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External Adjustment in a Resource-Rich Economy: The Case of Papua New Guinea

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External Adjustment in a Resource-Rich Economy: The Case of Papua New Guinea

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Abstract

How should resource-rich economies handle the balance of payments adjustment required after commodity price declines? This paper addresses the question theoretically by developing a simple two-period multi-sector model based on Nakatani (2016) to compare different exchange rate policies, and empirically by estimating elasticities of imports and commodity exports with respect to exchange rates using Papua New Guinean data. In the empirical part, using various econometric methods, I find the statistically significant elasticities of commodity exports to real exchange rates. In the theoretical part, by introducing the notion of a shadow exchange rate premium, I show how the rationing of foreign exchange reduces consumer welfare. Using the estimated elasticities and theoretical outcomes, I further discuss policy implications for resource-rich countries with a focus on Papua New Guinea.

JEL Classification Numbers: F31, F41, O13, Q17

Keywords: Papua New Guinea, Commodity Exporters, Balance of Payments, Agricultural Exports, Elasticities, Foreign Reserve, Intervention, Cointegration, ECM, ARDL, TSLS.

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Contents

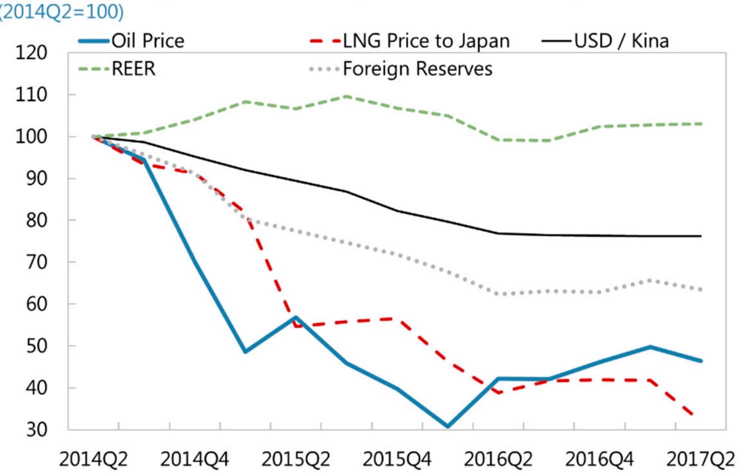
I. INTRODUCTION

The recent sharp decline in oil prices since mid-2014 had a huge impact on commodity exporting countries. Low commodity prices have created numerous challenges in resource-rich economies, particularly low-income ones. These include lower export revenues, shortage of foreign reserves and deterioration of fiscal situations. In this paper, we analyze the external adjustment following commodity price declines in a resource-rich economy from both theoretical and empirical viewpoints. In terms of policy implications, we focus primarily on exchange rate policy, although we also discuss its interaction with fiscal and monetary policies.

We provide a new framework to compare two exchange rate regimes – a fixed exchange rate regime with foreign exchange (FX) rationing and a flexible exchange rate regime – to address a negative terms-of-trade shock. The adjustments of terms-of-trade shocks have been studied in the wide literature on macroeconomics. Open-economy macro models show that a flexible exchange rate policy can be effective in handling the terms-of-trade shock because the nominal exchange rate adjusts immediately to the shock. If the Marshall-Lerner condition is satisfied, an exchange rate depreciation affects the trade balance favorably. Empirical studies have found that this condition holds in many advanced economies (e.g., Bahmani-Oskooee and Niroomand 1998). However, it is unclear whether this condition holds in a small resource-rich economy because most commodity exports are priced in U.S. dollars and are determined in world markets, and many countries import a large fraction of intermediate and final goods due to under-developed domestic industries, implying possible smaller price elasticities of both exports and imports. Thus, using data from one resource-rich country, we estimate elasticities of various commodity exports with respect to the exchange rate.

We focus on the case of Papua New Guinea (PNG), one of the most resource-rich countries in the world, to derive policy implications applicable for other commodity exporters. PNG is rich in various natural resources such as metals, oil, gas, agriculture, forestry and fisheries as illustrated in Box 1. Its experience with a very diverse set of commodity exports provides for a rich analysis of export price elasticities. The policy implications obtained in this paper should not only be useful for PNG but also other resource-rich economies.

Figure 1: Energy Prices, Exchange Rates, and Foreign Reserves
(2014Q2=100)



Source: IMF

Box 1: PNG's Rankings in Natural and Cultural Resources

PNG is the largest developing economy in the Pacific islands, and has abundant resources especially in mining and agricultural industries. PNG is rich in natural resources such as minerals, gas, agriculture, forestry and fisheries. For example, PNG is ranked as the 10th largest liquefied natural gas (LNG) exporting county and the 13th largest gold producing country in the world. PNG is also an exporter of various agricultural goods, and ranked 8th in palm oil, 12th in cocoa, and 17th in coffee producing countries. Furthermore, the country is located next to the world's largest sustainable tuna purse seine fishery and constitutes 30% of the total fish net catch among the Parties to the Nauru Agreement (PNA).[2] Last, the country has diverse cultural backgrounds represented by about 850 different languages (12% of world languages), which can be potential assets for boosting tourism in combination with its untouched wilderness and unique animals and birds. In sum, PNG has abundant natural and cultural resources to export.

Chart 1. LNG Exporting Countries

(Million tonnes per annum, 2015)

Rank	Country	LNG Exports
1	Qatar	77.8
2	Australia	29.4
3	Malaysia	25.0
4	Nigeria	20.4
5	Indonesia	16.1
6	Trinidad	12.5
7	Algeria	12.1
8	Russia	10.9
9	Oman	7.8
10	**Papua New Guine**	**7.0**

Source: International Gas Union

Chart 2. Gold Producing Countries

(Metric Tonnes, 2014)

Rank	Country	Gold Production
1	China	450
2	Australia	270
3	Russia	245
4	United States	211
5	Canada	160
6	South Africa	150
…	…	…
11	Brazil	70
12	Indonesia	65
13	**Papua New Guinea**	**60**
14	Chile	50

Source: Worldatlas

Chart 3. Coffee Producing Countries

(Kilograms, 2015)

Rank	Country	Coffee Production
1	Brazil	2,594,100,000
2	Vietnam	1,650,000,000
3	Colombia	810,000,000
4	Indonesia	739,020,000
5	Ethiopia	384,000,000
…	…	…
15	Kenya	49,980,000
16	Tanzania	48,000,000
17	**Papua New Guinea**	**48,000,000**
18	El Salvador	45,720,000
19	Ecuador	42,000,000

Source: Worldatlas

Chart 4. Cocoa Producing Countries

(Tonnes, 2013)

Rank	Country	Cocoa Production
1	Cote d'Ivoire	1,448,992
2	Ghana	835,466
3	Indonesia	777,500
4	Nigeria	367,000
5	Cameroon	275,000
…	…	…
10	Dominican Republic	68,021
11	Colombia	46,739
12	**Papua New Guinea**	**41,200**
13	Venezuela	31,236
14	Uganda	20,000

Source: Worldatlas

[2] PNA controls 25% of world tuna supply and consists of 3 key members (PNG, Federated States of Micronesia, and the Republic of Kiribati) and 5 members (Marshal Islands, Nauru, Palau, Solomon Islands, and Tuvalu).

Chart 5. Palm Oil Producing Countries

(Thousands of metric tonnes, 2016)

Rank	Country	Palm Oil Production
1	Indonesia	35,000
2	Malaysia	20,000
3	Thailand	2,300
4	Colombia	1,280
5	Nigeria	970
6	Ecuador	560
7	Honduras	545
8	**Papua New Guinea**	**522**
9	Ghana	520
10	Guatemala	515

Source: United States Department of Agriculture

Chart 6. Coconut Producing Countries

(Tonnes, 2014)

Rank	Country	Coconut Production
1	Indonesia	18,300,000
2	Philippines	15,353,200
3	India	11,930,000
4	Brazil	2,890,286
5	Sri Lanka	2,513,000
6	Vietnam	1,303,826
7	**Papua New Guinea**	**1,200,000**
8	Mexico	1,064,400
9	Thailand	1,010,000
10	Malaysia	646,932

Source: Worldatlas

Chart 7. Tropical Logs Exporting Countries

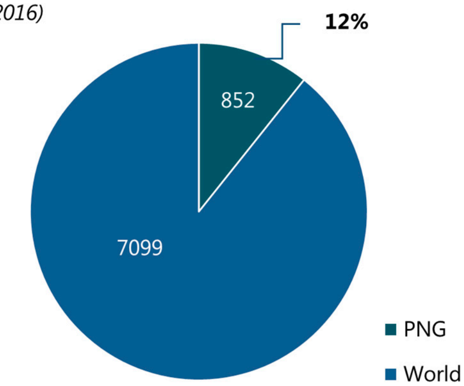
(Thousands of cubic meters, 2013)

Rank	Country	Tropical Logs Exports
1	Malaysia	3,455
2	**Papua New Guinea**	**3,100**
3	Myanmar	2,575
4	Solomon Islands	2,105
5	Democratic Republic of Congo	772
6	Cameroon	709
7	Lao PDR	454
8	Equatorial Guinea	431
9	Mozambique	348
10	Côte d'Ivoire	289

Source: Worldatlas

Chart 8. Languages Share

(Number, 2016)



Source: Ethnologue

PNG is a commodity exporter facing the challenge of external adjustment in an era of low commodity prices. As shown in Figure 1, since 2014 Q2, oil and gas prices have declined drastically by about 60%. With lower export revenues, coupled with the suspension of production in the mining and agricultural sectors due to a major drought,[3] the nominal exchange rate of Papua New Guinean Kina has depreciated by around 24% since June 2014. The Bank of Papua New Guinea (BPNG) has intervened in FX markets to support the Kina, which has contributed to a shortage of foreign reserves. However, the real effective exchange rate (REER) has been broadly stable since that period (Figure 1). Moreover, the nominal exchange rate has been stable since May 2016, and so have the foreign reserves as the BPNG has not actively intervened in the FX

[3] The drought brought by El Niño phenomena caused water levels to drop, which affected shipment operations and resulted in a 9 month shut down of Ok Tedi Mine commencing in July 2015.

market after the Ok Tedi Mine re-entered the market. A unique feature of the PNG experience is that the de facto exchange rate system changed from a floating to a fixed exchange rate regime with FX rationing. This policy response was motivated by concerns about the inflationary impact of currency depreciation and the limited responsiveness of net exports to the exchange rate. A theoretical as well as an empirical approach are deployed to evaluate this exchange rate policy.

This paper provides two innovations, a theoretical analysis of the exchange rate policy options in the context of a commodity price shock-induced balance of payments (BOP) problem and an empirical estimation of PNG's export and import elasticities with respect to the real exchange rate. Most theoretical papers on BOP problems have focused on inconsistent macroeconomic policy mixes, self-fulfilling prophecies, and financial frictions leading to problems of maintaining a fixed exchange rate regime with finite FX reserves. These studies have not explicitly investigated the role of commodity price shocks leading to BOP problems. At the same time, few papers have explicitly analyzed FX rationing as a policy response to a BOP problem, although a few studies analyzed the theoretical implications of shifting from a flexible to the fixed exchange regime under BOP problems.[4] In this paper, we extend the Nakatani (2016) model by introducing agriculture and mining into it, and compare a fixed exchange rate regime with FX rationing to a flexible regime. Furthermore, using commodity export data, we estimate elasticities of various commodities with respect to real exchange rates based on both panel regression techniques and cointegration estimation for each export commodity.

