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Adding financial flows to a CGE model of PNG

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Abstract

Traditionally, CGE models do not include equations modelling the financial sector of a country. Interest rates are therefore set exogenously and often the nominal exchange rate is set as the numeraire. Normally, these models would show that tighter monetary policy (i.e. increase in interest rates) would lead to a fall in investments and a decline in the domestic price level relative to foreign prices. This causes a real devaluation of the currency. The fall in domestic prices would be good for the trade balance because the country becomes more competitive with exports increasing and imports falling. However, there is another mechanism not captured in these models. If interest rates increase, we expect that foreigners would want to hold more domestic assets (due to the higher returns) and domestic agents would want to hold more domestic assets and less foreign assets. We expect a net inflow of capital and an appreciation of the currency. This appreciation would then hurt the trade account.

Our task is to develop a financial module and run simulations to investigate the impact of tighter monetary policy in Papua New Guinea (PNG). The financial module is a set of equations that are added, as an extension, to an existing dynamic model for PNG, see Kauzi (2003). For current purposes the dynamic model was run in short-run comparative static mode. In this paper we do not explain the equations of the core economic module. For a detailed description of the core module, see Dixon et al. (1982). The financial module is linked to the core CGE model via three conditions. Firstly, the current account deficit is equal to the net inflow of capital. Secondly, the government deficit is equal to the new acquisition of domestic bonds. Thirdly, investment in industry i is set equal to the new acquisition of assets in industry *i* by agents *z*. Once these equations are activated, we endogenously determine the nominal exchange rate, domestic bond rate and the change in the cost of funds to industries. In this paper we describe the theory underlying the financial module.

We simulate a 1 per cent increase in the interest rate the BPNG pays to the commercial banks for holding deposits with the BPNG. The first two simulations conducted are run with the financial module inoperative. This means that the financial module is not linked to the core economic module and that the nominal exchange rate and rates of interest are set exogenously. We expect the results of these two simulations to show that tighter monetary policy leads to an improvement in the trade balance. In simulations 3 we activate the first condition where we set the current account balance equal to the net capital inflow. This allows us to endogenously determine the nominal exchange rate. In simulation 4 we activate the second condition where we set the government deficit equal to the issuing of domestic bonds. We can now endogenously determine the domestic bond rate. In simulation 5 we activate the final constraint where we endogenously determine the change in the cost of lending funds to industries. By activating all the conditions we linked the financial module to the core economic module. We expect the results of the final three simulations to show that tighter monetary policy leads to a worsening of the trade balance.

Keywords: Computable general equilibrium (CGE) models, Financial markets, Interest rates, Monetary Policy

JEL Classification: C68, E44, E47, E52

Adding financial flows to a CGE model of PNG

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1 Introduction

Traditionally, CGE models do not include equations modelling the financial sector of a country. Interest rates are therefore set exogenously and often the nominal exchange rate is set as the numeraire. Normally, these models would show that tighter monetary policy (i.e. increase in interest rates) would lead to a fall in investments and a decline in the domestic price level relative to foreign prices. This causes a real devaluation of the currency. The fall in domestic prices would be good for the trade balance because the country becomes more competitive with exports increasing and imports falling. However, there is another mechanism not captured in these models. If interest rates increase, we expect that foreigners would want to hold more domestic assets (due to the higher returns) and domestic agents would want to hold more domestic assets and less foreign assets. We expect a net inflow of capital and an appreciation of the currency. This appreciation would then hurt the trade account.

Our task is to develop a financial module and run simulations to investigate the impact of tighter monetary policy in Papua New Guinea (PNG). The financial module is a set of equations that are added, as an extension, to an existing dynamic model for PNG, see Kauzi (2003). For current purposes the dynamic model was run in short-run comparative static mode. In this paper we do not explain the equations of the core economic module. For a detailed description of the core module, see Dixon et al. (1982). The financial module is linked to the core CGE model via three conditions. Firstly, the current account deficit is equal to the net inflow of capital. Secondly, the government deficit is equal to the new acquisition of domestic bonds. Thirdly, investment in industry i is set equal to the new acquisition of assets in industry *i* by agents *z*. Once these equations are activated, we endogenously determine the nominal exchange rate, domestic bond rate and the change in the cost of funds to industries. In this paper we describe the theory underlying the financial module.

Section 2 describes the financial theory. We impose a stock/flow mechanism where we model agents' behaviour in terms of holding different assets in their portfolio. At the start of year *t*, agent *z* decides on the combination of assets *j* to hold at the end of year *t* to maximise returns. Agents' decisions are motivated by changes in the relative rates of interest of the different assets and the amount of available money to buy new assets. The agents and assets modelled are listed in Table 1. There are six domestic agents (z=1, 3, 4, 5, 6, 7) and one foreign agent (z=2). Agents decide on which assets to hold. There are 7 domestic assets (j=1, 2, 3, 5, 6, 7, 8) and one foreign assets (j=4).

Table 1. Financial agents and assets

Agents (z)	**Assets (j)**
(1) Households	(1) Business assets (equity & credit), industry 1 to n
(2) Foreigners	(2) Bank Deposits
(3) Government	(3) Domestic bonds
(4) Commercial banks	(4) Foreign bonds
(5) Non-Bank Financial Institutions (NBFI)	(5) Deposits with Central bank
(6) Superannuation funds	(6) Loans to PNG Households
(7) Industries	(7) Deposits and equity in NBFI
	(8) Superfunds deposits

Apart from the optimising equations we also show how assets accumulate during the year. Assets at the end of year *t* are equal to assets held at the start of year *t* plus new assets acquired during the year. For all domestic optimising agents these equations are denoted in Kina. Foreigners are concerned about the value of their portfolio in foreign currency (e.g US$). Foreigners decide on which assets to hold in PNG and the rest of the world. We also include equations determining the rates of interest on the different assets as well as equations determining the amount of money available to buy new assets.

Section 3 describes the database. For each agent listed in Table 1 we need data on their holding of assets and liabilities for the most recent year. The financial database includes two large matrices. The first matrix shows the holding of assets *j* by agents' *z*, as listed in Table 1, at the start of 2008. The second matrix shows the net acquisition of assets by agents during 2008.

Section 4 describes the results of five simulations where we investigate the impact of tighter monetary policy in PNG. Our understanding of the functioning of monetary policy in PNG is that the Bank of Papua New Guinea (BPNG) varies the interest rate they offer on the deposits made by commercial banks to the BPNG. The BPNG offers competitive interest rates on the deposits made to the BPNG by commercial banks.

We simulate a 1 per cent increase in the interest rate the BPNG pays to the commercial banks for holding deposits with the BPNG. The first two simulations conducted are run with the financial module inoperative. This means that the financial module is not linked to the core economic module and that the nominal exchange rate and rates of interest are set exogenously. We expect the results of these two simulations to show that tighter monetary policy leads to an improvement in the trade balance. In simulations 3 we activate the first condition where we set the current account balance equal to the net capital inflow. This allows us to endogenously determine the nominal exchange rate. In simulation 4 we activate the second condition where we set the government deficit equal to the issuing of domestic bonds. We can now endogenously determine the domestic bond rate. In simulation 5 we activate the final constraint where we endogenously determine the change in the cost of lending funds to industries. By activating all the conditions we linked the financial module to the core economic module. We expect the results of the final three simulations to show that tighter monetary policy leads to a worsening of the trade balance.

2 Financial module

The financial module includes a set of equations describing:

- how assets held by agents accumulate;
- how domestic agents decide on which assets to hold at the end of the year;
- how foreign agents decide on which domestic assets to hold at the end of the year;
- how funds available to domestic optimizing agents for net acquisition of assets are determined; and
- how the rates of interest for the different assets are determined.

