A monetary policy rule in a CGE model

Abstract

This paper develops a CGE model with an explicit monetary policy rule which replaces typical exogenous numeraire so that the model can have endogenous absolute price. A model with exogenous numeraire can be derived as a special case of the current model through a flexible parameterization. It shows that in the presence of nominal rigidities, simulation results for the same shock can be different depending on the choice of exogenous numeraire. Moreover, the current model gives different results for the same shock by creating inflation. The paper highlights the importance of choosing numeraire or considering the interest rate rule instead of fixed numeraire in the presence of nominal rigidities.

Key words: a CGE model, monetary policy, Taylor rule
JEL: D58, E52

1. Introduction

The numeraire in real CGE models is a price or a price index to which all the remaining prices are relative and cannot be determined endogenously because of the interrelationship of the equilibrium conditions. However, this satisfies the Walras law – suppose that there are N markets and because of the efficiency conditions satisfying the budget constraints (e.g., the first order conditions of utility maximization and cost minimization problems), the sufficient condition for all markets to be in equilibrium is that N-1 markets are in equilibrium. One equilibrium condition becomes redundant so that its corresponding price is not determined endogenously. As a consequence, one price needs to be fixed exogenously and plays the role of the numeraire. The numeraire can be any price to be determined from any market equilibrium condition. In practice, the numeraire is usually either consumption price index or the nominal exchange rate in single country, open economy CGE models. In real CGE models (in the absence of nominal rigidities), the choice of numeraire does not matter as long as the model satisfies the nominal homogeneity test - that is, an increase in the numeraire increases all the prices proportionally hence the relative prices are left unchanged – i.e., no real effects.

One may now wonder about the implications of nominal rigidities which are common in real life, especially in the short-run. There are models such as the PEP standard models in which some nominal variables are exogenous. However, even such models must pass the nominal homogeneity test and show that the model is consistent with the classical dichotomy at least in the long-run. For that, nominal exogenous variables must maintain their ratios to the numeraire in the closure. Because of nominal rigidities in the short-run, however, a problem arises because the same shock could have different effects depending on the choice of the numeraire. So what is the numeraire in this context?

This paper argues that the numeraire in CGE models with nominal rigidities represents the target of monetary authority. A redundant equilibrium condition, mentioned above, has a flipside which is a money market equilibrium condition. The numeraire is essentially a target of central banks. Central banks adjust their policy instruments to control the numeraire. Different numeraire means different targets for central banks. For instance, if the consumption price index is the numeraire, a central bank wants to control the price level and thus inflation. The central bank adjusts its money supply in targeting the inflation rate. Shocking the numeraire implies that the price level changes exogenously which can have real effects because of nominal rigidities in the economy. This can be interpreted that the central bank renews its target and it is treated as an exogenous shock in the model. Depending on the central bank's target, the same shock could have different effects because of nominal rigidities. Basically, the central bank's action in achieving a specific target captured by the numeraire (either the price level or the exchange rate) could have real effects (i.e., money is not neutral). Such real effects could be different depending on the target of the central bank. Moreover, the real effects vary when the same numeraire changes to capture the central bank's new target. However, a money market operation is still implicit.

There is a body of literature that endogenises the numeraire by developing detailed financial markets within CGE models (see Thissen, 1999; Xiao, 2009). These are called financial CGE models. The numeraire in such models is replaced by explicit financial market equilibrium conditions and hence monetary policy actions are explicit. Such financial models, however, can be data intensive.

Here we present a simple approach to introduce an explicit monetary policy in CGE models. For this purpose, we consider the PEP-1-t (a recursive dynamic CGE) model of Decaluwé et al., (2013) which is calibrated to a XXX SAM for no particular reason. The numeraire in the PEP-1-t model is replaced by a Taylor-type interest rate monetary policy rule (e.g., Taylor, 1992). The Taylor rule is a kind of monetary policy rule used by central banks. Specifically, the central bank has a control over a short-term interest rate and adjusts it to reduce a gap between desired inflation rate and actual inflation rate, an output gap between the actual and natural levels and the exchange rate gap. Whether a central bank cares the inflation gap more or less than the other gaps is determined by the weights attached to the gaps. It is common that central banks care more about inflation and acts more aggressively to inflation by adjusting the interest rate. The modern macroeconomic (DSGE) models consider the interest rate rule commonly to study the short-run economic fluctuations (e.g., Christiana et al., 2005, Smets and Wouters, 2007).

We show that a particular choice of the numeraire in the standard PEP-1-t model can be derived as a special case of the interest rate rule through a flexible parameterization. The nominal interest rate is linked with the real interest rate through the Fisher equation with expected inflation rate which is adaptive. In the PEP-1-t model, the real interest rate determines the Tobin-Q condition through the user cost of capital. In the current model, given the adaptive expected inflation rate, a change in the nominal interest rate can change the real interest rate which affects the Tobin-Q and hence real investment. If we place sufficiently high weight on the inflation gap, the current model replicates the PEP-1-t model in which consumer price index is the numeraire. If we place sufficiently high weight on the the exchange rate depreciation gap, the model is the same as the PEP-1-t model in which the nominal exchange rate is the numeraire. If the output gap receives sufficiently high weight, the monetary policy becomes counter-cyclical. If we assume that a central bank does not care about the gaps, the model is basically the PEP-1-t model in which the real interest rate becomes the fixed numeraire. We demonstrate these arguments by simulating the PEP-1-t and the current monetary models for the same shock. The same treatment can be applied in other standard real CGE models like IFPRI, ORANI, MANAGE and MAMS for short-run analyses.

What is interesting is that the current model with the commonly used Taylor rule has absolute price (i.e., inflation). In response to a shock, now the monetary policy reacts in accordance with the interest rate rule hence changes the absolute price level which could then have real effects because of nominal rigidities. The results are very different from those derived from the PEP-1-t model with the fixed numeraire.

The paper is organized as follows. Section 2 presents the PEP-1-t model and the extensions. Section 3 outlines the scenario. Section 4 discusses the simulation results. Section 5 concludes the paper.

2. Model

2.1 The standard PEP-1-t model

We extend the PEP-1-t model, a recursive dynamic CGE model, of Decaluwé et al., (2013). Here we briefly outline the main specifications of this model.