Do commodity exports respond to exchange rates? Yes. Our empirical results of both panel and individual regressions indicate that the overall elasticity of exports with respect to real exchange rates is around -0.4. The empirical analysis on each export good implies that some agricultural and mining commodities – such as coffee and copper – have statistically significant export elasticity with respect to the exchange rate. The theoretical model shows that the shortage of foreign reserves leads to import compression and reduces consumer welfare. It also shows that depreciation of the domestic currency can be a policy tool to mitigate a BOP problem if trade is elastic to exchange rates. Using the trade elasticities estimated in the empirical part, we calibrate the effects of currency depreciation on foreign reserves.

The remainder of this paper is organized as follows. Section II provides a literature review and explains key contributions of this paper in the context of theoretical modeling and empirical findings. Section III analyzes empirically the effects of real exchange rates on exports and imports using PNG's trade volume data. Section IV builds a theoretical model to analyze the effects of a commodity price shock on BOP and derives policy implications. Section V discusses policy advice obtained in this study. Section VI concludes.

[4] See an "exchange rate freeze" in van Wijnbergen (1991).

II. Literature Review and Our Contributions

The adjustment to terms-of-trade shocks has been widely studied in the open-economy macroeconomics literature. A typical open-economy macro model suggests that economies with more flexible exchange rate regimes exhibit smaller output responses during commodity price boom and bust episodes (Céspedes and Velasco 2012). A flexible exchange rate helps stabilize the economy in response to terms-of-trade shocks because the nominal exchange rate adjusts immediately to the real shock in the presence of nominal rigidities. Empirically, countries with fixed exchange rate regimes experience large and significant declines in real GDP in response to negative terms-of-trade shocks because the real exchange rate depreciates slowly (Broda 2004; Edwards and Levy Yeyati 2005; IMF 2016b).[5] However, the terms-of-trade shocks have not been analyzed in the context of BOP problems as we discuss below.

An adverse commodity-price related terms-of-trade shock can challenge the viability of a fixed exchange rate regime, although the related literature has not focused on this shock. The first-generation models of BOP crises were developed by Krugman (1979) and Flood and Garber (1984). In these models, a BOP problem is caused by the inconsistent fiscal and monetary policy mix under the fixed exchange rate regime. The second-generation model was developed by Obstfeld (1996), who analyzed the self-fulfilling prophecy caused by the interaction of international investors and the monetary authority. The third-generation models focus on various financial frictions and banking problems, including debt denominated in foreign currency of firms (Nakatani 2014) and of banks (Nakatani 2016), liquidity problems due to international and domestic collateral constraints (Caballero and Krishnamurthy 2001), traditional bank runs triggered by stochastic patience of depositors (Chang and Velasco 2001), and moral hazard problems caused by explicit or implicit government guarantees (McKinnon and Pill 1999; Burnside et al. 2004). Nakatani (2017c) found that both productivity shocks and risk premium shocks trigger currency crises, but no literature analyzed the effects of commodity price shocks.

We compare the costs and benefits of two exchange rate regime options, a fixed exchange rate regime with FX intervention and a flexible regime, after a negative commodity price shock. An agricultural and a mining sector are introduced into the simple two-period model, with an easy-to-understand mechanism in a general equilibrium setting, by Nakatani (2016) for this purpose. The analysis highlights that the costs and benefits of currency depreciation depend importantly on the elasticity of each component of BOP with respect to the exchange rate. If net trade, especially exports, is elastic to exchange rates, the model shows that a depreciation of the domestic currency can improve a country's external position and be a superior tool in terms of consumer welfare. Therefore, we subsequently estimate elasticity of exports with respect to exchange rates using annual commodity export volume data of PNG. We also estimate import elasticity as well. By contrast, if the fixed exchange rate policy is chosen in response to negative commodity price shocks, the model shows that there is no room for authorities to avoid FX rationing, which creates the shadow exchange rate premium that consumers are facing. Although this paper focuses on exchange rate policy response during the period of commodity price shock

[5] Cashin et al. (2004) found the evidence of the long-run comovement of real exchange rate and commodity prices in commodity exporting countries.

and does not focus on the period after the policy response, it is worth noting here that if the budget deficit caused by a lower commodity price shock is financed by the monetary authority, the situation resembles the first-generation models of BOP problems.

Another innovation of this paper is an empirical analysis of the elasticity of export volumes with respect to exchange rates based on PNG data. The empirical literature shows export elasticity to real exchange rates has ranges between -0.7 and 0 depending on the characteristics of the export goods. For instance, the External Balance Assessment (EBA)-lite, which the IMF (2016a) developed, uses an export volume elasticity of -0.71 (and an import volume elasticity of 0.92), as estimated by Bayoumi and Faruqee (1998). For oil-exporting countries, the price elasticity is much smaller, close to zero, because oil exports are priced in U.S. dollars (Behar and Fouejieu 2016). Using cointegration methods without including an exchange rate variable, Aba et al. (2012abc) studied the price elasticity of coffee, cocoa, and palm oil in PNG, and found that results are not statistically significant. They stated, however, that the survey conducted by the BPNG showed that all producers interviewed had confirmed that exchange rate fluctuations affect the kina price they receive and a decline in commodity prices serves as a major disincentive for producers.[6] This is because under a currency depreciation, the domestic producer price of commodities become cheaper relative to foreign competitors, and the profits increase in domestic currency. In fact, Nkang at al. (2006) found that the short-run elasticity of cocoa exports in Nigeria with respect to the real producer price is -0.5. Thus, it is plausible to have statistically significant elasticities of those agricultural exports in PNG as well.[7] However, no empirical study has estimated export volume elasticity with respect to exchange rates using PNG data.

III. EMPIRICAL ANALYSIS

We now turn to analyze the effects of exchange rates on PNG's trade volumes, using commodity-level export volume data and overall import volume data. As we will show in the next theoretical analysis section, if a country has a large supply price elasticity of exports (and imports) with respect to exchange rates, the exchange rate depreciation can be an effective policy tool to tackle the external adjustment problem. Conversely, if a country's exports are not responsive to exchange rates, we cannot use a flexible exchange rate policy as a solution. So it is important to estimate the supply elasticity of exports (and imports) with respect to exchange rates. We first estimate the export elasticity below, and then the import elasticity later.

[6] In our own discussions with the Department of Agriculture and Livestock in PNG, officials corroborated that a higher producer price in domestic currency provides important incentives to crop producers and that the exchange rate plays a major role in determining the domestic prices accruing to producers.

[7] There are some empirical analyses that estimated the price elasticity of agricultural exports from developing countries. For example, Niemi (2004) found the evidence that agricultural commodity exports from ASEAN countries to EU are affected by the price competitiveness. However, the results differ across papers substantially in terms of signs, magnitude and statistical significance of estimated coefficients because of different specifications and samples as well as difficulty of getting precise data on agriculture, and hence it is difficult to make a comparison.

We estimate export supply elasticity with respect to real exchange rates for each export commodity in PNG. We follow a standard approach to estimate this elasticity by considering foreign demand and REER as the explanatory variables (see Eqs. [4] and [10] in the next theoretical analysis section) and controlling for supply shocks. The dependent variable is the volume of exports. We use the Southern Oscillation Index (SOI) to capture the supply-side weather shocks (e.g., drought and El Niño phenomena), as commonly used in the literature (Cashin et al. 2017; Duncan 2008). Summary statistics for each variable are shown in Table 1. Most data sources are the BPNG and the IMF.

Unit root tests indicate the presence of unit roots in almost all variables for estimation of export elasticity (Table 2). Given that not all data exhibit a trend, we show the results of unit root tests with and without the individual trend. The results show that there are no variables that can reject the null hypothesis of unit root, in both cases at the 5% level of statistical significance, except for SOI. For this reason, we use cointegration techniques to estimate the elasticity of each commodity export with respect to real exchange rates.

Cointegration tests show that variables are cointegrated (Table 3). We use Engel-Granger (1987) type cointegration tests for individual export commodities. The test results in Table 3 show that some commodities (gold, oil, coffee, palm oil, and tea) have cointegration at the 5% level of significance. Since it is known that Engel-Granger cointegration tests have a tendency to accept the null hypothesis of no cointegration, we further test the presence of cointegration based on an error correction model (ECM). Namely, we include the error correction term, which is a residual of the long-run cointegration equation, in the short-run equation presented in Table 4. The coefficients on the error correction term are negative and statistically significant at the 5% level in most export goods (11 out of 13 commodities), indicating the presence of cointegration in most commodity exports.

Results based on the Dynamic Ordinary Least Squares (DOLS) method show that some export commodities – copper, cocoa, coffee, rubber, tea and copra oil – respond to real exchange rates in the long-run. We use this estimation method with cointegration as our baseline estimation because the Ordinary Least Squares (OLS) estimation has a non-negligible bias in a finite sample. The DOLS estimator is known to be asymptotically more efficient than OLS. Specifically, the DOLS estimator corrects for possible simultaneity bias amongst the regressors, and provides the long-run elasticity (Stock and Watson 1993). The results of DOLS presented in Table 5 show that some commodities, such as copper, cocoa, coffee, rubber, tea, and copra oil, have theoretically consistent and statistically significant elasticities with respect to real exchange rates. For example, an elasticity of coffee to REER is -0.52, i.e., a 1% depreciation of REER is associated with about 0.5% increase in volume of coffee exports. We find a similar magnitude of elasticity for cocoa, whereas elasticities are higher for copper, copra oil and tea. Furthermore, we find that palm oil and marine products respond to foreign demand rather than the exchange rates. The elasticity of palm oil to foreign demand is 1.1, which is very close to the result estimated by Aba et al. (2012c). By contrast, the ECM results presented in Table 4 imply that only copper responds strongly to the exchange rates in the short-run in this specification.

Further analysis based on the Fully Modified OLS (FMOLS) method exhibits similar results with somewhat larger exchange rate elasticities for some commodities (e.g., copper,

coffee, rubber and tea). For robustness checks, we further estimate elasticities using another cointegration regression method, FMOLS, which is constructed by making corrections for endogeneity and serial correlation to the OLS estimator (Phillips and Hansen 1990). The results of FMOLS are presented in Table 6, which do not substantially change from Table 5. Elasticities with respect to the exchange rate are somewhat higher than before. For example, the elasticity of coffee with respect to the real exchange rate is -0.72, which is larger than that of DOLS. In addition, the results of FMOLS indicate that palm oil, rubber, logs and marine products have statistically significant elasticities with respect to foreign demand.