2.1 Asset accumulation by domestic agents

Assets accumulate via the following equation:

$$A_{t+1}(z, j) = A_t(z, j) * V_t(z, j) + D_t(z, j) \qquad \text{for all z and j} \tag{E.1}$$

where

$A_{t+1}(z, j)$ is asset j held by agent z at the end of year t (start of year t+1);

$A_t(z, j)$ is assets j held by agent z at the start of year t;

$V_t(z, j)$ is a valuation coefficient attached to assets j held by agent z; and

$D_t(z, j)$ is the acquisition of new assets j by agent z during the year.

Equation (E.1) shows that asset *j* held by agent *z* at the end of year t, is new assets *j* (net of sales) acquired by agent *z* during year *t plus* the stock of asset *j* held by agent *z* at the start of year *t*. The

$V_t(z,j)$ coefficient captures the idea that the value of start-of-year assets in agent z's portfolio may change during the year. In our simulations described in Section 5, we assume no valuation effects (i.e V = 1). The construction of the $A_t(z,j)$ and $D_t(z,j)$ matrices is described in Section 3.

2.2 Optimizing behaviour by domestic agents

At the start of year *t*, domestic agents choose a combination of assets *j* to hold at the end of year *t*, to maximise their returns. The domestic optimizing agents are Households (z=1), Commercial banks (z=4), NBFI (z=5) and Super funds (z=6).

We assume that the government (z=3) and industry i (z =7_i) maintain deposits in commercial banks to finance their transactions. They don't undertake portfolio optimizing behaviour.

We assume that at the beginning of year t, domestic optimizing agents:

choose which assets to hold at the end of year t , $A_{t+1}(z,j)$, for all j excluding Super[1],

to maximise $U_t\left[A_{t+1}(z,j) * R_t(z,j), \quad \text{for all j}\right]$

subject to (1) and

$$S(z) = \sum_{j=1}^{7} D(z,j) \qquad \text{for all z and j} \tag{E.2}$$

where

$A_{t+1}(z,j)$	is asset j held by agent z at the end of year t (start of year t+1);
$R_t(z,j)$	is one plus the rate of interest (the power of the interest rate) on asset *j* held by agent *z*;
U_t	is a utility function, which has a constant elasticity of substitution (CES) form;
$S(z)$	is the funds available for agent *z* to acquire new assets; and
$D(z,j)$	is the net acquisition of asset *j* by agent *z*.

Agents maximise utility by holding assets and earning interest on these assets. Agents may change their holding of assets in response to changes in the assets-specific interest rates. For example, when the interest rate on domestic bonds increases relative to the returns earned on other assets, agents may want to hold more domestic bonds and less of the other assets. We assume that assets are imperfect substitutes. Given our previous example, it means that agents will not invest only in domestic bonds. They will continue to spread their portfolio over various assets. They will however increase their holding of domestic bonds relative to other assets. See Appendix B for the deriviation of the optimising problem.

Equation (E.2) shows that the net acquisition of asset *j* by all agent *z*, (D(z,j)), is equal to the available funds of agent *z*, (S(z)). Available funds are defined as the amount of money the agent has available to buy new assets during the year.

For the functioning of the financial module, we need to specify equations for the (i) rates of return on assets and (ii) the funds available to each agent to buy new assets.

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[1] Only households accumulate superannuation assets. We assume that their contributions to Super are compulsory.

2.3 Funds available to domestic optimizing agents for net acquisition of assets

In this section we specify funds available to each domestic agent, for buying new assets during the year. For each domestic agent we define the S coefficient appearing in Eq. (E.2).

2.3.1 Households (z = 1)

The available funds households have to buy new assets are:

$$S(1) = Yd - Cons + D(4,6) - D(1,7) \tag{E.3}$$

where

S(1) is the funds available to households to acquire new assets during the year;

Yd is household disposable income;

Cons is household consumption expenditure;

D(4,6) is commercial banks' lending funds to households; and

D(1,7) is the superannuation payments made by households.

Eq. (E.3) shows that the amount of money households have available to buy new assets is dependent on their disposable income (income post direct tax), less their consumption spending plus the amount of money banks lend to households less the superannuation payments.

2.3.2 Commercial banks (z = 4)

Equation (E.4) shows that the funds available to commercial banks (S(4)) are equal to bank deposits by all agents z. We exempt foreigners (z=2) and commercial banks (z=4) because (a) foreigners don't normally make deposits in PNG commercial banks and (b) we are treating commercial banks as a single unified entity.

$$S(4) = \sum_{z \neq 2,4} D(z,2)\ , \text{ for all z agents except 2, 4} \tag{E.4}$$

2.3.3 Non-Bank Financial Institutions (NBFI) (z = 5)

Equation (E.5) shows that the available funds of non-bank financial institutions (S(5)) to buy new assets are equal to deposits by foreigners (z=2) and superannuation funds (z=6). No other domestic agent holds assets in NBFI.

$$S(5) = \sum_{z=2,6} D(z,8)\ , \text{ for all z agents except 2, 6} \tag{E.5}$$

2.3.4 Superannuation funds (z = 6)

Equation (E.6) shows that the funds available to superannuation funds (S(6)) to buy new assets are equal to the contributions made by only domestic households (z=1). We assume that no other agents make payments to superannuation funds.

$$S(6) = D(1,7) \tag{E.6}$$

2.4 Optimizing behaviour of foreigners (z = 2)

Foreigners are interested in their portfolio valued in foreign currency (e.g. US$), not in Kina. We therefore rewrite their utility function as:

$$U_t\left[E_{t+1} * A_{t+1}(2, j) * R_t(2, j),\ \text{for}\ \ j{=}1{,}3{,}7;\ AFO_{t+1} * RFO_t\right] \qquad \text{(E.7a)}$$

where AFO_{t+1} is assets held at the end of year t by foreigners in countries other than PNG. These assets are valued in foreign currency and RFO_t is one plus the rate of return on them. Foreigners hold the following PNG assets: equity in industries (j=1), PNG domestic bonds (j=3) and equity in NBFI (j=7).

The accumulation equations for foreigners can be written in terms of foreign currency as:

$$E_{t+1} * A_{t+1}(2, j) \ = \ E_{t+1} * A_t(2, j) * V_t(2, j) \ + \ E_{t+1} * D_t(2, j) \qquad \text{for j= 1, 3, 7} \qquad \text{(E.7b)}$$

and

$$AFO_{t+1} = AFO_t * VFO_t + DFO_t \qquad \text{(E.7c)}$$

where

$A_{t+1}(2, j)$ is PNG asset j held by foreigners (z=2) at the end of year t, denominated in Kina;

$A_t(2, j)$ is PNG asset j held by foreigners (z=2) at the start of year t, denominated in Kina;

E_{t+1} is the exchange rate defined at the start of end of year t;[2]

$V_t(2, j)$ and VFO_t are valuation coefficients; and

$D_t(2, j)$ and DFO_t are net acquisitions by foreigners of assets in year t.

As with domestic agents, foreigners have to choose which assets to hold in order to maximise their utility. Foreigners therefore have to decide on their holding of PNG assets and assets in other countries. If the rates of interest on PNG assets are higher relative to the rates of interest on assets in the rest of the world, foreigners would want to hold more PNG assets.