The production side of an economy is divided into different activities/sectors. Each sector has a nested structure and each level uses a production function with constant returns to scale. Specifically, the first level of production is a Leontief function of value added and intermediate consumption. At the next level, value added is a constant elasticity of substitution (CES) function of composite labor and composite capital. Each composite input is a CES function of different types. Intermediate consumption of each commodity, on the other hand, is proportional to sectorial production. Each sector may produce multiple commodities, which are aggregated by a constant elasticity of transformation (CET) function. Finally, quantities to sell domestically or to export are governed by a CET function and relative prices.

On the demand side, the consumption of a commodity is a CES function of domestic and imported quantities. A representative household allocates its disposable income, which derives from capital, labor and transfers from other agents, between consumption and savings. Its demand for commodities is governed by a linear-expenditure system (LES). This is a savings-driven-investment model, and the sum of household, government, and foreign savings determines the total amount of investment. Investment demand distinguishes between gross fixed-capital formation and changes in inventories. Direct government revenue (income), indirect taxes (production, commodities, and foreign trade), and transfers from other agents are divided among savings, spending on commodities, and transfers to other agents. The demand for commodities for investment and government spending purposes is proportional to respective total expenditures.

Export demand for domestic commodities is an isoelastic function of relative prices (foreign price in domestic currency divided by domestic price). Current account balance in the balance of payments is determined by the amount of exogenous foreign savings. The numeraire is normally the nominal exchange rate. Stock of each type of capital increased by investment but decreased by depreciation in growth models such as the one proposed by Solow (1956). Investment in public services sectors is normally exogenous while that in other sectors is endogenous depending on the return (ratio of the rental rate and user cost of capital – the depreciation and interest rate).

The model has nominal rigidities, as mentioned earlier. Nominal variables such as government spending and foreign savings are treated as exogenous variables.

The model considers population growth, but not technological change so that in the Balanced Growth Path (BGP) all variables but prices grow at the same same rate as the population growth rate.

2.2 Extensions

We assume zero population growth rate so that the BGP of the model represents the steady state – i.e., the endogenous variables are equal to their initial and SAM values when undisturbed by the exogenous shocks.

The first extension is the so-called Fisher equation linking the nominal and real interest rates as

$$ir(t) = \frac{1+i(t)}{1+d\_PIXCON\_exp(t+1)} - 1 \tag{1}$$

where $ir(t)$ is the real interest rate in period t, $i(t)$ is the nominal interest rate set by the central bank and $d\_PIXCON\_exp(t+1)$ is the expected inflation rate measured by consumer price index, $PIXCON(t)$.

In the PEP-1-t model, investment constitutes exogenous and endogenous parts. In public (pub) sectors such as education, health and public administration, real investment in type k capital, $IND(k, pub, t)$, is exogenous. On the contrary, real investment in business (*bus)* sectors, $IND(k,bus,t)$, is endogenous and depends negatively on the user cost of capital, $U(k,bus,t)$:

$$IND(k,bus,t) = phi(k,bus) \cdot \left(\frac{R(k,bus,t)}{U(k,bus,t)} \right)^{sigma\_INV(k,bus)} \cdot KD(k,bus,t) \tag{2}$$

$$U(k,bus,t) = PK\_PRI(t) \cdot \left(delta(k,bus) + ir(t) \right) \tag{3}$$

where $phi(k,bus)$ and $sigma\_INV(k,bus)$ are parameters, $R(k,bus,t)$ is rental price, $KD(k,bus,t)$ is capital, $PK\_PRI(t)$ is the investment price index and $delta(k,bus)$ is the capital depreciation rate.

In the PEP-1-t model, $ir(t)$ is determined from the following savings-investment equilibrium condition:

$$IT\_PUB(t) + IT\_PRI(t) + \sum_i PC(i,t) \cdot VSTK(i,t) = SH(t) + SG(t) + SROW(t) \tag{4}$$

$$IT\_PUB(t) = PK\_PUB(t) \cdot \sum_k IND(k, pub,t) \tag{5}$$

$$IT\_PRI(t) = PK\_PRI(t) \cdot \sum_k IND(k,bus,t) \tag{6}$$

where $IT\_PUB(t)$ is nominal public investment expenditure, $IT\_PRI(t)$ is nominal business investment expenditure, $VSTK(i,t)$ is an exogenous change in inventory for commodity i, $PC(i,t)$ is the composite price of commodity i, $SH(t)$ is private sector (households and firms) savings, $SG(t)$ is government savings, $SROW(t)$ is exogenous savings from the rest of the world and $PK\_PUB(t)$ is the public investment price index.

In the standard PEP-1-t model, any equilibrium price can be the exogenous numeraire and hence one equilibrium condition becomes redundant. Instead of dropping the redundant equilibrium condition, however, an endogenous variable, $leon(t)$, is introduced to ensure that all markets are in equilibrium – i.e., $leon(t) = 0$.[1] In practice, either the consumer price index or the nominal exchange rate is the numeraire. However, any equilibrium price can be the numeraire. This includes the real interest rate to be determined from (4).

In the current model, the central bank sets the nominal interest rate, $i(t)$. Without extending the model any further, one can set $i(t)$ as the numeraire.[2] However, we follow the DSGE models and consider

---

[1] They call this variable LEON making reference to the surname of Leon WALRAS.

[2] We assume adaptive expectation for inflation – i.e., $d\_PIXCON\_exp(t+1) = d\_PIXCON(t)$ where $d\_PIXCON(t)$ comes in (1) as an exogenous variable (not internalized in the solution of the model). Thus setting the nominal interest rate as the numeraire is the same as setting the real interest rate as the numeraire.

that the central bank adjusts the interest rate in response to the gaps occurring in the GDP growth rate, the inflation rate and the nominal exchange rate depreciation from their respective steady state values. Specifically, this behavior is reflected in the following Taylor-type interest rate rule:

$$i(t) = irO + \alpha_1 \cdot y(t) + \alpha_2 \cdot d\_PIXCON(t) + \alpha_3 \cdot \left(d\_E(t) - d\_E(t-1) \right) \tag{6}$$

where irO is the steady state (or initial) real interest rate, $y(t)$ is the output gap as the percentage deviation of real GDP growth rate from its steady state value, $d\_PIXCON(t)$ is the inflation gap as the percentage deviation of the current inflation rate from the target inflation rate in the steady state which is assumed zero and $d\_E(t)$ is the percentage deviation of the exchange rate depreciation in period t from its steady state value which is also assumed zero.

The degree of reaction to the gaps is captured by the coefficients α_1, α_2 and α_3 respectively.[3] Through the flexible parameterization, one could consider the following possibilities.

