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Resource Dependence, Commodity Shocks and the Role of the Exchange Rate: An Empirical Study of Papua New Guinea

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CAMA Working Paper 50/2022
Aug 2022

Rubayat Chowdhury
Centre for Applied Macroeconomic Analysis (CAMA), ANU

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Keywords

SVAR, natural resource, commodity shocks, forex market, exchange rate, devaluation, Papua New Guinea

JEL Classification

C51; E32; F43; F62

Address for correspondence:

(E) cama.admin@anu.edu.au

ISSN 2206-0332

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Resource dependence, commodity shocks, and the role of the exchange rate: an empirical study of Papua New Guinea*

Rubayat Chowdhury[2]

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The role of the exchange rate as a 'shock absorber' is often undermined in resource-dependent developing countries when a negative commodity price shock hits the economy. Rather than pursuing greater flexibility, the policymakers rely more on intervention strategies which further aggravates the balance of payment crisis by leading to a forex crisis. This paper presents an empirical study of Papua New Guinea which has been facing a severe shortage of foreign currency since 2013. It examines if a sudden depreciation shock to the exchange rate stimulates the overall trade balance while simultaneously evaluating its impact on inflation. Employing a structural vector autoregression model I find that the positive trade balance effect outweighs the negative inflationary effect. Further, I find external shocks as the major sources of real business cycles and a negative response of the non-resource economy to a positive resource shock.

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* The author is grateful to his Ph.D. supervisory panel Professor Renée Fry-McKibbin (Chair), Associate Professor Creina Day and Associate Professor Tatsuyoshi Okimoto at the Australian National University (ANU) for their guidance and support. The author would like to thank Professor Stephen Howes (ANU) for his valuable comments on this paper.

[2] Centre for Applied Macroeconomic Analysis, Crawford School of Public Policy, The Australian National University. Author's email address is Rubayat.Chowdhury@anu.edu.au.

1. Introduction

The foreign exchange market of Papua New Guinea (PNG) has been in persistent shortage of foreign currency over the past seven years. Since emergence of the shortage in early 2013, the central bank has exhausted around half of its foreign exchange reserves in intervention, however, with a little success in eliminating the backlog[3] of import orders. While the Bank of Papua New Guinea (BPNG), the central bank, responded to the shortfall with sizable intervention along with some preventive measures, the forex market remained illiquid with central bank being the only seller of forex in the interbank market.

The interbank foreign exchange market of PNG has not been operating efficiently. A well-functioning market is supposed to determine the value of domestic currency against foreign currencies so that the market forces match the demand with supply (Bollerslev & Domowitz 1993). However, there has been no active participation of the authorized foreign exchange dealers (AFEDs) in the interbank market since mid-2012; they take part in the market only to sell Kina, the domestic currency, when the central bank sells the U.S. dollar as part of its intervention strategy. The stock of outstanding sell Kina (or buy US$) orders in 2019 was K1.3 billion (US$381 million), equivalent to around 10 percent of the total imports and 16 percent of the forex reserves for the same year (BPNG 2019). However, there is a strong perception that the actual demand for forex is much higher than the orders placed in the market as a large number of small orders are usually not brought into the market on the assumption that those will not be served (Davies 2021).

The central bank responded to the crisis by selling forex in the interbank market and relying on several quantity-based measures. According to BPNG, net forex injection over the period 2013-2019 was US$4.5 billion which together with the foreign currency inflows was higher than the outflows (BPNG 2019). Besides, several directives were issued to improve foreign currency liquidity and to limit exchange rate volatility. For example, BPNG introduced an exchange rate trading band in June 2014 to the AFEDs requiring that the exchange rate applied to their clients cannot deviate by more than 75 basis points on either side of the reference rate (BPNG 2014). Other major measures included banning of foreign banks' Vostro accounts; restriction on foreign currency trade financing; 90-day retention period for export proceeds to be repatriated onshore; closing of many onshore foreign currency accounts, and so on. Despite these quantitative measures, the forex crisis prevailed.

Central bank's quantity-based approaches could only partially address the imbalance but could not eliminate the shortage. Critics have argued that such preventive measures have only been able to limit the exchange rate volatility without being able to improve the overall liquidity. Fox and Schroder (2017) argue that Kina has not depreciated enough in real term in response to falling capital inflows; they claim that Kina is overvalued by 20 percent. In fact, since implementation of the trading margin in 2014, Kina has depreciated by around 27 percent in the nominal term, but only by less than one percent in the real term (IMF 2020a). Nakatani

[3] Backlog results from transactions (import of goods and services) which are eligible to be paid in foreign currency, but the payment has not been paid and has been placed on AFED's outstanding order books.

(2017) finds that the shortage has led to severe forex rationing, which has adversely impacted imports of consumption goods and intermediate inputs. He argues that a more flexible exchange rate regime which induces a devaluation to an appropriate level can significantly improve the balance of payments.

Despite these recommendations, the central bank resorted to a regime of slow Kina depreciation on the argument that high import dependency and other infrastructural bottlenecks make the external sector less responsive to exchange rate changes; a devaluation would only lead to higher imported inflation without being able to bring any significant improvement to the overall trade balance (BPNG 2014). Nakatani (2018) addresses this elasticity pessimism by revealing that the Marshall-Lerner condition holds for PNG, i.e., a depreciation should improve the overall trade balance; however, he does not explore the cost of depreciation in terms of imported inflation, which is one of the major concerns for the central bank. For a highly import-dependent economy like Papua New Guinea, the fear of imported inflation cannot be ruled out; while there are no recent estimates, Sampson et al. (2006) finds that the exchange rate pass through to inflation can be as high as 50 percent.

This study attempts to fill the gap in the literature by evaluating the impact of an exchange rate depreciation on trade balance while simultaneously exploring the effect of the same size of depreciation on inflation. Using quarterly data for the period 1997-2019 and employing a structural vector autoregression (SVAR) model, it finds that the positive trade balance effect outweighs the negative inflationary effect. Specifically, it finds that a 10 percent depreciation shock to the real exchange rate immediately triggers inflation by one percentage point while improves the overall trade balance by 10-15 percent above the baseline, one year after the shock. Further, the trade balance response lasts longer than the inflation response. The positive trade balance effect remains even if liquified natural gas (LNG), which constitutes one-third of the total exports, but has a little contribution to the forex inflows, is taken out from the export basket. Overall, the results point to an effective role of the exchange rate in addressing the ongoing foreign exchange shortage in Papua New Guinea.

The specification of the SVAR model allows to explore additional research questions, not being addressed recently in the PNG-specific empirical literature. First, it finds that external shocks, particularly, commodity price shocks, are important sources of PNG's real business cycle movements, and reaffirms that Kina is commodity currency. Second, it finds the evidence of resource curse resulting from currency appreciation as well as reallocation of resources from mining to non-mining sector. While the overall domestic output responds positively to a resource export shock, the non-resource output falls immediately and remains below the baseline for around two years. Finally, this study proposes an alternative interpolated measure of quarterly gross domestic product for Papua New Guinea.

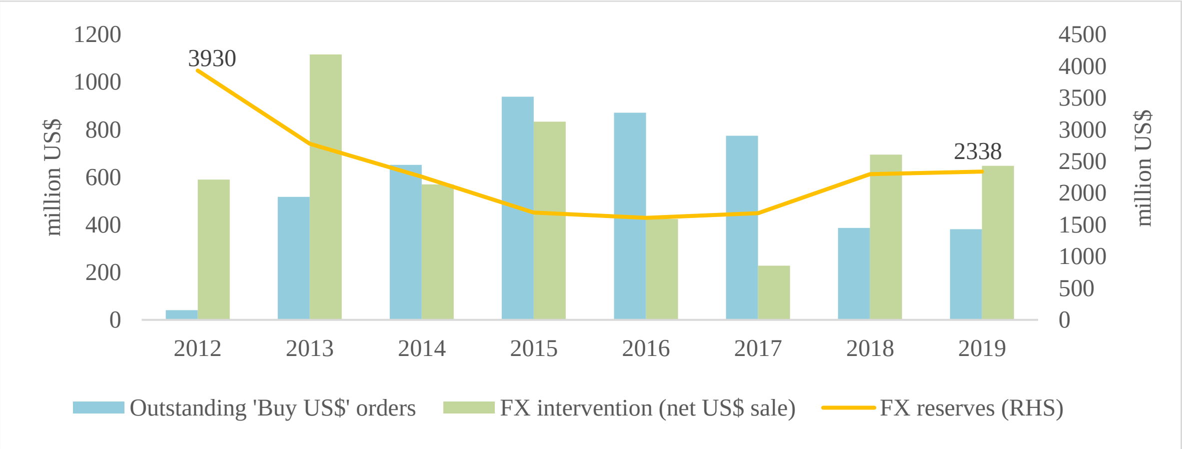
The remainder of the paper is structured as follows. Section 2 briefly discusses the forex shortage episode with a particular emphasis on the causes and consequences of the shortfall. Section 3 reviews the literature on the effectiveness a currency depreciation on output and trade. Empirical method and data descriptions are in Section 4. Section 5 summarizes and discusses the results, and Section 6 concludes.

2. Foreign exchange shortage in PNG: Causes and consequences

The ongoing shortage of foreign currency is believed to be one of the most pressing impediments to private sector investment and growth in Papua New Guinea (IMF 2020a). While the commencement of US$19 billion PNG-LNG Project in 2010 (the largest ever resource project of the country) led to 13.1 percent growth in output in 2014, growth slowed down to 3.5 percent in 2017 (NSO 2020). IMF (2020b) forecasts sluggish economic growth over the medium term due to depressed non-resource sector activity. Several private sector surveys reveal foreign exchange as the top concern for business in Papua New Guinea where Kina convertibility has been a major issue (PWC 2017; Smirk 2020; James 2021). The local entrepreneurs consistently complain about the delays (3-12 weeks) in getting foreign exchange, while foreign-owned businesses find it difficult to remit dividends and profits (Fox 2021). Further, falling employment in the non-resource sector reflects lack of domestic demand in the post-LNG period (Davies 2021).

There is also a debate on the true position of the foreign exchange market. While the AFEDs report that they are unable to serve a large amount of import orders, the central bank claims that foreign currency inflows accompanied by its own intervention should have been sufficient to clear the market; the imbalance is just a reflection of frontload of orders (BPNG 2017). However, it is observed that despite central bank's large infusion of the U.S. dollar, outstanding sell Kina (or buy US$) orders nearly doubled between 2013 and 2015 (Figure 1). Further, faster depletion of forex reserves forced BPNG to reduce its intervention during 2016-2017; net forex sale in 2017 was only one-third of the outstanding 'buy US$' orders. The issuance of US$500 million debut sovereign dollar bond, concessional loans of US$250 million from development partners, and commercial loans of US$180 in 2018 million improved forex reserves and net forex injection, however, could not eliminate the backlog. While the debate continues, two important questions arise- what are the driving forces behind the shortage and how does it translate to the economy?

Figure 1. Foreign exchange market of Papua New Guinea, 2012-2019.



Source: Bank of Papua New Guinea, Annual Reports.

2.1 Causes

There are several hypotheses that address the first question, i.e., what have contributed to the forex shortage. Some argue that PNG's high reliance on primary exports and the associated slowdown in the commodity prices are to blame (Barker 2016). Others add to this hypothesis by claiming that PNG earns enough foreign exchange from its exports which should have been sufficient to meet the demand; it is the placement of export proceeds in the offshore accounts that are not flowing back to the economy and therefore causing the shortage (BPNG 2018). Some others argue that the shortage is the result of an overvalued currency led by an exchange rate mismanagement for a long time (Fox and Schroder 2017; Nakatani 2017). International Monetary Fund (IMF) reclassified the exchange rate regime from 'floating' to 'crawl-like' in 2014 followed by 'stabilized' in 2016 and again to 'crawl-like' in 2017 (IMF 2021).

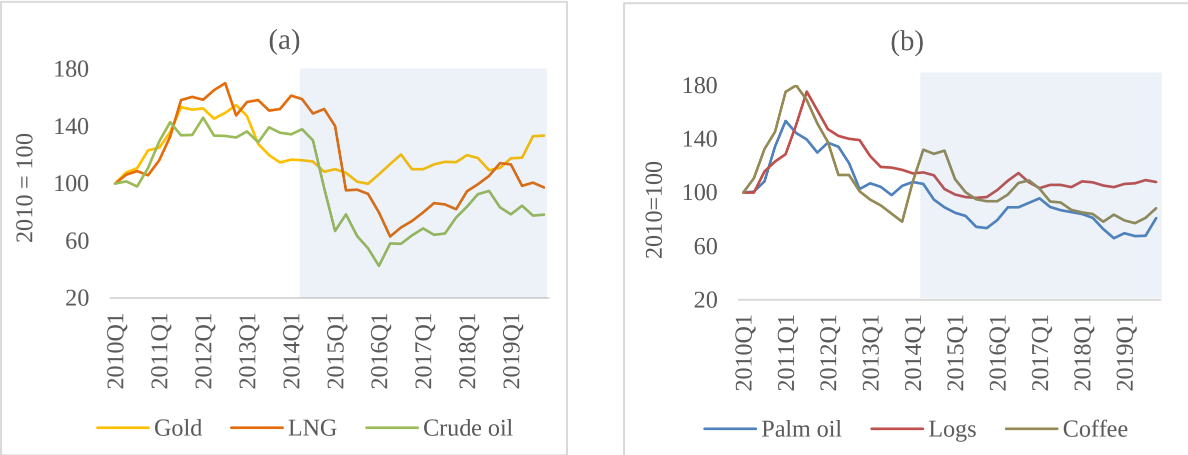
Resource dependent economies are usually vulnerable to external shocks and a negative price shock in the global commodity market can lead to severe balance of payment crisis (Nakatani 2018). Papua New Guinea is classified as an export-commodity-dependent country where around 98 percent of its exports are composed of commodities (UNCTAD 2021). PNG is in the group of world's top 10 LNG exporters and top 20 producers of gold, coffee, palm oil and cocoa (Nakatani 2017). Further, PNG's natural resource rent is the highest among the South Pacific economies and is higher than the average for the lower middle-income countries (World Bank 2020). Therefore, like any other resource-rich economies, a volatile international commodity price environment is a pressing challenge for PNG in maintaining a strong, stable growth path (Frankel 2010). With an export-to-GDP ratio of around 40 percent, it has been empirically observed that PNG's high growth periods were associated with the periods of higher export growth (Figure 2).

