qquad (2)$$

where:

Π_t denotes headline inflation in period *t*;

S_t is a seasonal factor;

N_t denotes the inflationary effect of temporary shocks to the economy; and

U_t is a stochastic error term.

Despite the absence of agreement on a theoretical framework to model underlying inflation, most empirical measures are based on a common approach.

Each period the components of the price index are re-weighted - the aim being to give greater weight to items whose price changes are indicative of underlying inflation. Roberts outlines different techniques used to achieve this goal and discusses their relative merits.

BPNG publishes two underlying inflation measures: exclusion-based inflation and trimmed mean inflation. Both these measures are calculated by re-weighting the cross-section of price changes in the CPI. The CPI can be disaggregated into 23 sub-groups. The exclusion-based measure zero weights the nine sub-groups that are considered the most volatile.[5] To calculate trimmed mean inflation, the sub-groups are ranked each quarter by inflation rate and the bottom 33 percent and top 27 percent of the distribution is zero-weighted. Therefore, whereas the exclusion-based measure excludes the same sub-groups every quarter, the trimmed mean measure excludes each quarter those sub-groups that lie in the tails of the distribution of price changes in that specific quarter.[6]

Table 1. Descriptive statistics for the three inflation measures

Period	Statistic	Headline	Trimmed mean	Exclusion-based
1976Q1 – 1989Q1	Mean (standard deviation)	1.54 (1.26)	-	-
1989Q2 – 1994Q3		1.08 (1.03)	1.04 (0.81)	1.18 (1.01)
1994Q4 – 2004Q4		2.56 (2.42)	2.26 (1.69)	2.74 (2.36)
1989Q2 – 2004Q4		2.04 (2.15)	1.83 (1.55)	2.19 (2.11)
1976Q1 – 2004Q4		1.94 (2.06)	-	-

Notes: Inflation rates are quarterly. Underlying inflation measures not available prior to 1989 Q2. 1999 Q3 excluded from all calculations due to introduction of Value Added Tax (VAT).

Source: Authors' calculations.

Table 1 shows descriptive statistics for headline, exclusion-based and trimmed mean inflation. Headline and exclusion-based inflation display similar volatility, but the volatility of trimmed mean inflation is noticeably lower. This

[5] The sub-groups excluded are: fruit and vegetables, betel nut and accompaniments, alcoholic drinks, cigarettes and tobacco, rents and council charges, fuel and power, fares, communication and medical and health care. These sub-groups together accounted for 36.4 percent of the CPI.
[6] For further details on the construction of underlying inflation measures see 'For the Record' in BPNG (2001).

paper estimates exchange rate pass-through using both measures of underlying inflation, in addition to headline inflation, as the dependent variable. If the underlying measures are successful in capturing the medium-term inflation trend then the model should explain a greater proportion of underlying inflation than of headline inflation.

3. Inflation Model

Several alternative modeling frameworks have been used to estimate exchange rate pass-through. The long-run relationship between the exchange rate and the price level has been analysed using co-integration analysis. This is the approach taken by Hampton (2001) to examine the link between import prices and consumer prices in New Zealand. McCarthy (1999) introduces a 'distribution chain' model in which pass-through is estimated in a recursive VAR framework that analyses how exchange rate movements affect prices at different stages of the production chain. Gueorguiev (2003) applies this method to estimate pass-through in Romania.

Asafu-Adjaye (1998) uses co-integration analysis on a quarterly dataset covering 1981-1996 to estimate the long-run relationship between domestic prices and excess money supply, foreign prices, price expectations and the exchange rate in PNG. Surprisingly, the estimated exchange rate coefficient is not significant in the co-integrated model. However, Granger causality tests with the variables in first-difference form show that while the exchange rate Granger causes domestic prices, the converse is not true. The author also estimates an error-correction model and finds a significant short-run effect of exchange rate movements on inflation. The estimated pass-through of exchange rate movements to inflation is 12 percent after one quarter and 32 percent after two quarters.

As part of a cross-country analysis of the relationship between inflation regimes and exchange rate pass-through, Choudhri and Hakura (2001) estimate pass-through for PNG using a quarterly dataset from 1979 to 2000. They find

pass-through of 11 percent after one quarter, 23 percent after two quarters, 36 percent after four quarters and 38 percent in the long-run.

Both Asafu-Adjaye and Choudhri and Hakura use datasets primarily covering the period prior to the floating of the kina. However, in their work, Choudhri and Hakura find 'strong evidence of a positive and significant association between the pass-through and the average inflation rate across countries and periods.' In other words, pass-through is lower in countries with low inflation regimes. As mentioned in the introduction average inflation in PNG has increased since the kina was floated in 1994. One question this paper addresses is whether exchange rate pass-through has also increased.