1. If the central bank does not care about any gaps – i.e., $\alpha_1 = \alpha_2 = \alpha_3 = 0$, the model becomes the same as the PEP-1-t model in which the real interest rate is the numeraire.
2. If the central bank cares only about inflation (α_2 is relatively large), the model becomes a PEP-1-t model in which $PIXCON(t)$ is the numeraire and the interest rates absorb the impact of the shock as the central bank aims $PIXCON(t) = 1$.
3. If the central bank cares only about the exchange rate (α_3 is relatively large), the model is the PEP-1-t model in which the nominal exchange rate, $E(t)$, is the numeraire and the interest rates absorb the impact of the shock as the central bank aims $E(t) = 1$.
4. The central bank could care only about the output gap (α_1 is relatively large). The interest rates absorb the impact of the shock as the central bank tries to ensure stable GDP growth.
5. In the literature, it is common to consider a case in which $\alpha_1 = 0.5$, $\alpha_2 = 1.5$ and $\alpha_3 = 0.45$. Accordingly the central bank responds to the inflation more aggressively.

In the standard PEP-1-t model, nominal foreign savings, $SROW(t)$, is exogenous and determines the nominal current account balance, $CAB(t)$. Given the nominal interest rate, the inflation rate and the expected depreciation of domestic currency in the current model, financial assets could move across economies and help determine the nominal exchange rate. Thus the following modification can be carried out on the balance of payments equation. The capital account, $SROW(t)$, constitutes 2 parts – $FDI(t)$ (foreign direct investment) and $NCF(t)$ (net capital flow):

[3] In general, the literature does not consider the last element – i.e., $\alpha_3 = 0$. When it is included, they consider the lagged exchange depreciation gap (e.g., Svensson, 2000).

$$SROW(t) = FDI(t) + NCF(t)\,. \tag{8}$$

Foreign direct investment is exogenous and fixed as $FDI(t) = FDIO \cdot pop(t)$ in the steady state where $pop(t)$ is the population index which makes $FDI(t)$ to be consistent with the BGP. Net capital flow, on the other hand, is endogenous and depends on the ratio of domestic and foreign nominal interest rates as follows:

$$NCF(t) = pop(t) \cdot NCFO \cdot \left(\frac{1 + i(t)}{\left(1 + i\_F(t)\right) \cdot \left(1 + d\_E\_exp(t+1)\right)} \right)^{\psi} \tag{9}$$

where $i\_F(t)$ is the exogenous foreign nominal interest rate and the parameter $\psi \geq 0$ exhibits the degree of flexibility in the financial market for investors in shifting their assets across economies. Larger the elasticity, the faster the financial assets move and the difference between the domestic and foreign interest rates diminish quickly.

Another additional variable for the balance of payments equation is a change in the official foreign reserves, $d\_FXR(t)$, which is defined as:

$$CAB(t) = SROW(t) + d\_FXR(t)\,. \tag{10}$$

$d\_FXR(t)$ is the difference between the current account balance, $CAB(t)$, and financial account balance, $SROW(t)$. In a fully flexible exchange rate system, it is set to zero. In a system where the central bank intervenes the exchange rate market to some extent, it could be either exogenous or an endogenous depending on the exchange rate.

We consider adaptive expectations for the expected inflation and the exchange rate depreciation.

$$d\_E\_exp(t+1) = d\_E(t) \tag{11}$$

$$d\_E(t) = \frac{E(t)}{E(t-1)} - 1 \tag{12}$$

$$d\_PIXCON\_exp(t+1) = d\_PIXCON(t) \tag{13}$$

$$d\_PIXCON(t) = \frac{PIXCON(t)}{PIXCON(t-1)} - 1 \tag{14}$$

3. Calibrations

We consider the 2017 XXX SAM.[4] For modifications in the current model, we consider the following calibrated values in the steady state.

[4] See Appendix for the tables showing the structure of the XXX economy.

$$irO = 0.12$$

In the steady state, we assume zero inflation and zero depreciation of the exchange rate so that the expected inflation rate and the expected depreciation of the exchange rate are calibrated as

$$d\_PIXCON\_exp(t+1) = d\_PIXCON(t) = 0$$

$$d\_E\_exp(t+1) = d\_E(t) = 0 \,.$$

Consequently, the nominal interest rate is 12%. The foreign interest rate is calibrated from the UIP (Uncovered Interest Parity) condition as

$$i\_F(t) = \frac{1+i(t)}{1+d\_E\_\exp(t+1)} - 1 = 0.12 \,.$$

In this paper, we set $\psi = 0$ deliberately to eliminate the impact of any shocks through the UIP condition.[5] Consequently, $NCF(t)$ and $SROW(t)$ are exogenous – i.e., the model has the same feature as in the PEP-1-t model. In addition, we set $d\_FXR(t) = NCFO = 0$. As a result, $CAB(t)$ adjusts to $SROW(t)$.

We assume $pop(t) = 1$ in the BGP which imitates the detrending in the business cycle literature so that all variables are stationary around their corresponding initial values (which are considered as mean values in the business cycle literature).

Given the calibrations and assumptions, the model exhibits the steady state for any α_1, α_2 and α_3 when there are no shocks.

3. Simulations

We assume that nominal wage is fixed to represent nominal rigidity. We simulate the model over 20 periods. However, because of the convergence nature of the results, we present the results of the first 10 periods. The shock is 10% increase in government spending in period 3 which is temporary as it reverts to the steady state value for the remaining periods. We consider 8 simulations (SIM1-SIM8). The SIM1, SIM2 and SIM3 are the PEP-1-t model in which the consumer price index, the nominal exchange rate and the real interest rate are chosen as the numeraire in turn. The SIM4, SIM5 and SIM6 are based on the current model which try to replicate the results of the SIM1, SIM2 and SIM3 by placing sufficiently high weights on the corresponding gaps in the interest rate rule. In SIM7, we consider the conventional interest rate rule (common in the business cycle literature) in which the central bank cares slightly more about the inflation gap than the other two other gaps. In SIM8, the central bank cares only about the output gap.

[5] We leave this for future work.

In addition to proving that the PEP-1-t model is a special case of the current model, the current model with the interest rate rule generates inflation so that the results are different.

SIM1. The consumer price index, $PIXCON(t)$, is the numeraire in the PEP-1-t model.

SIM2. The nominal exchange rate, $E(t)$, is the numeraire in the PEP-1-t model.

SIM3. The real interest rate, $ir(t)$, is the numeraire in the PEP-1-t model.

