A New, Simple SFC Open Economy Framework

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ABSTRACT

The paper presents a simple Stock-Flow Consistent open economy model with flexible exchange rates. It can reproduce the same dynamics and results of the flexible exchange rates 'benchmark' model by Godley and Lavoie (2007b). The latter is considered the "centre of gravity" of SFC open economy literature. Yet the new model uses only one-third of the equations of the original one and features a different mechanism of determination of the exchange rate. Its small size and its flexibility make the model suitable both for didactic purposes and for extensions with further building blocks to address a variety of research topics.

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1. INTRODUCTION

Stock-Flow Consistent models (SFC) have grown in popularity in recent years. The Canadian economist Marc Lavoie – one of the "founding fathers" of the field, together with the British economist Wynne Godley (1926-2010) – has even described the SFC approach as "an important new way of unifying all heterodox macroeconomics" (Lavoie 2015, p. 264). Indeed, in SFC models "the transaction flow matrix, which ties together real decisions and monetary and financial consequences, is the backbone of the monetary production economy that Keynes and his followers, the post-Keynesian, wish to describe and model" (Godley and Lavoie 2007b, p. 47).

A measure of this success is the application of the methodology to the study of crucial issues of our time, such as climate change and green policies (see, for instance, Jackson and Victor 2015, Naqvi 2015 and Berg, Hartley and Richters 2015, Dafermos, Nikolaidi

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and Galanis 2017 and 2018, Monasterolo and Raberto 2018, Bovari, Giraud and Mc Isaac 2018). SFC models are used as a 'general framework' to address complex topics via the incorporation of additional theme-specific building blocks. The strategy is based on a 'combination of knowledge' coming from different fields of research. Another example of a similar approach is the use of the SFC scheme to study inequality and financialization: see, for instance, the paper by Cardaci and Saraceno (2016) and Botta, Caverzasi, Russo, Gallegati and Stiglitz (2019). As a matter of fact, the Financial Crisis of 2007-2008 has exposed the weaknesses of models essentially based on the "classical dichotomy" which practically overlooked money, financial assets, and debt. The interest in SFC models has been boosted by their ability to properly integrate the financial accounts, where the early signs of fragility of the US pre-crisis growth pattern could be identified (and actually have been identified by economists who worked with them. See, for instance, Godley 1999). The European sovereign debt crisis has demonstrated once more the usefulness of Godley's sectoral balance approach to analyse the imbalances within the euro area, and the SFC framework has proved itself very effective in translate this approach into complete macroeconomic models[2] (for an analysis of the relationship between the System of National Accounts – SNA, which includes the financial accounts – and SFC models see Jonáš and Komínek 2017).

However, the complexity of the SFC framework has often limited these analyses - based on an 'adding up procedure' - to single countries or on groups of countries *considered individually.* Indeed, open economy SFC models have manly be used to test *open economy issues*, not to explore other issues *with an open economy perspective*. The distinction should be interpreted as follows: models used to test open economy issues are mainly focused on the dynamics of the exchange rates and the components of the balance of payments. These models are developed to study typically international economics topics, such as international trade, international finance and possibly their impact on the economic performance of a country. The second class of models are developed to study topics that are not strictly and directly related to international economics (e.g. fiscal policy, industrial policy, climate change, etc.). These topics can be studied with closed economy models, and often they are. However, the modeller can also choose to use an

[2] Several SFC models have analysed the imbalances of the euro areas from a sectorial balance perspective. Among them, the ones presented in Godley and Lavoie 2007a, Ehnts 2013, Ioannou 2018.

open economy model to account for the impact of the 'external world' on the internal dynamics of an economic system. In that case, the topic is studied from an open economy perspective.

This paper presents an ultra-simplified SFC (two-country) open economy model which could facilitate the incorporation of additional, complex building blocks into its structure with a maximum reduction of equations.

The "More Advanced open economy model" by Godley and Lavoie (2007 b) has been defined as the "centre of gravity of the open economy SFC literature" (Nikiforos and Zezza 2017, p. 1220). It is made of nearly 90 equations[3] and its closure for the flexible exchange regime (OPENFLEX model) has been widely used (Lavoie and Zhao 2010, Lavoie and Daigle 2011, Mazier and Tiou-Tagba Aliti 2012, Mazier and Valdecantos 2015, Mazier and Valdecantos 2019).

The OPENSIME (from OPEN + SIMplE)[4] model presented in this paper reproduces the same results of the OPENFLEX model. However, the OPENSIME model is made of only 36 equations. Therefore, although something is lost, it makes relatively easy to move from a 'close' to the 'open' economy context via a simple process of gradually embedding more and more modules initially developed for a single country.

The mechanism of determination of the exchange rate of the OPENSIME model differs from the one featured in the OPENFLEX. The new exchange rate equation makes the process of adjustment of the balance of payment more 'transparent' and improves the clarity of the economic dynamics captured by the model when the steady-state scenario is shocked. That's why the model could prove itself particularly useful for didactic purposes too.

Section 2 frames the paper into the wider debate on simplicity vs complexity in macroeconomic modelling. Section 3 features the equations of the model. Section 4 presents the result of the simulations and the comparison with the OPENFLEX model. Section 5 contains an example of an application of the 'closure' mechanism of the OPENSIME to a large, open Eco-SFC model. The example provides evidence of the ductility and effectiveness of the methodology. Section 6 features the conclusions.

The *Eviews* code of the OPENSIME model is available in the online Appendix.

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[3] The model in Godley and Lavoie (2007 b) is made of 91 equations, but there are some gaps in numbering (for instance equations OPENFLEX 12.73 and 12.74 do not exist). The final number also depends on optional equations that may or may not be included.

[4] In Godley and Lavoie (2007 b) the simplest model presented is called "Model SIM (for *simplest*)" (Godley and Lavoie 2007b, p. 58). That is a closed economy model.

2. COMPLEXITY VS SIMPLICITY IN MACRO MODELLING

The sequence of events started with the Financial Crisis in 2007-2008 has ushered in a general reappraisal of the 'state of the art' in macroeconomic modelling. And the Covid 19 pandemic will likely contribute even further to the theoretical reassessment of the discipline. A summary of the debate of the 'state of macro' goes far beyond the scope of this paper. However, it is worthwhile to recall some contributions that can help to put the paper presented here in a wider context.

According to Olivier Blanchard, macroeconomic modelling should become more pluralistic: "we need different types of macroeconomic models for different purposes (…) No model can be all things to all people" (Blanchard 2018, p. 43). Among the five classes of models that Blanchard envisages, there should be the so-called "toy models":

> "They allow for a quick first pass at some question, and present the essence of the answer from a more complicated model or from a class of models. For the researcher, they may come before writing a more elaborate model, or after, once the elaborate model has been worked out" (Blanchard 2018, p. 53).

The OPENSIME model presented in this paper tries to achieve the goals mentioned above. It offers a 'starting point' for 'more elaborate' open economy SFC models. It displays a simple description of the dynamics of the exchange rates determination which is suitable for didactic purposes. The level of complexity of the model is comparable with the Mundell-Fleming model (Mundell 1960, 1961a and 1961b and 1963, Fleming 1962) that still dominates the undergraduate university textbooks of International Economics. However, the 'theoretical massage' of the OPENSIME is consistent with the Harrodian open economy tradition which identifies in the current account position the main, long-term (fundamental) driver of the exchange rate mechanism (see Lavoie 2015, chapter 7 for an analysis of this approach to open-economy macroeconomics). For the same reasons, the simplicity of the model can be valuable in policymaking.

Stock-Flow Consistent modellers have taken part in the post-Financial Crisis debate on the 'state of macro'. While Blanchard and others (see, for instance, Wren-Lewis 2018) have challenged the claim of Dynamic stochastic general equilibrium (DSGE) models to be 'the only game in town', economists engaged in the SFC approach have put forward a concrete alternative to DSGEs (for a comparison between DSGE and SFC models see Burgess et al. 2016 and Carnevali et al. 2019).