We assume that at the beginning of year t, optimising foreigners

choose, $E_{t+1} * A_{t+1}(2, j)$, for all PNG assets j, and AFO_{t+1} to maximize U_t defined by (E.7a) subject to (E.7b), (E.7c) and

$$S(2) = \sum_{j=1,3,7} E_{t+1} * D(2, j) + DFO_t \quad . \qquad \text{(E.8)}$$

Equation (E.8) states that the funds available to foreigners [S(2)] is equal to the acquisition of PNG assets during the year and the acquisition of new assets in other countries.

2.5 Defining the powers of interest rates (the R's)

In this section we define the power of the rates of interest on assets j held by agents z. The power of the rates of interest is defined as 1 + r. These power of the rates of interest (1+r) on asset *j* are important as they influence agents *z* decision to holding these assets.

2.5.1 Interest paid to commercial banks for holding deposits with the BPNG

This interest rate is paid by the BPNG to commercial banks for holding deposits with the BPNG. This interest rate is set exogenously.

$$R(4, 5) = \text{exogenous} \qquad \text{(E.9)}$$

[2] The exchange rate is defined as $\frac{\$F}{\text{Kina}}$.

This interest rate is the main instrument of Monetary Policy in PNG. The BPNG pays a competitive interest rate to commercial banks for deposits held at the BPNG. To reduce the amount of money available in the market, the BPNG will increase the rate of interest paid to commercial banks for their deposits in the BPNG. At a higher interest rate, commercial banks will hold more deposits with the BPNG. For example, by increasing R(4,5), the BPNG will attract more deposits from commercial banks, leaving less funds available to lend to households for example.

2.5.2 Interest paid to domestic agents for holding foreign bonds

The interest paid to PNG agents z for holding foreign bonds (j=4) is set exogenously as it depends on factors determined outside the model. The interest rate is the same for all agents.

$$R(z, 4) = \text{exogenous}, \quad \text{for all z agents} \qquad \text{(E.10)}$$

2.5.3 Interest received by agents for lending money to industries

Equation (E.11) defines the rate of interest all agents receive for lending money to industries (j=I_q).

$$R(z,I\_q) = \left(R(4,5) * MU(z,I\_q)\right)^{DS(I\_q)} * \left(ROR(I\_q)\right)^{(1-DS(I\_q))} * SHIFT(I\_q) \qquad \text{(E.11)}$$

for all z agents

where

$R(z,I\_q)$	is the rate of interest agents z receives for lending (or investing) money in industry i;
$R(4,5)$	is the interest rate on deposits to the BPNG from commercial banks as specified in (E.9);
$MU(z,I\_q)$	is an exogenously set mark-up;
$DS(I\_q)$	is the debt share of agent z's holding of assets in industry I_q;
$ROR(I\_q)$	is the rate of interest on equity. This rate of return is defined in the core CGE model and reflects the scarcity of capital;
$SHIFT(I\_q)$	is a shift variable defined by industry.

By adopting (E.11) we assume that all agents that invest in industry q receive an average rate of return reflecting interest rates on debt and profitability of equity. In a more advanced version of this model we could take into account that the assets of some agents (e.g. banks) in industry q is predominantly debt while that of other agents (e.g. households) is predominantly equity.

2.5.4 Interest received by commercial banks for lending money to households

The interest rate received by commercial banks (z=4) for lending money to households (j=6) is defined as:

$$R(4, 6) = R(4, 5)*MU(4, 7) \qquad \text{(E.12)}$$

where

R(4, 5)	is the interest rate on deposits to the BPNG from commercial banks as specified in (E.9);
MU(4, 7)	is an exogenously set mark-up.

2.5.5 Interest received by agents for holding money in bank deposits

The interest rate received by agents *z* for holding money in bank deposits (j=2) is defined as:

$$R(z, 2) = R(4, 5)/MU(z, 2), \quad \text{for all z agents} \qquad \text{(E.13)}$$

where

$R(4, 5)$ is the interest rate on deposits to the BPNG from commercial banks as specified in (E.9);

$MU(z, 2)$ is an exogenously set mark-up.

Note that the interest rate on bank deposits is the same for all agents.

2.5.6 Interest received by agents for holding money in NBFI

The interest rate received by agents *z* for holding money in NBFI is defined as:

$$R(z, 8) = R(4, 5)*MU(z, 8) \text{, for all z agents} \qquad (E.14)$$

where

$R(4, 5)$ is the interest rate on deposits to the BPNG from commercial banks as specified in (E.9);

$MU(z, 8)$ is an exogenously set mark-up.

2.5.7 Interest received by agents for holding domestic bonds

The interest rate paid to all agents for holding domestic bonds (j=3) is the same, defined as:

$$R(z, 3) = FRDB\text{, for all z agents} \qquad (E.15)$$

When the financial model is fully operational, the bond rate is determined endogenously via changes in FRDB. We expand on the working of (E.15) in Section 2.8.2.

2.6 Percentage change equations describing asset acquisition

In this section we describe the percentage change equations of the optimisation equations defined in Sections 2.2 and 2.4. These are derived formally in Appendix 2.

2.6.1 Domestic optimizing agents

The optimising behaviour in levels form of domestic agents is described in Section 2.2. Converting the optimising equations into percentage change yields:

$$a_{t+1}(z,j) = \frac{S(z)}{\sum_k A_{t+1}(z,k)} * s(z) + (\sigma - 1) * \left(r(z,j) - \sum_k W_{t+1}(z,k) * r(z,k) \right) \qquad (E.16)$$

where $W_{t+1}(z,k) = A_{t+1}(z,k) \Big/ \sum_q A_{t+1}(z,q)$ (E.17)

$a_{t+1}(z,j)$ is the percentage change in the assets j held by agents z at the end of year t+1;

$\frac{S(z)}{\sum_k A_{t+1}(z,k)}$ is the share of available funds of agent z in the total assets held by agent z;

$s(z)$ is the percentage change in the funds available to agent z to buy assets;

$r(z,j)$ is the percentage change in the power of the rates of interest (1+r) paid on asset j to agent z;

$W_{t+1}(z,k)$ is the ratio of asset k held by agent z to the total assets held by agent z (the sum of the W’s for agent z over assets equals 1);

$(\sigma-1)$	is the elasticity of substitution and governs the ease with which agents can change their holding of assets. The elasticity is equal to 2.

In interpreting (E.16), begin by assuming that the rate of interest on asset *j* held by agent *z* remains unchanged. If s(z) increases by 1%, then the holding of assets j by agent z will increase, uniformly, but not by 1%. The uniform percent increase is the share of agent z's available funds in the total holding of assets by agent z.

Now, assume that s(z) remains unchanged. If the rate of interest on asset j held by agent z increases relative to the average rate of interest over all assets k, then agents would buy more of asset j. For example, if the rate of interest on domestic bonds increases relative to the average rate of interest, then agents would want to hold more domestic bonds in their portfolio and less of other assets.

2.6.2 Foreigners

The optimising behaviour in levels form of the foreign agent is described in Section 2.4. Converting this optimising equation into percentage change yields:

$$\left[a_{t+1}(2,j)+e_{t+1}\right]=\frac{S(2)}{\sum_k A_{t+1}(2,k)}*s(2)+(\sigma-1)*\left(r(2,j)-\sum_k W_{t+1}(2,k)*r(2,k)\right) \qquad \text{(E.18a)}$$

This percentage change equation has the same form as (E.16) except that the percentage changes in foreign holdings of each PNG asset [$a_{t+1}(2,j)$] is bracketed with the percentage change in the exchange rate (e_{t+1}). This reflects the multiplication of $A_{t+1}(2,j)$ by E_{t+1} wherever $A_{t+1}(2,j)$ appears in the foreign agent's optimization problem.