Figure 2. Relationship between GDP and export growth (%), 1997-2019.

Source: Bank of Papua New Guinea, Quarterly Economic Bulletin.

Global market prices of PNG's major resource and non-resource export commodities dropped sharply during the chronic forex shortage period, 2014-2016 (Figure 3). For example, LNG and crude oil prices in 2016Q4 were more than 50 percent lower than in 2014Q1. Over the same period, prices of top three non-resources commodities – palm oil, logs, and coffee dropped by 15 percent, on average.

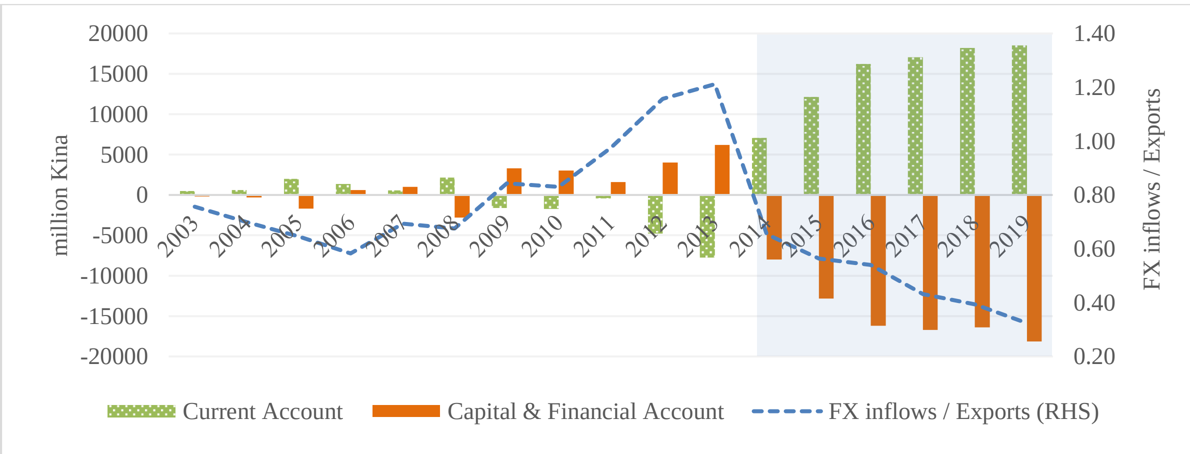
Figure 3. World prices, (a) resource commodities (b) non-resource commodities, 2010-2019.



Source: World Bank Commodity Price Data 2020.

It follows from the above discussion that a sharp decline in export prices may have resulted in the forex shortage. Theoretically, this should be reflected as a negative impact on the current account balance (Kilian et al. 2009). Interestingly, PNG experienced a large surplus in the current account during the episode of forex shortage which was offset by a deficit in the capital and financial account (Figure 4). This was due to foreign currency denominated debt repayments related to the LNG project. Further, LNG exporters are allowed to keep earnings in the offshore accounts to meet external liabilities under the Project Development Agreements (PDAs). Therefore, overall export volume in the post-LNG period may not truly reflect the availability of foreign exchange. The dotted line in Figure 4 shows the ratio of forex inflows relative to total exports; the ratio has become even smaller compared to the pre-LNG regime (2010 backwards). The average share of resource revenue in resource GDP during 2015-2019 was only 4.4 percent relative to 26 percent during 2005-2009 (PNG Economic Database 2021).

Figure 4. Balance of Payments and return from exports, 2003-2019.

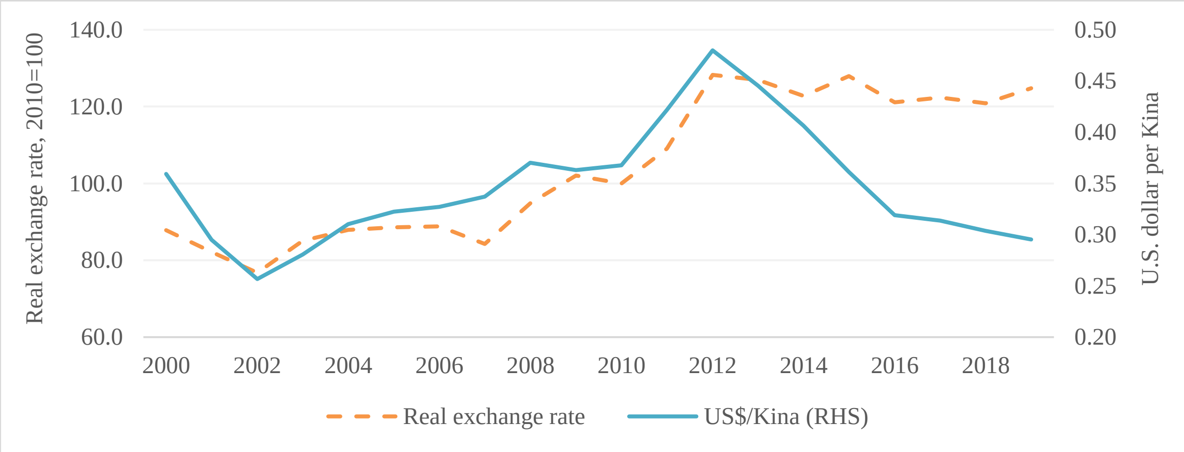


Source: Bank of Papua New Guinea, Quarterly Economic Bulletin, and Annual Reports.

Exchange rate rigidity has also been widely blamed for prolonged imbalance in the foreign exchange market. Critics have argued that Kina has not depreciated enough in response to falling commodity prices to discourage imports and encourage exports (Fox & Schroder 2017;

Nakatani 2017; Davies 2021). During the LNG construction phase (2010-2012), kina appreciated by around 30 percent, both in nominal and real terms. However, with the end of windfall gains, Kina began to depreciate from 2013. While nominal depreciation between 2013 and 2015 was around 19 percent, real depreciation was less than one percent. Therefore, nominal depreciation was not enough to induce a large real depreciation in Kina.

Figure 5. Nominal and real exchange rate, 2010-2019.



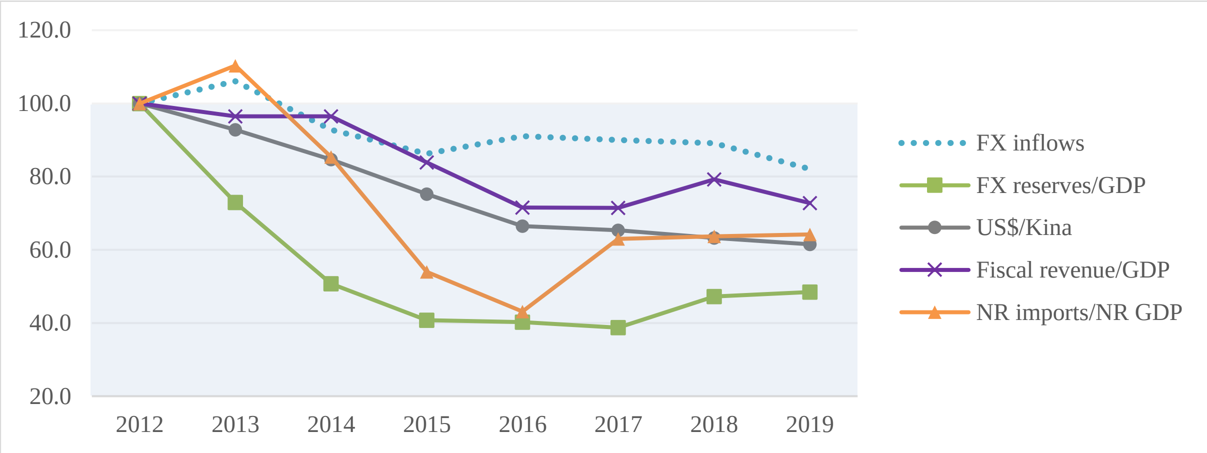
Source: International Monetary Fund.

2.2 Consequences

A forex shortage can hit a small open resource dependent economy in multiple ways. First, it immediately leads to import compression (Asafu-Adjaye & Chakraborty 2002; Jääskelä & Smith 2013). Second, an excess demand for foreign exchange leads to a currency depreciation in absence of central bank intervention (López-Villavicencio & Mignon 2017). Third, central bank's attempt to neutralize the excess demand results in a faster depletion of forex reserves (Fukuda & Kon 2010). Finally, lower capital inflows induce a reduction in public expenditure because of government's high dependence on resource revenue.

To examine if Papua New Guinea went through the similar outcomes, I compared the trends in above macroeconomic indicators taking 2012 as the base, the year before the beginning of forex shortage (Figure 6). Lower capital inflows led to severe import compression; non-resource import relative to non-resource GDP in 2015 was only half of the 2012 level. Kina depreciated by around 30 percent against the U.S. dollar during the same period; however, the pace of depreciation slowed down from 2016 due to various quantitative restrictive measures of the central bank. Persistent central bank intervention resulted in a faster depletion of foreign exchange reserves by around 50 percent. Finally, fiscal revenue dropped sharply in 2015 and yet to reach the pre-crisis level.

Figure 6. State of the PNG economy compared to the pre-crisis period, 2012=100.



Source: Bank of Papua New Guinea, Annual Reports and Quarterly Economic Bulletin; authors' calculation.
Note: NR: non-resource; FX: foreign exchange; Fiscal revenue excludes foreign grants.

To summarize, this section presents the evidence of forex shortage, identifies possible causes, examines the consequences for PNG economy. I argue that not a single source rather a combination of multiple factors, such as, a sharp drop in global commodity prices, lower than expected revenue from resource projects, and slow rate of Kina depreciation are responsible for the shortage. Since the beginning of the shortage, policymakers believed that this is a supply-side problem which could be resolved with quantity-based measures. Accordingly, the central bank continued its intervention strategy with limited foreign exchange reserves alongside issuance of several directives to the forex dealers. Eventually, it had to limit intervention with a fall in reserves which also contributed to the backlog of forex orders.

Persistent imbalance in the forex market indicates that quantity-based measures alone cannot solve the problem. This leads to an important question- what else could be done to eliminate the shortage? A common policy prescription in the face of external shocks is to employ price-based measures, which seeks to encourage the exchange rate to change to a level that clears the market. However, there is a general belief among the policymakers that the external sector does not react significantly to exchange rate adjustments; rather they fear that a currency depreciation would only lead to higher imported inflation (BPNG 2016). This paper, therefore, attempts to answer the following questions- can a depreciation of exchange rate improve the overall trade balance by encouraging higher exports and discouraging imports? Would a devaluation be inflationary? In short, is there a net benefit from currency depreciation?

3. Literature

The effectiveness of exchange rate depreciation in stimulating export and output is widely studied in the literature, however, with mixed results. While few studies confirm that currency devaluation improves trade balance and stimulates output (Narayan & Narayan 2007; Bahmani-Oskooee & Gelan 2013; Kim & Ying 2007), some others find that currency devaluation is contractionary on output (kamin & Klau 1998; Krugman & Taylor 1978; Kamin & Rogers 2000). The output and trade response to a currency depreciation may also vary over time. Senciceka and Upadhyaya (2010) show that a devaluation can be contractionary in the short run, expansionary over the medium term, and neutral in the long run.

Rodrik (2008) argues that an overvalued currency leads to currency shortage and current account imbalance while a devaluation spurs economic growth in the developing countries. Broda (2004) finds that developing countries that maintained a fixed exchange rate in the face of external shocks during the post-Bretton Woods era (1973-1996) experienced a significant decline in output. Bussiere et al. (2017) present empirical evidence of a positive trade balance response to exchange rate depreciation for 26 emerging economies during the period 1995-2012. Gervais et al. (2016) test the devaluation hypothesis for a large set of emerging economies for 1975–2008 and he also finds that a real exchange rate depreciation improved current account balances in those countries. For commodity exporters in Latin America, IMF (2017) finds the evidence of higher exports following a depreciation of the real exchange rate in the aftermath of commodity price decline in 2012.

Theoretically, exchange rate depreciation is assumed to stimulate domestic demand by triggering changes in relative prices of domestic and foreign goods. Devaluation makes foreign goods relatively more expansive than domestic goods in the short run leading to a rightward shift of the aggregate demand curve. This leads to an expansion of output in the Keynesian framework where output is determined solely by the aggregate demand under full employment (Goldstein & Khan 1985; Edwards 1989). In other words, due to higher prices of imports relative to exports, consumers switch their spending from foreign to domestic goods, leading to a positive impact on trade balance and aggregate demand (Obstfeld & Rogoff 2007). Towbin and Weber (2013) find that the expenditure switching effects are stronger for countries with high exchange rate pass through.

Studies employ a wide range of empirical methodologies to evaluate the effectiveness of devaluation on trade balance. One popular strategy is to examine the Marshall-Lerner (ML) condition which states that if the absolute value of the sum of export and import elasticity with respect to real exchange rate is greater than unity, depreciation leads to an improvement in trade balance. While some studies confirm that the ML condition holds for several advanced and developing economies (Bahmani-Oskooee & Niroomand 1988; Aghion et al. 2009; Leigh et al. 2017), some others find no empirical relationship between devaluation and trade balance for many other countries (An et al. 2014; Kamin & Rogers 2000; Upadhyaya & Upadhyay 1999). A limitation of the ML condition is that it only tells if the trade balance improves following a devaluation and ignores the impact of depreciation on other important variables such as inflation. For example, Prakash and Maiti (2016) find that strong inflation following devaluation led to insignificant impact on the real output of Fiji during the period 1975-2012.