This paper estimates variants of:

$$\widetilde{\Pi}_t = \sum_{i=1}^{4} \gamma_i \delta_{i,t} + \gamma_5 \lambda_t + C_1(L)\widetilde{\Pi}_{t-1} + C_2(L)\Delta E_t + C_3(L)\Pi_t^F + C_4(L)D_t + \varepsilon_t \qquad (3)$$

where:

$\widetilde{\Pi}_t$ is an inflation measure;

$\delta_{i,t}$ for i=1,…,4 are quarterly dummy variables;

λ_t is a dummy for the introduction of a VAT in 1999 Q3;

ΔE_t is the percentage change in the exchange rate;

Π_t^F is a foreign inflation measure;

D_t is a measure of excess domestic demand;

ε_t is a stochastic error term;

L is the lag operator; and

$C_1, \ldots, C_4$ are polynomials.

This simple model is similar to those used in Choudhri and Hakura (2001) and Debelle and Wilkinson (2002). Domestic inflation is postulated to be a function of inflationary expectations, which are proxied by past inflation

outcomes, exchange rate movements, foreign inflation, domestic demand characteristics and seasonal effects. The model allows both for direct effects of exchange rate movements on inflation and for 'feedback' effects caused by changes in inflation expectations. Exchange rate pass-through will be a combination of the two effects. Unit root tests[7] on headline CPI, the two underlying price indices, the exchange rate and foreign prices indicate that these variables are integrated of order one. They are therefore expressed in percentage change form in equation (3) to ensure stationarity and the equation is estimated using ordinary least squares.

As discussed in section 1, the underlying inflation measures are intended to eliminate the seasonality and reduce the noise in headline inflation. Therefore, it is expected that when the model is estimated with either exclusion-based or trimmed mean inflation as the dependent variable the estimated seasonal coefficients will be equal and the standard deviation of the residuals will be lower than when headline inflation is used.

The exchange rate is measured as the weighted average of the exchange rates of the kina against the US dollar, Australian dollar, Japanese yen, Singaporean dollar and New Zealand dollar. Two alternative weightings are used to calculate the effective exchange rate. One based on the average share of PNG's imports purchased from each country during 1989-2004 and the other based on the average share of PNG's imports purchased in each currency during 1996-2004 (table 2). The effective exchange rates calculated using these weightings are labeled the 'country-based' exchange rate and the 'currency-based' exchange rate respectively. Domestic inflation, exchange rate and import data are from BPNG. Exchange rates are expressed such that an increase denotes an appreciation of the kina. Foreign inflation is measured as the percentage change in a weighted average of the Consumer Price Indices of Australia, US, Japan, Singapore and New Zealand. The weights used are the

[7] Both the Augmented Dickey-Fuller test and the Phillips-Perron test give the same results.

same as the country-based weights used for the exchange rate. Foreign CPI data is from the IMF's *International Financial Statistics (IFS)*. The dataset covers 1989 Q2–2004 Q4. The disaggregated CPI data required to calculate the two underlying inflation measures is not available prior to 1989.

Table 2. Weights used to calculate weighted exchange rates and weighted foreign CPI

Weights based on:	Average share of PNG's imports coming from country		Average share of PNG's imports purchased in currency
	1989-2004	1977-93	1996-2004
Australia	62.1	53.1	35.1
US	16.7	11.3	52.6
Japan	8.7	18.2	4.9
Singapore	8.3	12.5	4.1
New Zealand	4.3	4.9	3.3

Notes: Weights normalised to sum to one hundred. All excluded countries had shares of less than 3 percent for the 1989-2004 and 1996-2004 data and less than 4 percent for the 1977-93 data.

Source: BPNG.

4. Estimation Results

The previous section was intentionally vague concerning the definition of the domestic demand measure, D_t, included in equation (3). The variable most commonly used to capture inflationary pressures resulting from excess demand is the output gap. Calculation of an output gap for PNG is complicated by the fact that GDP data is only published annually. Therefore, to obtain a quarterly output gap series the following steps are taken. Firstly, a quarterly GDP series is calculated by interpolating the annual data. Secondly, trend GDP is estimated by applying a Hodrick-Prescott filter to the quarterly GDP series and thirdly, the output gap is computed as the difference between the log of actual GDP and the log of trend GDP. The annual GDP series used consists of NSO data from 1989-2002 and Department of Treasury estimates for 2003-04.

Unit root tests are inconclusive in determining whether or not the output gap series is stationary. The Augmented Dickey-Fuller test indicates stationarity, while the Phillips-Perron test does not reject the null hypothesis of a unit root. In

addition, previous authors[8] have found that inflation may depend on both the level and the first difference of the output gap. Therefore, it is decided to include the current period value of both these variables in the model by assuming:

$$C_4(L) = \alpha_0 + \alpha_1(1 - L) \qquad (4)$$

The number of exchange rate lags to include is determined by a general-to-specific methodology. The model is first estimated with eight lags included and the Schwarz criterion is then used to determine which lags to exclude. It is assumed that expected inflation is a four quarter moving average of past inflation outcomes. Foreign inflation is also expressed as a four quarter moving average. That is,

$$C_j(L) = \frac{\beta_j}{4}\left(1 + L + L^2 + L^3\right) \qquad j = 1,3 \qquad (5)$$

where:

β_1, β_3 are the coefficients to be estimated. The validity of the restrictions on C_1, C_3 and C_4 will be examined below.