Recognizing that PNG assets are a tiny fraction of the foreign agent's portfolio and that actions in PNG will not affect foreign saving (allowing us to assume that s(2) = 0, we can simplify (E18a) to:

$$a_{t+1}(2,j)+e_{t+1}= \quad (\sigma-1)*\left(r(2,j)-rf(2)\right) \qquad \text{(E.18b)}$$

where

e_{t+1}	is the percentage change in the nominal exchange rate;
$a_{t+1}(2,j)$	is the percentage change in assets j held by the foreign agent at the end of year t+1;
$r(2,j)$	is the percentage change in the power of the rates of interest (1+R) paid on PNG asset j held by foreigners;
$rf(2)$	is the percentage change in the power of average rates of interest foreigners receive for holding assets; and
$(\sigma-1)$	is the elasticity of substitution, governing the ease with which foreigners can change their holding of assets.

The percentage change in the power of the average rate of interest foreigners receive on holding assets [$rf(2)$] is set exogenously as it depends almost entirely on the rate of interest received on assets held not in PNG but in the rest of the world - which is not determined by our model.

(E.18b) implies that in the absence of changes in expected rates of return, the foreign agent will reduce the Kina value of its PNG assets in response to appreciation of the exchange rate. This result follows from the assumption that the foreign agent is concerned about its foreign dollar exposure to PNG, which increases with appreciation. This assumption is built into the foreign agent's optimizing problem, see section 2.4.

If there are changes in rates of return, then the foreign agent reacts in a similar way to domestic agents. Assume that the rate of interest on PNG asset j increases relative to the average rate of interest foreigners receive. Foreigners would then change their holding of assets in favour of PNG asset j.

2.7 Investment behaviour

Equation (E.19) shows that investment in PNG industries is a function of the rental value of a unit of capital (rents), price of units of capital and the cost of funds.

$$\text{Inv}(\text{I\_q}) = \text{f}\left(\text{rents, prices of units of capital, costs of funds}\right) \qquad \text{(E.19)}$$

The cost of funds (R(z,I_q)) is defined in (E.11) and shows the cost of funds to industries (or the rate investors get by lending money or buying equity in industries). This rate of interest is endogenously determined and changes via the shift variable (SHIFT(I_q)) will be the uniform for all agents z.

2.8 Economy-wide financing constraints

In this section we describe the economy-wide financing constraints. These constraints link the financial module to the existing core economic module.

2.8.1 Current account deficit: opportunity for foreign investment

The first constraint equates variables describing foreign holding of PNG assets j and domestic agents z holding of foreign bonds to the current account and a phantom capital variable.

$$\sum_{j=1,3,7} \text{D}(2,\text{j}) - \sum_{z=4,6} \text{D}(\text{z},4) = \text{CAD + Phantom capital outflow} \qquad \text{(E.20)}$$

for assets 1, 3, 7

for agents 4, 6

where

$\sum_{j\neq 1,3,7} \text{D}(2,\text{j})$ is new PNG assets *j* held by foreigners. Foreigners hold (i) assets in industries; (ii) domestic bonds; and (iii) equity in NBFI;

$\sum_{z4,6} \text{D}(\text{z},4)$ is the holding of foreign bonds by domestic agents. PNG agents holding foreign assets are commercial banks and superannuation funds;

CAD is the current account deficit which is determined in the core economic model. In the current version of the PNG model, CAD is simply the difference between imports and exports; and a

phantom capital is a variable which is used to activate or deactivate this equation.

The LHS of (E.20) pertains to the inflow and outflow of capital related to the holding of assets. The RHS of (E.20) pertains to the inflow and outflow of capital related to trade. To understand the working of this equation, assume that the BPNG increases interest rates. We would expect foreigners to hold more PNG assets (inflow of capital increase) and domestic agents would want to hold more PNG assets (outflow of capital falls). If the CAD and the phantom variable is held fixed, the exchange rate would appreciate.

(E.20) is activated by exogenising the phantom term and endogenising the nominal exchange rate. Therefore, when operational in the policy simulation, (E.20) determines the nominal exchange rate.

2.8.2 Supply of bonds

The second constraint equates the sum of bond acquisitions (by agents who are allowed in the model to acquire bonds) to the budget deficit and a phantom money term.

$$\sum_{z\neq 3,7} D(z,3) = G - T - \text{Phantom public financing (money)} \tag{E.21}$$

where

G-T is the government budget deficit, defined as the difference between government spending (G) and government revenue (T); and

phantom public financing term which is used to activate or deactivate this equation.

Eq. (E.21) is activated by exogenising the phantom term and endogenising the shift term (FRDB) appearing in Eq. (E.15). When operational in the policy simulation (E.21) determines the rate of interest of domestic bonds (see E.15). For example, if there is a budget deficit, the government would want agents to hold more domestic bonds (D(z,3) should increase). For agents to hold more domestic bonds the rate of interest on domestic bonds, as defined in (E.15), should increase. This increase occurs via a change in FRDB.

2.8.3 Financing of investment in industry q

The third constraint equates investments in all industries to the acquisition of new assets by agents and a phantom investment term.

$$\text{Inv}(I\_q) = \sum_{z\neq 3,7} D(z,1\_q) + \text{Phantom investment financing} \tag{E.22}$$

for all z agents except except $z \neq 3,\ z \neq 7$

where

$\text{Inv}(I\_q)$ is the investment in industry I, where i=1-q;

$\sum_{z\neq 3,7} D(z,1\_q)$ is the assets held in industry 1-q by all agents except the government and other industries; and a

phantom investment financing term which is used to activate or deactivate this equation.

Equation (E.21) is not operational if the phantom term is endogenous. This equation is activated by exogenising the phantom term and endogenising the shift term ($\text{SHIFT}(I\_q)$) appearing in Eq. (E.11). When operational in the policy simulation, (E.22) determines the change in the cost of funds to industries.

3 Database

In this section we describe the database. Two matrices are fundamental to the working of the financial module. The first matrix, $A_{(t)}$, shows the holding of assets *j* by agent *z* at the start of year t. This matrix appear in Eqs. (E.1) and (E.7). The second matrix, $D_{(t)}$, shows the acquisitions of new assets *j* bought by *z* agents during year t. This matrix appears in Eqs. (E.1) to (E.8). Equation (E.16) includes a parameter, $(\sigma - 1)$, which governs agent *z* sensitivity to changes in the relative rates of return of asset *j*. This parameter is set to 2.

3.1 Creating the A matrix

Our task is to create the matrix, At, for the start of 2008. A summary of this matrix is presented in Table 2. The rows show *z* agents and the columns *j* assets that form part of the agents' portfolio. The assets and agents are defined in Table 1. For example, At(4,5) shows the value (5,079 million kina) of deposits by commercial banks (agent 4) with the BPNG (asset 5). Similarly, At (1,8) shows the value (5,263 billion kina) of household (agent 1) payments to the superannuation fund (asset 8).

Our strategy in completing this matrix is to:

- adopted data from BPNG;
- use expert knowledge on asset holding and liabilities by agents in PNG;
- adhere to balancing conditions; and
- if necessary some cells are calculated as a residual.

The following conditions should hold:

- household payments to superannuation is equal to the holding of all assets by the agent called Super. In Table 2 this implies that A(8,8) = A(6,9); and
- the holding of equity in NBFI (asset = 7) by foreigners and superannuation funds is equal to the holding of all assets by the agent called NBFI. In Table 2 this implies that A(8,7) = A(5,9).

We explain for each agent *z* their holding of *j* assets.