SIM4. The central bank cares only about inflation - $\alpha_1 = \alpha_3 = 0$ and $\alpha_2 = 10^8$ in equation (6) to replicate the results of SIM1.

SIM5. The central bank cares only about the exchange rate stability - $\alpha_1 = \alpha_2 = 0$ and $\alpha_3 = 10^8$ in equation (6) to replicate the results of SIM2.

SIM6. The central bank maintains the same real interest rate - $\alpha_1 = \alpha_2 = \alpha_3 = 0$ in equation (6) to replicate the results of SIM3.

SIM7. The conventional interest rate rule - $\alpha_1 = 0.5$, $\alpha_2 = 1.5$ and $\alpha_3 = 0.45$ in equation (6).

SIM8. The central bank cares only about the output gap - $\alpha_2 = \alpha_3 = 0$ and $\alpha_1 = 10^8$ in equation (6).

The following figures present the simulation results. Notice that quadrant 1 shows the simulation results of SIM1 and SIM4, quadrant 2 shows the results of SIM2 and SIM5, quadrant 3 shows those of SIM3 and SIM6 and quadrant 4 shows those of SIM7 and SIM8. Notice also that the scale of change in each variable under consideration is the same to compare the simulation results across the quadrants. As can be seen, there are no shocks in the first 2 periods so that the variables under consideration take their steady state values. The shock hits in period 3.

From the figures, the results in quadrant 1, 2 and 3 show that the current model replicates the results of the standard PEP-1-t model as its special cases as the lines more or less overlap.

Look across the quadrants to see the impact of the shock on the variable of interest under a particular case of the interest rate rule. For instance, real GDP responds much more in SIM3 and SIM6 than others as the central bank tries to maintain the same real interest rate.

Figure 1. Real GDP in base prices

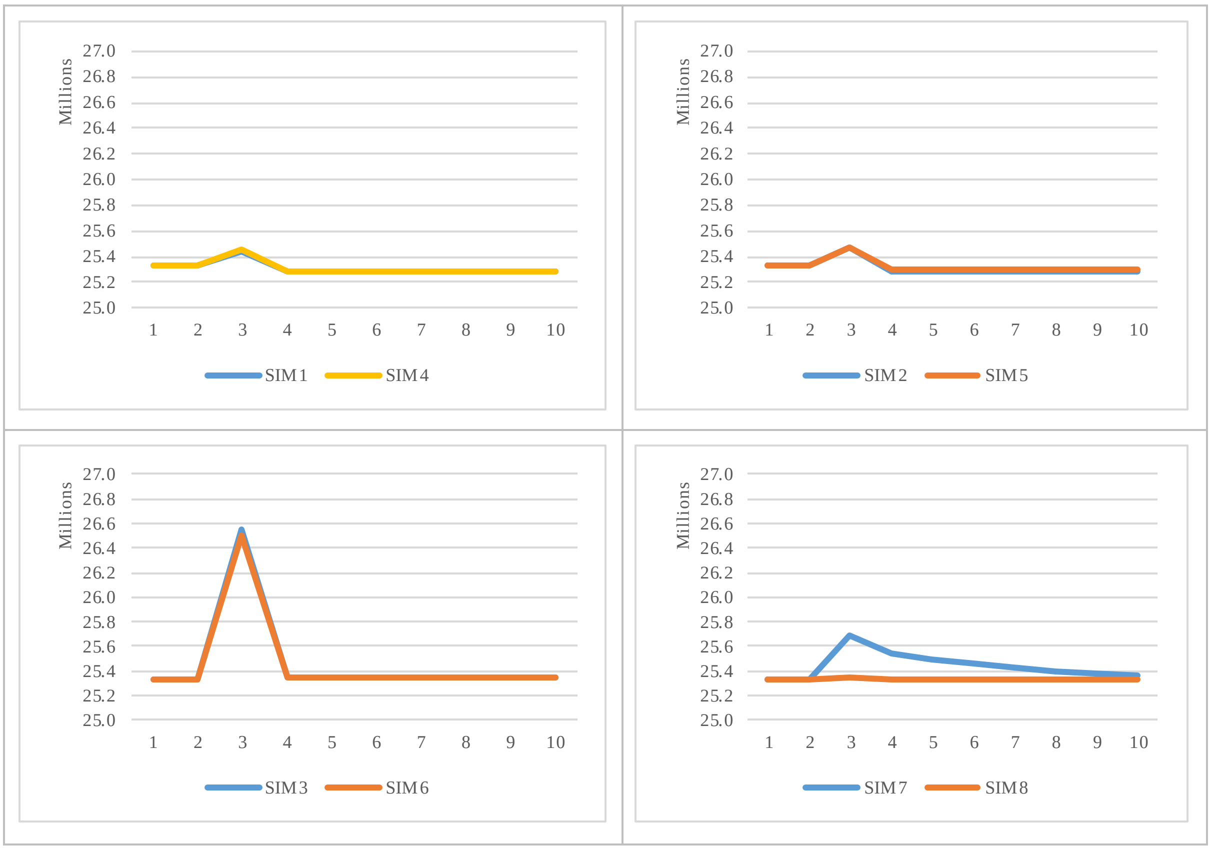


Figure 2. Nominal exchange rate

Figure 3. Government spending (real)