Table 3 shows the results obtained from estimating the model using the country-based exchange rate. In columns (a) and (b) headline inflation is the dependent variable. Exchange rate movements have significant effects at lags one, two and three and the largest impact is at lag one. Applying the Schwarz criterion results in dropping the current period exchange rate (column a). In column (b) the current period exchange rate is included; it has the theoretically correct sign, but is insignificant. The output gap has an insignificant effect, but its first difference has a positive effect that is significant at the 10 percent level. Foreign inflation is also significant at the 10 percent level and the hypothesis that the coefficient of foreign inflation equals one cannot be rejected. Past inflation outcomes have an insignificant effect. Consequently, exchange rate pass-through

[8] See for example Debelle and Wilkinson (2002) and Hampton (2001).

Table 3. Estimation results using country-based exchange rate					
Dependent variable	(a) Headline	(b) Headline	(c) Trimmed mean	(d) Trimmed Mean	(e) Exclusion-based
Exchange rate	-	-0.0613	-0.0818***	-0.0881***	-0.168***
		(0.0631)	(0.0233)	(0.0242)	(0.0510)
Exchange rate (-1)	-0.211***	-0.208***	-0.182***	-0.173***	-0.206***
	(0.0617)	(0.0613)	(0.0339)	(0.0307)	(0.0346)
Exchange rate (-2)	-0.100**	-0.0985**	-0.144***	-0.130***	-0.136***
	(0.0449)	(0.0465)	(0.0247)	(0.0273)	(0.0327)
Exchange rate (-3)	-0.151***	-0.142***	-0.107***	-0.0936***	-0.155***
	(0.0508)	(0.0479)	(0.0244)	(0.0213)	(0.0322)
Exchange rate (-4)	-	-	-0.0809***	-0.0601**	-0.0884**
			(0.0260)	(0.0288)	(0.0420)
Exchange rate (-6)	-	-	-0.0483**	-	-
			(0.0228)		
Output gap	0.859	0.490	-0.586	-0.388	3.48
	(5.37)	(4.79)	(2.44)	(2.38)	(5.14)
First difference of output gap	18.5*	20.1*	16.2**	13.7**	27.3**
	(10.3)	(10.2)	(6.35)	(6.36)	(11.4)
Past inflation	-0.110	-0.0544	-0.216	-0.0576	-0.0634
	(0.254)	(0.231)	(0.122)	(0.131)	(0.178)
Foreign inflation	1.03*	1.08*	1.19***	1.12***	1.48**
	(0.596)	(0.587)	(0.404)	(0.396)	(0.614)
Estimation period	1989 Q3-2004 Q4	1989 Q3-2004 Q4	1990 Q2-2004 Q4	1990 Q2-2004 Q4	1990 Q2-2004 Q4
R^2	0.57	0.58	0.83	0.81	0.74
Adjusted R^2	0.47	0.48	0.77	0.76	0.66
Regression standard error	1.72	1.71	0.81	0.83	1.27
Seasonal effects significant	Yes (0.03)	Yes (0.05)	No (0.44)	No (0.43)	No (0.20)
Exchange rate pass-through (long-run)	46%	51%	64%	55%	75%

Notes: Quarterly dummy variables and a dummy for the introduction of VAT in 1999 Q3 included in all regressions. White heteroscedasticity consistent standard errors in parentheses. * indicates significance at the 10 percent level, ** indicates significance at the 5 percent level, *** indicates significance at the 1 percent level. Regression standard error is an estimate of the standard deviation of the residuals. 'Seasonal effects significant' reports the results of a Wald Chi-squared test at the 10 percent significance level of the null hypothesis that the coefficients on the quarterly dummy variables are equal (p-value in parentheses). Exchange rate pass-through is calculated using the estimated coefficients of all the included exchange rate variables regardless of their level of significance.

Source: Authors' calculations.

is calculated as the cumulative sum of the estimated coefficients of the exchange rate variables. Estimated long-run pass-through is 46 percent if the current period exchange rate is excluded and 51 percent if it is included, and is complete after four quarters.

Columns (c) and (d) report the results obtained when the trimmed mean is used as the dependent variable. Exchange rate movements have a significant effect on inflation in the current period and at each of the first four lags. The effect is strongest at the first lag and declines thereafter. Application of the Schwarz criterion also results in the sixth exchange rate lag being included, even though the fifth lag is excluded (column c). When the sixth lag is dropped the estimated coefficients of the remaining variables are similar (column d), but long-run pass-through drops from 64 percent to 55 percent. Past trimmed mean outcomes and the output gap are insignificant, but foreign inflation is significant at the 1 percent level, and the first difference of the output gap is also significant.