Another group of studies evaluates the impact of exchange rate depreciation on output and trade in a dynamic environment by treating all variables as endogenous (Iwaisako & Nakata 2017; An et al. 2014; Shi 2006;). These studies employ a vector autoregression (VAR) method on the argument that exchange rate is an endogenous variable whose contribution is difficult to disentangle. For example, a real depreciation would come either through a nominal depreciation or a decline in inflation and these two channels may not be independent due to exchange rate pass through from depreciation (Chami 2007).

For small open resource dependent economies, devaluation may not always translate to a higher economic growth even when they have large elasticity of exports and imports with respect to real exchange rate. Galebotswe and Andrias (2011) find that currency devaluation had an adverse impact on the long run economic growth of Fiji because of its high import dependence. Williamson (2005) argues that if a large part of a country's fiscal deficit is financed by foreign borrowing, devaluation may not have a favourable impact due to higher foreign currency denominated principal and interest payments. Further, if import is constrained by foreign exchange inflows from exports, devaluation may not lead to an immediate improvement in the trade balance (Aziz 2012). Finally, if importers in the devaluing country do not pass on higher prices to consumers, rather absorb the cost by squeezing profit margins devaluation may not bring the desired outcome (Griffith 2015).

In resource-rich but import dependent economies, policymakers are often not so confident about devaluing the currency following an external shock because of elasticity pessimism and the fear of higher imported inflation from depreciation (Tsangarides et al. 2008). For Papua New Guinea, it is generally believed that poor infrastructure and the lack of market accessibility contribute to a weaker supply response of primary exports while high import dependency contributes to a weaker demand response to currency depreciation (BPNG 2016). However, by estimating the elasticity of exports and imports with respect to the real exchange rate, Nakatani (2018) finds that the ML condition holds, that is, the trade balance of PNG can be improved by inducing a currency devaluation. However, he acknowledges that the costs associated with such depreciation in terms of imported inflation need further assessment. In this study, I attempt to fill this gap in the literature by simultaneously evaluating the impact of a currency depreciation on trade balance and inflation. The outcome of this study would provide insights to employ exchange rate as an effective policy tool to address the forex shortage in PNG, the largest economy in the South Pacific region.

4. Empirical framework

4.1 Data

The dataset contains eight variables which are divided into two blocks- a foreign block and a domestic block. The foreign block includes international commodity price index *(pc_t),* and foreign output *(yw_t)* while the domestic block comprises resource exports *($resx_t$)*, total domestic output *(yd_t)*, inflation *(pd_t)*, exchange rate *(q_t)*, non-resource exports *(nrx_t)*, and non-resource imports *(nrm_t)*, where all variables are expressed in real terms.

The commodity price index (pc_t) was constructed as a geometrically weighted real index following Cashin et al. (2004),

$$pc_t = \left[\left(\prod_{i=1}^{n} pc_{it}^{w_i} \right)^{\frac{1}{\sum_{i=1}^{n} w_i}} \right] / CPI_{US_t}$$

where, pc_{it} is the price of commodity i in quarter t, w_i is the constant export weight for commodity i, n is the number of commodities in the export basket and CPI_US_t is consumer price index for the United States. First, quarterly average prices (in U.S. dollars) of eight major export commodities (gold, copper, crude oil, palm oil, logs, coffee, marine, and cocoa) were obtained from the World Bank Commodities Price Data (The Pink Sheet). Together, they constitute around 70 percent of the total exports. Constant average export weights over the period 1997-2019 were estimated from annual export data available online in BPNG Quarterly Economic Bulletin, where resource commodities (gold, copper, and crude oil) received 77.2 percent weight[4]. LNG was not included in the commodity price basket as LNG exports began in 2014. Finally, following Dungey et al. (2014), nominal price index was deflated by the U.S. consumer price index to construct a real commodity price index with 2010 as the base year.

The next variable in the foreign block is foreign output (yw_t) which controls for non-commodity sector shocks in the partner countries (Dungey et al. 2020). Foreign output was constructed as a simple average of export-weighted real GDP of PNG's top 15 export partners[5]. Quarterly real GDP (at 2010 prices) of partner countries was obtained from the World Bank, Global Economic Monitor, and constant average (1997-2019) export weights were calculated from IMF's Direction of Trade Statistics. The sample countries cover around 97 percent of the total exports over the sample period where top five export partners- Australia, Japan, China, Singapore, and Germany constitute around 75 percent of the total exports. It is important note that these five countries are also the main destinations for PNG's resource exports.

The domestic block represents the overall economy while identifies resource and non-resource exports separately. Resource export ($resx_t$), defined as the aggregate of all mining and energy commodity exports (gold, copper, crude oil, nickel, cobalt, and LNG), was obtained from BPNG Quarterly Economic Bulletin. Nominal export series (in million Kina) was converted into the U.S. dollar using period average Kina/US$ exchange rate and was deflated by the U.S. CPI. Non-resource export (nrx_t) was calculated as residual, i.e., the difference between total and resource exports. Non-resource import (nrm_t) was calculated as total imports minus imports by the mining and petroleum sector. The series was collected from various issues of BPNG Quarterly Economic Bulletin[6]. Like exports, nominal import series was converted into the U.S. dollar and was deflated by the U.S. consumer price index.

From three measures of consumer price index available for PNG (headline, exclusion-based, and trimmed mean), I chose to use trimmed mean inflation (pd_t) as some of the volatile seasonal items (e.g., betelnut) have large weights in the calculation of overall price index. As officially

[4] Gold, copper, and crude oil are considered as resource commodities while the rests are treated as non-resource commodities. Sample weights were distributed as, gold (42.6%), copper (17.7%), crude oil (17%), palm oil 7.0%), logs (5.9%), coffee (4.1%), marine (3.7%), and cocoa (2.1%). Fish meal prices were used as proxy for marine export prices.

[5] Weights were distributed as: Australia (37.4%), Japan (19.0%), China (14.7%), Singapore (7.2%), Germany (4.4%), South Korea (3.0%), Taiwan (2.5%), Philippines (2.5%), United Kingdom (2.1%), Netherlands (2.1%), United States (1.7%), Italy (1.4%), Spain (1.3%), New Zealand (0.5%), and Hong Kong (0.2%).

[6] 'General imports' and 'Imports by mining and petroleum sector' are reported in various issues of BPNG Quarterly Economic Bulletin.

reported series over the sample period had two base years (1977 and 2012), the series was rebased to a single year by setting CPI for 2012Q1 equal to 100[7]. Real exchange rate (q_t) was constructed as, $q_t = (\frac{US\$}{Kina})_t \times (\frac{CPI_{PNG}}{CPI_{US}})_t$. A real Kina appreciation (higher q_t) can result from higher nominal value of Kina against the U.S. dollar and/or higher relative domestic prices[8].

The final variable in the domestic block is the real domestic output. Empirical analysis of Papua New Guinea is challenged by the absence of high frequency data. For example, GDP is only reported annually and there is no close proxy for output such as industrial production index. Extant PNG-specific studies (Nguyen & Sum 2019; Tumsok et al. 2019; Ofoi & Sharma 2021) have so far relied on statistical techniques (e.g., Chow and Lin 1971) for quarterly interpolation of annual GDP data. However, quarterly series generated by such statistical methods are generally smoother than the original annual series (Miralles et al. 2003) which may not truly reflect the quarterly fluctuations, particularly for PNG whose short-run business cycles are highly affected by the resource sector's performance. This study proposes an alternate interpolated measure of quarterly GDP (yd_t) for Papua New Guinea based on the available information on employment and resource exports. The construction strategy is outlined in Appendix B, Box 1. Details on data and sources are in Appendix A, Table A1.

All variables (except inflation rate) were logged and linearly detrended following Dungey et al. (2020). Relevant and significant time dummy variables were used in variable-specific trend equations to consider the global financial crisis period (for foreign variables) and LNG regime (for domestic variables). The focus is therefore on the dynamics of a variable around the steady state, where steady state is given by its trend (Dungey & Pagan 2000). The inflation rate is in percent. The variables are plotted in Appendix A, Figure A1. The correlation of foreign variables with the domestic variables are reported in Appendix A, Table A2.

4.2 Structural VAR model and identification

The primary objective of this study is to examine the role of exchange rate in improving the overall trade balance. Simultaneously, it seeks to evaluate the potential costs of currency depreciation in terms of higher imported inflation. As PNG's export is based on primary commodities whose prices are determined exogenously in the international market, I am also interested to explore the transmission of a commodity price shock to the domestic economy. Finally, I examine if PNG is exposed to a resource curse arising from its historical dependence on mining and mineral exports. Resource curse can arise from a 'Dutch disease' phenomenon (currency appreciation led by large capital inflows from resource sector investments and exports) and/or reallocation of productive resources from mining to non-mining sector (Corden & Neary 1982; Sachs & Warner 1995).

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[7] BPNG reports quarterly CPI for 2012 in both old (1997) and new (2012) bases which allows construction of CPI with as single base. CPI for 2012Q1 was used as the link quarter for rebasing reported CPI prior to 2012.
[8] PNG's external trade is priced mostly in the U.S. dollar. Nominal exchange rates of Kina against other currencies are officially calculated as cross rates against the U.S. dollar; see, <https://www.bankpng.gov.pg/financial-markets/foreign-exchange-market-andreserves-management/exchange-rates/>.

This set of research questions can effectively be answered in an environment that treats all variables as endogenous. Accordingly, this study employed a structural vector autoregression (SVAR) model to investigate the dynamic responses of key domestic variables to a structural shock to commodity prices, resource exports, and exchange rate. The SVAR model was estimated with the ordinary least squares (OLS) method and using quarterly data for the period 1997-2019. The starting point is constrained by the focus on flexible exchange rate regime and the availability of core inflation series[9]. The model was estimated with two lags based on lowest information criteria, stability of the VAR, and no serial correlation in residuals.

The identification strategy and variable specifications follow Dungey et al. (2020), and Souza and Fry-McKibbin (2021) but tailored to the PNG economy[10]. This paper extends their models by treating resource and non-resource economy separately, which is relevant for a resource-rich country like PNG where the resource sector dominates overall exports while total imports are driven by the non-resource sector (Harding & Venables 2016). The hybrid nature of the model allows analysis of the dynamic responses of both resource and non-resource economy to an intrinsic shock to other variables in the system. The SVAR model is specified as,

$$B_0 X_t = c + B_1 X_{t-1} + B_2 X_{t-2} + \varepsilon_t \tag{1}$$

Where, X_t is the (8×1) vector of endogenous variables, c is an intercept, and ε_t is the (8×1) vector of structural shocks which are normally distributed with $E(\varepsilon_t \varepsilon_t') = D$ and $E(\varepsilon_t \varepsilon_{t+s}') = 0 \ \forall \ s \neq 0$. The variances of the structural shocks are captured by the diagonal matrix, D. The contemporaneous relationship between the variables is identified by the lower triangular impact matrix, B_0 while lag restrictions on the parameters are placed through $B_1$and B_2. The general ordering of variables follows Equation (2),

$$X_t = [pc_t \quad yw_t \quad resx_t \quad yd_t \quad pd_t \quad q_t \quad nrx_t \quad nrm_t]' \tag{2}$$

Contemporaneous and lag identification restrictions are specified in Equation (2a) and Equation (2b) respectively,

$$B_0 X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{2,1} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{3,1} & b_{3,2} & 1 & 0 & 0 & 0 & 0 & 0 \\ b_{4,1} & b_{4,2} & b_{4,3} & 1 & 0 & 0 & 0 & 0 \\ b_{5,1} & 0 & 0 & b_{5,4} & 1 & 0 & 0 & 0 \\ b_{6,1} & b_{6,2} & b_{6,3} & b_{6,4} & b_{6,5} & 1 & 0 & 0 \\ b_{7,1} & b_{7,2} & b_{7,3} & b_{7,4} & b_{7,5} & b_{7,6} & 1 & 0 \\ b_{8,1} & 0 & 0 & b_{8,4} & b_{8,5} & b_{8,6} & b_{8,7} & 1 \end{bmatrix} \begin{bmatrix} pc_t \\ yw_t \\ resx_t \\ yd_t \\ pd_t \\ q_t \\ nrx_t \\ nrm_t \end{bmatrix} \tag{2a}$$

[9] Bank of Papua New Guinea adopted a flexible exchange rate regime in October 1994. Headline inflation includes volatile items with large weights in CPI calculation, for example, 'Alcoholic Beverages, Tobacco and Betelnut'.
[10] Chinese steel production (csp_t), identified as the resource demand shock for Australia (Dungey et al. 2020) and Brazil (Souza and Fry-McKibbin 2021), would not be relevant to PNG as it does not export iron-ore. Therefore, csp_t was not included in the model. Policy interest rate (Kina Facility Rate) is available only from 2002 and other close proxies, such as, central bank bill and treasury bill rates are discontinuous over the sample period. Further, it is argued that interest rate channel is weak in PNG due to the presence of high excess liquidity in the banking system (Direye & Khemraj 2021).