Moreover, applying an Autoregressive Distributed Lag (ARDL) model to examine adjustment speeds of export commodities with respect to exchange rates, we found that lagged effects of exchange rate differ across commodities (from no lag for coffee to 3 years for copper). The ARDL approach is another popular method to examine long-run and cointegrating relationships between variables by yielding consistent estimates of coefficients that are asymptotically normal irrespective of whether the underlying regressors are I(1) or I(0) (Pesaran and Shin 1999) and it also enables us to study the lagged effects of regressors on export volumes. We set the maximum lag at three years following the literature on agricultural exports (Aba et al. 2012abc). The results in Table 7 show that the lagged effects of exchange rates differ across commodities. For instance, coffee and oil respond to exchange rates contemporaneously, while other commodities take a few years to respond; it takes one year for cocoa and copra oil, two years for tea, and three years for copper.

Next, we employ panel regression methods using the same commodity export data to estimate the overall elasticity of exports. The results of three panel unit root tests (Im, Pesaran and Shin 2003; Maddala and Wu 1999; Choi 2001), in which we assume individual unit root process, are shown in Table 8. Although the results indicate that there is a unit root in REER (and some cases in export goods and foreign demand especially when we include individual trends) and that all variables become stationary when taken in first difference, variables are not first differenced when we conduct panel estimation for three reasons. First, to obtain a supply elasticity of exports to the real exchange rate, it is natural to include a log of REER as a regressor. Second, we can compare this elasticity with the elasticities of individual series estimated above. Third, from a theoretical viewpoint, the real exchange rate is close to the notion of equilibrium exchange rate in the long-run. For these reasons, we include a log level of REER in the explanatory variables following the standard empirical literature.

Panel unit root and cointegration tests show mixed results and do not necessitate the use of panel cointegration regression. Results of Pedroni (1999)'s panel cointegration tests in Table 9 show that three of the seven statistics do not reject the null hypothesis of no cointegration at the 5% level of significance. An alternative test proposed by Kao (1999) does not reject the null hypothesis either. Given these results based on the panel unit root and cointegration tests, we also examine alternative estimation methods other than cointegration for panel data.

Table 1. Summary Statistics for Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Variable	Gold	Copper	Oil	Silver	Copra	Cocoa	Coffee	Palm Oil	Rubber	Tea	Copra Oil	Logs	Marine Products	REER	Foreign Demand[1]	SOI
Period	1990-2015	1990-2015	1992-2015	1992-2015	1976-2015	1976-2015	1976-2015	1976-2015	1990-2015	1990-2015	1976-2015	1990-2015	1990-2015	1980-2015	1980-2015	1980-2015
Unit	tonnes	thousands of tonnes	thousands of barrels	tonnes	thousands of tonnes	thousands of tonnes	thousands of tonnes	thousands of tonnes	thousands of tonnes	thousands of tonnes	thousands of tonnes	thousands of cubic meters	thousands of tonnes	2010=100	billion international dollars	Index
Mean	58.33	165.15	19555.97	55.65	57.31	36.00	57.25	48.03	3.80	5.65	37.81	2318.04	30.17	108.38	2354.27	-1.54
Median	58.15	176.90	14534.50	53.25	58.55	35.35	54.85	38.25	3.75	5.85	38.25	375.40	17.75	109.76	2295.90	-2.15
Max	72.80	230.60	45842.60	92.60	103.50	53.30	85.00	71.90	5.40	9.30	62.00	3868.00	95.40	138.00	4153.15	13.30
Min	33.60	46.40	5823.25	35.00	8.40	26.00	36.97	24.53	2.20	1.30	11.10	990.20	1.30	77.27	778.42	-13.08
Std. Dev.	8.92	48.71	12170.45	12.25	30.05	7.05	11.60	160.50	0.88	2.00	11.39	849.74	29.00	18.48	998.52	7.15
Source	BPNG	BPNG	BPNG	BPNG	BPNG	BPNG	BPNG	BPNG	BPNG	BPNG	BPNG	BPNG	BPNG	IMF	IMF	Australian Government

[1] Foreign Demand variable is calculated as a weighted average of GDP in major trading partner countries (Australia, Japan, China, Germany and Korea) that accounts for 77% of PNG's export destination during the data period.

Table 2. Unit Root Tests for Exports

	Trend for Individual	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
log(Variable)	—	Gold	Copper	Oil	Silver	Copra	Cocoa	Coffee	Palm Oil	Rubber	Tea	Copra Oil	Logs	Marine Products	REER	Foreign Demand	SOI
ADF Stat	No	-2.68 *	-0.44	-0.56	-2.93 *	-1.41	-2.68 *	-3.79 ***	-3.71 ***	-2.26	1.77	-1.56	-1.93	-1.16	-2.12	-5.21 ***	-4.12 ***
ADF Stat	Yes	-4.39 ***	-0.99	-8.83 ***	-5.44 ***	-3.98 **	-7.26 ***	-3.25 *	-2.21	-1.36	1.24	-1.61	-2.29	-3.52 *	0.97	-1.88	-4.25 ***
ADF Stat 1st diff	No	-5.56 ***	-4.79 ***	-9.33 ***	-4.99 ***	-7.84 ***	-7.21 ***	-7.57 ***	-8.27 ***	-4.87 ***	0.01	-5.83 ***	-4.48 ***	-2.73 *	-2.32	-3.75 ***	-6.75 ***
ADF Stat 1st diff	Yes	-3.82 **	-5.02 ***	-8.86 ***	-3.81 **	-7.72 ***	-7.26 ***	-7.96 ***	-4.98 ***	-5.36 ***	-6.39 ***	-6.00 ***	-4.10 **	-2.73	-6.74 ***	-4.48 ***	-6.67 ***

* significant at 10%, ** significant at 5%, *** significant at 1%. The null hypothesis is the presence of a unit root.

Table 3. Cointegration Tests for Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
log(Export Goods)	Gold	Copper	Oil	Silver	Copra	Cocoa	Coffee	Palm Oil	Rubber	Tea	Copra Oil	Logs	Marine Products
ADF Stat	-4.68 **	-1.95	-6.43 ***	-3.21	-2.42	-3.49	-6.39 ***	-4.60 **	-3.18	-5.20 ***	-3.25	-2.91	-3.99 *

* significant at 10%, ** significant at 5%, *** significant at 1%. The null hypothesis is no cointegration.

Table 4. Error Correction Model (ECM) for Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
dlog(Export Goods)	Gold	Copper	Oil	Silver	Copra	Cocoa	Coffee	Palm Oil	Rubber	Tea	Copra Oil	Logs	Marine Products
Constant	0.03	0.04	-0.06	-0.03	-0.13	-0.06	0.08	-0.07	0.03	-0.07	-0.11	-0.09	0.33
Error Correction Term	**-0.71** **	**-0.64** ***	-0.72 *	**-0.65** **	**-0.52** **	**-0.58** **	**-1.23** ***	**-0.93** ***	**-0.71** ***	**-0.99** ***	**-0.41** **	-0.27	**-0.72** **
dlog(REER)	0.03	**-1.20** ***	0.46	-0.10	1.03	0.78 **	0.29	0.96 *	1.21 ***	0.53	0.26	0.51	-1.18
dlog(Foreign Demand)	-0.55	-1.74	0.44	0.32	2.62	1.58	-1.72	**3.39** **	-1.01	0.75	1.62	3.93	-4.76
SOI	-0.00	0.00	-0.01	0.01	0.01	0.35	-0.01	-0.00	-0.01 ***	0.00	-0.01	-0.00	-0.01
R-squared	0.27	0.45	0.20	0.38	0.26	0.35	0.54	0.40	0.65	0.40	0.17	0.22	0.29

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 5. Dynamic Ordinary Least Squares (DOLS) for Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
log(Export Goods)	Gold	Copper	Oil	Silver	Copra	Cocoa	Coffee	Palm Oil	Rubber	Tea	Copra Oil	Logs	Marine Products
Constant	6.76 ***	14.12 ***	21.14 ***	6.24 *	0.10	4.20 **	5.65 ***	-2.79 *	1.53	17.02 ***	19.44 ***	-4.67	-32.71 ***
log(REER)	-0.57 *	**-1.12** **	0.09	0.50	2.11 ***	**-0.45** **	**-0.52** ***	0.01	**-0.67** **	**-2.08** ***	**-1.87** ***	1.10	-1.58
log(Foreign Demand)	0.00	-0.52	-1.47 ***	-0.58	-0.74 ***	0.17	0.11	**1.10** ***	0.38 *	-0.73 **	-0.90 **	0.93 *	**5.32** ***
R-squared	0.39	0.50	0.89	0.33	0.70	0.72	0.50	0.96	0.74	0.77	0.55	0.60	0.90

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 6. Fully Modified Ordinary Least Squares (FMOLS) for Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
log(Export Goods)	Gold	Copper	Oil	Silver	Copra	Cocoa	Coffee	Palm Oil	Rubber	Tea	Copra Oil	Logs	Marine Products
Constant	5.77 ***	17.01 ***	26.32 ***	5.43 ***	2.05	3.95 **	7.38 ***	-4.81 ***	2.88 *	17.51 ***	16.61 ***	-4.11	-32.58 ***
log(REER)	**-0.61** ***	**-1.30** ***	-0.23	0.50	1.40 **	-0.30	**-0.72** ***	-0.11	**-0.97** ***	**-2.26** ***	**-1.85** ***	0.85 *	-1.07
log(Foreign Demand)	0.14	-0.76 ***	-1.96 ***	-0.47 **	-0.62 **	0.13	0.01	**1.40** ***	**0.37** **	-0.69 ***	-0.57 ***	**0.99** ***	**5.07** ***
R-squared	0.24	0.42	0.80	0.22	0.49	0.26	0.36	0.92	0.31	0.62	0.42	0.58	0.86

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table 7. Autoregressive Distributed Lag (ARDL) Model for Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
log(Export Goods)	Gold	Copper	Oil	Silver	Copra	Cocoa	Coffee	Palm Oil	Rubber	Tea	Copra Oil	Logs	Marine Products
Constant	6.07 ***	15.19 **	22.81	2.38	-8.03 *	3.54 ***	7.82 ***	-3.42 **	3.48	31.15 ***	8.91	-5.14 **	-15.40
Dependent Variable (-1)	0.42 *	0.54 **	-0.57 *	0.20	0.47 **	0.37 ***	-0.01	0.32 *	0.51 *	-0.20	0.51 ***	0.33 *	0.16
Dependent Variable (-2)	-0.26		0.38	0.50 **	-0.24			0.15	-0.60	-0.26			-0.25
Dependent Variable (-3)	-0.24		0.09	-0.73 ***	0.54			-0.46 ***	-1.24 **	-0.58			0.37
log(REER)	-0.16	-0.08	**-1.71** **	-0.09	0.03	0.86 ***	**-0.57** **	0.72 **	1.28 **	-0.53	0.58	0.74 **	1.83
log(REER(-1))	0.08	0.10	0.63	0.46	1.51	**-1.24** ***		**-0.80** **	**-1.70** **	-0.13	**-1.63** **		-1.05
log(REER(-2))	-0.61 *	0.66	0.31	**-1.53** **					0.94	**-2.83** ***			-0.22
log(REER(-3))		**-2.08** **	1.24	1.46 **					**-1.58** **				-3.05
log(Foreign Demand)	0.18	-0.91 ***	-0.37	2.09 *	0.22	0.92	-2.94 **	1.27	1.17	1.85	0.30 **	**4.24** **	-1.88
log(Foreign Demand (-1))			-0.66	-2.05		0.73	**2.82** **	-1.30	1.22	-2.38		-3.39	14.39 *
log(Foreign Demand (-2))			0.96			-1.60 *		-0.68	-1.83	5.94			-16.82 *
log(Foreign Demand (-3))			-1.76					1.93		-6.93 **			7.97
SOI	0.00	0.01	0.01 *	**0.01** **	0.02 *	**0.01** **	0.01 *	-0.00	0.00	**0.04** ***	0.00	-0.00	-0.03
SOI(-1)	-0.01 *		0.01	-0.02 ***	0.00			**0.01** **	**0.03** ***	0.01	-0.01	-0.00	-0.05 *
SOI(-2)			-0.01	0.00	-0.02			-0.01 **	0.01	-0.01	-0.01	-0.02 **	
SOI(-3)			-0.02 **	**0.01** **	-0.02				-0.01 **	0.01	-0.01		
R-squared	0.69	0.79	0.99	0.87	0.83	0.75	0.47	0.98	0.91	0.96	0.79	0.82	0.96

* significant at 10%, ** significant at 5%, *** significant at 1%. Lag lengths for explanatory variables are determined by AIC (maximum 3 years).