When exclusion-based inflation is used (column e) the exchange rate and its first four lags are significant, but higher lags are excluded. The estimated effect of the current period exchange rate is substantially larger than was the case for either headline or trimmed mean inflation, with pass-through of 17 percent after one quarter. Long-run pass through is 75 percent and is complete after five quarters. Once again the output gap and past inflation outcomes are insignificant, while the first difference of the output gap and foreign inflation are both significant at the 5 percent level.

Comparing the estimation results for the two underlying inflation measures with those for headline inflation there is evidence that both underlying measures succeed in reducing the seasonality and noise present in headline inflation. The significant seasonal effects found in the headline inflation regressions are absent when using either underlying measure. The regression standard errors for the trimmed mean regressions are less than half the values for the headline regressions, with the regression standard error for the exclusion-based model approximately halfway between the two. Similarly, the model R^2 is greater than 0.80 for trimmed mean inflation, 0.74 for exclusion-based inflation and less than 0.60 for headline inflation. These results also suggest that the

trimmed mean is a better indicator of underlying inflation than exclusion-based inflation.

Table 4. Estimation results using currency-based exchange rate			
Dependent variable	(a) Headline	(b) Trimmed mean	(c) Exclusion-based
Exchange rate	-	-0.0851***	-0.171***
		(0.0304)	(0.0619)
Exchange rate (-1)	-0.219***	-0.170***	-0.185***
	(0.0555)	(0.0248)	(0.0330)
Exchange rate (-2)	-0.0869**	-0.105***	-0.0963**
	(0.0422)	(0.0215)	(0.0294)
Exchange rate (-3)	-0.157***	-0.0727***	-0.129***
	(0.0468)	(0.0256)	(0.0316)
Output gap	1.65	0.286	2.83
	(5.38)	(2.39)	(5.09)
First difference of	14.2	5.92	16.9
output gap	(9.36)	(5.46)	(10.4)
Past inflation	-0.0774	0.225**	0.272**
	(0.224)	(0.106)	(0.118)
Foreign inflation	0.954*	0.956**	1.15**
	(0.553)	(0.364)	(0.571)
Estimation period	1989 Q3-2004 Q4	1990 Q2-2004 Q4	1990 Q2-2004 Q4
R^2	0.59	0.80	0.70
Adjusted R^2	0.50	0.75	0.62
Regression standard error	1.67	0.85	1.34
Seasonal effects significant	Yes (0.02)	No (0.36)	No (0.34)
Exchange rate pass-through (long-run)	46%	56%	80%
Notes: Quarterly dummy variables and a dummy for the introduction of VAT in 1999 Q3 Included in all regressions. White heteroscedasticity consistent standard errors in parentheses. * indicates significance at the 10 percent level, ** indicates significance at the 5 percent level, *** indicates significance at the 1 percent level. Regression standard error is an estimate of the standard deviation of the residuals. 'Seasonal effects significant' reports the results of a Wald Chi-squared test at the 10 percent significance level of the null hypothesis that the coefficients on the quarterly dummy variables are equal (p-value in parentheses).			
Source: Authors' calculations.			

Table 4 shows the results from estimating the model using the currency-based exchange rate. For headline inflation (column a) the results are similar to those obtained using the country-based exchange rate, except that the first

difference of the output gap is no longer significant. However, for the trimmed mean and exclusion-based measures there are substantial differences from the results obtained using the country-based exchange rate. In both cases the first difference of the output gap is no longer significant, but past inflation outcomes now have a positive and significant effect (columns b and c). In addition, the fourth lag of the exchange rate is excluded from both models. The estimated coefficients on the included exchange rate variables are similar to those obtained when the country-based exchange rate is used.

The persistence in inflation outcomes reported in columns (b) and (c) of table 4 must be included when calculating exchange rate pass-through. For instance, a fall in inflation resulting from an appreciation of the exchange rate will, because of persistence, cause further decreases in future inflation outcomes thereby increasing the deflationary impact of the initial exchange rate movement. Long-run exchange rate pass-through is estimated to be 56 percent for trimmed mean inflation and 80 percent for exclusion-based inflation. Nine-tenths of the pass-through is complete after six quarters in both cases.

Are the maintained assumptions on the lag polynomials for past inflation, foreign inflation and the output gap valid? Past inflation outcomes enter the model as a four-quarter moving average. To examine this assumption an alternative specification is estimated in which:

$$C_1(L) = \beta_0 + \beta_1 L + \beta_2 L^2 + \beta_3 L^3 \qquad (6)$$

When the null hypothesis that $\beta_0 = \beta_1 = \beta_2 = \beta_3$ is tested, it is not rejected at the 10 percent level when either trimmed mean or exclusion-based inflation is used and the exchange rate is either country-based or currency-based.[9] However, it is rejected at the 10 percent level for both exchange rate weightings when headline inflation is the dependent variable. In each of these cases the

[9] Although, the results do suggest that for both trimmed mean and exclusion-based inflation the significant impact of past outcomes when the currency-based exchange rate is used is driven by the effect of the first lag. The estimated coefficients of other variables are robust to including in the model only the first lag of inflation.

second lag of headline inflation has a negative and significant effect and the magnitude of the exchange rate coefficients is larger than previously estimated. The negative persistence counteracts the larger exchange rate coefficients and long-run pass through is 48 percent for the country-based exchange rate[10] and 50 percent for the currency-based exchange rate. These estimates are close to the 46 percent long-run pass-through estimated for both exchange rate weightings when past inflation was written as a four quarter moving average.