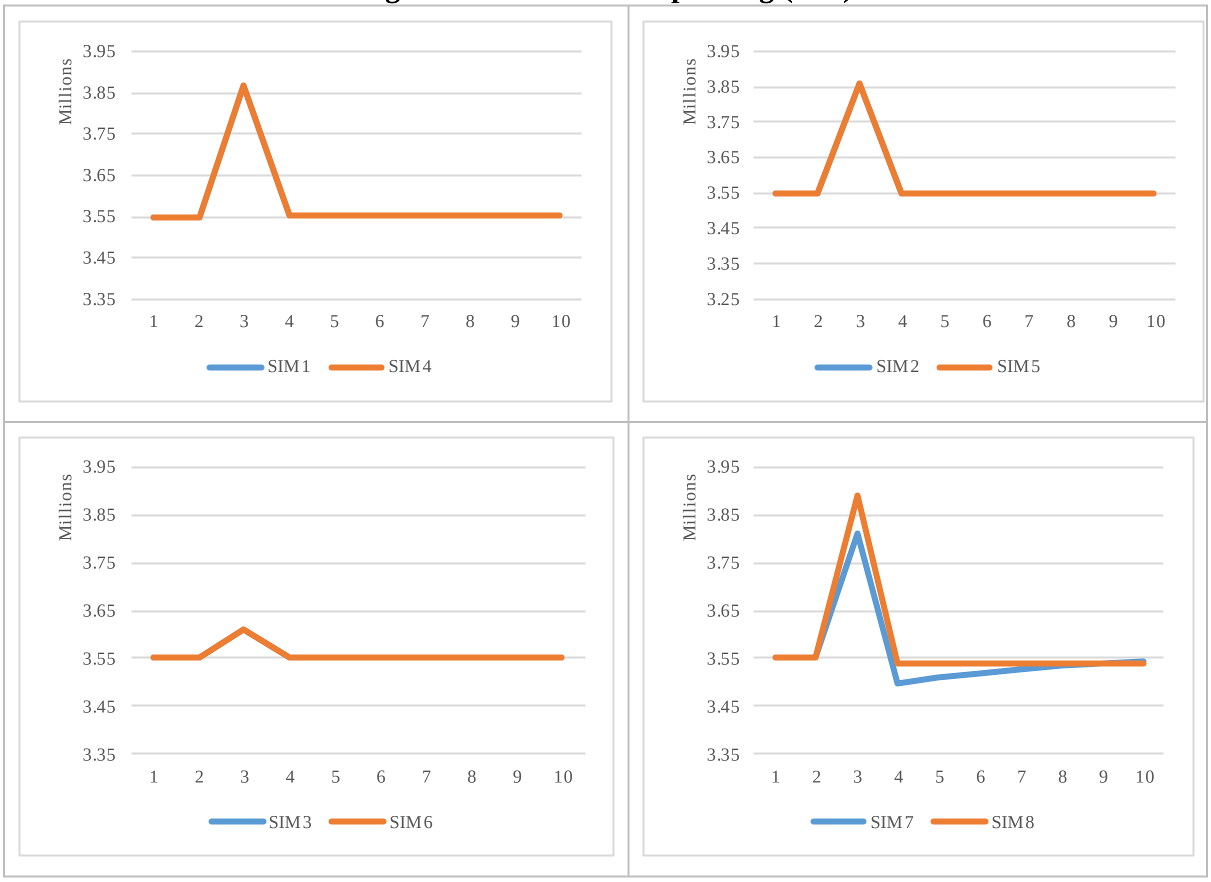


Figure 4. Real interest rate

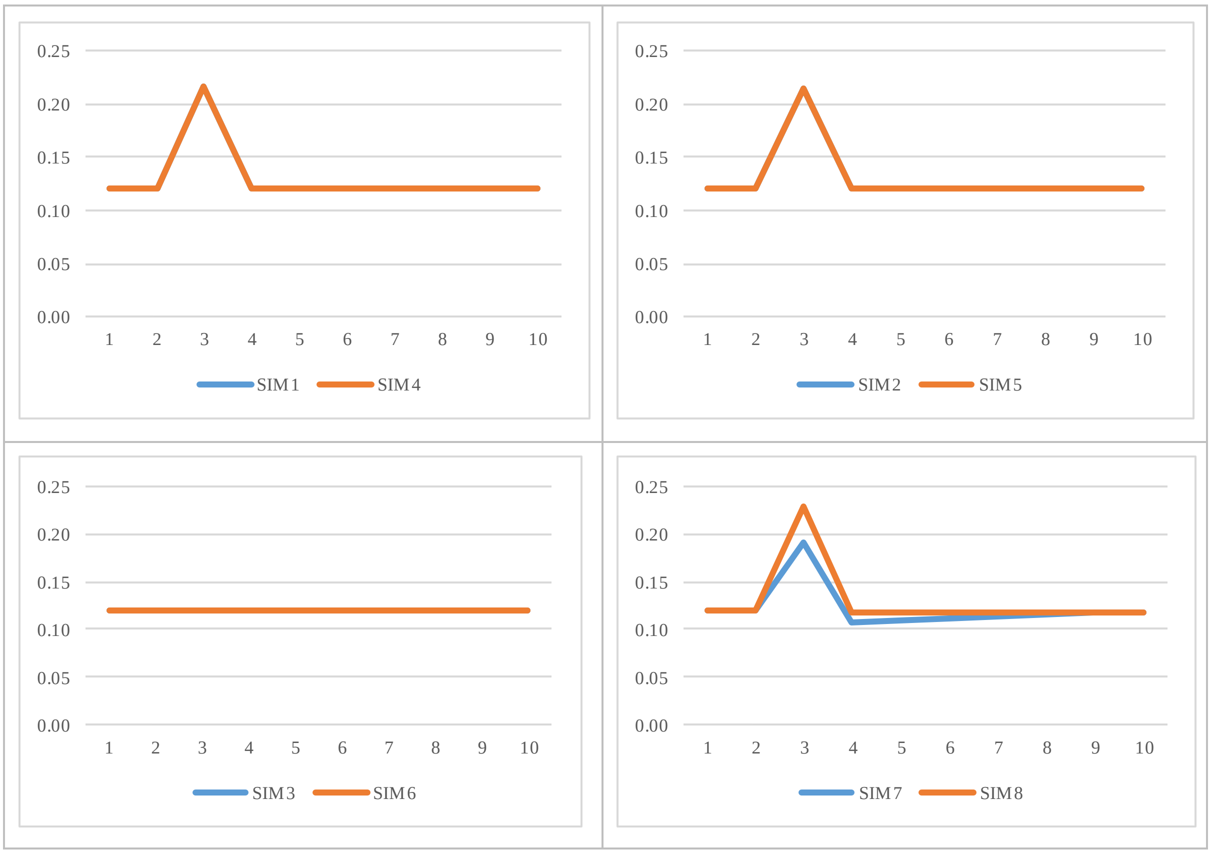


Figure 5. Investment (nominal)