Table 8. Panel Unit Root Tests for Exports

	(1)	(2)	(3)	(4)	(5)	(6)
Test Type	Im, Pesaran and Shin		Maddala and Wu		Choi	
Trend	No	Yes	No	Yes	No	Yes
log(Export Goods)	-1.24 (-14.51***)	-0.25 (-13.80***)	39.04**	30.19 (205.05***)	49.39***	64.03 (811.58***)
log(REER)	0.43 (-14.41***)	8.01 (-19.41***)	14.82 (223.48***)	0.33 (289.98***)	12.53 (264.38***)	0.34 (292.86***)
log(Foreign Demand)	-4.31***	1.25 (-7.64***)	59.27***	11.54 (101.95***)	206.94***	44.88**
SOI	-10.84***	-9.04***	162.79***	123.21***	159.78***	111.60***

* significant at 10%, ** significant at 5%, *** significant at 1%.
Test statistics for first differenced variables are in parenthesis.

Table 9. Panel Cointegration Tests for Exports

Pedroni's Test Statistics	
Panel variance ratio Statistic	0.118 (0.453)
Panel rho-Statistic	-1.015 (0.155)
Panel Phillips-Perron Statistic	-4.926*** (0.000)
Panel ADF t-Statistic	-2.647*** (0.004)
Group mean rho-Statistic	0.606 (0.728)
Group mean Phillips-Perron Statistic	-6.583*** (0.000)
Group mean ADF t-Statistic	-4.143*** (0.000)
Kao's Test Statistic	
ADF t-Statistic	-0.297 (0.383)

* significant at 10%, ** significant at 5%, *** significant at 1%.
Critical probabilities are in parenthesis.

Panel estimation results suggest that the export supply elasticity with respect to the real exchange rate ranges between -0.3 to -0.7. We employ three panel estimation methods. First, we use FMOLS estimator for panel cointegration analysis because this estimator is asymptotically unbiased for both the standard case without intercepts as well as the fixed effects model with heterogeneous intercepts (Pedroni 2000). Second, we estimate fixed effects (FE) model with Driscoll and Kraay (1998)'s standard errors because there may be a cross-sectional dependence especially in agricultural and mining production. For instance, if cocoa prices increase relative to coffee prices, people shift production from coffee to cocoa. Similar things might occur in mining production as well because some major mines produce different metals. Furthermore, we use an instrumental variable method, which is the two-stage least squares (TSLS) estimator, to control potential endogeneity in exchange rates and exports. We employ the lagged exchange rate as an instrument since this variable appears both strongly correlated with the current exchange rate and exogenous in the sense that it is predetermined. We show the results for both all commodities and agricultural commodities because the elasticity to the exchange rate may differ across types of commodities. The estimated results are shown in Table 10. The long-run elasticity of exports with respect to real exchange rates based on FMOLS is -0.43 for all commodities and -0.67 for agricultural commodities. The short-run (one-year) elasticity of all commodity exports to real exchange rates is -0.30 in FE and -0.42 in TSLS estimation. By contrast, the short-run elasticity of agricultural exports to the exchange rates is -0.53 in FE and -0.71 in TSLS estimation. Thus, our panel regression analyses also confirm that exports respond to the real exchange rate.

Table 10. Panel Regression for Exports

log(Export Goods)	(1)	(2)	(3)	(4)	(5)	(6)
Commodities	All	Agricultural	All	Agricultural	All	Agricultural
Estimation Method	FMOLS		Driscoll and Kraay		TSLS	
Constant	—	—	1.998*** (0.414)	2.709*** (0.565)	2.311*** (0.559)	3.233*** (0.602)
log(REER)	**-0.428***** (0.128)	**-0.674***** (0.153)	**-0.296**** (0.126)	**-0.533**** (0.210)	**-0.421**** (0.213)	**-0.709***** (0.220)
log(Foreign Demand)	**0.322**** (0.152)	-0.012 (0.027)	**0.059*** (0.032)	-0.014 (0.032)	0.051 (0.038)	-0.036 (0.035)
SOI	—	—	**0.002**** (0.001)	**0.003**** (0.001)	0.002 (0.002)	0.003* (0.002)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	379	227	384	232	379	227
R-squared	0.98	0.89	0.29	0.55	—	—
First-Stage Regression: log(REER(-1))	—	—	—	—	0.951*** (0.026)	0.963*** (0.034)
F Statistic	—	—	—	—	482.61***	337.32***

* significant at 10%, ** significant at 5%, *** significant at 1%.
Previous year's REER is used as an instrument in TSLS estimation.

Overall, the results from regressions for individual commodities and panel regressions suggest that supply elasticity with respect to the REER for total exports is around -0.4 in PNG. Finally, we compare the results of regressions based on individual and panel data. The total export supply elasticity based on the results of individual commodities is calculated as a weighted average of the elasticities for individual commodities, where the weight is an export share of each commodity. In the first two columns of Table 11, we show the total export supply elasticity based on DOLS (from Table 5) and FMOLS (from Table 6). We find that the total export elasticity with respect to real exchange rate is -0.43 for DOLS and -0.51 for FMOLS, which are very close to those obtained from the panel regressions shown in the last three columns in Table 11. Thus, we can conclude that our estimated results of total export elasticity are robust, at around -0.4.

Table 11. Summary of Total Export Elasticity with Respect to Exchange Rates

log(Export Goods)	(1)	(2)	(3)	(4)	(5)
Estimated Data (Aggregation Method)	Individual Data Series (Weighted Average[1])		Panel Data Series		
Estimation Method	DOLS	FMOLS	FMOLS	Driscoll and Kraay	TSLS
log(REER)	-0.43	-0.51	-0.43	-0.30	-0.42

[1] Export shares in 2016 were used so that we can use our results for future economic projections.

Next, we estimate import volume elasticity with respect to the real exchange rate. We take a standard approach to estimate this elasticity by including REER and domestic demand in the explanatory variables. The domestic demand variable is calculated as real GDP minus exports (Leigh et al. 2015; Senhadji 1998). The dependent variable is the volume of imports. In contrast to data on exports, there is no official import volume data. Thus, we use the import price deflator for PNG in the Global Economic Environment (GEE) database published by the IMF to calculate import volume data. In GEE database, the deflator is calculated by using a trade share for each trading partner country and the deflator in its trading partner country. Data on domestic demand variable is calculated from real GDP series published by the National Statistical Office (for data until 2014) and the IMF's estimate of 2015 GDP. Summary statistics for each variable are shown in Table 12.

Table 12. Summary Statistics for Imports

	(1)	(2)	(3)
Variable	Imports	REER	Domestic Demand[1]
Period	1990-2015	1990-2015	1990-2015
Unit	2005=100	2010=100	million Kina constant price
Mean	146.47	100.92	2354.27
Median	129.72	100.42	2295.90
Max	299.65	130.98	4153.15
Min	97.52	77.27	778.42
Std. Dev.	54.41	15.76	998.52
Source	BPNG, IMF	IMF	NSO, IMF

[1] Domestic Demand variable is calculated as real GDP minus exports.

Unit root tests presented in Table 13 indicates the presence of unit roots in all variables for estimation of import elasticity. Since some data have trend and others don't, we show the results of unit root tests with/without individual trend as in the case for exports. Table 13 shows that there are no variables that can reject the null hypothesis of a unit root, in both cases. Thus, we use cointegration techniques to estimate the import volume elasticity, too.

Table 13. Unit Root Tests for Imports

	Trend for Individual	(1)	(2)	(3)
log(Variable)	—	Imports	REER	Domestic Demand
ADF Stat	No	-2.02	-1.79	-0.72
ADF Stat	Yes	-2.59	0.14	-2.25
ADF Stat 1st diff	No	-3.18 **	-1.60	-5.19 ***
ADF Stat 1st diff	Yes	-3.10	-6.59 ***	-5.06 ***

* significant at 10%, ** significant at 5%, *** significant at 1%.
The null hypothesis is the presence of a unit root.

A cointegration test based on ECM shows the presence of cointegration. Although the Engel-Granger type cointegration test presented in table 14 does not show the evidence of cointegration, this cointegration test has a tendency to accept the null hypothesis of no cointegration. Therefore, we further test the presence of cointegration based on an ECM. The results of ECM presented in Table 15 shows that the coefficient on the error correction term is negative and statistically significant at the 5% level, indicating the presence of cointegration in import. Note that the coefficient on domestic demand is positive and statistically significant as well, which is consistent with the economic theory.

Table 14. Cointegration Test for Imports

log(Imports)	
ADF Stat	-3.15 **

* significant at 10%, ** significant at 5%, *** significant at 1%.
The null hypothesis is no cointegration.

Table 15. ECM for Imports

dlog(Imports)	
Constant	0.00
Error Correction Term	**-0.53** **
dlog(REER)	0.54
dlog(Domestic Demand)	**0.12** **
R-squared	0.44

* significant at 10%, ** significant at 5%, *** significant at 1%.

Our results based on DOLS and FMOLS show that the import elasticity with respect to the REER ranges between 0.8 and 1.1. The result of DOLS presented in column (1) of Table 16 show that the import elasticity with respect to REER is 1.15, whilst FMOLS in column (2) shows that the elasticity is 0.82, and this elasticity is statistically significant at the 5% level in both columns. For instance, a 1% appreciation of REER is associated with about 0.8% increase in volume of imports according to FMOLS. Our estimated results are close to the import elasticity with respect to REER in the EBA-lite (0.92). Furthermore, we find that the import elasticity to domestic demand is 0.13 and statistically significant at the 5% level in both specifications.

Table 16. DOLS and FMOLS for Imports

log(Imports)	(1)	(2)
Estimation Method	DOLS	FMOLS
Constant	-1.47	0.07
log(REER)	**1.15** ***	**0.82** **
log(Domestic Demand)	**0.13** **	**0.13** ***
R-squared	0.80	0.68

* significant at 10%, ** significant at 5%, *** significant at 1%.