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Table 2. Assets held by agents at the start of 2008: values in thousands of Kina

		1	2	3	4	5	6	7	8	9
	Assets Agents	IND	Bank Deposit	Domestic Bonds	Foreign Bonds	Deposit with Bank of PNG	Loans to HH	Equity in NBFI	Super	Total
1	**Households**	75,022,011	2,230,500	112,200	-	-	-	-	5,263,100	**82,627,811**
2	**Foreigners**	4,988,000	-	1,000,000	-	-	-	246,600	-	**6,234,600**
3	**Government**	-	2,629,000	-	-	-	-	-	-	**2,629,000**
4	**Commercial Banks**	5,499,100	-	1,728,500	1,548,500	5,079,100	677,900	-	-	**14,533,100**
5	**NBFI**	571,400	600,000	352,900	-	-	-	-	-	**1,524,300**
6	**Super**	1,972,500	672,500	658,900	681,500	-	-	1,277,700	-	**5,263,100**
7	**IND**	-	6,341,000	-	-	-	-	-	-	**6,341,000**
8	**Total**	**88,053,011**	**12,473,000**	**3,852,500**	**2,230,000**	**5,079,100**	**677,900**	**1,524,300**	**5,263,100**	**119,152,911**

Table 3. Net acquisition of assets j by agents z during 2008: values in thousands of Kina

		1	2	3	4	5	6	7	8	9
	Assets Agents	IND	Bank Deposit	Domestic Bonds	Foreign Bonds	Deposit with Bank of PNG	Loans to HH	Equity in NBFI	Super	Total
1	**Households**	4,368,071	133,830	4,369	-	-	-	-	315,786	**4,822,056**
2	**Foreigners**	390,027	-	38,936	-	-	-	14,796	-	**443,759**
3	**Government**	-	157,740	-	-	-	-	-	-	**157,740**
4	**Commercial Banks**	345,634	-	67,300	92,910	304,746	40,674	-	-	**851,264**
5	**NBFI**	39,429	36,000	13,740	-	-	-	-	-	**89,170**
6	**Super**	154,236	40,350	25,655	40,890	-	-	76,662	-	**337,793**
7	**IND**	-	380,460	-	-	-	-	-	-	**380,460**
8	**Total**	**5,297,396**	**748,380**	**150,000**	**133,800**	**304,746**	**40,674**	**91,458**	**315,786**	**7,082,240**

3.1.1 Households (At(1,j))

Table 2 show that households (row 1) hold the following assets:

- assets in industry *i*, where *i* = 1 – 42. This is cell A(1,1);
- bank deposits, cell A(1,2);
- domestic bonds, cell A(1,3); and
- payment to superannuation, cell A(1,8).

Data from the BPNG shows that households hold 2,230 million Kina in bank deposits (A(1,2)). Table 4 shows the composition of total bank deposits.

Table 4. Households' holding of assets, 2008: values in thousands of Kina

Holding of assets	Kina	Reference in Table 2
Household transferable deposits	1,524,600	
Household other deposits	705,900	
Total Bank Deposits*	**2,230,500**	**A(1,2)**

* Bank of Papua New Guinea, 2012, Table 3.9.

We do not have explicit data on households holding of business assets (A1,1 in Table 2) or domestic bonds (A1,3). These values are calculated in Section 3.1.7. Household payment to superannuation funds (A(1,8)) is equal to the total value of superannuation holding of assets (see Section 3.1.5)

3.1.2 Government (At(3,j))

Table 2 shows that the Governments' only asset is bank deposits of 2,629 million Kina (Bank of Papua New Guinea, 2012, Tables 3.9). This is cell (A(3,2)).

3.1.3 Commercial banks (At(4,j))

Table 2 show the commercial banks portfolio consists of:

- assets in industry I_q, cell A(4,1));
- domestic bonds, cell A(4,3));
- foreign bonds, cell A(4,4));
- deposits with the BPNG, cell A(4,5)); and
- lending funds to households, A(4,6).

Table 5 presents the commercial banks holding of assets for 2008. Column 4 in Table 5 shows the corresponding cell in Table 2. Commercial banks also hold 1,5 billion Kina in foreign bonds (row 12 in Table 5), 5 billion Kina as deposits with the BPNG (row 17 in Table 5) and loans to households of 677 thousand Kina. The total value of assets held by commercial banks are 14,5 billion Kina (row 29 in Table 5).

Table 5. Commercial Banks holding of assets, 2008

Row	Holding of assets	Kina	Reference in Table 2
1	*Business Assets*		
2	Shares and Other Equity	17,400	
3	Insurance Technical Reserves	100	
4	Financial Derivatives	0	
5	Other Assets	303,700	
6	Non-Financial Assets	541,200	
7	**Total holding of business assets**[1]	**862,300**	
8	*Domestic bonds*		
9	Treasury bills	1,374,700	
10	Inscribed Stocks	1,353,800	
11	**Domestic Bonds**[1]	**1,728,500**	**(A4,3)**
12	**Foreign assets**[1]	**1,548,500**	**(A4,4)**
13	*Central Bank deposits*		
14	Currency Deposits with Bank of PNG	211,000	
15	Deposits	808,400	
16	BPNG CBB	4,059,700	
17	**Total deposits with the BPNG**[1]	**5,079,100**	**(A4,5)**
18	*Loans to private sector (business and*		
19	Central Government	2,400	
20	BPNG	0	
21	Provincial and Local Level Government	4,000	
22	Nonfinancial Corporations	133,200	
23	Private Sector (Kina)	4,929,100	
24	Private Sector (Foreign Currency)	226,400	
25	Other Depository Corporation	19,600	
26	**Total loans to private sector**[1]	**5,314,700**	
27	**Total advances to persons**[2]	**677,900**	**(A4,6)**
28	**Total loans to PNG business (row 26 minus 27)**	**4,636,100**	
29	**Total assets held by commercial banks**	**14,533,100**	**(A4,9)**
30	**Total holdings to PNG business (row 28 + 7)**	**5,498,400**	**(A4,1)**

1. Bank of Papua New Guinea, 2012, Table 3.7.

2. Bank of Papua New Guinea, 2012, Table 3.10.

3.1.4 Non-Bank Financial Institutions (NBFI) (At(5,j))

Table 2 shows that NBFI hold the following assets:

- assets in business, cell A(5,1);
- bank deposits, cells A(5,2); and
- domestic bonds, cell A(5,3).

The holding of assets for NBFI are summarised in Table 6. BPNG data shows that the total asset holding of NBFI is 1,524,300 thousands of Kina (A(5,9) in Table 2). Of this amount, net holding of domestic bonds by NBFI is 352,900 thousand Kina and bank deposits of 600,000 thousand Kina. This is cells A(5,3) and A(5,2) respectively in Table 2. Net investment in business is 571,400 million kina.

Table 6. NBFI holding of assets, 2008: values in thousands of Kina

Holding of assets	**Kina**	**Reference in Table 2**
Domestic bonds	352,900	**A(5,3)**
Bank depositis	600,000	**A(5,2)**
Holdings in PNG business*	571,400	**A(5,1)**
Total assets of NBFI	**1,524,300**	**A(5,9)**

Bank of Papua New Guinea, 2012, Table 3.7.

*Calculated as a residual.

3.1.5 Superannuation funds (At(6,j))

BPNG data suggests that superannuation funds hold the following assets:

- 1,972,500 thousands of Kina in business assets, cell A(6,1);
- 672,500 thousands of Kina in bank deposits , cell A(6,2);
- 658,900 thousands kina in domestic bonds, cell A(6,3);
- 681,500 thousands kina in foreign bonds, cell A(6,4) and
- 1,277,700 thousands kina in equity in NBFI, cell A(6,7).