Within the SFC literature, it is not identifiable a debate on simplicity vs complexity dilemma *stictu sensu*. Yet the strands of research within the SFC framework can be classified along a wide spectrum of contributions with respect to their empirical foundation: from purely theoretical models based on parameters whose values are set "using stylised facts or rules of thumb" (Caverzasi and Godin 2015, p. 163) to fully empirical models (for a guide on empirical SFC models see Veronese Passarella 2019 and Zezza and Zezza 2019). To some extent, a growing interest towards fully empirical models has coincided with a growth in complexity of the models themselves. Indeed, these types of models are built on the sectoral balance sheets and flow of funds available from the national account statistics of specific countries, which contain thousands of variables and entries.

This paper makes the argument for 'small-scale' SFC theoretical models via a practical example in a pure flexible exchange rate regime.

3. THE EQUATIONS OF THE OPENSIME MODEL

The OPENSIME model features the fundamental theoretical pillars of SFC models developed in the literature in recent years. The balance sheet and the transaction flow matrices follow the same accounting rules and principles presented in Godley and Lavoie (2007 b) and are included in Appendix A (Table 1A and 2A). The role of aggregate demand is central and there are no natural forces that lead the economy to full employment, both in the short and in the long run. Money is endogenous.

The OPENSIME model is a two-country model. The countries will be called the US and the UK to keep the same names and symbols used by Godley and Lavoie's original benchmark and facilitate the comparison.

The model works in a 'pure' flexible exchange rate regime. This means that the central banks do not intervene to stabilise – or to influence – the 'price'[5] of the currency they issue. Thus, international reserves – which are assumed to be fixed in a 'pure' flexible exchange rate regime – are not even modelled as assets held by the central banks. For this reason, it is virtually irrelevant that one of the two currencies is the American dollar, that is to say the main reserve currency held by monetary institutions all over the world.

[5] Of course, the price of a currency must be interpreted as a price *against* another currency: in other words, the exchange rate against a foreign currency.

Besides, no gold is held by the central banks of the OPENSIME model (in the OPENFLEX model gold was modelled, by in practice it was 'silenced' and played no role even in the fixed exchange regime).
As in the OPENFLEX model, in the OPENSIME model there is no banking sector and firms do not hold assets (neither financial assets nor fixed and working capital).

Income and wealth

The first building block of the OPENSIME model includes the equations of income and wealth of British and American households. The explanation will be focused on the British side, as the American side follows symmetrically:

$$YD_r^{£} = Y^{£} + r_{-1}^{£} B_{£s-1}^{£} + r_{-1}^{\$} B_{£s-1}^{\$} xr^{\$} - T^{\$} \quad (1)$$

Disposable income of British households is made of UK total factor income $Y^{£}$ and the interests from British and American bills held by UK households as savers ($B_{£s-1}^{£}$and $B_{£s-1}^{\$}$), minus taxes ($T^{\$}$). Haig-Simons disposable income ($YD_{hs}^{£}$) is derived by the disposable income plus capital gains (capital losses), which in this model are brought about by the revaluation (devaluation) of foreign bills caused by the appreciation (depreciation) of the foreign currency in which foreign bills are denominated. In turn, the accumulation of wealth by British households ($\Delta V^{£}$) is given by the saving of each period out of Haig-Simons disposable income (where $C^{£}$ stands for UK consumption):

$$YD_{hs}^{£} = YD_r^{£} + \left(\Delta xr^{\$}\right) B_{£s-1}^{\$} \quad (2)$$

$$\Delta V^{£} = YD_{hs}^{£} - C^{£} \quad (3)$$

The analogous equations for the US are:

$$YD_r^{\$} = Y^{\$} + r_{-1}^{\$} B_{\$s-1}^{\$} + r_{-1}^{£} B_{\$s-1}^{£} xr^{£} - T^{£} \quad (4)$$

$$YD_{hs}^{\$} = YD_r^{\$} + (\Delta xr^{£}) B_{\$s-1}^{£} \quad (5)$$

$$\Delta V^{\$} = YD_{hs}^{\$} - C^{\$} \quad (6)$$

Taxes are given as a simple share ($\theta^{£}$) of disposable income:

$$T^{£} = \theta^{£}(Y^{£} + r_{-1}^{£}B_{£s-1}^{£} + r_{-1}^{\$}B_{£s-1}^{\$}xr^{\$}) \quad (7)$$

$$T^{\$} = \theta^{\$}(Y^{\$} + r_{-1}^{\$}B_{\$s-1}^{\$} + r_{-1}^{£}B_{£s-1}^{£}xr^{£}) \quad (8)$$

UK total factor income equals the aggregate demand of the economy: consumption, plus an exogenous public expenditure ($G^{£}$), plus trade balance (export, $X^{£}$, minus import, $IM^{£}$). The OPENSIME follows the so-called Keynesian, or Kaleckian, quantity adjustment mechanism: "production is the flexible element of the model. Producers produce exactly what is demanded" (Godley and Lavoie 2007b, p. 65):

$$Y^{£} = C^{£} + G^{£} + X^{£} - IM^{£} \quad (9)$$

$$Y^{\$} = C^{\$} + G^{\$} + X^{\$} - IM^{\$} \quad (10)$$

Finally, UK consumption is determined – as in most of SFC models – by the so-called Modigliani consumption function (Modigliani 1966), which attaches a propensity to consume to both the (Haig-Simons) disposable income[6] ($\alpha_1^{£}$) and to the accumulated wealth ($\alpha_2^{£}$):

$$C^{£} = \alpha_1^{£}YD_{hs}^{£} + \alpha_2^{£}V_{-1}^{£} \quad (11)$$

$$C^{\$} = \alpha_1^{\$}YD_{hs}^{\$} + \alpha_2^{\$}V_{-1}^{\$} \quad (12)$$

Trade

[6] Different 'varieties' of disposable income are commonly used in SFC models for the consumption equations. In the original OPENFLEX these equations feature the expected Haig-Simons disposable income (see OPENFLEX 12.37 and 12.38 in Godley and Lavoie 2007b, p. 456), which is given by the average of the current Haig-Simons disposable income and the same variable with one lag. To limit the number of unknowns, in the OPENSIME we refrained from any expectation modelling and resorted to the standard Haig-Simons disposable income. Equations 11 and 12 are further simplified in experiment 3 (see section 4).

The equations of import and export in the OPENSIME model are much simplified in comparison with the ones featured in the OPENFLEX model. Domestic prices are assumed fixed in domestic currency, as in the Mundell-Fleming model, which still represents an important reference in open economy academic and political debates (Bernanke 2016). UK nominal export is a function of the pound exchange rate ($xr^{£}$; in the following formulas bold characters denote natural logarithm of the variables) and US total factor income ($Y^{\$}$). When the US total factor income grows, American consumers spend more both on domestic and foreign products. Consequently, American import – which is equivalent to British export from the point of view of the UK – grows.
Given that the exchange rate is quoted in indirect terms (dollar units per 1 pound), when the UK currency appreciates (higher $xr^{£}$), British goods become more expensive for American consumers and this hinders British export (this is the reason of the minus sign of the ε_1 parameter). By contrast, when US income rises, American consumers spend more and import more British goods, boosting UK export:

$$\boldsymbol{X}^{£} = \varepsilon_0 - \varepsilon_1 \boldsymbol{xr}^{£}_{-1} + \varepsilon_2 \boldsymbol{Y}^{\$} \quad (13)$$

UK import follows the same principles. When their currency is stronger, British consumers buy more American goods. Likewise, when their income rises, they spend more on both domestic and foreign goods, and consequently the UK imports more:

$$\boldsymbol{IM}^{£} = \mu_0 + \mu_1 \boldsymbol{xr}^{£}_{-1} + \mu_2 \boldsymbol{Y}^{£} \quad (14)$$

The exchange rate is lagged in both import and export equations to formally account for the delay in the response of consumers to a change in the exchange rate. Indeed, import and export orders are usually placed well in advance. This is the international trade time structure behind the famous J-Curve, which shows a worsening of the current account balance after depreciation of the currency.[7] American export and import are just the

[7] For the sake of simplicity and to keep the analogy with the OPENFLEX model the income variable is not lagged (the lag would have created problems when the model is initially run with all starting values at 0 except the exchange rate: the natural log of 0 is undefined). However, the total factor income does not include the capital gains/loss linked to the depreciation/appreciation of the domestic currency. Therefore, it is quite isolated from the shock which is affecting the currency in the same period.