When the validity of writing foreign inflation as a four quarter moving average is investigated using the same test, the null hypothesis is accepted in all cases except for when the exclusion-based model is estimated using the country-based exchange rate. Even in this case, however, the estimated coefficients of other variables are not sensitive to including foreign inflation and its first three lags separately. The results also indicate that the impact of foreign inflation is strongest in the current period and at the first lag. Additionally, the findings described above are robust to excluding the output gap from the model and to including lags of the first difference of the output gap.

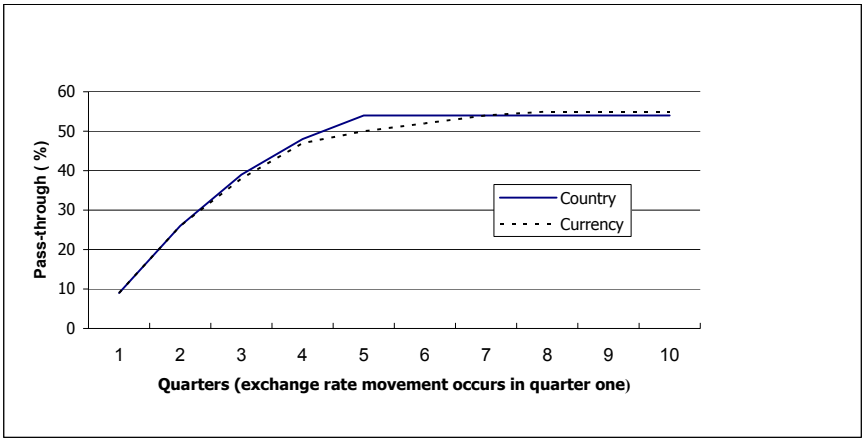
The results in this section show that pass-through is sensitive to the inflation measure used. Long-run pass-through estimates range from 46 percent to 80 percent and are lowest for headline inflation and highest for exclusion-based inflation. In all cases pass-through takes a minimum of four quarters and is at least 90 percent complete after six quarters. Of the three inflation measures, trimmed mean inflation has the lowest volatility and is considered to be the best indicator of underlying inflation. Estimates of pass-through to trimmed mean inflation range from 55 percent to 64 percent.

Estimation output is also sensitive to the exchange rate weighting. When the country-based exchange rate is used the first difference of the output gap is significant. However, this is not the case when the currency-based exchange rate is used. Furthermore, when the trimmed mean and exclusion-based inflation

[10] Current period exchange rate not included in estimation (cf. Table 3, column a).

models are estimated using the currency-based exchange rate fewer exchange rate lags are significant and there is evidence of persistence in the inflation process. Despite these differences the magnitude and timing of pass-through is similar across exchange rate weightings (figure 2). This is because the significant persistence when the currency-based exchange rate is used is offset by the effect of extra exchange rate lags when the country-based exchange rate is used. Note also that, when past inflation outcomes are significant pass-through is sensitive to the estimated level of persistence. A one standard deviation decrease in the persistence coefficient for trimmed mean inflation reduces long-run pass-through to 49 percent from 56 percent, while a one standard deviation increase raises it to 65 percent.

Figure 2: Pass – through to trimmed mean inflation as estimated using country-based and currency-based exchange rates

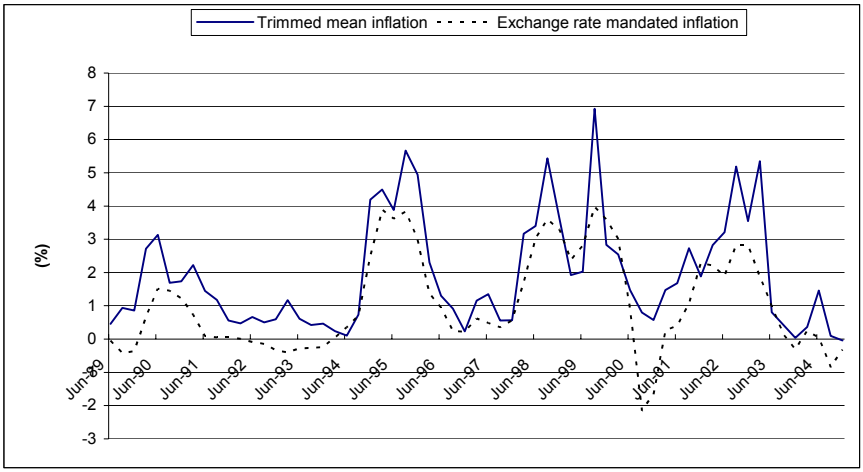


Source: Authors' calculations.