The total value of superannuation assets are 5,263,100 thousands of Kina (A(6,9)). With only Households contributing to the superannuation funds we know the total value of cell A(1,7).

3.1.6 PNG business (At(7,j))

We know turn our attention to industry holdings of assets. This is row 7 in Table 2Table 2. The only asset PNG business holds is bank deposits (A(7,2)). BPNG data suggests that total bank deposits equal 12,4 billion Kina (A(8,2)). With all other agents holding of bank deposits known, cell A(7,2) is calculated as a residual.[3] The value of industry bank deposits is 6,341,000 thousands of Kina.

3.1.7 Calculating residual values

Based on all the known data described in Section 3.1.1 to 3.1.6, we can calculate some cells as residuals. We now turn our attention to column 7 in Table 2, which shows agents holdings of equity in NBFI. BPNG data suggests that the total assets held by NBFI are 1,524,300 thousands of Kina (see Section 3.1.4). Assuming this is the total value of equity in NBFI (A(8,7)) we calculate foreigner holding of equity in NBFI at 246,600 thousands of Kina (A(2,7) in Table 2).

The total value of domestic bonds held by agents *z* is 3,852,500 thousands of Kina (Table 2, A(8,3)). With the total value of domestic bonds known, we can calculate the value of bonds held by households as a residual. Based on our calculations, households hold 112,200 thousand Kina in domestic bonds.

We know turn our attention to column 1 in Table 2. We do not have information on the total value of industry assets. Based on capita stock data we estimate that the total value of assets in each industry is approximately 38% more than industry-specific capital stock.[4] The total value of industry assets

[3] Industry bank deposits are equal to the total value of bank deposits (12,473,000) – minus all agents' holdings of bank deposits (2,230,500; 2,629,000; 600,000; 672,500).

[4] Capital stock*1.38 = total value of assets in PNG business (63,944*1.377=88,053 thousand of Kina)

(A8,1) is approximately 88 billion Kina. We assume that foreigners hold approximately 5.5% of the total value of industry assets as assets in PNG industries (A2,1). Finally we calculate the assets held by households in PNG industries as a residual.[5]

3.2 Creating the D matrix

The structure of the D matrix is presented in Table 3. This matrix shows the acquisition of new assets *j* by agents *z* during 2008. We have no information to inform us on the values of new acquisitions of assets by the various agents. We therefore assume that the:

- value of new domestic bonds held by agents *z* is 4% of the stock of domestic bonds held at the start of 2008;
- value of new assets held in PNG business by agents *z* varies between 6 and 8% of the stock of business assets at the start of 2008;
- values of all other assets held by agents *z* is 6% of the stock of assets held at the start of 2008.

4 Simulations

The results of 5 scenarios are presented in Table 7. The scenarios are run with a dynamic model but for our purposes it was set to short-run comparative static mode. As mentioned before, this model consists of two independent modules. The first module is an ORANIG-style model and contains core economic equations. The second module contains equations related to the financial theory described in Section 2. We link these two modules by activating the three conditions described in Section 2.8. All simulations are conducted in a short-run environment. In the short-run, we assume that there is not enough time for capital stock to accumulate and it is therefore held fixed. In Table 7, we see that the results for aggregate capital stock (row 8) and aggregate land (row 9) are zero in all the simulations. Rates of return are then endogenously determined (rows 24-29). Real wages are assumed to be exogenous in simulation 1 (marked sim 76 in Table 7) and the level of employment adjusts. In the other simulations the nominal wage is held fixed. In all simulations employment adjusts. We also assume that there is no valuation effects on assets j held by agents z. Therefore, in these simulations, the valuation variable V in Eq. (E.1) is set to 1.

In all the simulations we introduce a 1% increase in the rates of interest commercial banks receive from holding deposits with the BPNG. That is, an increase in R(4,5) of 1%.

The first two simulations represent scenarios before the inclusion of the financial module. That is, we do not activate the constraints described in Section 2.8. We expect the results to show that tighter monetary policy (i.e. increase in interest rates) leads to a fall in investments and a decline in the domestic price level relative to foreign prices. The fall in domestic prices would benefit the trade balance because the country becomes more competitive with export increasing and imports falling. The trade balance moves toward surplus. The results for simulations 1and 2 are listed in columns 3 and 4 of Table 7.

In simulations 3 to 5 we activate the constraints described in Section 2.8. In these simulations we report the impact of a mechanism not captured in the first two simulations. Our expectation is that if interest rates increase, foreigners would want to hold more domestic assets (due to the higher returns) and domestic agents would want to hold more domestic assets and less foreign assets. We expect a net inflow of capital and an appreciation of the currency. This appreciation would then hurt the trade account.

The results for simulation 3 are listed in column 5 of Table 7. In this simulation we activate the first constraint via the exogenous setting of the phantom variable in Eq. (E.20). When operational, (E.20) determines the nominal exchange rate.

[55] 88,053 - 1,972 - 5,499 - 4,988 = 75,022.

In simulation 4, we activate the second constraint via (E.21). The second constraint equates the acquisition of domestic bonds to the government deficit. When operational, this equation determines the rate of interest on domestic bonds (R(z,3)). The rate of interest on domestic bonds is determined via (E.15).

In simulation 5, we activate the final constraint described in Section 2.8.3 and via the exogenous setting of the phantom variable in (E.22). The third constraint equates the investment in industries to the acquisition of assets by all agents in industries. When operational, (E.23) determines the rate of return agents' z receives for lending (or investing) money in industry I as defined in (E.11).

4.1 Simulation 1 (no finance, real wage exogenous)

In this simulation the financial module is not operational. This means that the constraints defined in Eqs. (E.20) to (E.22) are inactive. The results of this simulation are presented in column 3, Table 7. In the short-run simulation we hold real wage and capital stock exogenous (rows 10 and 8) with the nominal exchange rate set as the numeraire (row 18).

The increase in the rates of interest leads to a fall in investment of 0.519 (row 2). The average domestic price level falls, and with real wage held fixed, nominal wage falls (row 11). The fall in the domestic prices makes PNG more competitive via a real devaluation of the exchange rate. The trade balance improves via an increase in exports (row 4) and a fall in imports (row 5).

In this simulation, with real wages held fixed, there is not much of an impact on aggregate employment (row 7) and real GDP (row 6).

With domestic rates of interest increasing, foreigners would want to hold more PNG assets and domestic agents would also want to hold more of these assets, that is we would expect increased capital inflow. At the same time PNG needs less capital inflow-the trade balance moved towards surplus. This tension is resolved in simulation 1 by a large phantom capital outflow (row 20), K 90,069.9 thousand.

4.2 Simulation 2 (no finance, nominal wage exogenous)

As in simulation 1, the financial module is not operational. The results of simulation 2 are presented in column 4 of Table 7. In this simulation we hold the nominal wage exogenous (row 11). The real wage can therefore change due to change in the consumer price level. The nominal exchange rate is set as the numeraire (row 18).

The results presented in column 4 are very similar to column 3. The increase in the rates of interest leads to a fall in investments (row 2). With the average price level falling and with nominal wage held fixed, real wage increases (row 10). The fall in domestic price makes PNG more competitive. Thus, export increase slightly (row 4) and imports fall (row 5), improving the trade balance.

The slight increase in real wage leads to a fall in aggregate employment (row 7) and real GDP (row 6). With the trade balance improving and interest rates increasing, simulation 2 exhibits the same tension as was apparent in simulation 1. As in simulation 1 the tension is resolved by a phantom capital outflow, K 89,122.2 thousand (row 20).