'other side' of the UK's trade flows (adjusted by the exchange rate, since their original values are expressed in pounds):

$$X^{\$} = IM^{£} xr^{£} \quad (15)$$

$$IM^{\$} = X^{£} xr^{£} \quad (16)$$

Asset demand and supply

The equations of asset demand are set following the principles of Tobin's portfolio model (Tobin 1969), one of the pillars of SFC macro models.[8] However, in the simplified context of the OPENSIME model, UK households demand of domestic ($B^{£}_{£d}$) and foreign bills ($B^{\$}_{£d}$) are only functions of the rates of return (interest rates) of these assets:

$$B^{£}_{£d} = V^{£}(\lambda_{10} + \lambda_{11} r^{£} - \lambda_{12} r^{\$}) \quad (17)$$

$$B^{\$}_{£d} = V^{£}(\lambda_{20} - \lambda_{21} r^{£} + \lambda_{22} r^{\$}) \quad (18)$$

It is worthwhile to notice three features of these equations: 1. When the wealth of the households ($V^{£}$) is on the right-hand side, the dependent variable is given by the absolute value of the demand of an asset rather than its percentage on the total value of wealth; 2. The demand for an asset in open economy SFC models is always expressed in local currency (whereas its supply is expressed in the currency in which that asset is denominated). 3. The parameters λ related to interest rates have to respect the 'horizontal constraints' stated by Godley (1996) to guarantee the logical consistency of portfolio choices; by contrast, Tobin's 'vertical constraints'[9] can be assumed as respected by default given the fact that one of the asset – money – is set as a residual variable.
US portfolio equations are established precisely in the same way:

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[8] The Nobel Memorial Lecture of James Tobin (1982) can be considered the first 'manifesto' of the SFC approach to macroeconomic modelling. Among the principal features that differentiate Tobin's framework from the standard macro-model of the time, there is the inclusion of "several assets and rates of return" (Tobin 1981, p. 13). Here the number of assets is reduced to the minimum (6 in total: 3 types for each country). But the structure of the model is set in line with Tobin (1969) and in a way that it can incorporate as many additional assets and corresponding returns as desired by the modeller.

[9] Tobin's vertical constraints impose that the vertical sum of the first λ for each country/households group is 1 and the vertical sums of the remaining λs attached to the returns' variables are 0.

$$B_{\$d}^{\$} = V^{\$}(\lambda_{40} + \lambda_{41} r^{\$} - \lambda_{42} r^{£}) \quad (19)$$

$$B_{\$d}^{£} = V^{\$}(\lambda_{50} - \lambda_{51} r^{\$} + \lambda_{52} r^{£}) \quad (20)$$

As just anticipated, money held by UK households ($H_h^{£}$) is obtained as a residual variable: the wealth which is not invested in financial assets is kept in the form of cash. Money can be held in domestic currency only. Of course, it was possible to define an equation for cash similar to the ones of the other assets.[10] However, the residual form allows preventing problems related with the approximation in the calculus when the model is run: any 'loss' of wealth due to the approximation would imply a leakage in the Stock-Flow Consistent model that is supposed to be 'watertight'.

Therefore, the equations of money held by the UK and US households are the following:

$$H_h^{£} = V^{£} - B_{£s}^{£} - B_{£s}^{\$} xr^{\$} \quad (21)$$

$$H_h^{\$} = V^{\$} - B_{\$s}^{\$} - B_{\$s}^{£} xr^{£} \quad (22)$$

Equations 21 and 22 feature the exchange rates of the two currencies. This is because the variables of domestic and foreign government bills refer to assets actually held by households and not just demanded by them (note the s as subscript instead of the d). The distinction is crucial conceptually, but with limited practical implications at this stage of the presentation of the OPENSIME model, since the supply of assets *for the private sector* is assumed to follow its demand.

Equations 23-26 represent the supply of assets consistently with these principles:

$$B_{£s}^{£} = B_{£d}^{£} \quad (23)$$

$$B_{£s}^{\$} = B_{£d}^{\$} xr^{£} \quad (24)$$

$$B_{\$s}^{\$} = B_{\$d}^{\$} \quad (25)$$

[10] The possibility for this complete symmetry to be given rests also on the fact that money has actually its own 'rate of return', which is assumed to be zero in the OPENSIME model.

$$B^{£}_{\$s} = B^{£}_{\$d} xr^{\$} \quad (26)$$

It is essential to draw attention now on equation 24. There is no equivalent equation in Godley and Lavoie's closure of the OPENFLEX model. In that model, a 'rearranged' version of this equation sets the level of the pound exchange rate (see equation OPENFLEX 12.89FL in Godley and Lavoie 2007b). The closure of the OPENSIME model, by contrast, treats every asset and every country equally, so that there is perfect symmetry in the equations of the asset supply between the UK and the US.

Public Sector

The OPENSIME model assumes that central banks act as lenders of last resort, or "the residual purchaser of bills. Any outstanding bill not purchased by households of both regions [countries in our case] will be purchased by the central bank[s]" (Godley and Lavoie 2007b, p. 176). The behavioural equations that capture this institutional arrangement "allow us to assume that the central bank set the rate of interest on bills of its choice" (Godley and Lavoie 2007b, p. 176).

This approach appears particularly realistic in a time when central banks in all major Western countries (the Federal Reserve, the Bank of England, the European Central Bank) have unequivocally demonstrated, via the so-called Quantitative Easing, their power to control the whole term structure of interest rates, not only its shortest-term segment. Some central banks (The Bank of Japan from 2016 and the Reserve Bank of Australia from March 2020) have explicitly adopted a *yield curve control* policy. Elsewhere targets of long-term government bonds are not explicitly declared, but they are equally influenced by the central banks purchase strategies. Indeed, the ten-year government bonds yields during the Covid 19 crisis have decreased in all major countries. This occurred while the public debt of the same countries was ballooning due to lockdown induced recessions and unprecedented income support measures passed by governments of different political orientations.

Yet in the OPENFLEX model this role of the central bank is somehow opaque. The quotations above (Godley and Lavoie 2007b, p. 176) come from the open economy model described in chapter 6 of Godley and Lavoie (2007 b). In the model OPENFLEX model, UK central bank *does act* as lender of last resort, but the equation that captures this behaviour is, in fact, the *redundant equation* behind the model. Equation 12.82A in the book *must be removed* for the model to run if the modeller chooses to keep equation 12.82, which has already set the variable of the supply of UK bills to UK central bank (this is also made in the 'official code' of the model endorsed in Godley and Lavoie 2007b.)[11]

With respect to the US, in the OPENFLEX model the lender of last resort seems to be – not intuitively – the British private sector:

$$B_{£s}^{\$} = B_{s}^{\$} - B_{\$s}^{\$} - B_{cb\$s}^{\$} - B_{cb£s}^{\$} \quad \text{(12.90FL in Godley and Lavoie 2007b)}$$

In practice, UK households 'are offered' to purchase all the remaining US bills in the system. And the equation of exchange rate makes sure that what is offered ends up to be equal to what is originally demanded:

$$xr^{£} = \frac{B_{£s}^{\$}}{B_{£d}^{\$}} \quad \text{(12.89FL in Godley and Lavoie 2007b)}$$

It is true that "when the whole model is solved as a completely interdependent system" (Godley and Lavoie 2003, p. 24) the whole process brings the balance of payments in equilibrium and the dynamic of the exchange rate mirrors this 'itinerary' toward equilibrium. The cat catches the mouse. But it does it… in a 'black box'!