For $j = 1, 2$,

$$B_j X_{t-j} = \begin{bmatrix} b_{1,1}^j & b_{1,2}^j & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{2,1}^j & b_{2,2}^j & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{3,1}^j & b_{3,2}^j & b_{3,3}^j & b_{3,4}^j & 0 & b_{3,5}^j & 0 & 0 \\ b_{4,1}^j & b_{4,2}^j & b_{4,3}^j & b_{4,4}^j & b_{4,5}^j & b_{4,6}^j & b_{4,7}^j & b_{4,8}^j \\ b_{5,1}^j & b_{5,2}^j & b_{5,3}^j & b_{5,4}^j & b_{5,5}^j & b_{5,6}^j & b_{5,7}^j & b_{5,8}^j \\ b_{6,1}^j & b_{6,2}^j & b_{6,3}^j & b_{6,4}^j & b_{6,5}^j & b_{6,6}^j & b_{6,7}^j & b_{6,8}^j \\ b_{7,1}^j & b_{7,2}^j & b_{7,3}^j & b_{7,4}^j & b_{7,5}^j & b_{7,6}^j & b_{7,7}^j & b_{7,8}^j \\ b_{8,1}^j & b_{8,2}^j & b_{8,3}^j & b_{8,4}^j & b_{8,5}^j & b_{8,6}^j & b_{8,7}^j & b_{8,8}^j \end{bmatrix} \begin{bmatrix} pc_{t-j} \\ yw_{t-j} \\ \text{resx}_{t-j} \\ yd_{t-j} \\ pd_{t-j} \\ q_{t-j} \\ nrx_{t-j} \\ nrm_{t-j} \end{bmatrix} \quad (2b)$$

While ordering is not important for VAR estimation, impulse response functions derived from the VAR depend crucially on how variables are ordered in the system (Sims 1980). Usually, the most endogenous variable is placed last, and the least endogenous variable is placed first so that the variables in the higher order are assumed not to be contemporaneously affected by the variables in the lower order. As PNG is a small open economy, it has a little influence on the global commodity market and the rest of the world. Accordingly, the domestic block is placed after the foreign block with additional lag restrictions to satisfy the assumption that PNG has no contemporaneous or lag effects on the global markets. Variables in the foreign block are allowed to affect each other, however, commodity market responds to foreign output only a quarter after the shock (Dungey et al. 2020).

Resource export is placed first in the domestic block as it depends mostly on foreign demand, project negotiations, and commodity price movements. I further assume that only domestic output and exchange rate in the domestic block have lag effects on resource exports[11]. The remaining domestic variables follow a general lower triangular matrix except that domestic inflation and non-resource imports are not contemporaneously affected by resource exports. The additional zero restrictions in the contemporaneous matrix, B_0 imply that the SVAR is overidentified[12]. Exchange rate is placed before non-resource exports and imports to evaluate the ‘Dutch disease’ hypothesis which may arise from currency appreciation led by higher commodity prices and resource exports[13].

The role of currency depreciation in improving net capital inflows through the trade balance effect is examined by estimating Model (3) where resource exports, non-resource exports, and non-resource imports in Model (2) are replaced by the real trade balance, tb_t, defined as the difference between total exports and total imports (in the U.S. dollar), deflated by the U.S. CPI[14]. Trade balance is allowed to respond to a shock to all variables in the system, both

[11] Foreign investors are assumed to be incentivized by better economic prospect and prudent exchange rate management over time.

[12] The Likelihood Ratio (LR) test confirmed that the overidentification restrictions are valid at 5 percent level of significance.

[13] This assumption is relaxed in the robustness check in Section 5.4 by treating exchange rate as the monetary policy variable and is placed after all variables in the system.

[14] Overall trade balance is chosen over non-resource trade balance because non-resource exports comprised only 25% of the total exports while non-resource imports contributed to more than 70% of the total imports, on average, over the study period. However, Section 5 presents the results with non-resource trade balance as well.

contemporaneously and through lags. Further, total domestic output in Model (2) is replaced by non-resource output, yd_nr_t, in Model (4) to evaluate the resource curse hypothesis. It was observed that non-resource output fell sharply and remained below the trend following LNG exports in 2014 (see Appendix A, Figure A1).

$$X_t = [pc_t \quad yw_t \quad yd_t \quad pd_t \quad q_t \quad tb_t]' \tag{3}$$

$$X_t = [pc_t \quad yw_t \quad resx_t \quad yd\_nr_t \quad pd_t \quad q_t \quad nrx_t \quad nrm_t]' \tag{4}$$

5. Results

5.1 Impulse response functions to commodity, resource export, and exchange rate shocks

This section presents the impulse response functions (IRFs) of the impact of one standard deviation shock to commodity prices (pc_t), resource exports ($resx_t$), and exchange rate (q_t). The point estimates are given by the solid lines while the dotted lines indicate one standard deviation error band about point estimates. The impulse responses are reported for 36 quarters. As variables in SVAR are logged and detrended, the IRFs are interpreted as the dynamics of a variable around its trend (or baseline).

Commodity price shock

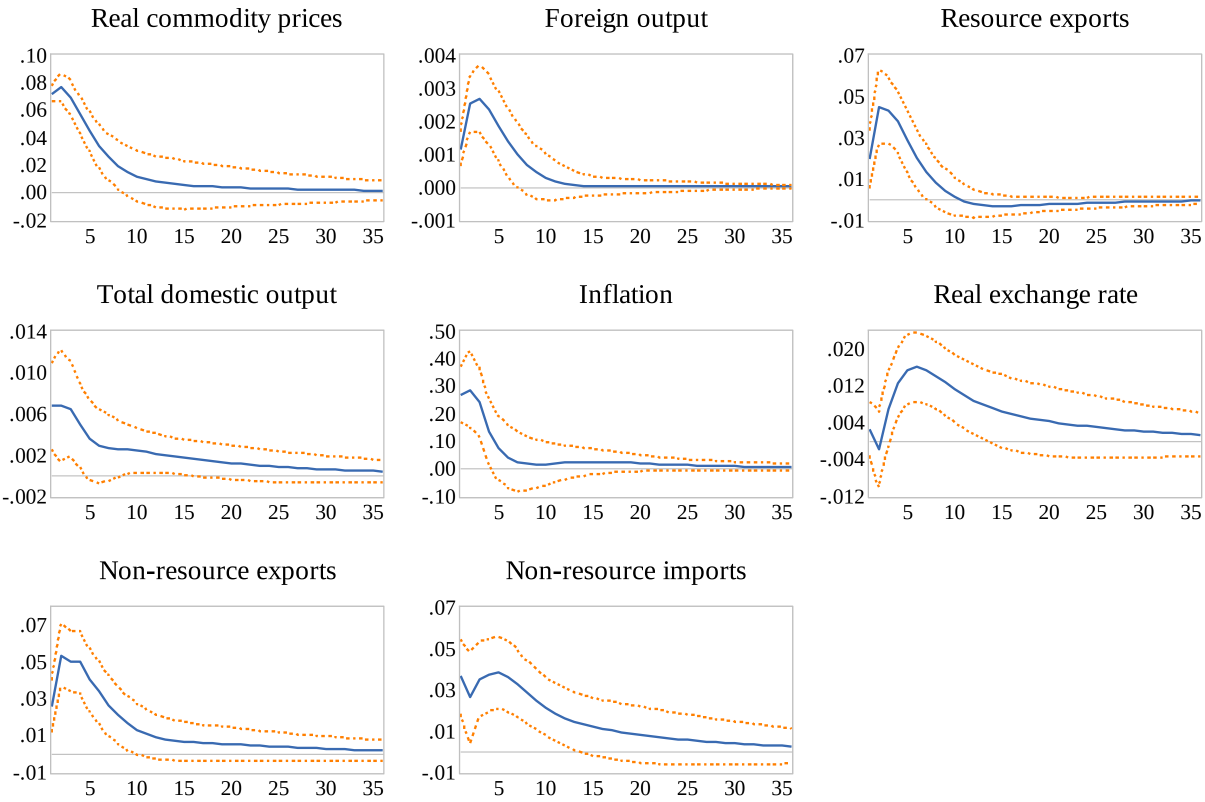
In response to a positive commodity price shock, resource exports jump immediately 1.9% above the baseline, peaks at 4.4% in the next quarter and significantly remains above the baseline for 6 quarters after the shock (Figure 7). Higher resource exports translate to an expansion of overall domestic output 0.68% above the baseline; the output response lasts for a year. Higher domestic demand causes inflation to rise by around 0.30 percentage points which then falls gradually as the demand pressure eases. Higher export prices improve net capital inflows and leads to an appreciation of domestic currency. Exchange rate responds significantly a year after the shock and peaks at 1.6% after six quarters. Importers respond immediately to a higher domestic demand and to a stronger currency; non-resource imports peaks at 3.6% above the baseline six quarters after the shock. In contrast, non-resource exports rise even with a currency appreciation, implying a stronger response of basic agricultural exports to higher commodity prices relative to exchange rate movements (Aba et al. 2012a; 2012b; 2012c).

In general, the results are consistent with those found in the commodity and PNG-specific studies. Dungey et al. (2020) find a strong positive response of Australian iron ore exports to a commodity price shock while Souza and Fry-McKibbin (2021) find the same for Brazilian resource exports. For a panel of major commodity-exporting emerging markets[15], Shousha (2016) find that a 10% shock to commodity export prices leads to around 1% higher domestic output one year after the shock, which is close to the estimates found in this study. All these studies find an exchange rate appreciation following a positive commodity price shock.

[15] Sample emerging economies: Argentina, Brazil, Chile, Colombia, Peru, and South Africa. The average share of commodity exports in total exports over the study period 1997-2013 was 50%.

Strong and persistent response of exchange rate to commodity prices confirms that Kina is commodity currency. For the period 1995-2005, Kauzi and Sampson (2009) estimate that Kina appreciates by 4-6% in the nominal term to a 10% increase in commodity prices. According to my estimates, a 10% shock to commodity prices leads to 2.2% real appreciation of Kina which is close to their estimate as inflation differential of PNG with its trading partners generally lies between 3-5%. However, I find a delayed response of exchange rate to a commodity price shock which may be the result of frequent central bank interventions in recent years.

Figure 7. Impulse response functions to a positive shock to real commodity prices.



Resource shock

While higher resource exports give a stimulus to the overall economy (Figure 7), I am interested to examine the evidence of a resource curse given PNG's historical experience of large mining and mineral projects. Accordingly, I replaced total domestic output (yd_t) in Model (2) by non-resource output (yd_nr_t) and estimated Model (4). The responses are plotted in Figure 8, Column (a). The result points to a strong evidence of resource curse arising from a contraction of the non-resource economy. To a positive shock to resource exports, non-resource output falls immediately and remains below the baseline for two years after the shock. According to the estimates, non-resource output can fall 0.75% below the baseline in response to a 10% positive shock to resource exports. Inflation falls as the non-resource economy, which constitutes two-thirds of the overall economy, goes through a recession. Non-resource exports and imports also fall over the medium term.

Contrary to the expectation, higher resource exports do not lead to a currency appreciation implying an absence of Dutch disease. However, this could be due to the inclusion of LNG in the resource export basket. As discussed in Section 2, most of the LNG export proceeds are kept offshore which do not contribute to the forex inflows. Accordingly, I re-estimated Model (4) while took LNG out of the resource export basket. Figure 8, Column (b) plots the results. Kina now appreciates in response to a higher resource export which in turn causes non-resource exports to fall over the medium term through a loss of competitiveness in the international market. It is further observed that contraction of the non-resource economy is more pronounced when LNG is included in the export basket.

Empirical studies find strong evidence of Dutch disease in major commodity exporting countries, such as, Australia (Dungey et al. 2020), Canada (Shousha 2016), Brazil (Chang et al. 2021), and Russia (Mironov & Petronevich 2015). However, the evidence for Papua New Guinea is inconclusive. While Chowdhury (2004) finds some signs of Dutch disease during the early investment and mineral boom period 1971-1997, Avalos et al. (2015) and Izvorski & Ollero (2010) find no definitive evidence for the latter period 2000-2010. However, the results of my study point to the existence of resource curse arising from both reallocation of resources (including LNG) and Dutch disease (excluding LNG).

Exchange rate shock

This study particularly seeks to examine if a currency devaluation improves the overall trade balance. Accordingly, I normalized the q_t series so that a positive shock to q_t now represents a depreciation of exchange rate. Figure 9 reports impulse responses of the variables specified in Model (2) while the trade balance responses, defined in Model (3), are presented in Figure 10.

A positive (depreciation) shock to exchange rate causes an immediate drop in non-resource imports 1.5% below the baseline which reaches the minimum at 2.6% three quarters after the shock, and significantly remains below the baseline for about a year. In contrast, non-resource exports respond positively to a currency depreciation but not significantly over the forecast horizon (Figure 9). Nevertheless, the overall trade balance improves two quarters after the shock and peaks at 8.0% above the baseline after one year (Figure 10, Column (a)). The cost of devaluation is a subsequent increase in inflation resulting from higher import costs. Inflation jumps up by around 0.5 percentage points in the next quarter but falls gradually thereafter. As LNG exports, in practice, do not contribute to the overall cash flow, I re-estimated Model (3) while excluded LNG exports from the overall trade balance. Figure 10, Column (b) plots the results. I find that the positive trade balance effect is not compromised if we ignore the LNG export receipts. Further, Figure 10, Column (c) confirms that a depreciation improves the non-resource real trade balance (non-resource exports minus non-resource imports), albeit by a lower magnitude than in the overall trade balance.

Overall, the results suggest that a 10% real depreciation can immediately trigger inflation by one percentage point while improve the trade balance by 10-15% above the baseline, one year after the shock. Instant response of inflation to an exchange rate shock implies high import dependence and the resulting increase in import costs from a weaker currency. However, inflation returns to the baseline relatively faster than the trade balance implying a net gain from currency depreciation. This finding confirms a recent assessment by the IMF that the overvaluation of Kina can be eliminated by inducing a depreciation without having an excessive pressure on inflation (IMF 2020a). While Nakatani (2018), and Nguyen and Sum (2019) also find a positive trade balance effect from currency depreciation, they do not evaluate its impact on inflation.