4.3 Simulation 3 (finance CAD)

In this simulation we active the first of the three economy-wide constraints included in the financial module. The first constraint described in (E.20) shows that the change in foreign holding of PNG assets (inflow of capital) minus the change in domestic holdings of foreign bonds (outflow of capital) is equal to the current account balance. This constraint is activated by exogenising the phantom capital term and endogenising the nominal exchange rate. The results of this simulation are presented in column 5 (sim 3), Table 7.

As with the previous two simulations, our shock of an increase in the interest rates leads to a fall in investment (row 2). What is noticeable in this simulation is that the increase in interest rates has a much stronger impact on the endogenous variables. The domestic price level falls, and with nominal wage held fixed, real wages increase by 0.51% (row 10). The increase in real wage has a negative impact on employment with employment falling by 1.11% (row 7). With capital stock exogenous and employment falling, GDP falls by 0.65% (row 6).

The fall in the domestic price level makes PNG more competitive. We expected the trade balance to improve, but the results shows that exports fall by 0.51% (row 4) which exceeds the fall in imports (row 5). This is because the nominal exchange rate is now endogenously determined which impacts the trade account. With higher interest rates, our results show that the nominal exchange rate appreciates (row 18) which hurts PNG exports.

Table 7. Effects of a one percentage point increase in Central Bank interest rate paid on deposits by commercial banks (percentage effects, unless otherwise indicated)

			Sim 1	**Sim 2**	**Sim 3**	**Sim 4**	**Sim 5**
	1	2	3	4	5	6	7
			Sim 76	Sim 77	Sim 78	Sim 79	Sim 80
	Variable	Description	No finance, real wage exog	No finance, nom wage exog	Finance CAD	Finance CAD and GovDef	Finance CAD, GovDef, investment
1	cr	Real private consumption	0.01	-0.00	-0.57	-0.65	-1.48
2	ir	Real iinvestment	-0.519	-0.520	-0.56	-0.57	-1.43
3	chie	Real public consumption	0.01	-0.00	-0.57	-0.65	-1.48
4	efcreal	Real exports	0.03	0.01	-0.51	-0.58	-1.32
5	mfcreal	Real imports	-0.13	-0.13	-0.37	-0.40	-0.94
6	gdpexpr	Real GDP	0.00	-0.02	-0.65	-0.74	-1.68
7	emp_wb	Aggregate employment	0.00	-0.03	-1.11	-1.27	-2.88
8	ks	Aggregate capital	0.00	0.00	0	0	0
9	agg_lnd_r	Aggregate land	0.00	0.00	0	0	0
10	realwage	Real wage	0	0.01	0.51	0.59	1.35
11	p1lab_io	Nominal wage	-0.02	0.00	0	0	0
12	epsilon3	Consumer price index	-0.02	-0.01	-0.51	-0.58	-1.33
13	epsilon2	Investment price index	-0.30	-0.30	-1.02	-1.13	-2.59
14	p5tot	Government price index	-0.10	-0.10	-0.52	-0.58	-1.32
15	xi4	Export price index	-0.01	-0.00	-0.56	-0.65	-1.47
16	xim	Import price index	0.00	0.00	-0.67	-0.76	-1.73
17	p0toft	Terms of trade	-0.01	-0.00	0.10	0.12	0.27
18	phi	Nominal exchange rate	0.00	0.00	0.67	0.77	1.76
19	***Changes in thousands of Kina***						
20	d_ff_phi	Phantom capital outflow	90,069.9	89,122.2	0	0	0
21	d_money	Phantom public financing	22,309.2	22,419.0	32,599.9	0	0
22	d_ff_indtot	Phantom invest financing	-47,803	-47,047.4	28,446.7	53,438.5	0
23	***Percentage point changes in rates***						
24	roipow_ave(BankDeposit)	Bank deposit rate	1.00	1.00	1.00	1.00	1.00
25	roipow_ave(DomBonds)	Domestic bond rate	0.00	0.00	0	0.48	1.01
26	roipow_ave(ForeignBonds)	Foreign bond rate	0.00	0.00	0	0	0
27	roipow_ave(DepCenBank)	Central bank rate	1.00	1.00	1.00	1.00	1.00
28	roipow_ave(LoansHH)	Comm bank lending rate	1.00	1.00	1.00	1.00	1.00
29	roipow_ave(EqNBFI)	NBFI deposit rate	1.00	1.00	1.00	1.00	1.00
30	intbuspow_ave	Cost of funds to industries	0.39	0.39	0.38	0.38	1.01

4.4 Simulation 4 (finance CAD and government deficit)

In simulation 4 we active the second of the economy-wide constraints included in the financial module. The second constraint equates the demand for domestic bonds to the government budget deficit (see E.21). We activate this equation by exogenising the phantom public finance term in Eq.(E.21) and endogenising FRDB appearing in (E.15). We are now able to determine the change in the domestic bond rate. The results of this simulation are presented in column 6, Table 7.

As with the previous simulations described above, the increase in the interest rate causes investment to fall by 0.57% (row 2). With nominal wages held fixed and the domestic price level falling, real wages increase by 0.59% (row 10). With higher real wages, the level of employment falls by 1.27% (row 7). GDP falls by 0.74% (row 6). Public consumption is linked to private consumption, which falls by 0.57% (rows 1 and 3). With a smaller economy, tax revenues decline and the government budget moves towards deficit. To finance this deficit, the government wants agents to hold more domestic bonds. For agents to hold more domestic bonds the domestic bond rate has to increase. Our results show that the domestic bond rate increases by 0.48% (row 25). With higher bond rates, the exchange rate in simulation 4 is stronger than in simulation 3. Higher bond rates encourage capital inflow which has to be chocked off by appreciation.

4.5 Simulation 5 (finance CAD, government deficit and investment)

In simulation 5 we active the last of the three economy-wide constraints included in the financial module. By activating the final constraint, the financial module is now fully operational. The final equation equates investment in all domestic industries to the acquisition of new assets in these industries and a phantom financing variable (see E.22). This constraint is activated by exogenising the phantom investment term in (E.22) and endogenising the shift variable appearing in the equation determining the interest rate investors receive for lending funds to PNG industries (see E.11). The results of this simulation are presented in column 7, Table 7.

With the financial model fully operational, the impact of tighter monetary policy has a much stronger impact on the endogenous variables. Investments falls by 1.43% (row 2), the lower price level causes an increase of 1.35% in real wage (row 10), employment falls by 2.88% (row 7) and GDP by 1.68% (row 6). With higher rates of return paid by PNG businesses capital inflow is stronger in simulation 5, than in simulation 4. This is chocked off by extra exchange rate appreciation (row 18). Notice that the exchange rate appreciation in simulation 5 is 1.76% whereas it was 0.77% in simulation 4.

5 Concluding remarks

Most CGE models including those developed by the Centre of Policy Studies do not specify explicitly the behaviour of financing agents. In these models an increase in interest rates imposed by the central bank typically leads to the following sequence of outcomes:

- an increase in the rates of return on capital required to justify investment;
- a reduction in investment as less potential projects are able to meet the increased required rate of return;
- a reduction in the domestic price level relative to the foreign price level (that is real devaluation) as reduced demand for non-traded investment-related goods (e.g. construction) causes a squeeze on profit margins represented in CGE models as rentals on capital;
- further reduction in the domestic price level relative to the foreign price level (that is further real devaluation) caused by reductions in nominal wages reflecting stickiness in real wages; and
- increased exports and reduced imports induced by real devaluation.