A clearer narrative can be offered if the whole mechanism is explicitly 'extracted'. Both central banks act as lenders of last resort. UK bills held by the Bank of England ($B_{cb£s}^{£}$) are the bill issued by the UK Government ($B_{s}^{£}$) and not purchased by households of both countries. The same applies to the US. Of course, central banks pay for these bills with the money they create themselves. This is the device whereby liquidity is pumped into the system. Thus the 'supply of money'[12] equals the volume of government bills purchased by both central banks. Still, this does not mean that one of the foremost theoretical

[11] http://gennaro.zezza.it/software/eviews/gl2006.php. This is a 'translation' in *Eviews* made by Gennaro Zezza of the original code written by Wynne Godley in *Modler*.

[12] The supply of money (M1) is generally defined as the sum of cash money in circulation plus current bank deposits. The OPESIME model does not include commercial banks: it does not feature any variable for commercial bank deposits and for deposits of banks at the central bank (reserves). Consequently, the monetary base (M0) is made only of cash money. Since the money supply (M1) is only made by cash money too, the two measures of narrow money (M0 and M1) coincide. For convenience - and for consistency with the terminology used in Godley and Lavoie 2007b - we have used the expression 'money supply' to refer to cash money in this paper.

assumptions of Post-Keynesian SFC models – the endogeneity of money – is breached: money supply depends on bills purchased, but the latter in turn depends on the behaviour of households. As the redundant equations will show later, the supply of money is ultimately driven by its demand. The following equations capture both the role of central banks as lenders of last resort and the supply of money that derives from it:

$$B^{£}_{cb£s} = B^{£}_{s} - B^{£}_{£s} - B^{£}_{\$s} \quad (27)$$

$$B^{\$}_{cb\$s} = B^{\$}_{s} - B^{\$}_{£s} - B^{\$}_{\$s} \quad (28)$$

$$H^{£}_{s} = B^{£}_{cb£s} \quad (29)$$

$$H^{\$}_{s} = B^{\$}_{cb\$s} \quad (30)$$

Central banks are assumed to give back to the government profits gained from interests on domestic bills held ($F^{£}_{cb}$). The government finances the discrepancy between its gains (taxes plus profits of the central bank) and its expenditure (exogenous government expenditure plus interest paid to bills holders) with the issue of new bills. These four relationships complete the public sector set of equations:

$$F^{£}_{cb} = r^{£}_{-1} B^{£}_{cb£s-1} \quad (31)$$

$$F^{\$}_{cb} = r^{\$}_{-1} B^{\$}_{cb\$s-1} \quad (32)$$

$$\Delta B^{£}_{s} = G^{£} - T^{£} + r^{£}_{-1} B^{£}_{£s-1} - F^{£}_{cb} \quad (33)$$

$$\Delta B^{\$}_{s} = G^{\$} - T^{\$} + r^{\$}_{-1} B^{\$}_{\$s-1} - F^{\$}_{cb} \quad (34)$$

Exchange rates

Finally, the equation of the exchange rate, which provides the *closure* to the system of the OPENSIME model. This step is of the utmost importance. Given an identical accounting framework, different closures of a SFC model can imply different behaviours of the

modelled economic system based on different "causal relationships" (for instance, Álvarez and Ehnts (2015) have managed to find eight different closures even for the simplest – SIM model – of the series of benchmark models developed in Godley and Lavoie 2007b).
The price of the currency in this model is determined by market forces, as in every flexible exchange rate regime. Let us look at the model – as usual – from the 'point of view' of the United Kingdom. In addition, let us assume that every international payment of a good or an asset must be made in the currency of the country which produced that good or issued that asset.

British current account, $CA^{£}$, is given by the trade balance plus unilateral transfers of income, which in the OPENSIME model are just interests yielded on foreign bills. $CA^{£}$ is expressed in pounds, therefore the entries not denominated in pound must be converted from dollars:

$$CA^{£} = X^{£} - IM^{£} - r^{£}_{-1} B^{£}_{\$s-1} + r^{£}_{-1} B^{\$}_{£s-1} xr^{\$}$$

The formula above has not been numbered as it will not be part of the model: it just represents the first step to find the 'final equation' of the exchange rate.

Even if in the $CA^{£}$ equation everything is expressed in pounds – to compare homogenous entries – British households need dollars for their import. They receive part of the dollars they need from the interests that the US government pays to them due to the US bills they hold. Furthermore, they can be confident to 'find' these dollars in the foreign exchange market at the existing exchange rate level as far as US households need pounds to import British good in the US (this import is represented in the $CA^{£}$ equation by the variable $X^{£}$, since it is British *export* from the point of view of the UK). American households receive themselves some pounds from the interests of UK bills they hold, but we can assume they still need other foreign currency for trade. Now, let us assume that the net sum of all these entries in the $CA^{£}$ equation is negative: it means that British households need dollars for international trade more than American households need pounds. Exchange of currencies at the current exchange rates appears to be impossible at this stage.

However, British households could find the dollars that they need thanks to international transactions of financial assets. The following equation represents the British financial account (expressed in pounds):

$$FA^{£} = \Delta B^{£}_{\$s} - \Delta B^{\$}_{£s} xr^{\$}$$

Again, British households need dollars to buy the US bills they demand,[13] but they can rely on the fact that American households need pounds too if they want to buy the UK bills they desire. Let us assume that the net sum of these entries is zero. This means that UK households, *for now*, cannot find the money to 'finance' their current account deficit from their financial account. UK balance of payments (current account plus financial account) is – *notionally* – negative (*notionally*, because the balance of payments *always equals zero* by definition. When it is said to be *notionally* negative the reader should interpret the expression as 'thought experiment' to track down the forces at work behind the currency fluctuations before the adjustment of the price of the currency itself). Indeed, the demand for dollars by UK households is greater than the dollars offered by US households on the foreign exchange market to buy the pounds that American agents need. As the demand for dollars is greater than the supply, the dollar will appreciate. Symmetrically, the pound will depreciate.

In other words, the exchange rate of the dollar $xr^{\$}$ will go up (1 dollar will be exchanged with more pounds than before). This will not affect the trade balance, since the exchange rate enters the equations of import and export with a lag. However, it will affect the international trade of financial assets via two different channels.

Let us imagine US households want to invest the equivalent of 20% of their wealth in foreign bills; for instance, they would like to hold \$ 20 of securities issued by the UK government out of a total wealth of \$ 100. Given an exchange rate $xr^{\$}$ = £ 1, they will buy bills denominated in pounds for £ 20. Yet, if the pound depreciates – say, the exchange rate becomes $xr^{\$}$ = £ 1.5 – they will have to buy £ 30 of UK bills to reach their ideal threshold of \$ 20. It means that the first term of the equation of the financial account ($\Delta B^{£}_{\$s}$) will rise. The contrary is true for UK households: in order to hit their target of foreign bills as a share of their wealth they will need fewer US bills denominated in dollars as their value in pounds has increased ($\Delta B^{\$}_{£s}$ will go down, even if this will not affect directly the equation of the financial account where everything is denominated in pounds and $\Delta B^{\$}_{£s}$ is multiplied by an increasing value of $xr^{\$}$).

[13] The variables in the equations are actually the supplies of assets, but we have seen with equation 23-26 they correspond to the demand of assets (the use of the supply variables just ensures currency consistency).