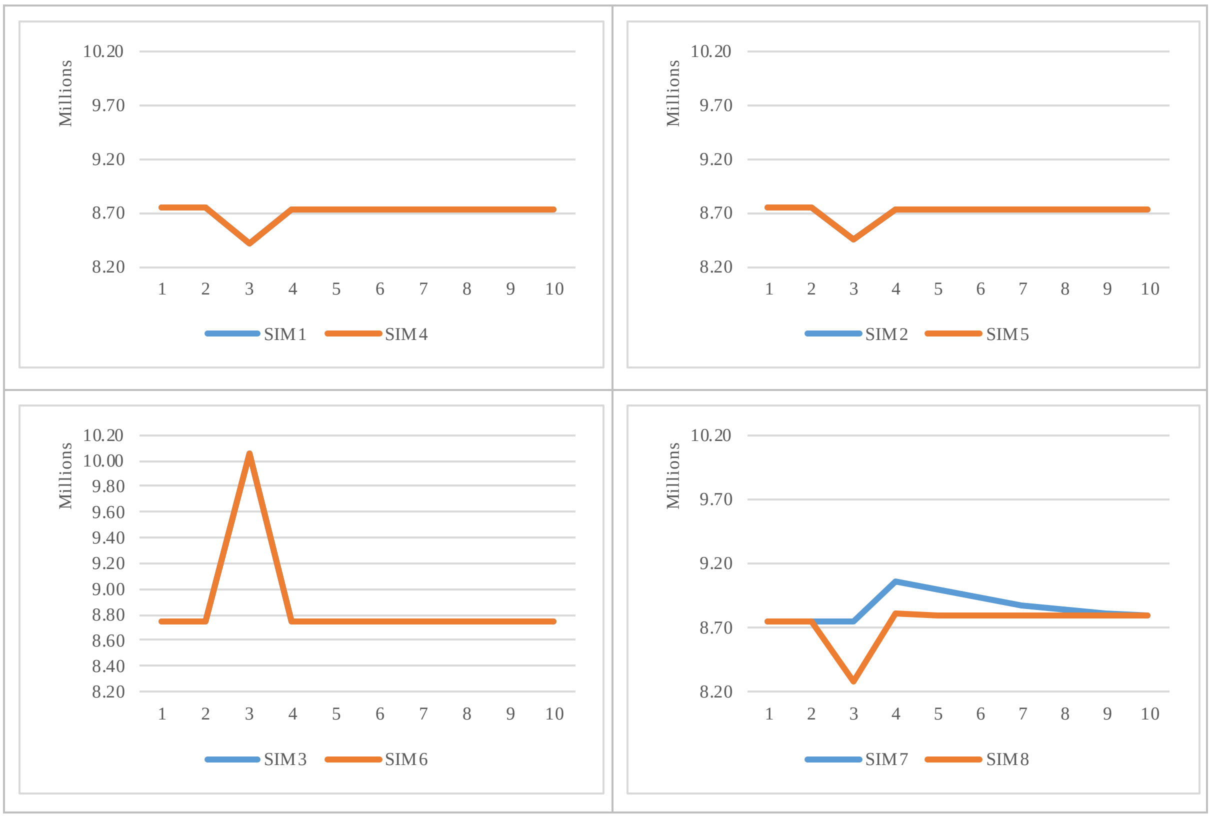


Figure 6. Employment index

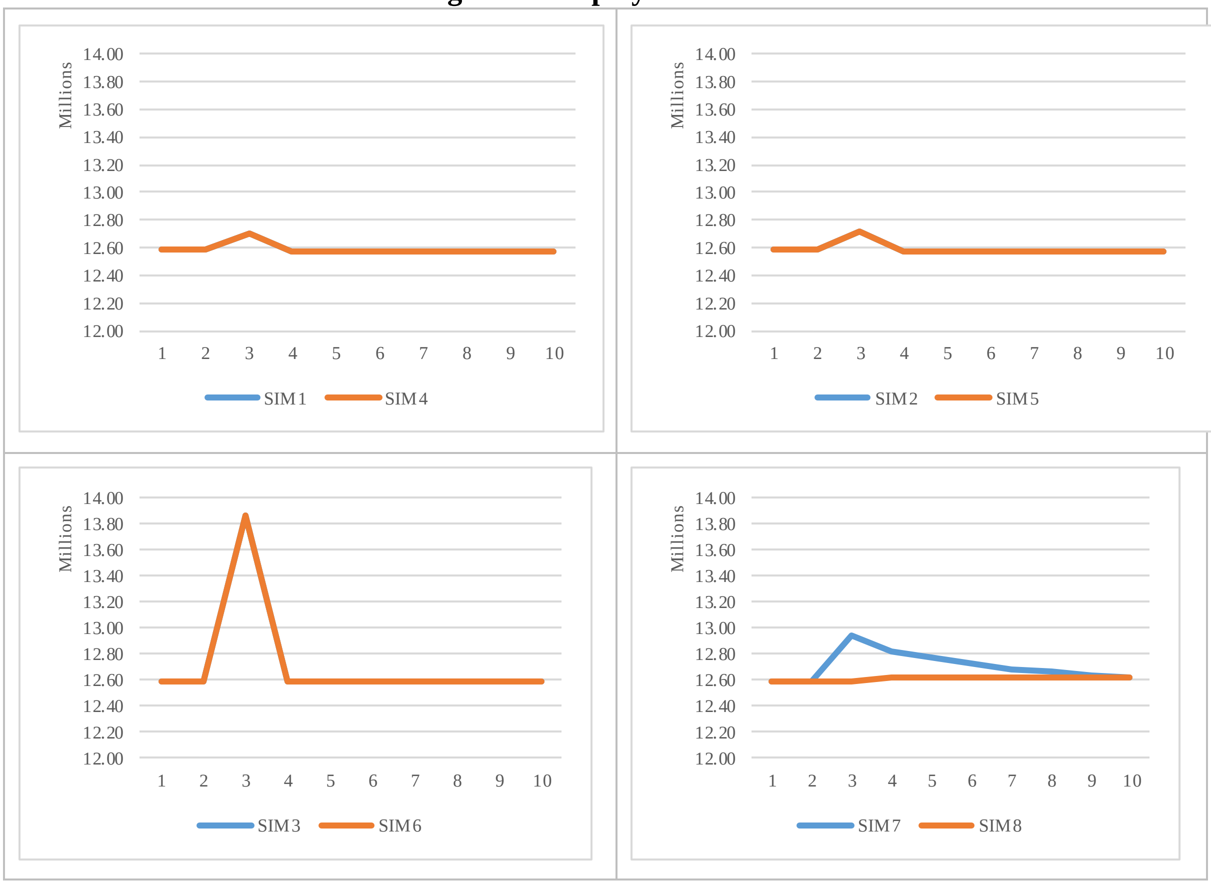


Figure 7. Consumer price index

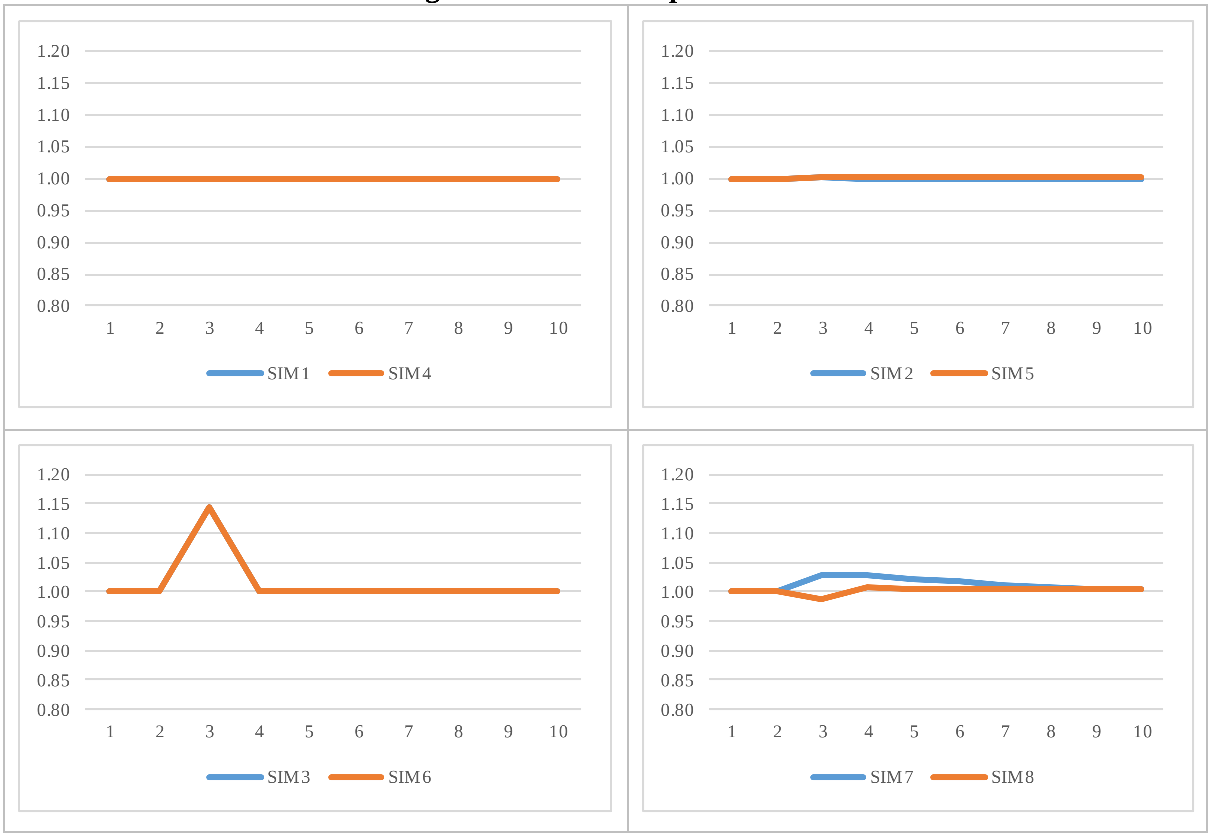


Figure 8. Government revenue (nominal)

Given the results above, one could say that the results in quadrant 1 and 2 are more or less the same. This can be understood that the choice of numeraire (either the consumer price index or the nominal exchange rate) does not matter in the real PEP-1-t model despite small differences. In the monetary model, however, this can be interpreted that the central bank's effort to maintain price stability through either the nominal exchange rate or the consumer price index yields similar outcome. In both cases, nominal investment falls to accommodate the increase in government spending as the real interest rate increases. Because of the nominal rigidity reflected by the nominal wage, there is a temporary small positive effect on real GDP and employment.

The results in quadrant 3 show that the central bank maintains the real interest rate in response to the shock and hence the variables under consideration all increase substantially. This can be explained that the initial upward pressure on the real interest rate due to the shock is neutralized by the central bank by increasing money supply which in turn creates inflation and the real effect is much more profound.

The SIM8 results in quadrant 4 are interesting. The central bank's objective to stabilize GDP so that it increases the real interest rate more than that in SIM4 and SIM5. As a result, investment falls more to keep real GDP more or less at the steady state level. This could happen as the central bank reduces the money supply. We can see that both nominal exchange rate and consumer price index decrease in period 3. This scenario can be seen as a counter-cyclical monetary policy.