Finally, all the models estimated above indicate that movements in the exchange rate were the main factor driving the substantial variations in inflation outcomes from 1989-2004. Figure 3 shows both trimmed mean inflation and

inflation mandated by exchange rate movements as calculated from the results in column (d) of table 3. Changes in trimmed mean inflation closely track changes in exchange rate-mandated inflation.

Figure 3: Quarterly trimmed mean inflation and exchange rate mandated inflation (from Table 3, column d)



Source: Authors' calculations.

5. Alternative Proxies for Domestic Demand

To construct the output gap variable included in the regressions estimated in section 3 quarterly GDP was calculated from annual data by interpolation. If the output gap does not accurately capture excess domestic demand then there is a potential for omitted variable bias in the estimated coefficients. For instance, if an increase in domestic demand leads to an increase in import demand, which causes the exchange rate to depreciate, then the magnitude of the exchange rate coefficients may be biased upwards because they will capture the inflation caused by the increased domestic demand in addition to the exchange rate effect. Conversely, if high export prices were to cause a simultaneous

appreciation of the exchange rate and increase in domestic demand the estimated exchange rate coefficients will be biased towards zero.

This section assesses the impact on estimated exchange rate pass-through of excluding the output gap and its first difference from the model and including instead proxies for domestic demand that are available quarterly. The variables used are the budget deficit and non-mineral exports. The budget deficit is measured as the ratio of government expenditure, excluding foreign interest payments, to government receipts, excluding foreign grants. Unit root tests indicate that the budget deficit series is stationary and the non-mineral exports series is integrated of order one.[11] Consequently, the percentage change in non-mineral exports is included in equation (3). Fiscal and export data are from BPNG.

The results obtained using trimmed mean inflation and including the domestic demand proxies are shown in table 5. Both the budget deficit and the percentage change in non-mineral exports are expressed as four quarter moving averages to smooth seasonal variations in the fiscal and agricultural cycles. When either the country-based or currency-based exchange rate is used neither the budget deficit (columns a and b) nor non-mineral exports (columns c and d) are significant. All other variables have very similar effects to those recorded in the regressions that included the output gap. The same is true if either the budget deficit or non-mineral exports is included in the models for headline or exclusion-based inflation. These findings are robust to redefining the budget deficit calculation to include foreign interest payments and foreign grants and to including the variables and their lags separately instead of as four-quarter moving averages.

There is no link between the domestic demand proxies considered in this section and inflation outcomes. This suggests that they are less successful than

[11] Both the Augmented Dickey-Fuller test and the Phillips-Perron test give the same results.

Table 5. Estimation results including alternative domestic demand proxies				
Dependent variable	(a) Trimmed mean	(b) Trimmed Mean	(c) Trimmed Mean	(d) Trimmed Mean
Exchange rate weighting	Country	Currency	Country	Currency
Exchange rate	-0.0860***	-0.0859***	-0.0861***	-0.0849***
	(0.0247)	(0.0298)	(0.0245)	(0.0303)
Exchange rate (-1)	-0.162***	-0.166***	-0.162***	-0.165***
	(0.0258)	(0.0235)	(0.0261)	(0.0224)
Exchange rate (-2)	-0.123***	-0.107***	-0.124***	-0.105***
	(0.0266)	(0.0212)	(0.0264)	(0.0210)
Exchange rate (-3)	-0.0892***	-0.0736***	-0.0903***	-0.0695**
	(0.0233)	(0.0260)	(0.0224)	(0.0245)
Exchange rate (-4)	-0.0532*	-	-0.0533*	-
	(0.0292)		(0.0291)	
Past inflation	-0.0164	0.248**	-0.0139	0.240**
	(0.138)	(0.112)	(0.138)	(0.112)
Foreign inflation	1.02**	0.864**	0.998**	0.957***
	(0.382)	(0.338)	(0.384)	(0.337)
Budget deficit	-0.165	0.528	-	-
	(0.795)	(0.772)		
Non-mineral exports	-	-	-0.00150	0.00838
			(0.0197)	(0.0146)
Estimation period	1990 Q2-2004 Q4	1990 Q2-2004 Q4	1990 Q2-2004 Q4	1990 Q2-2004 Q4
R^2	0.80	0.80	0.80	0.80
Adjusted R^2	0.75	0.75	0.75	0.75
Regression standard error	0.85	0.84	0.85	0.85
Seasonal effects significant	No (0.46)	No (0.35)	No (0.47)	No (0.37)
Exchange rate pass-through (long-run)	51%	57%	52%	56%

Notes: Quarterly dummy variables and a dummy for the introduction of VAT in 1999 Q3 included in all regressions. White heteroscedasticity consistent standard errors in parentheses. * indicates significance at the 10 percent level, ** indicates significance at the 5 percent level, *** indicates significance at the 1 percent level. Regression standard error is an estimate of the standard deviation of the residuals. 'Seasonal effects significant' reports the results of a Wald Chi-squared test at the 10 percent significance level of the null hypothesis that the coefficients on the quarterly dummy variables are equal (p-value in parentheses).