What is happening is that the demand for dollars is decreasing and the demand for pounds is increasing. How long will this process of devaluation of the pound last? Naturally, until the markets of the two currencies reach the equilibrium. That is to say until the UK balance of payments – and, symmetrically, the US balance of payments – are finally at zero (again: the balance of payment is always equal to zero by definition. As explained above, the *notionally negative* position of the balance of payment should be interpreted by the reader as a 'thought experiment' to follow the dynamic process of the adjustment). *This is the closure* of the model: if it is the equilibrium of the balance of payments that set the 'final' (or better: the *inter-period*) level of the exchange rate, the latter is given by the equation of the balance of payments set at zero:

$$CA^{£} + FA^{£} = X^{£} - IM^{£} - r_{-1}^{£} B_{\$s-1}^{£} + r_{-1}^{£} B_{£s-1}^{\$} xr^{\$} + \Delta B_{\$s}^{£} - \Delta B_{£s}^{\$} xr^{\$} = 0$$

With some basic algebra, it is easy to end up with an equation with only $xr^{\$}$ on the left-hand side:

$$xr^{\$} = \frac{-X^{£} + IM^{£} + r_{-1}^{£} B_{\$s-1}^{£} - \Delta B_{\$s}^{£}}{r_{-1}^{£} B_{£s-1}^{\$} - \Delta B_{£s}^{\$}} \quad (35)$$

Finally, the other value of the exchange rate ($xr^{£}$) is nothing but the inverse of the result obtained with equation 35:

$$xr^{£} = 1/xr^{\$} \quad (36)$$

Will this level of the exchange rate be the new stationary state level of the exchange rate? Probably not: in the next period the trade balance will also be affected by the same chain of events just described and a new equilibrium will be found. Only when the UK current account will have reached the equilibrium, there will be no need for the financial account to 'adjust' any longer to cover excess or lack of demand of dollars and the US exchange rate will settle on its long-term value.

Does this mean that the financial account plays a merely 'passive role' and it is not able to influence the exchange rate directly? Not at all. An increase of the interest rate in the UK, for instance, would imply a rise of demand for UK assets by US households and the appreciation of the pound. However, contrary to what happens in the standard Mundell-

Fleming model (and in its more recent variants), the inflow of capitals from the US does not continue forever. When US portfolios have adjusted to the new level of interest rate the flow stops and the pressure on the exchange rate ends. This dynamic is based on the set of assumptions typical of open economy SFC models: even if 'perfect capital mobility' is supposed to hold, 'perfect asset substitutability' is discarded as unrealistic. Rates-of-return differentials can persist, as long as asset holders do not want to 'put all their eggs in the same basket'.

The redundant equations

The consistency of flows and stocks in the SFC accounting framework implies that each system of equations (each model) must contain a redundant equation. This should be dropped for the model not to be overidentified. In the original OPENFLEX model equation 12.82A (UK central bank acting as a lender of last resort) had to be dropped.

The closure of the OPENSIME model is based on the principle that each central bank explicitly acts as a lender of last resort of the respective government and the exchange rate is set via the principle that the balance of payments must always equal zero. Two watertight systems are built, one for each country. In fact, the OPENSIME model could be considered as the combination of two separate models which communicate with each other via international trade of goods and financial assets. After all, this seems to be a good approximation of both the behaviour of contemporary economies and their institutional frameworks: even if most of the industrial economies are deeply intertwined in terms of flows of commodities, services and financial assets, national governments and central banks are entrusted with the managing of economic policies on a national level.[14] Indeed, no buyer of last resort for government securities exists at the international level and no institution is in charge of a *global* fiscal policy; monetary and fiscal policies are usually conducted taking into account national interests – and sometimes at the expense of a more balanced international order.

As a two-country model made of two communicating sub-models, the OPENSIME has two different redundant equations. In line with the principle of complete symmetry that has characterised the model so far, the equations state that the money held by UK and US

[14] From this point of view the euro area could be modelled as a single 'country', given the existence of a single currency and a single central bank.

households (derived by equation 21 and 22) equal the money 'created' by the respective central banks via the purchase of domestic bills (see equations 29 and 30):

$$H_h^{£} = H_s^{£} \quad \text{(redundant equation I, 37)}$$

$$H_h^{\$} = H_s^{£} \quad \text{(redundant equation II, 38)}$$

In all the computer simulations made with the OPENSIME model in the next section, it has been verified that both conditions have always been respected.

4. THE BEHAVIOUR OF THE OPENSIME MODEL: COMPUTER SIMULATIONS AND DISCUSSION

One of the most attractive features of the OPENSIME model is that it yields essentially the same results[15] of the original OPENFLEX model, while representing a much more simplified version of a SFC two-country model with flexible exchange rates. It seems to be a successful application of the 'Occam's razor', which states that it is futile to use many means when the same task can be carried out with fewer.

This section will replicate the same shocks which are applied to the OPENFLEX model in Godley and Lavoie 2007b, chapter 12. It will be shown that when the OPENSIME model is shocked the behaviour of its main variables is qualitatively the same as the behaviour of the equivalent variables after an identical shock in the OPENFLEX model.

Before going forward with the computer simulations, it is worth to point out that the initial values of all the stocks of the OPENSIME model have been set to 0. The exchange rate has been set to 1. The shocks are triggered after that the model has settled in its

[15] Of course, this is true for the economic dynamics that can be represented through the limited number of variables of the OPENSIME model. As no system of prices is embedded in the OPENSIME model, the 'price-related dynamics' of the OPENFLEX model cannot be replicated.
This also suggests that the results of other models based on the OPENFLEX's *closure* (see section 1: "Introduction") could be replicated with a new version of those models based on the OPENSIME's *closure*. Indeed, in the code of Carnevali et al. (2020) – see section 5 of this paper – both closures have been embedded, and the modeller can select which one should be used (the selection is made through a "dummy" variable which activates and deactivates a handful of equations related to the two closures). The results of the experiments are not affected by the closure (although the OPENFLEX's closure appears to be more resistant to "very big shocks" as it is computationally simpler to solve by the software, given the high "simultaneity" of variables in the exchange rate equation of the OPENSIME. Note that we are just referring to the *closures*: the code of Carnevali at al. 2020 has been built on the OPENSIME's *structure*, not the OPENFLEX's).

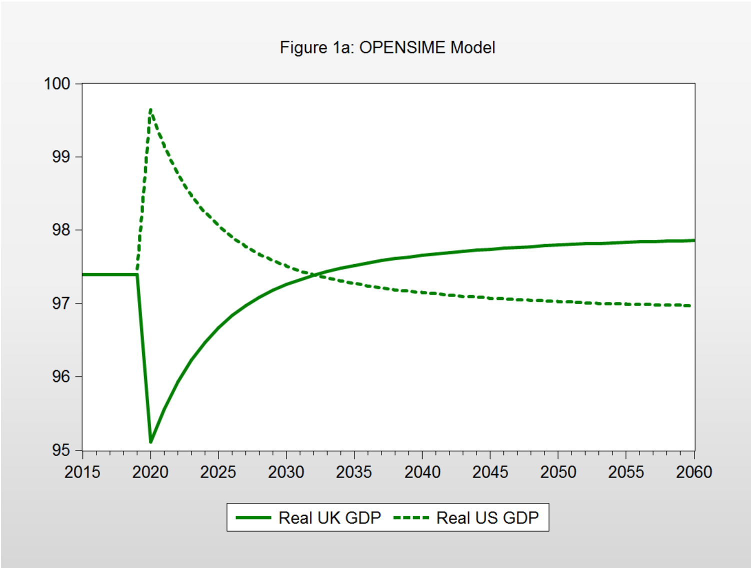
steady state. For the sake of comparison, most of the parameters[16] of OPENSIME's equations are the same as the ones featured in the OPENFLEX model (a complete list of the variables and parameters of the model – with the corresponding values – is featured in Appendix B). At any rate, the qualitative results of the simulations are extremely stable with respect to the parameter setting.[17] All simulations are carried out via *Eviews*.

Experiment 1: a step fall in the UK exports

In this experiment the value of the parameter ε_0 of the equation of British export passes from -2.1 to -2.2 in 1960 (ε_0 can be considered a 'residual indicator' of the international competitiveness of British productive system, capturing elements such as the reputation of its brands, the quality of its products, etc.).