Summing up the absolute values of export and import price elasticities, we find that the Marshall-Lerner condition is satisfied even in a resource-rich economy like PNG. We will use the export and import elasticities estimated here in the policy discussion section later, applying our theoretical model explained in the next section.

IV. THEORETICAL ANALYSIS

Given the empirical evidence of responsiveness of international trade to the exchange rate, we develop a theoretical model to derive implications for exchange rate policy in a resource-rich economy. So far, we have tested empirically for evidence of statistically significant exchange rate elasticities of exports and imports in a resource-rich economy. We found that imports and commodity exports can respond to the real exchange rate in a resource-rich economy using PNG data. In this section, we build a theoretical model to study the mechanism through which the commodity price shock leads to a BOP problem, and derive policy implications focusing on the external adjustment of the resource-rich economy. Specifically, we compare two exchange rate policies – a FX intervention policy versus a flexible exchange rate policy – to handle the external adjustment required after a permanent negative commodity price shock.

This is a two-period model with three agents: firms, households, and the government that includes a central bank. The timing of events is summarized as follows. At the beginning of the first period, prices are preset before the commodity price shock occurs. Given prices, all agents choose their actions. Then, an unanticipated negative commodity price shock occurs, creating a shortage of FX by reducing export revenues. Following the shock, only the government can respond by choosing the amount of intervention to provide foreign reserves in the FX market or the degree of flexibility in exchange rate, so that it can satisfy all equilibrium conditions at the end of the first period. In the second period, the other two agents, households and firms, can then choose their actions in the wake of the government policy action undertaken at the end of the first period.

There are two types of firms: agricultural firms and mining firms. Agricultural firms sell their products to both foreign and domestic consumers, and the firms maximize their profits net of wage payments to employees:

$$\Pi_t^a = (1-\tau)P_t^{a,f}E_tY_t^{a,f} + P_t^{a,d}Y_t^{a,d} - W_t^aL_t^a \tag{1}$$

where $Y_t^{a,f}$ and $Y_t^{a,d}$ are the amount of agricultural goods sold to foreign consumers and to domestic households respectively; L_t^a is the number of employees in the agricultural sector; τ is the tax rate; $P_t^{a,f}$ is the price of agricultural export goods in foreign currency; $P_t^{a,d}$ is the price of agricultural domestic goods in domestic currency; E_t is the nominal exchange rate (the price of foreign currency in terms of domestic currency) and W_t^a is the nominal wage in the agricultural sector. Agricultural firms satisfy the following production function

$$Y_t^a = A_t^aL_t^a \tag{2}$$

where A_t^a is the total factor productivity and Y_t^a is the total output of agricultural firms,

$$Y_t^a = Y_t^{a,f} + Y_t^{a,d}. \tag{3}$$

The agricultural export goods are subject to the following demand function that is determined by the real exchange rate and foreign income:

$$Y_t^{a,f} = Y_t^{a,f,D}\left(E_tP_t^{a,F}/P_t^{a,f}, Y_t^F\right) \tag{4}$$

where $P_t^{a,\mathrm{F}}$ is the price of agricultural goods in foreign countries and Y_t^F is the income in foreign countries. The first order condition of the optimization problem of agricultural firms yields:

$$A_t^a = W_t^a/P_t^{a,d} \tag{5}$$

which implies that employment in the agricultural sector is determined at the level where the marginal product of agricultural goods equals the real wage. Agricultural firms pay dividends to both the government and foreign investors as elaborated later.

Mining firms have a similar profit function. Variables are denoted the same as for the agricultural firms (the superscript m indicates mining goods), with the following differences. First, the price of mining goods (P_t^m) is determined in foreign currency (e.g., oil or LNG price is in U.S. dollars), and is the same for both domestic and foreign consumers. Second, the government can tax both export goods and domestically-sold mining goods. Third, mining firms invest (I_t) in physical capital (K_t) each period and make interest rate payments at an i_t rate in the next period. Fourth, mining firms issue foreign currency denominated bonds (B_t) of which foreign investors earn an interest rate (i^*), assumed constant over time. Thus, the firms maximize the following profits

$$\Pi_t^m = (1-\tau)P_t^m E_t\left(Y_t^{m,f} + Y_t^{m,d}\right) - W_t^m L_t^m - I_t - i_{t-1}K_{t-1} - (1+i^*)E_t B_{t-1} + E_t B_t, \quad (6)$$

subject to the Cobb-Douglas mining production function:

$$Y_t^m = A_t^m (K_t)^{\propto} (L_t^m)^{1-\propto} \quad (7)$$

where Y_t^m is the total output of mining firms,

$$Y_t^m = Y_t^{m,f} + Y_t^{m,d}. \quad (8)$$

The equation of motion for capital can be written as

$$I_t = K_t - (1-\delta)K_{t-1} \quad (9)$$

where δ is the depreciation rate of capital. The foreign demand for mining goods is characterized by a similar function to the one on the agricultural goods:

$$Y_t^{m,f} = Y_t^{m,f,D}\left(E_t P_t^{m,F} / P_t^{m,f}, Y_t^F\right). \quad (10)$$

The first order conditions of mining firms show that the marginal product of labor equals the real wage rate (in domestic currency) in the mining sector:

$$(1-\propto)A_t^m (K_t/L_t^m)^{\propto} = W_t^m / \{(1-\tau)P_t^m E_t\} \quad (11)$$

and the marginal product of capital equals the real interest rate on capital plus the depreciation rate:

$$\propto A_t^m (L_t^m/K_t)^{1-\propto} = (i_t + \delta)/\{(1-\tau)P_t^m E_t\}. \quad (12)$$

Households maximize utility function $U\left(L_t^a, L_t^m, Y_t^{a,d}, Y_t^{m,d}, Y_t^i\right)$, where $U_{L_t^a} < 0$, $U_{L_t^m} < 0$, $U_{Y_t^{a,d}} > 0$, $U_{Y_t^{m,d}} > 0$, $U_{Y_t^i} > 0$, subject to the following budget constraint

$$P_t^{a,d} Y_t^{a,d} + P_t^m E_t Y_t^{m,d} + P_t^i E_t Y_t^i + I_t \le W_t^a L_t^a + W_t^m L_t^m + i_{t-1}K_{t-1} + G_t \quad (13)$$

where Y_t^i is the amount of imported consumer goods, P_t^i is its imported price in foreign currency and G_t is a government lump-sum transfer to households. The first order conditions of the household's problem yield the following equations that contain the Euler equation:

$$U_{Y_t^{a,d}}/U_{Y_t^i} = P_t^{a,d}/\left(P_t^i E_t\right), \tag{14}$$

$$U_{Y_t^{m,d}}/U_{Y_t^i} = P_t^m/P_t^i, \tag{15}$$

$$U_{L_t^a}/U_{Y_t^{a,d}} = -W_t^a/P_t^{a,d}, \tag{16}$$

$$U_{L_t^m}/U_{Y_t^{m,d}} = -W_t^m/(P_t^m E_t), \tag{17}$$

$$\beta\, U_{Y_{t+1}^{a,d}}(1 + i_t - \delta)P_t^{a,d}/\left(U_{Y_t^{a,d}} P_{t+1}^{a,d}\right) = 1, \tag{18}$$

where β is the discount factor.

The government satisfies the budget constraint, the balance sheet condition and non-negativity constraint of foreign reserves. The budget constraint sets tax revenues plus dividends from two firms (α^a is a fraction of dividend paid from agricultural firms to foreign investors and the remaining portion $1 - \alpha^a$ is paid to the government; the same notation α^m applies to mining firms) equal the transfers to households. The government redistributes the national wealth from the country's resources in mining and agricultural sectors to its citizens.

$$\tau\left(P_t^{a,f} E_t Y_t^{a,f} + P_t^m E_t Y_t^m\right) + (1 - \alpha^a)\Pi_t^a + (1 - \alpha^m)\Pi_t^m = G_t. \tag{19}$$

The central bank's balance sheet imposes the condition

$$M_t^S = \overline{DC} + F_t E_t \tag{20}$$

where M_t^S is the nominal money supply, $\overline{DC}$ is domestic credit, which is fixed in this model[8], and F_t is amount of foreign reserves expressed in foreign currency term. We assume that the central bank does not earn the interest rate on foreign reserve assets. Furthermore, the government needs to satisfy the non-negativity constraint of foreign reserves.

[8] If the domestic credit to the government is endogenous, under the condition that the negative commodity price shock lowers the government revenue while the expenditure cut is politically difficult, thereby resulting in a fiscal deficit, the revenue requirement of the government puts additional pressure on exchange rate depreciation through incentives of inflation tax (van Wijnbergen 1991). For instance, if domestic credit grows over time (e.g., $\overline{DC}_{t+1} = (1 + \mu_t)\overline{DC}_t$ where $\mu_t > 0$ is the rate of domestic credit growth that reflects expected monetary financing of government deficits), the model includes the feature of the first-generation model, and hence the inconsistent macroeconomic policy regime leads to a BOP crisis equilibrium (Cumby and van Wijnbergen 1989). An economic intuition is that the Krugman-Flood-Garber type first-generation model shows that under the fixed exchange rate regime, an increase in domestic credit is offset one-for-one by a fall in foreign reserves, such that the money supply remains constant. Once foreign reserves deplete, the fixed exchange rate regime becomes unsustainable. I further discuss related issues in the next policy discussion section.

$$F_t \geq 0. \tag{21}$$

A money market equilibrium can be expressed by an LM equation:

$$M_t^S = P_t m_1^d \tag{22}$$

where $P_t = \vartheta^a P_t^{a,d} + \vartheta^m P_t^m E_t + \vartheta^i P_t^i E_t$ is a domestic price index, in which each goods is multiplied by its share in the consumption basket, and a real money demand, $m_1^d = m^d(Y_t^a + Y_t^m, i_t)$, has the standard properties of increasing in total output ($Y_t^a + Y_t^m$) and decreasing in i_t. Since the price is preset at the beginning of each period, it is the interest rate i_t that adjusts to equilibrate the money market. Thus, Eq. (22) yields

$$i_t = \emptyset(M_t^S, Y_t^a + Y_t^m) \tag{23}$$

where $\emptyset$ is the inverse of the m^d function with respect to i_t. The relationship between i_t and M_t^S is negative due to the standard liquidity effect; either of the two variables can be used to discuss the effects of monetary policy.

The interest rate on foreign currency bond and that on capital satisfy the following uncovered interest parity condition[9] since firms are indifferent between borrowing from abroad and borrowing from domestic households

$$1 + i_1 = (1 + i^*)\, E_2^e / E_1 \tag{24}$$

where E_2^e is the expected nominal exchange rate in period 2. If a parallel exchange rate market exists, the exchange rate in this market contains higher premium in the case of FX rationing and is equivalent to what we call a "shadow exchange rate ($\tilde{E}_t$)" later. Thus, if the parallel market emerges under the FX rationing in practice, the interest parity condition holds for this shadow exchange rate, i.e., $1 + i_1 = (1 + i^*)\, E_2^e / \tilde{E}_1$. If i_1 is decreased, but E_2^e is unchanged, then E_1 must increase (depreciate).