Source: Authors' calculations.

the output gap in capturing excess domestic demand.[12] However, in spite of the failure to find an improved measure of excess domestic demand, it is reassuring to note that estimated exchange rate pass-through is not sensitive to the replacement of the output gap by either the budget deficit or non-mineral exports.

6. Pass-through and the Inflation Regime

This section considers the sensitivity of the results presented above to: (a) varying the sample period and; (b) re-weighting the CPI expenditure groups to reflect 1996 expenditure patterns.

The sample used previously commences in 1989 Q2; the first quarter for which trimmed mean and exclusion-based inflation are available. However, as discussed in the introduction, there is extensive cross-country evidence that the level of pass-through is linked to the inflation regime, with higher inflation outcomes leading to higher pass-through. Figure 1 suggests the possibility that the inflation regime in PNG may have changed following the floating of the kina in 1994. Is there any evidence of a change in pass-through in PNG since 1994?

To test this question, the headline inflation regression shown in column (b) of table 3 is re-estimated using data for 1977-93. The exchange rate and foreign CPI are weighted based on the average share of PNG's imports purchased from each country during 1977-93 (table 2). Exchange rate and foreign CPI data are from the IMF *IFS*.

There is a clear difference between the results obtained using the pre-float sample (table 6, column a) and the results for the 1989-2004 sample. For the earlier period the exchange rate is only significant at lags one and two and pass-through is 25 percent, compared to 51 percent for the latter period. The results indicate that exchange rate pass-through has doubled since the floating

[12] Note however that this conclusion relies on the assumption that a relationship exists between excess domestic demand and inflation and consequently, that a successful measure of excess domestic demand must have a significant effect on inflation. If it is assumed that no such relationship exists then the results suggest that the output gap is the less successful measure.

of the kina in 1994 and that the time taken for exchange rate movements to fully impact domestic prices has increased. The estimated effects of other variables are remarkably similar in both samples.

Table 6. Estimation results using alternative samples and CPI weightings

Dependent variable	(a) Headline	(b) Trimmed mean	(c) Trimmed mean	(d) Headline (1996 weights)
Exchange rate weighting	Country (1977-93)	Country (1989-2004)	Currency (1996-2004)	Country (1989-2004)
Exchange rate	-0.0292	-0.0685**	-0.0533	-0.0696
	(0.0549)	(0.0261)	(0.0326)	(0.0450)
Exchange rate (-1)	-0.0964*	-0.176***	-0.172***	-0.175***
	(0.0544)	(0.0222)	(0.0219)	(0.0431)
Exchange rate (-2)	-0.124***	-0.132***	-0.106***	-0.0879**
	(0.0460)	(0.0259)	(0.0213)	(0.0355)
Exchange rate (-3)	-0.00134	-0.0950***	-0.0723**	-0.154***
	(0.0529)	(0.0248)	(0.0266)	(0.0385)
Exchange rate (-4)	-	-0.0547*	-	-
		(0.0325)		
Output gap	-2.11	-15.4**	-14.1*	2.09
	(3.57)	(7.32)	(8.16)	(4.57)
First difference of output gap	21.3*	21.5**	12.0	12.0
	(11.8)	(8.65)	(8.91)	(9.68)
Past Inflation	-0.0658	-0.0710	0.255	-0.0149
	(0.261)	(0.173)	(0.172)	(0.164)
Foreign Inflation	1.03***	1.88***	1.33**	1.37**
	(0.298)	(0.524)	(0.602)	(0.571)
Estimation period	1978 Q1 – 1993 Q4	1995 Q1 - 2004 Q4	1995 Q1 - 2004 Q4	1990 Q1 – 2004 Q4
R^2	0.52	0.87	0.84	0.65
Adjusted R^2	0.42	0.80	0.77	0.56
Regression standard error	0.93	0.81	0.88	1.39
Seasonal effects significant	Yes (0.00)	No (0.14)	No (0.14)	No (0.14)
Exchange rate pass-through (long-run)	25%	53%	40%	49%

Notes: Quarterly dummy variables included in all regressions. Dummy for the introduction of VAT in 1999 Q3 included in all regressions except column (a). White heteroscedasticity consistent standard errors in parentheses. * indicates significance at the 10 percent level, ** indicates significance at the 5 percent level, *** indicates significance at the 1 percent level. Regression standard error is an estimate of the standard deviation of the residuals. 'Seasonal effects significant' reports the results of a Wald Chi-squared test at the 10 percent significance level of the null hypothesis that the coefficients on the quarterly dummy variables are equal (p-value in parentheses). Exchange rate pass-through is calculated using the estimated coefficients of all the included exchange rate variables regardless of their level of significance.