Let us move onto the results of SIM7. The central bank cares about the gaps of aggregate output, inflation and the exchange rate. We can see that the real interest rate increases but by smaller than those in SIM4, SIM5 and SIM8 which leads to more or less stable investment expenditure. As a result, real GDP, the consumer price index and the nominal exchange rate grow in period 3. As the central bank allows an increase in the consumer price index, the real wage falls leading to the increase in employment and output.

Another interesting result is that the effect of the shock persists over time in SIM7 while being temporary in the other simulations. This could be because of the lagged exchange rate depreciation in equation (6) and the nature of adaptive expectation of future inflation.

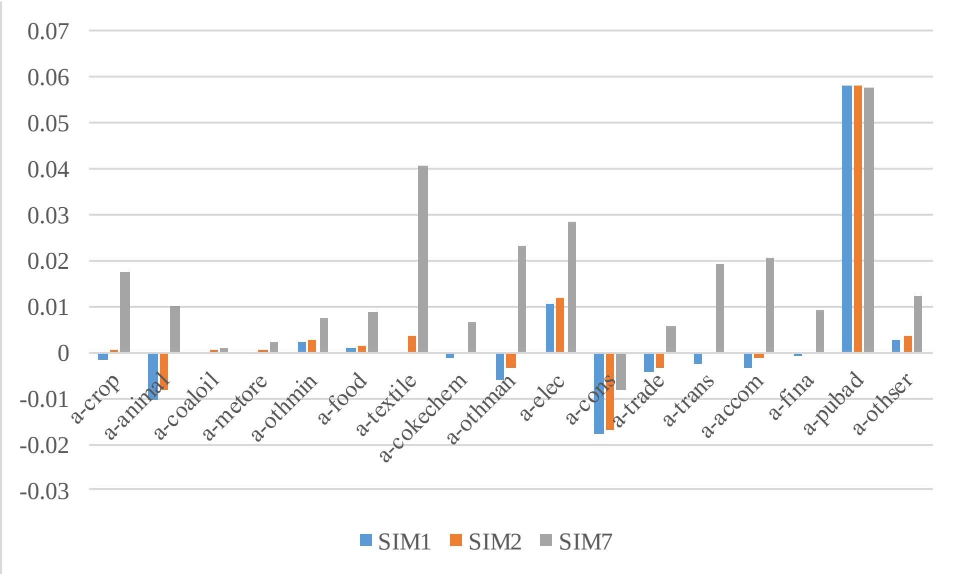
The following figures show the changes in sectoral production. The lines of SIM1 and SIM4, SIM2 and SIM5 and SIM3 and SIM6 overlap as the PEP-1-t model with the corresponding numeraire is a special case of the current model. In addition, the lines of SIM1, SIM2, SIM3 and SIM4 are not visible so that we can see only distinct 4 lines out of 8 simulations. Again, all sectors grow in SIM3 and SIM6 as the central bank keeps the same real interest rate. In SIM8, the most non-public sectors experience a drop in production in period 3 as the central bank tries to neutralize the increase in the production the a-pubad sector. In SIM7, the most sectors grow in period 3 except the a-cons sector as the central bank responds to the shock through the conventional interest rate rule. Moreover, the effects persists over time in SIM7.