[16] Obviously, as far as there are equivalent equations, variables and parameters in the two models.
[17] Sensitivity test has been conducted to prove this point. The stability of the results of the OPENSIME model comes with no surprise given its simplicity. And this another of its strength: the model cannot be suspected to carry results due to a tailor-made calibration. That is not always the case with larger SFC model, where it can happen that some parameters must be tweaked to 'make the model run'. In the OPENSIME model the path to the new stable state following a shock *does depend* on the parameters of the import and export equations. However, different (reasonable) values for those parameters can alter the *speed* of the adjustment, not the fundamental dynamics of the model.

Figure 1: US and UK GDP following a step fall in the UK exports (OPENSIME and OPENFLEX models)



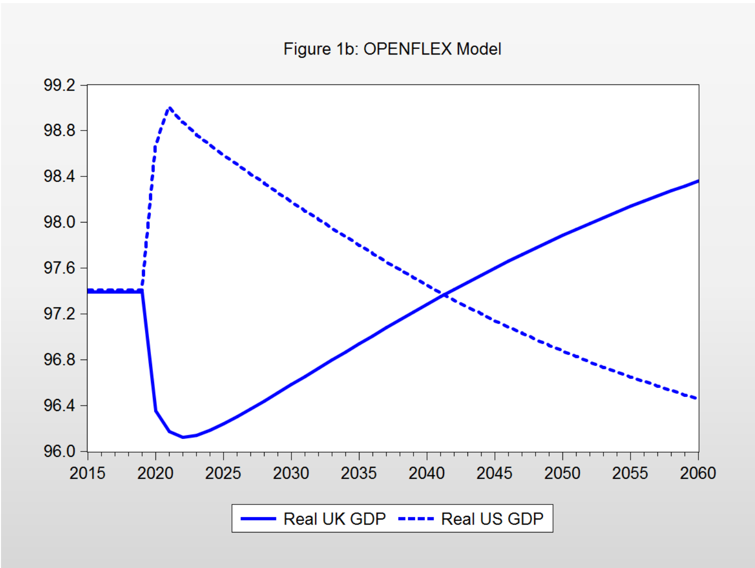
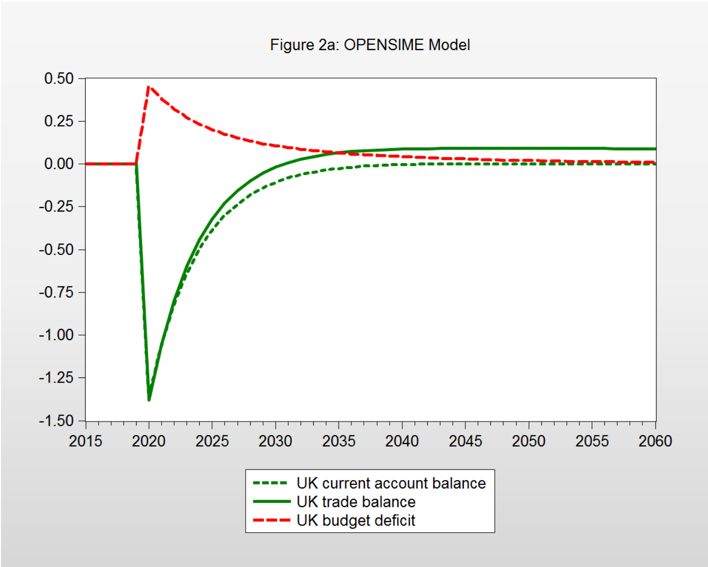
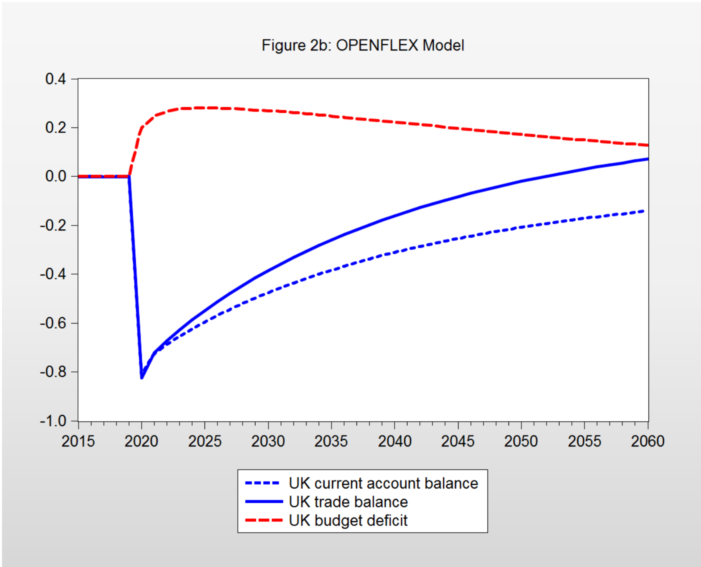


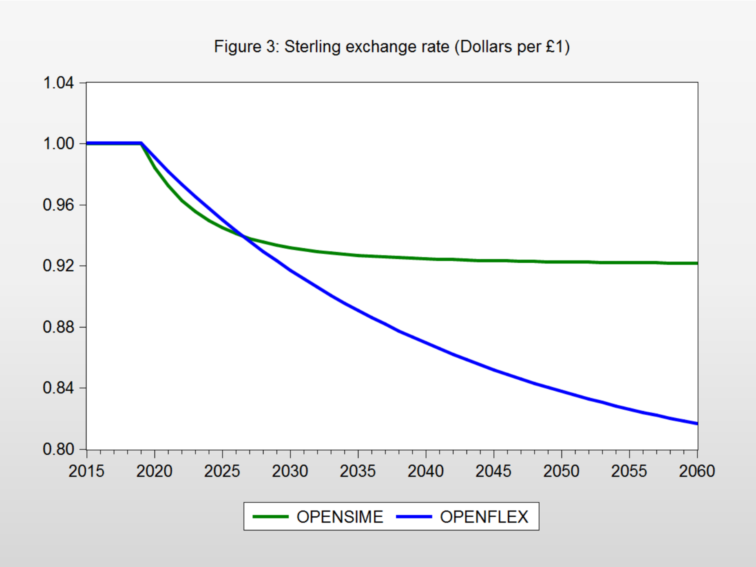
Figure 2: UK Current Account, Trade Balance and Budget Deficit following a step fall in the UK exports (OPENSIME and OPENFLEX models)





The behaviour of real GDP is similar in the two models, although in the OPENSIME it stabilises much earlier. The depreciation of the pound affects import and export more ‘directly’ in the OPENSIME model given equations 13 and 14. Therefore, the adjustment of the economy is much faster and the new steady state is reached earlier than in the OPENFLEX model, where a far more complicated system of prices is in place. These dynamics are also reflected by the path of the pound, which needs to depreciate far more in the OPENFLEX model in order to drive the current account to the equilibrium (see Figure 3).

Figure 3: UK currency following a step fall in the UK exports (OPENSIME and OPENFLEX models)



Experiment 2: a step increase in the US government expenditures

This experiment allows testing the effects of fiscal policy in an open economy framework. One of the most interesting results of the original OPENFLEX model is that fiscal policy turns out to be effective even in a flexible exchange rate regime. By contrast, 'mainstream' models tend to consider fiscal policy utterly ineffective in a context of floating exchange rates: the positive impact of government spending on GDP is thought to be offset by the tendency of the interest rate to rise and by the resulting appreciation of the currency.
In this experiment (real)[18] US public expenditure is raised by one unit (from 16 to 17).

[18] The distinction between real and nominal variables applies only to the OPENFLEX model, given the fact that the OPENSIME model assumes fixed price and real and nominal variables coincide.