Note that the BOP identity in domestic currency is written as

$$P_t^{a,f} E_t Y_t^{a,f} + P_t^m E_t Y_t^{m,f} - P_t^i E_t Y_t^i = \alpha^a \Pi_t^a + \alpha^m \Pi_t^m + (1 + i^*) E_t B_{t-1} - E_t B_t + \Delta F_t E_t \tag{25}$$

where $\Delta F_t = F_t - F_{t-1}$. Dividing this by E_t, the BOP identity can be rewritten in foreign currency (i.e., U.S. dollars) as

$$P_t^{a,f} Y_t^{a,f} + P_t^m Y_t^{m,f} - P_t^i Y_t^i = (\alpha^a \Pi_t^a + \alpha^m \Pi_t^m)/E_t + (1 + i^*) B_{t-1} - B_t + \Delta F_t. \tag{26}$$

The initial equilibrium in period 1 is defined as follows. An equilibrium at the beginning of period 1 is a set of allocations $\{L_1^a, L_1^m, Y_1^a, Y_1^{a,d}, Y_1^{a,f}, Y_1^m, Y_1^{m,d}, Y_1^{m.f}, Y_1^i, K_1, I_1, B_1, \Pi_1^a, \Pi_1^m, M_1^S, m_1^d, F_1\}$

[9] Underlying assumptions behind this condition are (1) perfect capital mobility and (2) perfect substitutability of domestic and foreign assets. We use the uncovered interest parity condition rather than the covered interest parity condition because the forward market is not well-developed in PNG.

and a set of prices and wages as well as interest and exchange rates $\{P_1^{a,f}, P_1^{a,d}, P_1^m, W_1^a, W_1^m, i_1, E_1\}$, given $\{P_1^{a,F}, P_1^{m,F}, P_1^i, Y_1^F, A_1^a, A_1^m, K_0, B_0, F_0, i_0, i^*, \overline{DC}, E_2^e, \tau, \propto, \alpha^a, \alpha^m, \vartheta^a, \vartheta^m, \vartheta^i, \beta, \delta\}$ such that:

1. $\{L_1^a, L_1^m, Y_1^a, Y_1^{a,d}, Y_1^{a,f}, Y_1^m, Y_1^{m,d}, Y_1^{m.f}, K_1, B_1, \Pi_1^a, \Pi_1^m\}$ solve the firms' problem and satisfy Eqs. (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11) and (12).

2. $\{L_1^a, L_1^m, Y_1^{a,d}, Y_1^{m,d}, Y_1^i, K_1\}$ solve the household's problem and satisfy Eqs. (13), (14), (15), (16), (17) and (18).

3. $\{G_1, F_1, M_1^S\}$ solve the government's problem and satisfy Eqs. (19), (20) and (21).

4. $\{m_1^d\}$ satisfies the money market equilibrium condition Eq. (22).

5. $\{E_1, F_1\}$ satisfies the interest parity condition Eq. (24) and the BOP identity Eq. (26).

The model can be solved with the number of endogenous variables matching with the equilibrium conditions (24 in total).

The remainder of the paper focuses on the external adjustment of a negative commodity price shock. Although a domestic adjustment it is not the main focus, it is discussed here given its implications on fiscal and monetary policies, as well as in next section which discusses policy. Under negative shocks to commodity prices (i.e., $P_1^{a,f,shock} < P_1^{a,f}$ and $P_1^{m,shock} < P_1^m$), the BOP identity in U.S. dollars (26) will be

$$P_1^{a,f,shock} Y_1^{a,f} + P_1^{m,shock} Y_1^{m,f} - P_1^i Y_1^i = \frac{\left(\alpha^a \pi_1^{a,shock} + \alpha^m \pi_1^{m,shock}\right)}{E_1} + (1+i^*)B_{t-1} - B_t + \Delta F_1^{shock} \tag{27}$$

where superscript $shock$ denotes the variable after the shocks. Taking a difference between (27) and (26), we find that negative commodity price shocks reduce foreign reserves by:

$$F_1 - F_1^{shock} = \Delta P_1^{a,f} Y_1^{a,f} + \Delta P_1^m Y_1^{m,f} - (1-\tau)\left(\alpha^a \Delta P_1^{a,f} Y_1^{a,f} + \alpha^m \Delta P_1^m Y_1^m\right)/E_1 \tag{28}$$

where $\Delta P_1^{a,f} \equiv P_1^{a,f} - P_1^{a,f,shock}$ and $\Delta P_1^m \equiv P_1^m - P_1^{m,shock}$.

Fiscal Policy

The negative commodity price shocks also affect tax revenues and government expenditures. Government revenues and expenditures decline by the following amount:

$$\Delta G_1 = E_1\left[\tau\left(\Delta P_1^{a,f} Y_t^{a,f} + \Delta P_1^m Y_t^m\right) + (1-\tau)\left\{(1-\alpha^a)\Delta P_1^{a,f} Y_t^{a,f} + (1-\alpha^m)\Delta P_1^m Y_t^m\right\}\right]. \tag{29}$$

Since household income declines as a result of a reduced government lump-sum transfer, household consumption, including imported goods, would also decline (Eq. [13]). Thus, if we endogenize the household behavior after the commodity price shock in period 1, an amount of import compression is somewhat smaller than the arguments below. If the government raises the tax rate in response to commodity price shocks and redistributes its revenue to households, it can support consumption but at the same time it will lower firms' profits, leading to lower dividend revenues in period 2.

Exchange Rate and Monetary Policies

Next, we discuss four policy options for the government in response to the BOP problem caused by the negative commodity price shocks. The focus is strictly on the effects of shocks on the external balance, setting aside any effects on domestic adjustment (i.e., the tax revenue shortfall illustrated above). This assumption can be justified when the government can maintain the level of expenditure by getting additional revenues from exogenous sources such as withdrawing from its sovereign wealth funds or relying on grants from foreign governments. By contrast, if we consider the fiscal consolidation channel, an amount of import compression is somewhat smaller than the arguments below. An equilibrium at the end of period 1 depends on the government's policy response.

1) Without Any Policy (Severe FX Rationing)

If the government does not respond—that is, if the central bank does not provide additional FX and does not change the exchange rate and the interest rate in the face of shocks—import volumes would decrease by the following amount:

$$Y_1^i - Y_1^{i,shock} = \frac{\Delta P_1^{a,f} Y_1^{a,f} + \Delta P_1^m Y_1^{m,f} - (1-\tau)\left(\alpha^a \Delta P_1^{a,f} Y_1^{a,f} + \alpha^m \Delta P_1^m Y_1^m\right)/E_1}{P_1^i}. \tag{30}$$

If importers do not reduce orders, an amount of import orders are unmet and become backlogs.[10] This is a situation in which imports are fully compressed by the shortage of FX. In this case, the equilibrium condition (26) is replaced by (27) and the amount of imports is equivalent to $Y_1^{i,shock}$ at the end of period 1. In this policy mix of fixed exchange rate and severe FX rationing, the asset side of the central bank's balance sheet shrinks in the face of shocks, i.e., lower M_1^S in Eq. (20). If the central bank keeps the nominal interest rate (i_1) constant and the decline in money supply, $\Delta M_1^S = \left(F_1 - F_1^{shock}\right)E_1$, is greater than the decline in nominal money demand, $\Delta P_1 m_1^d = \vartheta^m \Delta P_1^m E_1 m_1^d$, the monetary condition is tightened compared to the situation before the commodity price shocks where the economy was in initial equilibrium.

2) Partial Intervention Policy (Modest FX Rationing)

If the central bank provides an additional ΔF_1^* amount of foreign reserves in the market without changing the exchange rate, the amount of import compression is smaller than the previous case (30):

$$Y_1^i - Y_1^{i,*} = \frac{\Delta P_1^{a,f} Y_1^{a,f} + \Delta P_1^m Y_1^{m,f} - (1-\tau)\left(\alpha^a \Delta P_1^{a,f} Y_1^{a,f} + \alpha^m \Delta P_1^m Y_1^m\right)/E_1 - \Delta F_1^*}{P_1^i}. \tag{31}$$

In this modest FX rationing case, the equilibrium condition (26) is replaced by

[10] Assuming unchanged export volumes at 2014 levels for each commodity in 2015, commodity price declines in 2015 reduced export revenues by approximately 3 billion Kina in PNG, whereas the unmet import orders amounted around 2 billion Kina at that time. Considering the BPNG's FX intervention, our next modest FX rationing case can explain the PNG situation well.

$$P_1^{a,f,shock}Y_1^{a,f} + P_1^{m,shock}Y_1^{m,f} - P_1^i Y_1^{i,*} = \frac{\left(\alpha^a \pi_1^{a,shock} + \alpha^m \pi_1^{m,shock}\right)}{E_1} + (1+i^*)B_{t-1} - B_t + \Delta F_1^{shock} + \Delta F_1^* \quad (32)$$

at the end of period 1 and import volume is $Y_1^{i,*}$, which is greater than the previous case of severe FX rationing (i.e., $Y_1^{i,*} > Y_1^{i,shock}$). In the case of unsterilized partial FX intervention, if all other things being equal, the decline in money supply is larger than the previous case of no intervention, and hence the effects of monetary tightening is stronger than the previous one.

3) Full Intervention Policy (No FX Rationing)

If the central bank wants to clear all backlogs of imports, it should provide an amount of foreign reserves shown in (28), which we define ΔF_1^{full}, in the market to fully offset the loss of FX inflows caused by declines in commodity prices. The BOP identity in the equilibrium at the end of period 1 becomes

$$P_1^{a,f,shock}Y_1^{a,f} + P_1^{m,shock}Y_1^{m,f} - P_1^i Y_1^{i} = \frac{\left(\alpha^a \pi_1^{a,shock} + \alpha^m \pi_1^{m,shock}\right)}{E_1} + (1+i^*)B_{t-1} - B_t + \Delta F_1^{shock} + \Delta F_1^{full} \quad (33)$$

so that import volume does not change in the face of commodity price shock. This policy is feasible as long as the government has enough reserves to clear all backlogs of imports. In other words, the central bank should satisfy the non-negativity constraint for foreign reserves (21), which becomes in this case:

$$F_1 - \left\{\Delta P_1^{a,f}Y_1^{a,f} + \Delta P_1^m Y_1^{m,f} - (1-\tau)\left(\alpha^a \Delta P_1^{a,f}Y_1^{a,f} + \alpha^m \Delta P_1^m Y_1^{m,f}\right)\right\}/E_1 \geq 0. \quad (34)$$

In this case, the unsterilized full intervention could be justified only when the inflation rate has been too high and the monetary authority wants to take this opportunity to reduce inflation. Otherwise, the sterilized intervention shall be preferred to avoid the effects of excessive monetary tightening effects in an economic downturn.