The idea that increased interest rates lead to real devaluation and improvement in the trade balance is at odds with mainstream macroeconomics which suggests that increased interest rates stimulate capital inflow with a consequent real appreciation and deterioration in the trade balance. The financing specifications that we have introduced in this paper to the CGE framework produce results consistent with the mainstream macro story.

6 References

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Appendix 1. Present value of a unit of capital

$$PV = -P2TOT + \frac{Q1}{1+ROI} + P2TOT1 * \frac{1-D}{1+ROI} \qquad (A1.1)$$

where

PV is the present value of purchasing a unit of capital;

P2TOT is the cost of buying or constructing a unit of capital;

Q1 is the rental rate on capital in year 1;

ROI is the rate of interest; and

D is the depreciation rate.

Defining the rate of return (ROR) as PV/P2TOT, we can rewrite eq. (A1.1) as:

$$ROR = -1 + \frac{Q1}{P2TOT1} * \frac{P2TOT2}{P2TOT} * \frac{1}{1+ROI} + \frac{P2TOT1}{P2TOT} * \frac{1-D}{1+ROI} \qquad (A1.2)$$

Simplifying eq. (A1.2) yields

$$ROR = -1 + \left(\frac{1+INF2}{1+ROI}\right) * \left(\frac{Q1}{P2TOT1} + 1 - D\right) \qquad (A1.3)$$

Under static expectations this yields:

$$ROR = -1 + \left(\frac{1+INF2}{1+ROI}\right) * \left(\frac{Q}{P2TOT} + 1 - D\right)$$

In change form we have:

$$\begin{aligned} d\_ROR = {} & \left(\frac{Q}{P2TOT} + 1 - D\right) * \left(\frac{d\_inf\,2}{1+ROI} - \left(\frac{1+INF2}{(1+ROI)^2}\right) * d\_roi\right) \\ & + \left(\frac{1+INF2}{1+ROI}\right) * \left(0.01 * \frac{Q}{P2TOT} * (q - p2tot)\right) \end{aligned} \qquad (A1.4)$$

Appendix 2. Allocation problems for domestic and foreign agents

A2.1. Domestic agents

Choose A_{j1} for all j to maximize

$$\left[\sum_j \left(A_{j1}R_j\right)^{-\rho}\delta_j\right]^{\frac{-1}{\rho}} \tag{A2.1}$$

subject to

$$A_{j1} = A_{j0}V_j + D_j \quad \text{and} \quad \sum_q D_q = S \tag{A2.2}$$

We combine the two constraints in (A2.2) into one:

$$\sum_q A_{q1} = S + \sum_q A_{q0}V_q \; = Z \tag{A2.3}$$

where

A_{j1}	is asset j held at the end of year 0 (beginning of year 1);
R_j	is one plus the rate of interest (the power of the interest rate) on asset j;
δ_j	is the "share" parameter for asset j in the total holding of assets;
A_{j0}	is asset j held at the start of year 0;
V_j	is a coefficient capturing a valuation effect;
D_j	is the net acquisition of j during year 0; and
S	is the amount of new investable funds available to buy new assets in year 0.

First-order conditions

$$\left[\sum_k \left(A_{k1}R_k\right)^{-\rho}\delta_k\right]^{\frac{-1}{\rho}-1} * A_{j1}^{-\rho-1} * R_j^{-\rho} * \delta_j = \Lambda \text{ for all j, plus constraint (A2.3).} \tag{A2.4}$$

That is,

$$A_{j1}^{-\rho-1} * R_j^{-\rho} * \delta_j = \Gamma \text{ plus constraint (A2.3)} \tag{A2.5}$$

where $\Gamma = \Lambda \Big/ \left[\sum_k \left(A_{k1}R_k\right)^{-\rho}\delta_k\right]^{\frac{-1}{\rho}-1}$.

Notice Γ is independent of j.

From here we obtain

$$A_{j1} = \left(\Gamma * R_j^{\rho} * \delta_j^{-1}\right)^{\frac{-1}{1+\rho}} \text{ and summing over j gives} \tag{A2.6}$$

$$Z = \Gamma^{\frac{-1}{1+\rho}} * \sum_j \left(R_j^{\frac{-\rho}{1+\rho}} * \delta_j^{\frac{1}{1+\rho}}\right).$$

Rearranging

$$\Gamma^{\frac{-1}{1+\rho}} = Z * \left[\sum_k \left(R_k^{\frac{-\rho}{1+\rho}} * \delta_k^{\frac{1}{1+\rho}} \right) \right]^{-1} \tag{A2.7}$$

Hence from (A2.6) we have

$$A_{j1} = Z * \left[\sum_k \left(R_k^{\frac{-\rho}{1+\rho}} * \delta_k^{\frac{1}{1+\rho}} \right) \right]^{-1} * R_j^{\frac{-\rho}{1+\rho}} * \delta_j^{\frac{1}{1+\rho}} \tag{A2.8}$$

In percentage change form the equation is:

$$a_{j1} = z - \frac{\rho}{1+\rho} * r_j + \left(\frac{\rho}{1+\rho} \right) * \frac{\sum_h \left(R_h^{\frac{-\rho}{1+\rho}} * \delta_h^{\frac{1}{1+\rho}} \right) * r_h}{\sum_k R_k^{\frac{-\rho}{1+\rho}} * \delta_k^{\frac{1}{1+\rho}}} \tag{A2.9}$$

$$a_{j1} = z + (\sigma - 1) * \left(r_j - \sum_h S_h * r_h \right) \tag{A2.10}$$

where

a_{j1} is the percentage change in asset j held by agents at the end of year 0;

z is the percentage change in funds available to buy new assets;

r_j is the percentage change in the power of the rate of interest on asset j;

$\sigma = 1/(1+\rho)$ is the parameter regulating the strength of response to changes in relative rates of interest; and

$$S_h = \frac{R_h^{\frac{-\rho}{1+\rho}} * \delta_h^{\frac{1}{1+\rho}}}{\sum_k R_k^{\frac{-\rho}{1+\rho}} * \delta_k^{\frac{1}{1+\rho}}} = \frac{A_{h1}}{\sum_k A_{k1}} \quad \text{[see (A2.8)].}$$

That is S_h is the share of asset h in the total value of assets.

A2.1. Foreign agents

The foreign agents' optimization problem has the same form as that for domestic agents except that the values of PNG assets are multiplied by E_{t+1}. Taking this into account we see that the percentage change equations for foreign demands for PNG assets take the form

$$a_1(2,j) + e_1 = z(2) + (\sigma - 1) * \left(r(2,j) - \sum_h S(2,h) * r(2,h) \right) \tag{A2.11}$$

where

$a_1(2,j)$ is the percentage change in asset j held by foreign agents at the end of year 0;

$z(2)$ is the percentage change in funds available to foreign agents to buy new assets in PNG;

$r(2,j)$ is the percentage change in the power of the rate of interest on asset j held by foreigners;

$\sigma = 1/(1+\rho)$ is the parameter regulating the strength of response to changes in relative rates of interest; and

S(2,h) is the share of asset h in the portfolio of the foreign agent.

The dominant component of the foreign agents' portfolio is AFO. S(2,AFO) is approximately one while S(2,h) is close to zero if h refers to an asset in PNG. This allows us to simplify (A2.11) to

$$a_1(2,j) + e_1 = z(2) + (\sigma - 1) * (r(2,j) - rfo) \tag{A2.12}$$

where rfo is the percentage change in the power of the rate of return that foreigners earn on their assets outside PNG.