Figure 8. Impulse response functions to a positive shock to resource exports, (a) including LNG, (b) excluding LNG.

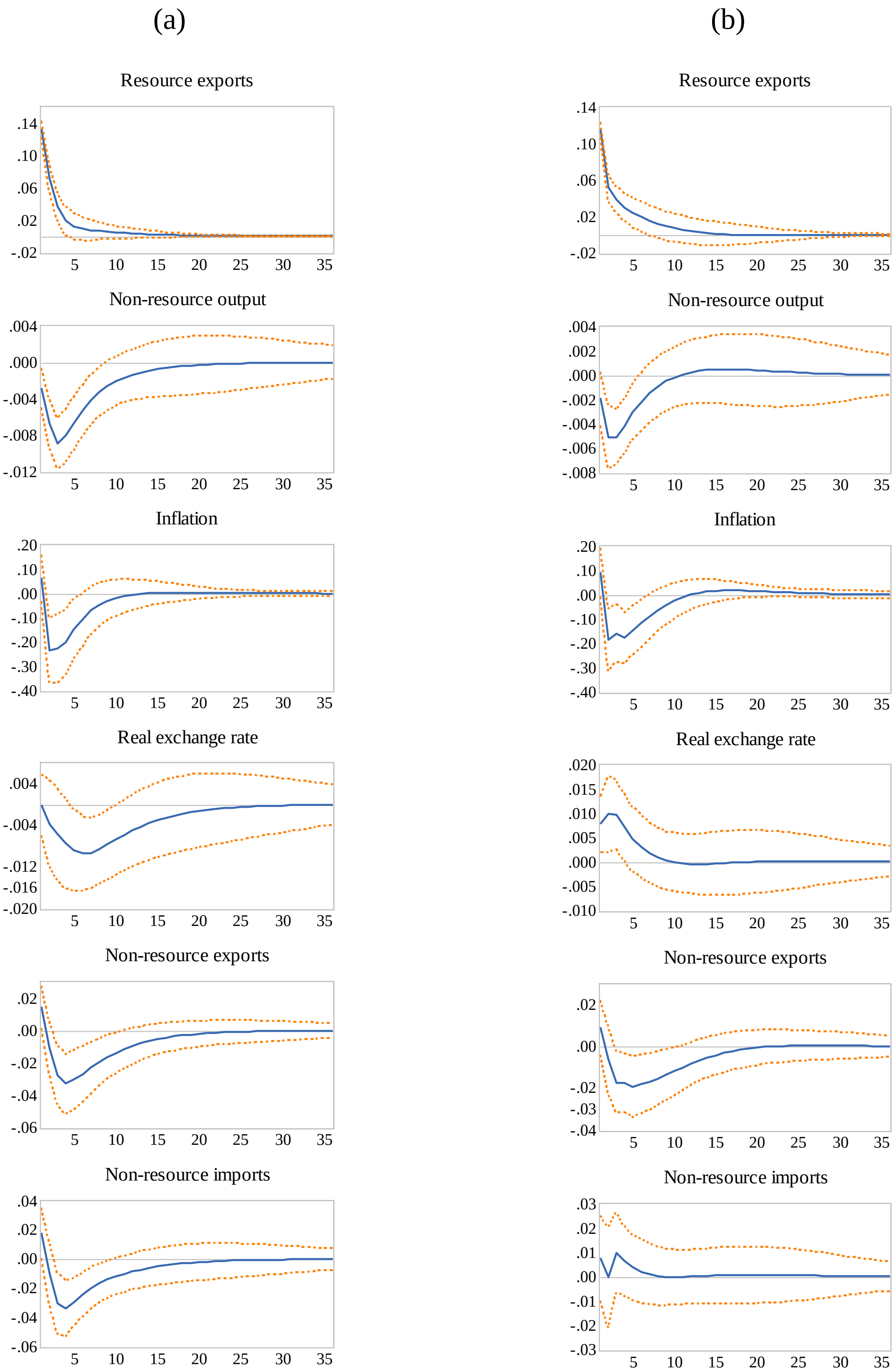


Figure 9. Impulse response functions to a positive (depreciation) shock to exchange rate in Model (2).

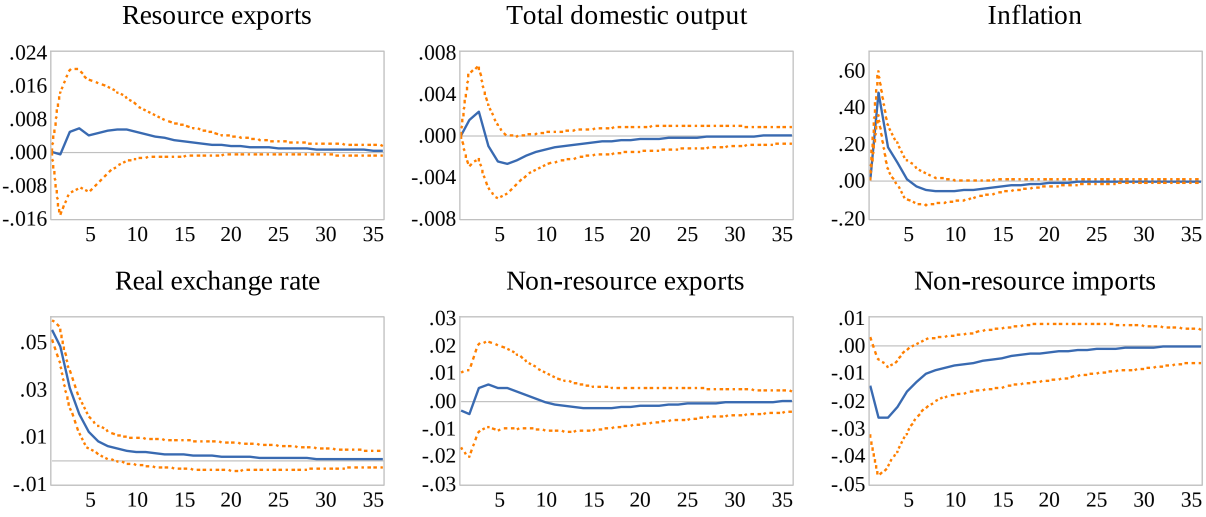
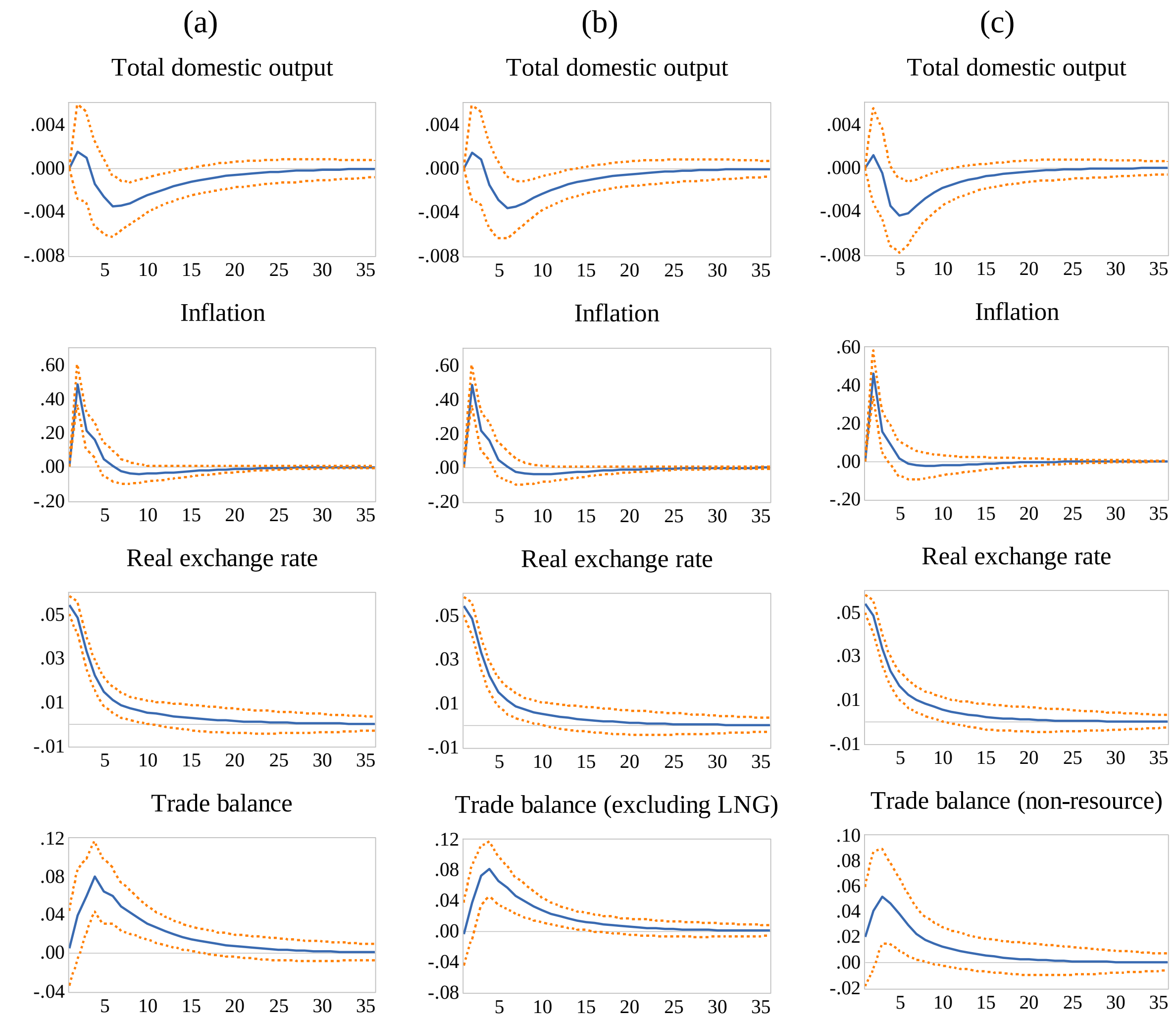


Figure 10. Impulse response functions to a positive (depreciation) shock to exchange rate in Model (3)-- (a) overall trade balance including LNG, (b) overall trade balance excluding LNG, (c) non-resource trade balance.



5.2 Variance decomposition

The VAR model allows decomposition of the sources of variance of each endogenous variable, known as variance decomposition. While impulse response functions indicate the dynamic impact of a one-time shock, variance decompositions measure the importance of such shock in the VAR system. Table 1 presents the variance decomposition of key domestic variables specified in Model (2) - overall domestic output, resource and non-resource exports, and non-resource imports over forecast horizon of 1, 4, 8, 12, and 24 quarters. Further, Panel B shows variance decomposition if the model were estimated without the foreign variables (pc_t, yw_t).

Table 1. Variance decomposition (in %) of output and trade variables in Model (2). Panel B compares decomposition for a model estimated without foreign variables (pc_t, yw_t).

	Horizon (quarter)						Horizon (quarter)				
	1	4	8	12	24		1	4	8	12	24
	A. With foreign variables						B. Without foreign variables				
	Total domestic output										
pc_t	2.86	5.96	6.80	7.27	7.36						
yw_t	0.14	3.19	3.39	4.62	11.50						
$resx_t$	36.82	26.73	26.90	26.50	24.50	$resx_t$	40.61	32.50	31.00	30.45	30.13
yd_t	60.18	62.61	60.22	58.56	53.63	yd_t	59.39	64.88	61.23	59.23	57.61
pd_t	0.00	0.72	0.70	0.71	0.68	pd_t	0.00	1.39	1.58	1.67	1.78
q_t	0.00	0.32	1.19	1.39	1.40	q_t	0.00	0.38	3.61	4.84	5.53
nrx_t	0.00	0.22	0.42	0.52	0.52	nrx_t	0.00	0.45	1.79	2.84	3.90
nrm_t	0.00	0.25	0.38	0.43	0.41	nrm_t	0.00	0.39	0.79	0.96	1.04
	Resource exports										
pc_t	2.13	16.52	18.87	18.59	18.58						
yw_t	0.02	14.54	14.71	14.90	14.98						
$resx_t$	97.85	66.03	60.77	60.13	59.65	$resx_t$	100.00	97.66	94.31	93.02	91.58
yd_t	0.00	2.73	5.13	5.55	5.76	yd_t	0.00	2.11	5.27	5.89	6.11
pd_t	0.00	0.02	0.04	0.05	0.08	pd_t	0.00	0.02	0.10	0.16	0.24
q_t	0.00	0.15	0.37	0.57	0.68	q_t	0.00	0.19	0.25	0.63	1.20
nrx_t	0.00	0.01	0.06	0.12	0.16	nrx_t	0.00	0.00	0.04	0.21	0.71
nrm_t	0.00	0.00	0.05	0.09	0.11	nrm_t	0.00	0.02	0.03	0.08	0.16
	Non-resource exports										
pc_t	3.76	22.57	26.37	25.09	22.52						
yw_t	1.48	6.97	7.78	13.12	22.62						
$resx_t$	1.86	6.04	9.09	9.32	8.56	$resx_t$	7.27	4.90	5.72	6.40	6.91
yd_t	0.07	0.55	0.90	1.37	1.60	yd_t	0.01	0.88	0.86	1.07	1.33
pd_t	0.87	3.13	4.37	4.37	3.88	pd_t	4.27	8.00	8.56	8.70	8.72
q_t	0.07	0.24	0.30	0.29	0.36	q_t	1.39	3.43	3.73	3.78	3.95
nrx_t	91.88	60.30	50.87	46.14	40.18	nrx_t	87.06	82.11	80.56	79.51	78.54
nrm_t	0.00	0.20	0.32	0.30	0.28	nrm_t	0.00	0.68	0.57	0.54	0.54
	Non-resource imports										
pc_t	4.52	9.88	16.54	16.86	14.10						
yw_t	0.15	1.15	3.36	12.02	30.98						
$resx_t$	0.57	6.98	8.61	8.21	6.60	$resx_t$	0.01	0.79	1.78	2.61	3.51
yd_t	1.84	2.32	2.93	3.29	2.89	yd_t	1.23	1.37	1.40	1.73	2.15
pd_t	0.55	1.47	1.73	1.60	1.24	pd_t	2.77	5.06	5.06	5.08	5.10
q_t	0.73	4.48	4.90	4.54	3.62	q_t	2.75	15.24	20.87	21.64	21.76
nrx_t	4.14	4.44	3.72	3.21	2.45	nrx_t	5.79	10.38	12.58	13.94	15.08
nrm_t	87.50	69.29	58.22	50.27	38.11	nrm_t	87.45	67.17	58.31	55.00	52.39

Own shock and resource exports explain most of the variances in domestic output, both in the short and long run. Together, they contribute to around 90% of the total variations in overall domestic output in the impact quarter (horizon one) where resource exports explain around one-third of the total fluctuations. Resource sector's contribution remains persistent over the forecast horizon while other domestic variables have a little impact on output; this reaffirms sensitivity of PNG's business cycles to resource sector's performance (Howes et al. 2019; Gani 1997). In the long-run, external shocks (pc_t, yw_t) contribute around 20% to the variances of output.