4) Flexible Exchange Rate Policy

Another way to deal with the BOP problem is to use exchange rate flexibility as a shock absorber. In the case of a perfectly flexible exchange rate policy, all equilibrium conditions at the end of period 1 are the same as before except that the exchange rate is changed to the market clearing level (i.e., $E_1^{flex} > E_1$). To analyze the effects of a flexible exchange rate policy, we take a derivative of the BOP identity in U.S. dollars (26) with respect to the exchange rate

$$P_t^{a,f}\frac{\partial Y_t^{a,f}}{\partial E_t} + P_t^{m,f}\frac{\partial Y_t^{m,f}}{\partial E_t} - P_t^i\frac{\partial Y_t^i}{\partial E_t} = \frac{\frac{\partial(\alpha^a\pi_t^a + \alpha^m\pi_t^m)}{\partial E_t}E_t - (\alpha^a\pi_t^a + \alpha^m\pi_t^m)}{E_t^2} + \frac{\partial \Delta F_t}{\partial E_t}. \quad (35)$$

Using elasticity term (ξ^i: elasticity of goods i with respect to the exchange rate), we can rewrite the equation (35) as follows:

$$P_t^{a,f}\xi^a\frac{Y_t^{a,f}}{E_t} + P_t^{m,f}\xi^m\frac{Y_t^{m,f}}{E_t} - P_t^i\xi^i\frac{Y_t^i}{E_t} = \left\{\alpha^a\left(\frac{\partial\pi_t^a}{\partial E_t}E_t - \pi_t^a\right) + \alpha^m\left(\frac{\partial\pi_t^m}{\partial E_t}E_t - \pi_t^m\right)\right\}/E_t^2 + \xi^{\Delta F}\frac{\Delta F_t}{E_t}. \quad (36)$$

Multiplying both sides by E_t, we get

$$\xi^a P_t^{a,f} Y_t^{a,f} + \xi^m P_t^{m,f} Y_t^{m,f} - \xi^i P_t^i Y_t^i = \Gamma_t + \xi^{\Delta F} \Delta F_t$$

where $\Gamma_t = \alpha^a \left\{(1-\tau)\xi^a P_t^{a,f} Y_t^{a,f} - \frac{P_t^{a,d} Y_t^{a,d} - W_t^a L_t^a}{E_t}\right\} + \alpha^m \left\{(1-\tau)\xi^m P_t^{m,f} Y_t^{m,f} - \frac{-W_t^m L_t^m - (1+i_{t-1}^B)B_{t-1} + B_t + (1-\delta)K_{t-1} - K_t}{E_t}\right\}$. (37)

In the previous empirical analysis section, we showed that both agricultural and mining exports increase ($\xi^a > 0$ and $\xi^m > 0$) and imports decrease ($\xi^m < 0$) when there is a currency depreciation. Under the latter, the left-hand side of (37) shows that both agricultural and mining exports will increase, whereas imports will decrease. The total change in trade account on the left-hand side of the equation must be equal to the right-hand side, which is the sum of increased dividend payments to foreign investors (as a result of higher profit stemming from [i] lower costs due to valuation effects for domestic currency components and [ii] increased export volumes) and the change in foreign reserves.

The monetary policy can be also used to affect exchange rate dynamics under the flexible exchange rate regime. The interest parity condition (24) in combination of Eq. (23) indicates that the central bank can lower the interest rate i_1 or increase money supply M_1^S to induce currency depreciation. This monetary easing is appropriate especially when the economy is hit by negative commodity price shocks because the inflation rate is slowing down and hence there is more room for accommodative monetary policy to support the economy. However, the loose monetary policy and resulting exchange rate depreciation may lead to a higher inflation depending on the degree of exchange rate pass-through, and the monetary policy needs to be tightened after the period of commodity price shocks.

The optimization problems and equilibrium conditions in period 2 differ slightly from the previous period as follows. Suppose the commodity price levels are the same as the ones at the end of period 1 after the shock ($P_1^{a,f,shock} = P_2^{a,f}$ and $P_1^{m,shock} = P_2^m$). Put differently, negative commodity price shocks are assumed to be permanent. Then, some equilibrium conditions differ from those in period 1 as follows. First, there is no issuance of bonds ($B_2 = 0$) in period 2 because the model ends in this period. Second, depending on the policy measure chosen by the central bank at the end of period 1, the exchange rate and/or household behavior change. Namely, if the central bank adopts the flexible exchange rate policy, the exchange rate should depreciate in period 2 ($E_2 > E_1$) to clear all markets, and the households face higher domestic price for imported goods. By contrast, if the authority rations FX with fixed exchange rate ($E_2 = E_1$), household's optimization problem includes the following additional constraint on import volume,

$$Y_2^i \leq Y_2^{i,Rationing} \tag{38}$$

where $Y_2^{i,Rationing}$ is the upper limit of imports in period 2, which is automatically determined by the amount of FX intervention by the central bank. Given the same import price due to the same exchange rate, in this FX rationing case, the household's optimization problem results in a corner solution of $Y_2^i = Y_2^{i,Rationing}$.

To understand the welfare impact of FX rationing, it is helpful to consider the shadow exchange rate that households are facing under import compression. We define the *shadow exchange rate* ($\tilde{E}_t$) as the exchange rate that would prevail if allowed to float and attain equilibrium in the imported goods market. Figure 2 illustrates the shadow exchange rate in three FX rationing cases, severe, modest, or no rationing corresponding to no, partial and full intervention by the central bank in the FX market. Suppose that the supply of imported goods is inelastic to its price; in other words, the price of imported goods in foreign currency is exogenously determined in the global market, which is a plausible assumption for a small open economy. Also, suppose the case of a linear demand curve for simplicity. The equilibrium volume of imports is determined at the intersection of demand and supply curves, Y_1^i. If there is a negative commodity price shock and the central bank does not intervene in the FX market, import volume is compressed to $Y_1^{i,shock}$ due to the FX shortage. In this case, households face the high shadow exchange rate $\tilde{E}_1^{shock}$ as shown in the figure. Next, if the central bank provides FX partially to offset the effects of negative commodity price shock, imports are higher than ($Y_1^{i,*} > Y_1^{i,shock}$) and the shadow exchange rate is lower than in the case without intervention ($\tilde{E}_1^* < \tilde{E}_1^{shock}$). Finally, if the full amount of FX is supplied by the central bank to meet all import orders determined at the beginning of period 1, imports remain the same as in the initial equilibrium level. In each case, consumer welfare loss is depicted in the trapezoidal shaded area below the demand curve and above the supply curve. Not to mention, the welfare loss is larger in the case of severe FX rationing (red shaded area) than in the modest one (light blue shaded area), owing to the shadow exchange rate. It is worth mentioning that this welfare loss is larger when the price elasticity of import demand is higher (i.e., steeper slope of demand curve). The relationship between the shadow exchange rate premium, which is defined as the shadow exchange rate minus the actual exchange rate, and amount of FX intervention is shown in Figure 3. The more the central bank rations FX, the higher the shadow exchange rate premium becomes. If a parallel exchange rate market emerges under the FX rationing in practice, the shadow exchange rate prevails in this market, and hence the import price inflation is $P_1^i\tilde{E}_1$ under the rationing.

Figure 2. Welfare Loss by Import Compression

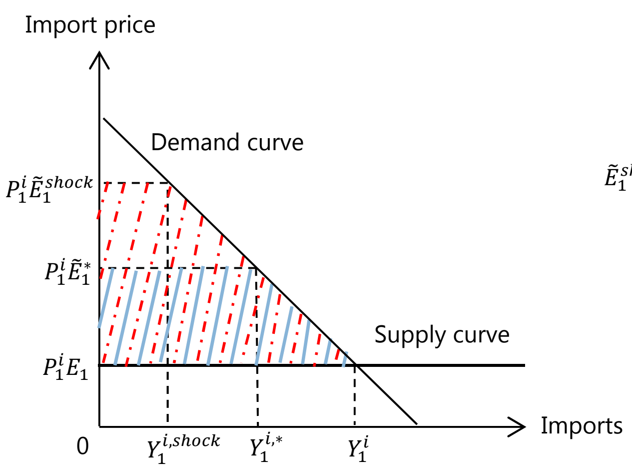
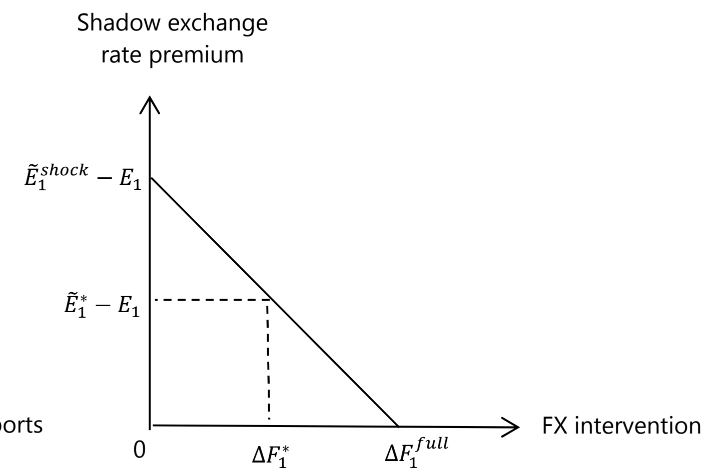


Figure 3. Shadow Exchange Rate Premium



Which is the better policy, FX intervention (and rationing) policy with fixed exchange rate or flexible exchange rate policy? The pros and cons of each are weighed and presented in Table 17. For example, currency depreciation will increase price competitiveness of export sector on one hand, but also increase debt burden denominated in foreign currency unless the exchange rate risk is fully hedged. Thus, there is a tradeoff between the sectors and the total benefit of depreciation depends on the elasticity of exports and the relative size of foreign currency debt to exports (Nakatani 2017a). We will discuss this issue in the context of PNG in the next policy discussion section.

Table 17. Comparison of Two Exchange Rate Policies

Pros (if Yes) and Cons (if No)	FX Rationing with Fixed Exchange Rate Policy	Flexible Exchange Rate Policy
1. Import price stability as a nominal anchor	Yes	No
2. Exchange rate stability without overshooting	Yes	No
3. Minimizing opportunity cost of holding reserves	Yes	No
4. Management of unhedged exchange rate risk	Yes	No
5. Holding reserves as a buffer	No	Yes
6. Competitiveness in export sector	No	Yes
7. Absence of restriction on imports	No	Yes
8. Market-clearing price mechanism	No	Yes
9. Demand shift from imports to domestic goods	No	Yes
10. Avoiding the need for internal devaluation	No	Yes
11. Easiness to implement	No	Yes
12. Independent monetary policy	No	Yes
13. Less need for prudent fiscal consolidation	No	Yes
14. Impossible collapse of the exchange rate regime	No	Yes

V. POLICY DISCUSSION

Based on the estimated elasticities, we can calculate the impacts of currency depreciation policy on FX. We have estimated the elasticities of exports and imports in the previous empirical part. Using these elasticities, we can provide a rough calculation of the effects of exchange rate depreciation on net trade and FX (see Box 2 for details). Our results show that a 10% depreciation in the REER is associated with an increase of about $150 million in exports and a decrease of about $100 million in imports, suggesting that the FX will increase by $250 million in 2017. Taking into account the fact that PNG had experienced a large real depreciation of Kina (i.e. more than 10% points) only in the late 1990s coinciding with a difficult economic situation, a 6% depreciation is deemed to be a reasonable scenario. Guided by the estimation detailed in Box 2, a 6% REER depreciation will increase FX by $150 million.