Figure 4: US and UK GDP following a step increase in the US government expenditures (OPENSIME and OPENFLEX models)

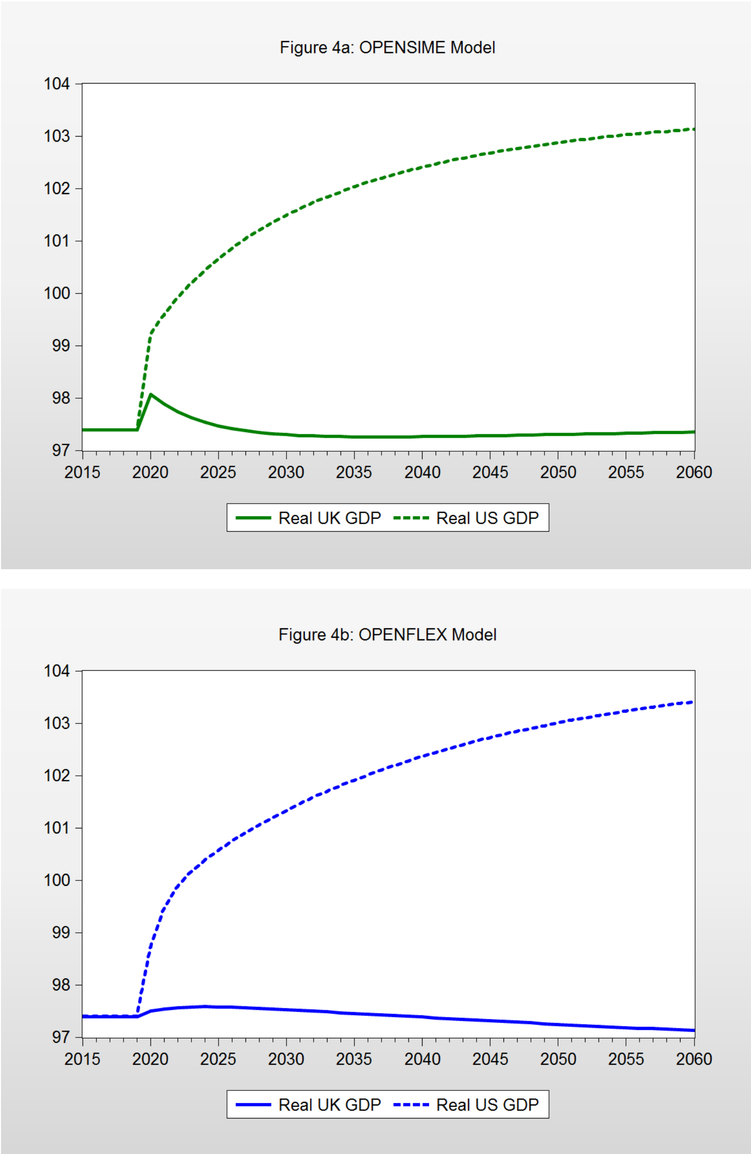
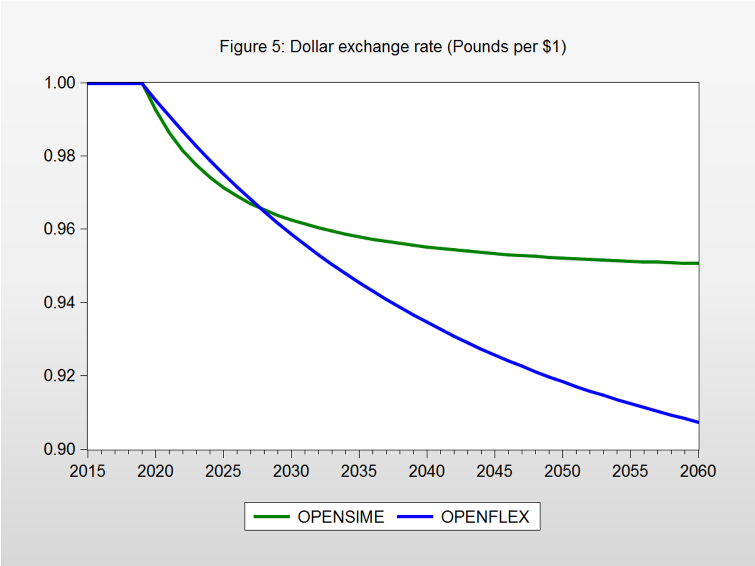


Figure 4 shows that the behaviour of the two models is, again, very similar: in both cases, fiscal policy is effective in pushing up US GDP. In both models not only does the public expenditures contribute to the increase in aggregate demand, but the depreciation of the currency - which follows the appearance of a current account deficit - reinforces the process: a weaker currency curbs import (which have been boosted by the fiscal stimulus) and facilitate export. Far from being the factor which annuls the effort of the government to promote expansionary policies, the flexible exchange rate is an additional help to deliver the task. Indeed, the path of the dollar following the US policy intervention is very close to the path of the pound following the shock to the UK propensity to export (experiment 1).

Figure 5: US currency following a step increase in the US government expenditures (OPENSIME and OPENFLEX models)



Experiment 3: a change in liquidity preference

To conduct the comparison of the models over all the cases tested in Godley and Lavoie (2007 b) it is now necessary to deal with the effect of a change in interest rate, liquidity preference or exchange rate expectations.[19] Following the example of Godley and Lavoie (2007 b) only the 'liquidity preference case' will be taken into consideration, since the other two are virtually equivalent: "an increase in liquidity preference of asset holders in favour of US treasury bills (through the constant λ_{i0}) and an expected increase in the dollar exchange rate, just as an increase in the interest rate on US treasury bills, lead to an attempt by households to increase their share of US securities in their portfolios" (Godley and Lavoie 2007b, p. 484).

However, to reproduce the size of the shock applied to the original model, the OPENSIME model needs a little amendment to its consumption equations. In the OPENFLEX model these equations feature the expected real disposable income (see OPENFLEX 12.37 and 12.38 in Godley and Lavoie 2007b), which in turn is calculated as an average of the current Haig-Simons disposable income and the same variable with one lag (see OPENFLEX 12.39 and 12.40). It means that capital gains produced by a sudden depreciation of a currency

[19] Exchange rates expectations are not included in the OPENSIME due to the effort to keep the model as simple as possible. If one would like to incorporate them, an additional variable should be added to equations 17-20. Then a theory to model the expectations should be introduced, like for instance in Lavoie and Daigle (2011).

do not *fully* affect the behaviour of consumers in the very same period in which the depreciation comes about. In the versions of the OPENSIME model used so far, the expected real disposable income variable has been scrapped to limit the total number of the unknowns: consumption equations (11 and 12) encompass the standard, current Haig-Simons disposable income, which *fully* takes into account capital gains. With large currency shocks, as the one tested in this case, the effects of capital gains are so large that computational issues arise (setting aside the fact that too significant effects of capital gains on consumption are not realistic). Thus, the Haig-Simons disposable income variable is substituted with the one of regular disposable income. The new consumption equations are:

$$C^{£} = \alpha_1^{£} YD_r^{£} + \alpha_2^{£} V_{-1}^{£} \quad \text{(11 bis)}$$

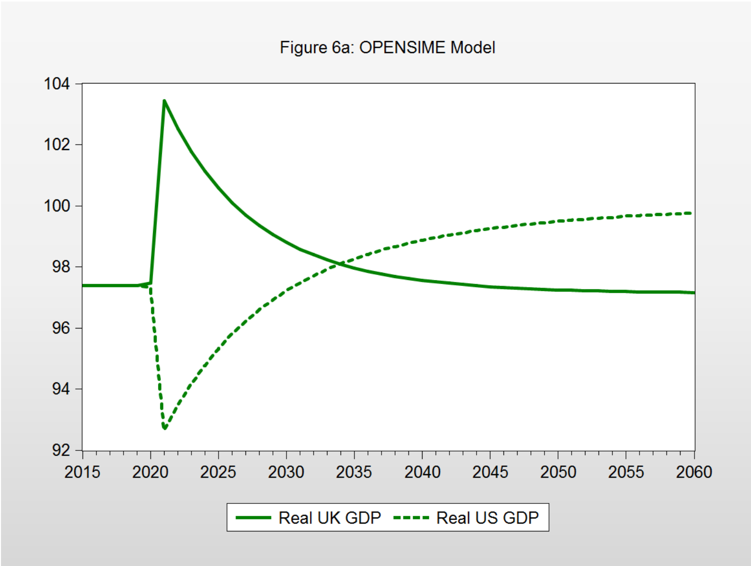
$$C^{\$} = \alpha_1^{\$} YD_r^{\$} + \alpha_2^{\$} V_{-1}^{\$} \quad \text{(12 bis)}$$

Now, capital gains affect consumption only via the wealth channel.[20]

The shock of experiment 3 consists of an increase of λ_{20} from 0.25 to 0.3 and an increase of λ_{40} from 0.7 to 0.75. In other words, since a specific moment in time onwards (the year 1960 in the computer simulations below), both UK and US households desire a larger share of their wealth in the form of American bills. The following figure captures the consequences on the economic system.