While the contribution of foreign shocks in the variance of total domestic output is relatively low, they explain around 40% of the variations in external trade over the medium to longer term. Commodity price shock explains 17% and 23% of the variances in resource and non-resource exports respectively, just a year after the shock, which indicates the importance of commodity prices to explain PNG's export dynamics. Non-resource import is described mostly by its own shock in the short-run; however, foreign shocks dominate in the long-run.

Empirical studies often ignore the role of foreign shocks in explaining domestic business cycles. Accordingly, I estimated a model without foreign variables; Panel B of Table 1 presents variance decompositions of the same domestic variables specified in Model (2) but excluding the foreign variables (pc_t, yw_t). It was found that in absence of foreign shocks, variations in the domestic variables, particularly, resource and non-resource exports, are mostly explained by their own shocks while exchange rate explains around 20% of the variances in non-resource imports over the medium and longer term. The validity of the foreign shocks was further checked by the likelihood ratio (LR) test[16] and the Granger causality test (Granger 1969). The first two rows of Table 2 report the LR test results for individual significance of commodity prices and foreign output, and the last row reports the significance of their combined effects. The LR test points to the validity of foreign shocks, both individually and jointly, which is further confirmed by the Granger causality test (see Appendix A, Table A3). Based on these test results and variance decomposition, it can be confidently concluded that foreign shocks are important determinants of PNG's business cycles.

Table 2. Likelihood ratio tests for foreign variables in SVAR, 1997Q2-2019Q4.

Hypothesis		Test Statistic	p-value
H_0:	No commodity prices	780.55	0.000*
H_0:	No foreign output	97.74	0.000*
H_0:	No commodity prices and foreign output	562.69	0.000*

* Indicates rejection of H_0 at 1% level of significance.

[16] Likelihood Ratio test was carried out as, $LR = -2T(LogL_R - LogL_{UR}) \sim \chi^2(df)$; where, T is the sample size, df is the number of restrictions, $LogL_R$ and $LogL_{UR}$ are the log-likelihood estimates in the restricted and unrestricted model respectively. The restricted model blocks the impact of foreign variable(s) by imposing zero contemporaneous restrictions.

5.3 Historical decomposition

The evolution of a time series can be traced by the contribution of all shocks in the SVAR system at each point in time, known as historical decomposition. One advantage of historical decomposition over variance decomposition is that the former considers both size and sign of the shocks, i.e., one can tell which shock had a dominant and positive/negative influence on the actual development of a particular time series. The univariate historical decomposition contains two parts- first, an exogenous component, referred to as the baseline projection, which tells how a time series would evolve over time in the absence of any shock. Second, the deviation of that time series from its projection due to the shocks (Dungey & Pagan 2009). Therefore, one can recover the actual series at time t by summing up the baseline projection and the weighted contribution of each shock at time t. If the VAR is stationary, the baseline projection converges to a steady state in the long run (Wong 2017).

Figure 11 presents the historical decompositions of total domestic output (yd_t), resource exports ($resx_t$), and non-resource exports (nrx_t) as deviation around their trends, where the variable-specific trend is given by the horizontal axis. The bars represent the actual value of a time series while the contributions of shocks at each point in time are indicated by the lines. The contribution of each shock was estimated after netting off the effect of baseline projections.

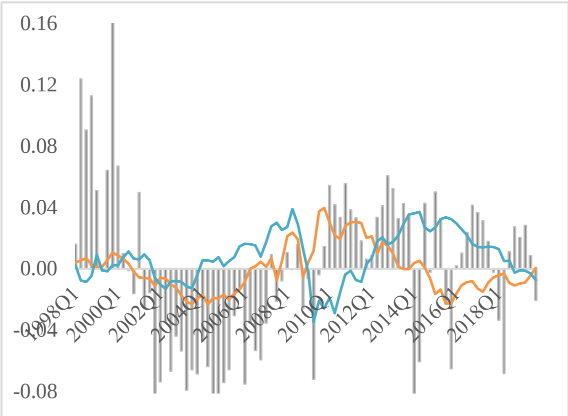
The deviation of domestic output from its trend is mainly driven by its own shock and the shocks to resource exports, commodity prices, and foreign demand. The contribution of shocks can be linked to major economic events. For example, resumption of two major mining projects (Ok Tedi and Porgera Gold Mine) following a severe drought in 1997 led to an economic recovery during 1998-1999 (Allen & Bourke 2001). A negative shock in foreign output following the global financial crisis coupled with a sharp decline in resource exports contributed mostly to the negative economic growth in 2018. Conversely, a positive commodity price shock contributed to a higher domestic output during the LNG construction period, 2010-2012. However, the post-LNG growth regime (2014 onwards) is mostly explained by the resource shock.

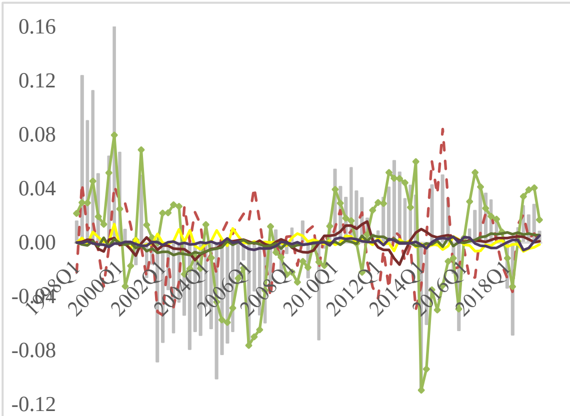
Apart from own shocks, the deviations of resource and non-resource exports from their trends are explained mostly by the shocks to foreign output. Resource exports remained below the trend during the periods 2001-2005 (mostly led by commodity price shock) and 2010-2013 (LNG construction period). The contraction of foreign output followed by a gradual recovery explains most of the deviations of resource and non-resource exports during the period of global financial crisis, 2008-2009. Afterwards, commodity price shock explains most of the variations in non-resource exports till 2012. Overall, the historical decomposition results suggest that PNG’s business cycle is highly sensitive to the performance of the resource sector, which eventually depends on the shocks emerging from export partners and global commodity markets.

Figure 11. Historical decomposition of domestic output and exports, 1998Q1-2019Q4.

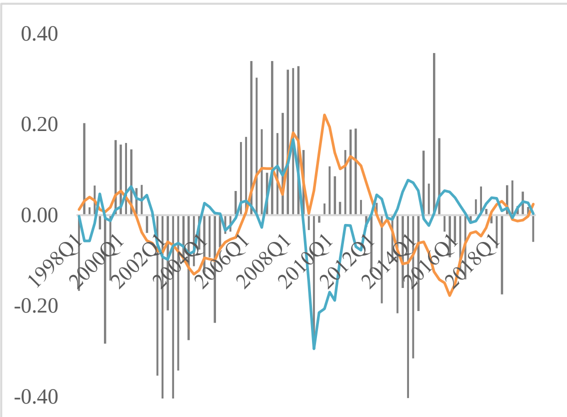
(a) Foreign variables (b) Domestic variables

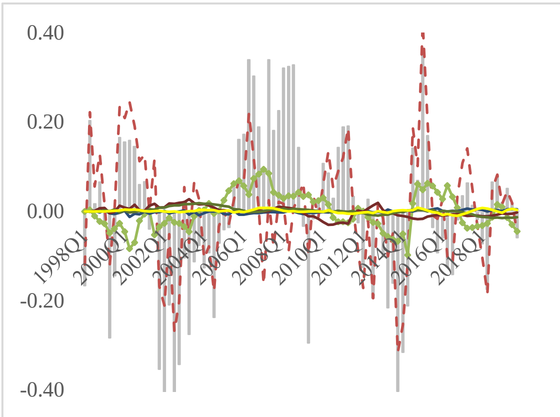
Domestic output



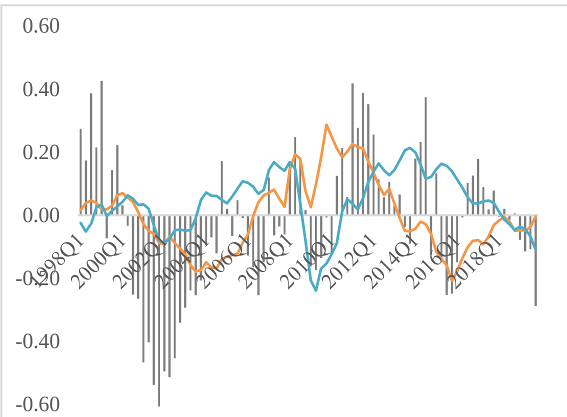


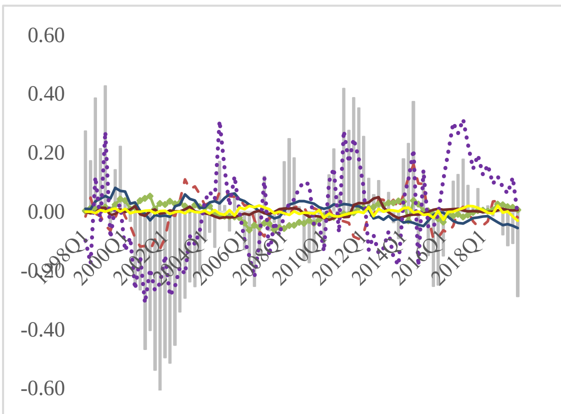
Resource exports





Non-resource exports





Actual | Commodity price | Foreign output
Resource exports | Domestic output | Inflation
Real exchange rate | Non-resource exports | Non-resource imports

5.4 Robustness

The robustness of the benchmark model (Model 2) was tested against four alternative specifications. First, it is often argued that exchange rate is the main monetary policy instrument in Papua New Guinea in the absence of an effective interest rate and money supply channel (Direye & Khemraj 2021). Accordingly, the VAR was re-estimated with the ordering, $(pc_t, yw_t, resx_t, yd_t, pd_t, nrx_t, nrm_t, q_t)'$, by treating exchange rate as the most endogenous variable which can react to all shocks in the system. Second, instead of deflating by the U.S. CPI, nominal exports, and imports (in national currency) were expressed in relation to nominal GDP (Zeev et al. 2017). Third, Model (2) was estimated for the sub-sample 1997-2013 to avoid structural change caused by the LNG exports which began in 2014. Finally, the VAR was estimated in log-levels of the variables. The impulse response functions to a positive shock to real commodity prices in the alternative models are plotted in Appendix A, Figure A2.

The impulse responses generated by the benchmark model are generally consistent with those obtained with the alternative specifications. Treating exchange rate as the most endogenous variable does not alter the results; the central bank responds to a positive deviation of domestic output from its trend and to a higher inflation by intervening in the forex market which results in currency appreciation. The responses of exports and imports die out relatively faster than in the benchmark model when they are expressed in relation to GDP; however, the direction of responses does not change. The size of the responses of domestic variables to a commodity price shock is slightly larger when LNG-export period is excluded from the sample. Finally, the impulse responses generated by the level VAR do not seem to converge to the steady state over time, although have the same directions.

The robustness of Model (3) and Model (4) against the abovementioned alternate specifications are presented in Appendix A, Figure A3 and Figure A4 respectively. Overall, the directions of impulse responses are not greatly affected, and the story remains the same.

6. Conclusion

This paper analyses the recent episode of foreign exchange shortage in Papua New Guinea. I find that the shortage has resulted from a combination of external and domestic sources. While a sharp decline in the global commodity prices as well as winding up of the country's largest mineral project (PNG LNG) contributed to the shortfall, lower than anticipated forex inflows relative to resource exports and slow rate of real Kina depreciation amplified the shortage. Further, the shortage had a severe consequence for the economy in terms of slower growth of the non-resource sector, import compression, faster depletion of the foreign exchange reserves and lower government revenue.

Central bank's persistent effort to address the prevailing shortage with its intervention strategies had a little success in eliminating the backlog of import orders. Rather, the adoption of several quantity-based preventive measures has limited the role of the exchange rate to act as an automatic stabilizer in the face of external shocks. A common policy prescription in this situation is to allow greater exchange rate flexibility so that the real value of the currency adjusts to a level that clears the market. However, general scepticism about the trade balance response to exchange rate coupled with the fear of imported inflation makes it difficult for the central bank to induce a large depreciation, even if justified by the market condition.