Box 2: Simulated Analysis on Foreign Exchange

A 10% depreciation of REER will increase FX by around $250 million. To analyze the effects of exchange rate depreciation policy on international trade and FX, we use elasticities of exports and imports estimated in the empirical analysis section.[11] Specifically, we first employ an export elasticity of -0.43 from column (1) of Table 11, and an import elasticity of 0.98 which is an average of cointegration regressions in Table 16. As for imports, we assume that only non-resource imports can respond to exchange rates because imports in the resource sector are not facing the FX constraint and may even increase when resource exports increase under the currency depreciation. Putting these elasticities into the IMF's framework of BOP forecasts, we find that a 10% depreciation of REER will increase exports by about $200 million and decrease imports by about $100 million in 2017. Next, to control a cross-sectional dependence in agricultural and mining production, we multiply the amount of increase in exports by the ratio 0.30/0.43 (=column (4)/column (3) of Table 11). Then, we get the adjusted increase in export of around $150 million. Thus, the impact of 10% REER depreciation on the total increase in net trade is about $250 million ($150 million from exports and $100 million from imports).

Beyond external adjustment, there are also gains from domestic adjustment – fiscal side and expenditure switching – if the country adopts a flexible exchange rate policy. Low commodity prices reduce government tax revenues from resource companies, which in turn lead to lower government expenditure to maintain the budget balance (Eq. [19]). This reduction in government expenditures will reduce household income and hence consumption (Eq. [13]). Note that the response of consumption (and investment) depends on the duration of commodity price shocks (Spatafora and Warner 1995; Kent and Cashin 2003). If the negative commodity price shock is permanent as assumed in our model, households are forced to reduce consumption faced with permanent income decreases.[12] As such, the negative commodity price shock can transmit to the real economy not only through the external adjustment process but also through the domestic side via fiscal consolidation (Eq. [29]). This effect is prominent in resource-rich economies because they tend to rely heavily on resource revenues to fund their budgets (Danforth et al. 2016). However, one merit of flexible exchange rate policy is that if the domestic currency depreciates as a shock absorber, profits of firms and hence the tax revenues collected by the government will increase in the domestic currency. Also, if the government has an incentive to hold a certain amount of foreign reserves as a buffer against further external shocks, the flexible exchange rate policy is superior to the FX intervention policy. Moreover, although we assumed no interest income from foreign reserve assets in our model, in practice, the government can use capital gains from foreign reserves in terms of domestic currency for fiscal financing if there is a currency depreciation. Furthermore, a currency depreciation raises the

[11] Some studies argue the lagged effects of exchange rate depreciation on imports and exports are different (the J-Curve effects), although such an argument is inconclusive to date (Bahmani-Oskooee and Ratha 2004). In this paper, it does not matter since our calibrated analysis uses the long-run elasticities of exports and imports.

[12] Spatafora and Warner (1995) showed that the permanent negative terms-of-trade shocks have a strongly significant negative effect on investment as well due to lower profits and the reduced demand.

domestic price of imported goods, which induces expenditure switching (Eqs. [14] and [15]) from imported goods to domestic goods (Shiells et al. 1986), assuming the absence of a supply-side constraint. Towbin and Weber (2013) found that this effect of expenditure switching is stronger for countries with a small foreign currency debt[13] and high exchange rate pass-through, which is the case for PNG, as a flexible exchange rate regime can insulate output better from a negative terms-of-trade shock compared to a fixed regime. Recent observations show that the real exchange rate depreciation has led to an increase in exports and a stronger reduction in imports, with the expenditure switching in commodity exporting countries in Latin America (IMF 2017b). These domestic adjustments also help the government and domestic industry.

Our analysis supports the flexible exchange rate policy, though it depends on the associated cost (i.e., pass-through of exchange rates to inflation). Our empirical analysis showed that both imports and commodity exports in PNG certainly respond to real exchange rates, indicating that a depreciation of real exchange rate increases exports and decreases imports. As pointed out in Table 17, each policy has benefits and costs. One argument against the exchange rate depreciation policy is that this policy may increase import prices and result in higher inflation. To assess the costs associated with an exchange rate depreciation policy, we need further analysis of exchange rate pass-through into import and domestic prices.[14] If the country has large share of imported goods in its consumption basket, these countervailing effects from currency depreciation are not negligible. Import price inflation also eventually affects REER by changing CPI inflation in the medium-term.

Preserving a fixed exchange rate regime can provide a helpful nominal anchor for policymakers but only if credible fiscal adjustments are possible in the face of persistent adverse commodity price shocks. In the presence of a negative permanent shock to primary balance, the monetary authority can choose to postpone an exchange rate collapse if there exists a sufficient quantity of long-term government bonds by letting the price of bonds fall, although this is just a buying time strategy and the collapse is eventually inevitable (Daniel 2001). Choosing a fixed exchange rate policy is sustainable in the medium- and long-term only if the fixed exchange rate regime is credible. The credibility of an exchange rate peg can be established only when appropriate fiscal adjustments are possible under persistent negative commodity price shocks (Husain et al. 2015). van Wijnbergen (1991) showed that a domestic credit policy designed to offset loss of foreign reserves while the fixed exchange rate regime lasts, is necessary but not sufficient to prevent speculative attacks. The fixed exchange rate policy can be more favorable compared to the flexible exchange rate policy if the country has a limited capacity to conduct independent monetary policy. In contrast, a currency depreciation can help facilitate fiscal and external adjustment especially in countries with more diversified economies (Sommer et al. 2016).

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[13] The relative size of foreign currency debt to exports also matters for vulnerability of the economy against shocks (Nakatani 2017a).

[14] See Sampson et al. (2006) for early estimates of exchange rate pass-through in PNG. The degree of pass-through might be reduced recently because of increased competition between wholesalers and retailers. Firms have absorbed the cost associated with currency depreciation by squeezing their margins and sought alternative cheaper inputs from either external or domestic sources.

Why has REER not depreciated over the past three years and is there any implication for monetary policy? Our data shows that PNG's REER has not depreciated since the economy was hit by the huge negative commodity price shocks in mid-2014 (Figure 1). This evidence implies that domestic inflation in PNG has been higher than in its trading partners. This is not surprising for a country like PNG where the economy develops faster than foreign countries because the famous Balassa-Samuelson effects imply that an increase in productivity and wages in the tradable goods sector will also lead to higher productivity and wages in the non-tradable sector of the economy. In the case of PNG, since a highly productive LNG industry emerged recently, this became a driving force of real exchange rate appreciation even in times of falling global commodity prices.[15] In addition, a high level of liquidity, partly due to the past unsterilized FX intervention, ongoing long FX queues and current monetary financing of the budget deficit, also might create pressure on domestic inflation (IMF 2017a). In this regard, a tighter monetary policy would moderate the relatively high domestic inflationary effects.[16]

From a medium-term development perspective, it is important to raise productivity in agriculture. A recent study by Adamopoulos and Restuccia (2017) indicates that, given high soil fertility, temperature and precipitation, potential agricultural productivity is quite high in PNG from the viewpoints of geography and land quality. Increasing the productivity in agriculture is also emphasized in the government's Development Strategic Plan (Department of National Planning and Monitoring 2010). Supporting the agricultural sector is an important goal in PNG because the sector provides income for 85% of the rural population.[17] To achieve this, several institutional and structural reforms, although falling outside the analytic scope of this paper, are needed. First of all, land reform is necessary to provide the incentives to landowners to release their land for agricultural development because most lands in PNG are customary lands, which make it difficult for all community members agree on the use of commercial purposes. Moreover, building road infrastructure, including bridges, is critical to connect fertile regions of PNG with markets. This will enable development of key supply chains that link producers to markets. Introducing new technology such as high-yielding planting material to produce high yielding crops is also essential for raising productivity in agriculture because PNG's agricultural sector is low yielding due to poor farming practices.

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[15] Another commonly observed phenomenon in resource-rich economies is Dutch disease (Brahmbhatt et al. 2010). This happens when a boom in the natural resource sector attracts capital and labor from the rest of the economy. However, this effect is less likely to happen in low-income countries where most inputs in the resource sector are imported from abroad.

[16] To mop up excess liquidity in the banking system, an appropriate monetary policy instrument is open market operation. This is because if the policy interest rate is used, it will also affect the exchange rates through interest rate parity. For example, Nakatani (2017b) used panel data on 51 developing countries, including PNG, and found that a 1% increase in the policy interest rate is associated with a 1% appreciation of domestic currency.

[17] Coffee and cocoa are important cash crops for many PNG people. For instance, according to the Minister for Agriculture and Livestock, the cocoa industry is the livelihood of about 2 million people throughout the 14 cocoa producing provinces. According to the Chairman of the Productive Partnerships in Agriculture Project, the coffee industry provides the livelihood of 3.5 million rural growers in 16 coffee growing provinces.

VI. Conclusion

This study developed a theoretical model in which a commodity price shock causes a BOP problem. An unanticipated negative commodity price shock lowers export revenues and inflows of FX, thereby resulting in a shortage of foreign reserves. To deal with this situation, two exchange rate policies—(i) FX rationing with fixed exchange rate policy and (ii) flexible exchange rate policy—are compared. Our model shows that FX rationing reduces consumer welfare by creating the shadow exchange rate premium that consumers are facing (Figures 2 and 3). The model also shows that the flexible exchange rate policy, i.e., a depreciation of the exchange rate can be a superior policy tool if international trade, especially exports, respond to the real exchange rate.

We found that export commodities in PNG – coffee, cocoa, copper, rubber, tea, etc. – have statistically significant supply elasticities with respect to the exchange rate. Our panel regression analyses show that the short-run (one-year) elasticity of exports to REER has ranges between -0.3 and -0.7 depending on estimation methods. Several cointegration regressions and the ARDL model for each commodity also support this evidence of statistically significant export elasticity. The cointegration regressions by DOLS and FMOLS estimators provide the evidence that the elasticity of each commodity is between -0.5 and -2.3, showing much higher long-run elasticities for some commodities. So the results are robust to different specifications. Our analysis on import elasticity showed that imports are also responsive to the exchange rate. This implies that if REER in PNG had depreciated since the economy had been hit by the negative commodity price shock three years ago, export volumes and hence FX would have been higher than the current level even when we take into account the lagged effects of exchange rates.

Currency depreciation proves better than competing policy options, and it brings many additional benefits to the economy. First, as shown in our theoretical analysis, it lowers costs of domestic currency components (such as wages to employees) in the mining firms' balance sheet, which is in foreign currency (Eq. [37]). Second, it can increase tax revenues in domestic currency as a result of higher profits of firms. Third, it may boost goods exports (as shown in our analysis), as well as service exports such as tourism by lowering traveling costs in PNG for foreigners. Fourth, the BPNG is able to preserve foreign reserves as a buffer against further external shocks. Fifth, it induces expenditure switching from imported goods to domestic goods, and encourages a development of domestic industry in the medium-term. Sixth, the flexible exchange rate restores the market-clearing price mechanism and diminishes the long unmet import orders arisen under FX rationing, which hinder badly the business and government activities. Seventh, the flexible exchange rate regime alleviates the pressures on fiscal consolidation and allows more independent monetary policy.

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