Figure 10a. Production by sectors

Figure 10b. Production by sectors

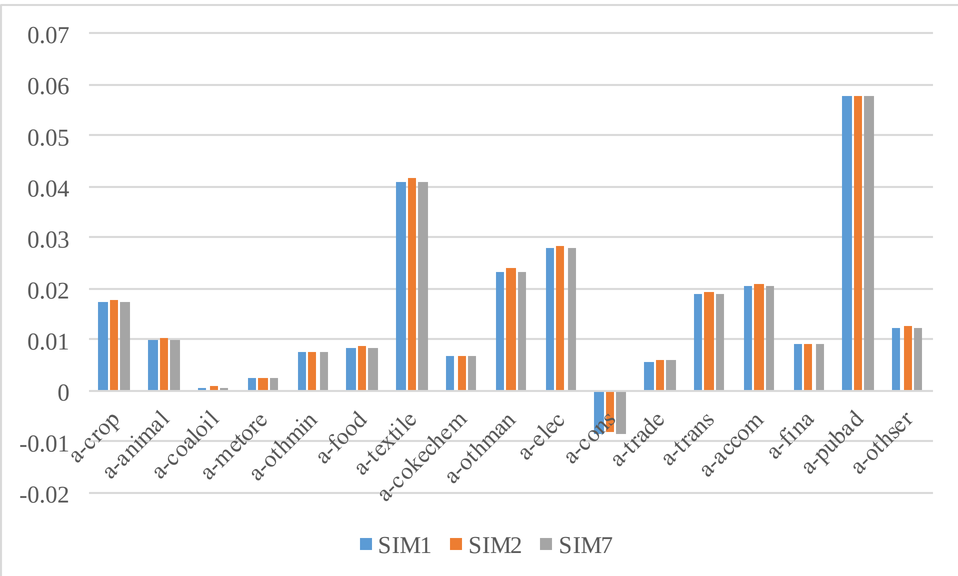
Given the results in Figure 10a and 10b, we shock the numeraires in SIM1 and SIM2 in the PEP-1-t model with those generated from SIM7 to show that the results of the two models converge. Figure 11 compares the production by sectors of SIM1, SIM2 and SIM7 as percentage deviation from the steady state values in period 3 before shocking the numeraire in the standard model. The differences are significant. Notice that the results of the standard model with different numeraire are similar.

Figure 11. Production by sectors in period 3 (% deviation from the steady state values)



Now we shock the numeraires in SIM1 and SIM2 in the PEP-1-t model with those generated from SIM7 in which the consumer price index in period 3 increases to 1.029 and the nominal exchange rate increases to 1.038. Figure 12 shows the simulation results. As can be seen, the changes are now more or less the same.

Figure 12. Production by sectors in period 3 (% deviation from the steady state values)



6. Conclusion

In this paper, we intend to show that simulation results under fixed exogenous numeraire in the presence of nominal rigidities could be misleading as it does not account for changes in absolute price. In doing so, we extend the PEP-1-t recursive dynamic CGE model with the Taylor-type interest rate rule through which the central bank responds to the gap-measures for output, inflation and exchange rate. The interest rate rule replaces the exogenous numeraire. We show that the standard model with the fixed numeraire can be derived as a special case of the current model. The interest rate rule determines absolute price level endogenously. Consequently, the same shock could have different effects from those in the model with the fixed numeraire. In the simulations, we consider nominal rigidity through fixed nominal wage to replicate the short-run business cycle phenomenon. The simulation results suggest that the interest rate rule is important in the short-run as being different. The standard model with the fixed numeraire can generate the same results as the current model if we know exactly how to shock the numeraire.

References

Christiano, L., Eichenbaum, M., and Evans, C. (2005). *Nominal rigidities and the dynamic effects of a shock to monetary policy*. Journal of Political Economy, 113 (1), pp. 1–45.

Decaluwé, B., Lemelin, A., Robichaud, V., and Maissonnave, H. (2013). *The PEP Standard Single-Country, Recursive Dynamic CGE Model.* Partnership for Economic Policy. Available at https://www.pep-net.org/pep-standard-cge-models.

Smets, F., and Wouters, R. (2007). *Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach*. American Economic Review, 97(3), pp. 586-606.

Svensson, Lars E. O., (2000). *Open-Economy Inflation Targeting.* Journal of International Economics, 50 (1), pp. 155-183.

Taylor, John B., (1993). *Discretion Versus Policy Rules in Practice*. Carnegie-Rochester Conference Series on Public Policy, 39, pp. 195-214.

Appendix

XXX macro SAM 2017 (% of GDP)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Labor**								0.6	45.2						46
2	**Capital**								0.1	45.4						45
3	**Households**	44.8	33.6		11.6				2.1							92
4	**Government**			3.2		13.1	1.7	7.4	0.2	0.4		0.0				26
5	**Direct taxes**			13.1												13
6	**Import duties**										1.7					2
7	**Indirect taxes**										7.4					7
8	**Rest of the world**	0.9	11.9	0.7	2.0						56.3					72
9	**Sectors**										126.2	53.8				180
10	**Commodities**			53.5	12.7					89.1	15.2	4.9	18.7	5.9	6.7	207
11	**Export**								58.7							59
12	**Private invest**			17.4	-0.3				8.3							26
13	**Public invest**			4	-0.1				1.9							6
14	**Inventories**												6.7			7
15	**TOTAL**	46	45	92	26	13	2	7	72	180	207	59	25	6	7	