In this study, I explore the impact of an exchange rate depreciation on the overall trade balance while simultaneously evaluate the effect of the same size of depreciation on inflation. The results obtained from the SVAR model point to a net gain from currency depreciation. While a sudden 10 percent real depreciation leads to a one percentage point higher inflation, trade balance improves by 10-15 percent, one year after the shock. Further, the trade balance response is persistent and lasts longer than the inflation response. The positive trade balance effect results mostly from a reduction in imports. In addition, I find that global commodity price movements are important sources of domestic real business cycles. Both resource and non-resource exports rise in response to higher commodity prices despite an appreciation of the real exchange rate. However, the non-resource economy contracts following a resource boom which points to a presence of resource curse in Papua New Guinea.

The finding of this study has important policy implications. First, it confirms that there is a positive trade balance effect from currency depreciation as found in the other empirical studies. However, the slow rate of real Kina depreciation for a prolonged period indicates that the policymakers are not confident about a purely floating exchange rate regime, perhaps due to the unpredictability of the pace of depreciation and the fear of inflation. This study addresses this concern by empirically showing that the overvaluation can be eliminated by inducing a sharp depreciation and without having an excessive pressure on inflation. A correction of the exchange rate misalignment would remove uncertainty in the forex market, boost foreign investors' confidence to bring in the desired capital, and reduce frontload of import orders. Second, the exposure of the Papua New Guinea economy to external shocks, particularly, commodity price shocks, suggests that external developments are crucial in shaping the domestic macroeconomic outcome, and therefore, should be given appropriate weight in the design of exchange rate and reserve management policy. Third, future resource projects should be negotiated prudently so that a fair share of the resource revenue flows to the economy. Finally, in addition to promote growth and employment in the non-resource sector, the government should create a large revenue buffer from the future resource projects to compensate for the possible contraction of the non-resource economy as experienced with the PNG-LNG project.

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Appendix A

Table A1. Data descriptions and sources

Variable	Code	Description	Source
Real commodity prices	*pc*	Export-weighted real commodity price index (2010=100) of 8-commodity basket. Quarterly nominal prices were derived by taking average of monthly prices over the quarter and were weighted by constant average export weight of each commodity over the sample period. Nominal price index was constructed as a geometric weighted-average index, which was then deflated by the U.S. CPI to obtain the real price index. The series was seasonally adjusted (s.a.) by Census X-13.	World Bank Pink Sheet (commodity prices); IMF (US CPI); BPNG (export); author's calculation (weight and index).
Foreign output	*yw*	Export-weighted real GDP of top 15 export partners (2010 price). Constant average export shares (1997-2019) were applied, and the series was s.a. by Census X-13.	World Bank, Global Economic Monitor (GDP); IMF, Direction of Trade Statistics (bilateral exports); author's calculation (weight and index).
Resource exports	*resx*	Real exports of resource commodities (gold, copper, crude oil, cobalt, nickel, LNG, and condensate). Nominal exports (f.o.b., million Kina) were converted into US dollar using period average Kina/US$ exchange rate, and then were deflated by the U.S. CPI, and s.a. by Census X-13.	BPNG Quarterly Economic Bulletin, Table 8.2.
Domestic output	*yd* *yd_nr*	Domestic total real GDP (2013 price). Quarterly series was constructed from annual GDP using employment indices (for non-resource GDP) and resource exports (for resource GDP). The series was s.a. by Census X-13. Domestic non-resource real GDP (2013 price), calculated as the difference between total and resource GDP. Resource GDP comprises crude petroleum, natural gas (from 2014) and mining.	1995-2002 (BPNG 2007) 2003-2005 (Department of Treasury (DOT), National Budgets 2007, 2009 and 2010; Table 1) 2006-2018 (NSO) 2019 (DOT, National Budget 2020, Table 1).
Inflation	*pd*	Trimmed mean CPI inflation (quarterly percentage change), 2012Q1=100.	BPNG Quarterly Economic Bulletin, Table 9.1.
Real exchange rate	*q*	Real exchange rate relative to the U.S. dollar (2010=100). $q = \frac{US\$}{Kina} \times \frac{CPI_{PNG}}{CPI_{US}}$	IMF (nominal exchange rate and consumer price indices); author's calculation.
Non-resource exports	*nrx*	Non-resource real exports calculated as, total exports minus resource exports. Nominal exports (f.o.b., million Kina) were converted into the U.S. dollar using period average Kina/US$ exchange rate, deflated by US CPI, and s.a. by Census X-13.	BPNG Quarterly Economic Bulletin, Table 8.2.
Non-resource imports	*nrm*	Non-resource real imports calculated as, total imports minus resource imports (imports by mining and petroleum sector). Nominal imports (f.o.b., million Kina) were converted into the U.S. dollar using period average Kina/US$ exchange rate, deflated by US CPI, and s.a. by Census X-13.	BPNG Quarterly Economic Bulletin, various issues (1997-2009), Table 8.2 (2010-2019).
Trade balance	*tb*	Overall trade balance calculated as total exports minus total imports, converted into the U.S. dollar using period average Kina/US$ exchange rate, deflated by US CPI, and s.a. by Census X-13.	

Table A2. Correlation of domestic variables with foreign variables, 1997Q1-2019Q4.

	Foreign variables (X_i)	
Domestic variables (X_j)	Commodity prices	Foreign output
Resource exports	0.27***	0.51***
Domestic output	0.24***	0.38***
Inflation	-0.10	0.06
Real exchange rate	0.54***	0.29***
Non-resource exports	0.52***	0.51***
Non-resource imports	0.52***	0.36***

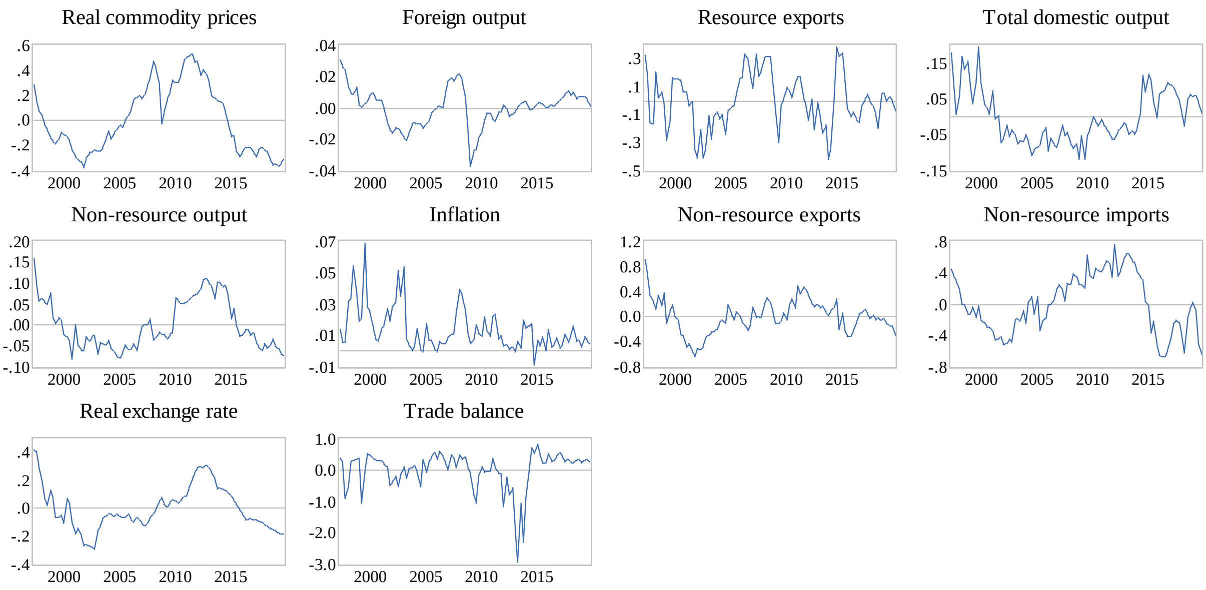
Note: *** indicates significance of $Corr(X_i,X_j)$ at 1% level. All variables (except inflation rate) are in logs and linearly detrended.

Table A3. Granger causality test for the foreign variables, 1997Q1-2019Q4.

Hypothesis		p- value
H_0:	Commodity price does not Granger cause	
	Resource exports	0.117
	Domestic output	0.665
	Inflation	0.001
	Real exchange rate	0.013
	Non-resource exports	0.005
	Non-resource imports	0.037
H_0:	Foreign output does not Granger cause	
	Resource exports	0.001
	Domestic output	0.157
	Inflation	0.000
	Real exchange rate	0.343
	Non-resource exports	0.044
	Non-resource imports	0.629

Note: $p < 0.05$ indicates rejection of H_0 at 5% level.

Figure A1. Plots of variables in the SVAR models, 1997Q1-2019Q4.



Note: All variables (except inflation rate) are logged and detrended.

Figure A2. Impulse response functions to a positive shock to commodity price in Model 2 - (a) real exchange rate ordered last, (b) exports and import deflated by output, (c) estimation on sub-sample, 1997-2013, and (d) VAR estimated in level.

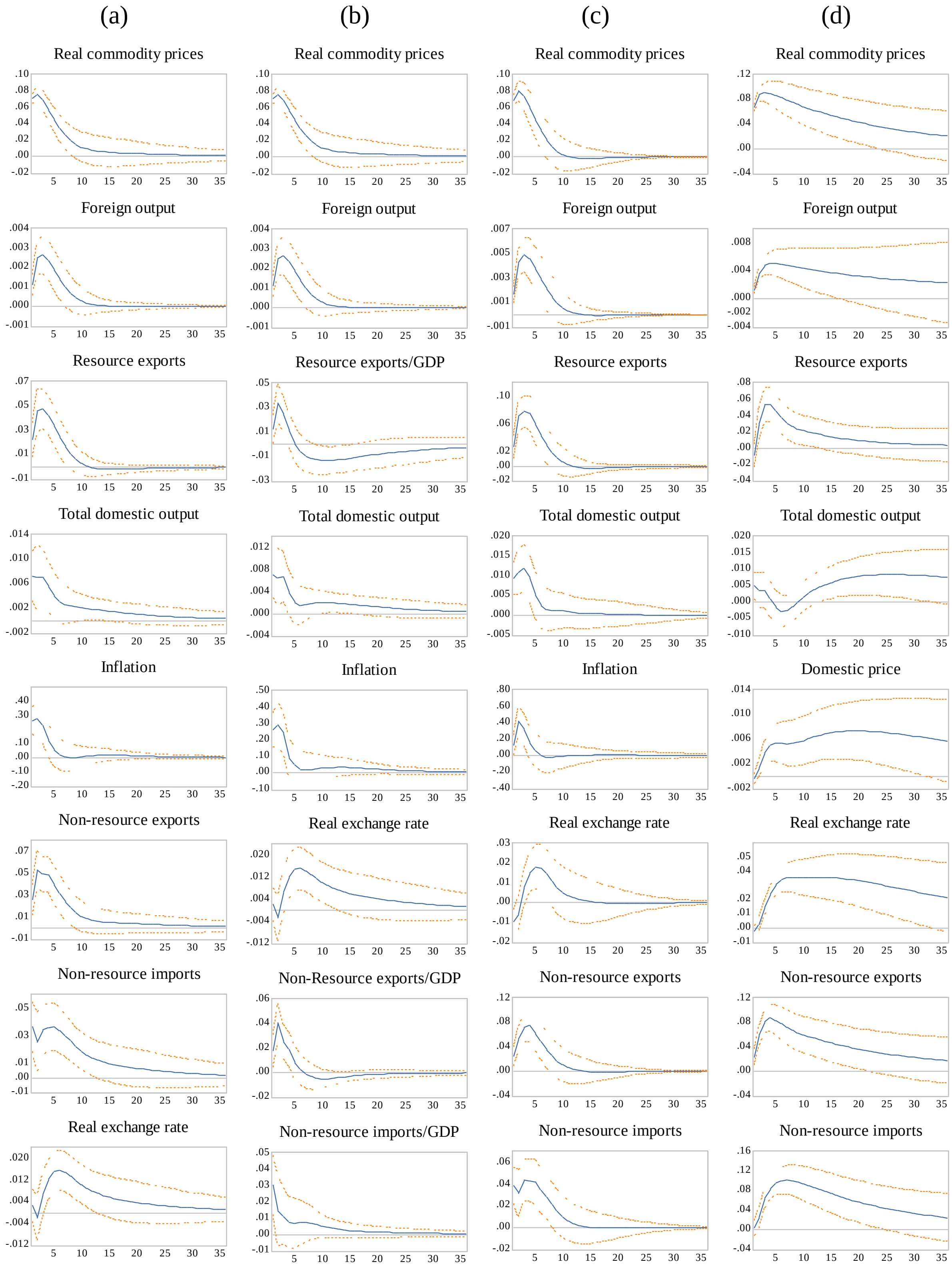


Figure A3. Impulse response functions to a positive shock to resource exports in Model (4) - (a) real exchange rate ordered last, (b) export and import deflated by output, (c) estimation on sub-sample, 1997-2013, and (d) VAR estimated in level.