Source: Authors' calculations.

Given these results, it is interesting to examine whether excluding data from before the float alters estimated pass-through. Asafu-Adjaye (1998) and Choudhri and Hakura (2001) both estimated pass-through to be in the 30-40 percent range using samples that included primarily, but not exclusively, pre-float data. Columns (b) and (c) of table 6 show the results of re-estimating the trimmed mean models in column (d) of table 3 and column (b) of table 4 using data starting from 1995 Q1.

When the country-based exchange rate is used (column b), the only noteworthy differences from the results in column (d) of table 3 are firstly, that the coefficient on foreign inflation increases from 1.12 to 1.88 and is significantly different from one at the 10 percent level and secondly, that in the 1995-2004 sample the output gap has a negative effect that is significant at the 5 percent level. Pass-through is 53 percent in the 1995-2004 sample, compared to 55 percent in the 1989-2004 sample.

When the currency-based exchange rate is used (column c), past inflation is not significant and consequently pass-through is only 40 percent, compared to 56 percent in the 1989-2004 sample. The current period exchange rate is also insignificant, while the output gap again has a negative and significant effect. However, overall, the results obtained using the 1995-2004 sample are similar to those from the 1989-2004 sample. This finding also holds when the models for headline and exclusion-based inflation are estimated using the reduced sample.

The problems with measuring inflation using the PNG CPI were discussed in section 1. One of the difficulties is that the weights given to different items do not reflect current expenditure patterns. The CPI is made up of seven expenditure groups. Table 7 shows the weight given to each of the expenditure groups in the CPI alongside weights based on the expenditure patterns recorded by the 1996 PNG Household Survey. CPI weights are from the NSO. 1996 PNG Household Survey weights are shown in Box 1.2 of World Bank (1999). The main differences evident in the 1996 data are that substantially more weight is given

to the 'Rents, council charges, fuel and power' group, while the 'Food' and 'Drinks, tobacco and betel nut' groups have noticeably lower weights.

Table 7. Expenditure group weights		
Expenditure group	CPI weight	1996 PNG Household Survey weight
Food	40.9	33.2
Drinks, tobacco and betel nut	20.0	8.8
Clothing and footwear	6.2	2.7
Rents, council charges, fuel and power	7.2	25.1
Household equipment and operation	5.3	5.5
Transport and communication	13.0	12.2
Miscellaneous goods and services	7.5	12.5
Source: World Bank 1999. *Papua New Guinea: improving governance and performance*, World Bank, Washington DC; NSO.		

To examine whether estimated pass-through is sensitive to the weighting of the expenditure groups, an alternative headline inflation measure is calculated by re-weighting the expenditure groups using the 1996 weights. The model is then estimated using this inflation measure and the country-based exchange rate; the results are shown in column (d) of table 6. The first difference of the output gap is not significant, but otherwise there are no substantial differences from the results obtained when estimating the model using published headline inflation (table 3, columns a and b). Most importantly, re-weighting the CPI to reflect 1996 expenditure patterns at the group level does not affect estimated pass-through. However, this re-weighting does not alter the fact that the items included in the CPI groups are based on the 1975-76 survey and themselves require updating to reflect changes in consumption.

7. Conclusion

The evidence presented in this paper is insufficient to justify definitive conclusions on the magnitude and timing of exchange rate pass-through in PNG. Findings have displayed sensitivity to both the inflation measure used and the

weightings applied to calculate the effective exchange rate. However, on balance the results support the following four stylised facts about exchange rate pass-through in PNG.

i. Pass-through to underlying inflation is approximately 50-60 percent.
ii. Pass-through is complete after between four and six quarters.
iii. Pass-through is strongest in the quarter following an exchange rate movement and declines thereafter.
iv. Since the floating of the kina in 1994 pass-through has doubled and the time taken for pass-through to be complete has increased.

None of these conclusions is indisputable, but they provide a set of benchmarks that policy makers can use to think about the inflationary impact of exchange rate movements and with which future work on pass-through can be compared.

Although the results confirm the hypothesis that exchange rate movements have been the main cause of variations in inflation, the paper also sheds light on other determinants of inflation in PNG. Foreign inflation has a significant impact that is robust across all specifications considered. The hypothesis that the pass-through from foreign inflation to domestic inflation is one-to-one is rejected in only one of the models estimated. There is some evidence of persistence in the inflation process and of a role for the first difference of the output gap in causing inflation, but these results are not robust to the exchange rate weighting used. Headline inflation displays seasonality, but the underlying inflation measures do not. The trimmed mean is judged to be the best measure of underlying inflation available.

Future work should focus on achieving a better understanding of the relationship between domestic variables and inflation and on developing a model of the exchange rate. Both researchers and policy makers should also remain alert to the possibility that the dynamics of exchange rate pass-through will vary over time.

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