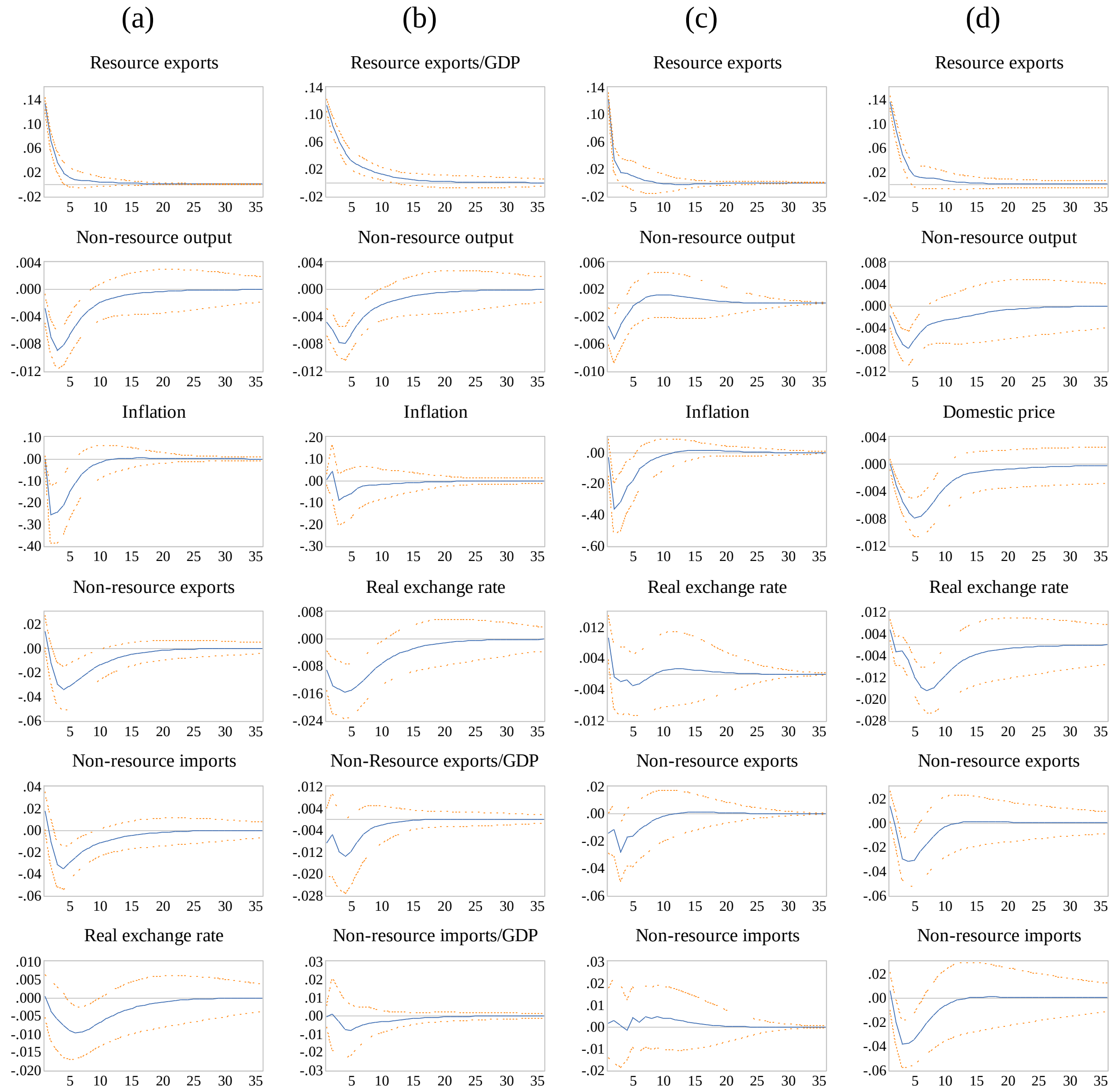
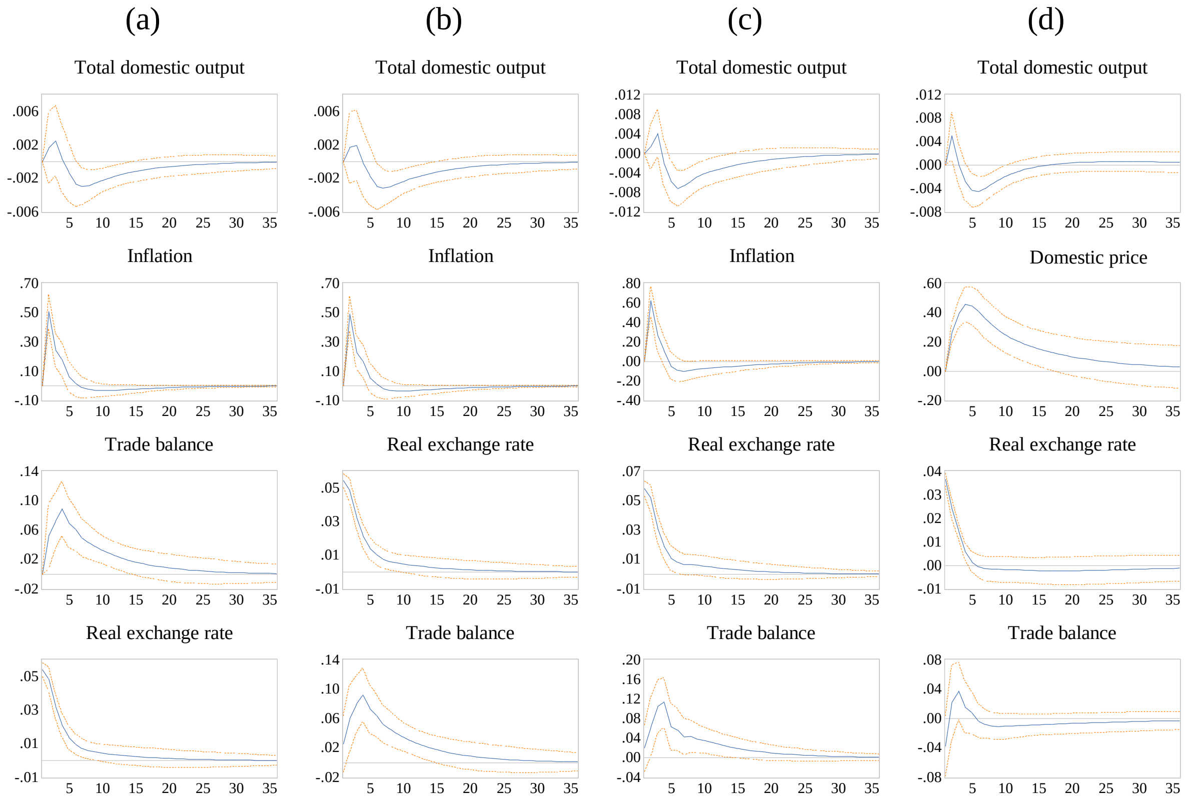


Figure A4. Impulse response functions to a positive (depreciation) shock to exchange rate in Model (3) - (a) real exchange rate ordered last, (b) trade balance deflated by output, (c) estimation on sub-sample, 1997-2013, and (d) VAR estimated in level.



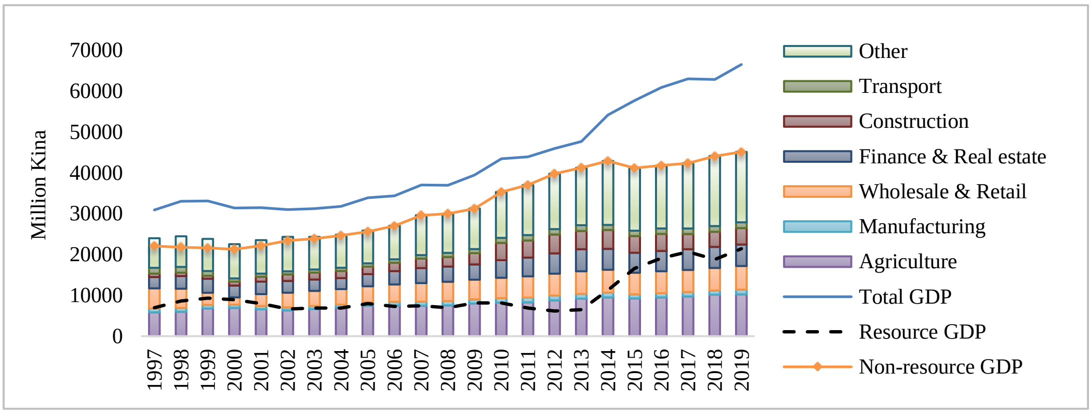
Appendix B

Box 1. **Construction of quarterly GDP for Papua New Guinea**

Gross domestic product (GDP) for Papua New Guinea is officially estimated as a production or output approach. Overall GDP can be decomposed into resource and non-resource GDP. Resource GDP includes the extraction of crude petroleum, natural gas, and mining while non-resource GDP is estimated as residual. From 2006, more sectors were included in the non-resource GDP; however, they can be classified into the following major categories- agriculture, manufacturing; construction; wholesale and retail trade; transport, finance, and real estate; and other. The 'Other' category includes professional and technical services; government and public administration; education; health; and taxes less subsidies. Resource sector contributes to around 25-30 percent of the total GDP.

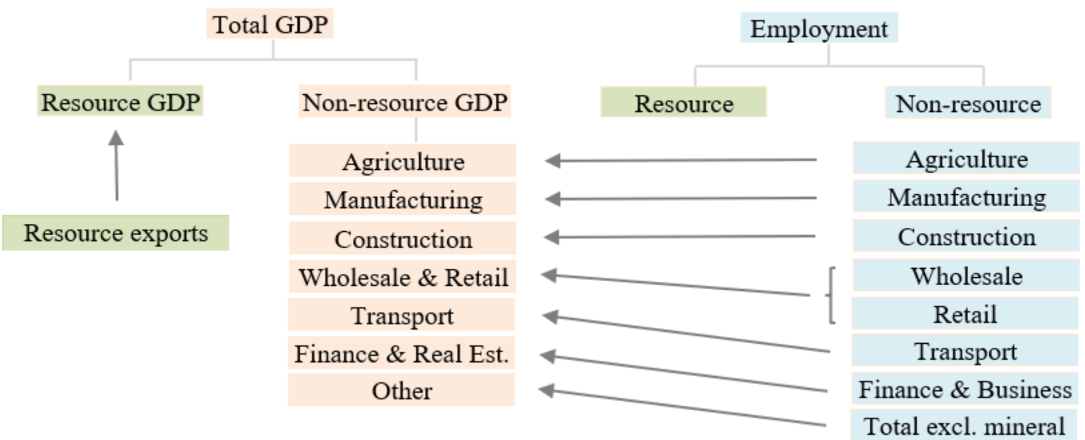
Sectoral annual real GDP is extracted from multiple national sources as no single source reports GDP for the entire sample period (1997-2019). For example, the National Statistics Office (NSO) reports GDP only from 2006. This study collects GDP for 1997-2002 from BPNG (2007), 2003-2005 GDP from national budgets (National Budget 2007, 2009 and 2010, Table 1), 2006-2018 GDP from NSO online database, and 2019 GDP from 2020 National Budget. As the official series is reported in two different base years (1997-2005 GDP in 1998 price and 2006-2019 GDP in 2013 price), the entire series was rebased to 2013 price using 2006 as the link year (National Budget 2010 reports real GDP for 2006 in 1998 price). Figure B1 plots annual real GDP and its composition.

Figure B1. Annual real GDP and its composition, 1997-2019.



Temporal disaggregation strategy employed in this study links information on two observable quarterly indicators- sectoral employment index and resource exports, to the target variables- non-resource GDP and resource GDP. It was estimated that, annual non-resource GDP is highly correlated with non-resource employment (0.90) while the correlation of resource GDP is higher with resource exports (0.94) than with resource employment (0.83). Therefore, resource GDP is interpolated using resource exports and non-resource sectoral output is estimated using sectoral employment index (Figure B2). Further, a summation restriction is imposed to ensure that quarterly GDPs in each year add up to their actual annual GDP. Quarterly employment index was taken from BPNG Quarterly Economic Bulletin and was rebased from 2002 to 2013 to keep the same base year as for GDP.

Figure B2. Quarterly GDP construction strategy.



The construction follows,

Non-resource sectoral GDP $$x_{i,t} = \frac{x_{i,T}}{4} \times \frac{emp_{i,t}}{\frac{\sum_{t=1}^{4} emp_{i,t}}{4}}$$

Resource GDP $$z_t = \frac{z_T}{4} \times \frac{resx_t}{\frac{\sum_{t=1}^{4} resx_t}{4}}$$

Total GDP $$yd_t = \sum_{i=1}^{n} x_{i,t} + z_t$$

where, x_i is the output of sector i, emp_i is the employment index for sector i, and $resx_t$ is quarterly resource exports. t is the quarter in year T.

Constructed GDP is plotted in Figure B3 and is compared with the GDPs interpolated by the Chow-Lin method (Figure B4). Clearly, constructed GDP captures quarterly fluctuations better than those suggested by the Chow-Lin method. For example, it identifies an overshoot of the overall GDP in 2014Q2 driven by the first shipment of LNG exports followed by a slowdown in 2015 led by negative growth in the non-resource sector, particularly in the agriculture and transport sector during the last two quarters of that year. Other major economic events such as 1997-1998 drought, which led to a six-month closure of the Ok Tedi Mine through 1997Q3-1998Q1 and a six-week shutdown of the Porgera Gold Mine beginning in 1997Q4 (Allen & Bourke 2001), and 2018 earthquake (six-week stoppage of the LNG project in 2018Q1) can also be traced from the constructed GDP.

Figure B3. Quarterly real GDP (constructed)

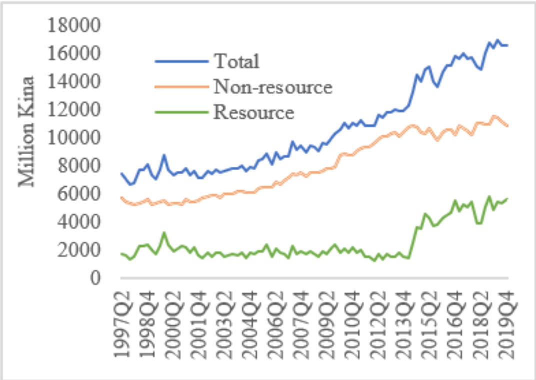


Figure B4. Quarterly real GDP (Chow-Lin)