[20] Obviously, if one does not want to modify the OPENSIME model, the same kind of experiment can still be conducted, as far as the magnitude of the shock is scaled down.

Figure 6: US and UK GDP following a change in liquidity preference (OPENSIME and OPENFLEX models)



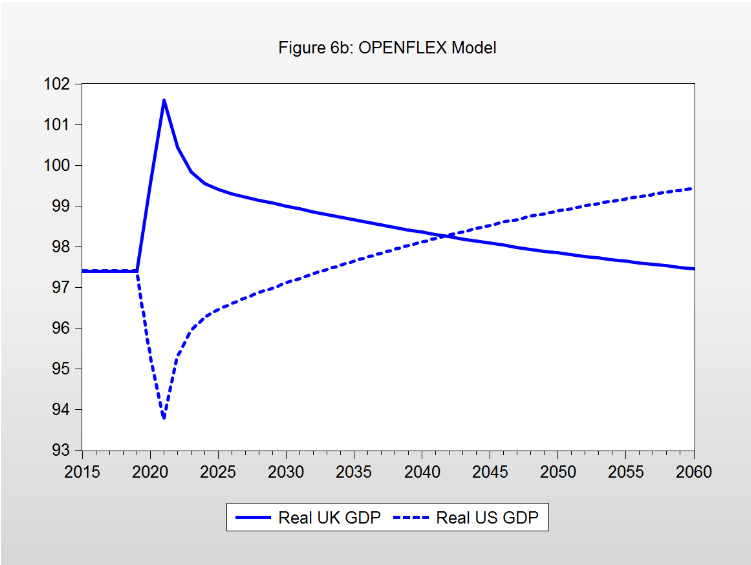


Figure 7: US currency following a change in liquidity preference (OPENSIME and OPENFLEX models)

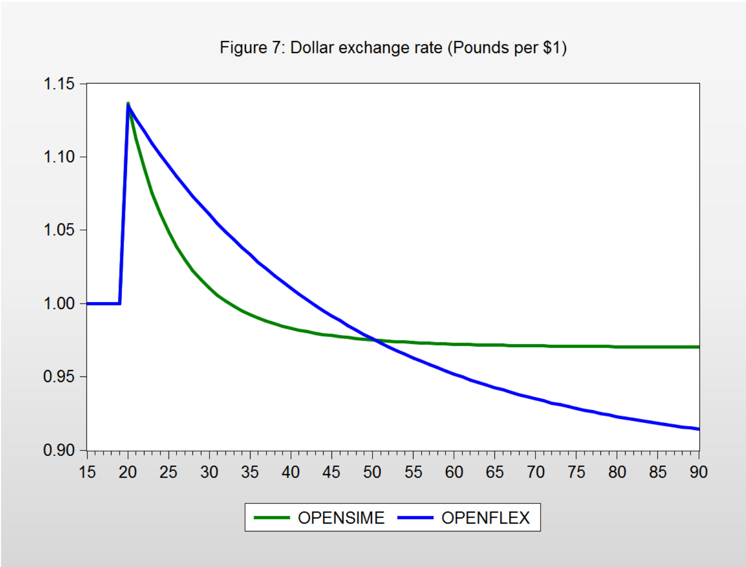
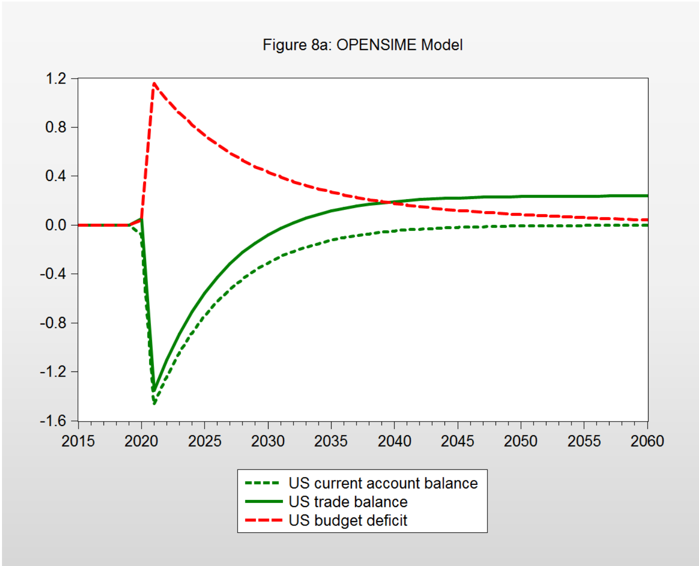
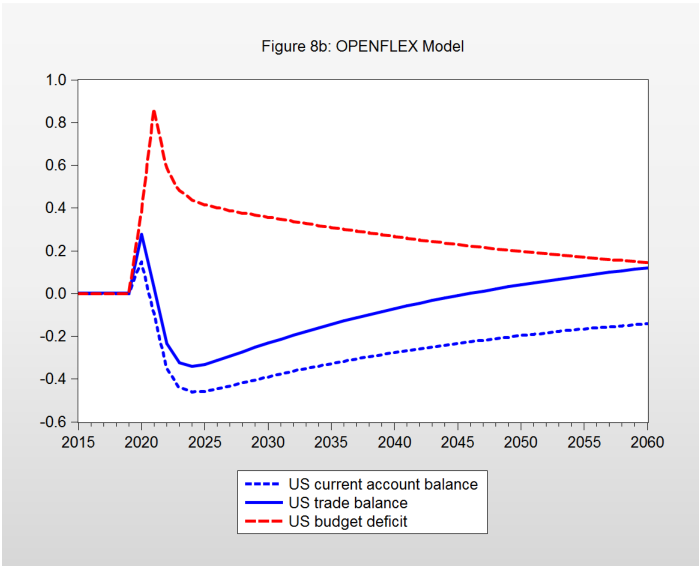


Figure 8: US Current Account, Trade Balance and Budget Deficit following a change in liquidity preference (OPENSIME and OPENFLEX models)





Figures 6, 7 and 8 show, once again, that the OPENSIME and the OPENFLEX model behave analogously after the same type of shock. The higher preference for American bills initially brings about an appreciation of the dollar. A weaker pound helps the UK to improve its external position and pushes up UK GDP in the first periods after the shock. However, in the long-run, US deficit in the current account reverses the gains of the dollar: the American currency starts to depreciate and the US ends up with a higher GDP than before thanks to a lower level of the dollar. Godley and Lavoie's explanation of the paradox applies to both models: "Because of the additional costs of servicing the now larger external debt, the US current account balance will be brought back to zero only if trade balance remains positive. (…). As a consequence, the new steady-state value of the dollar exchange rate is lower than its original steady-state value, and the new US GDP steady-state value is higher than what it was before the change in portfolio preferences" (Godley and Lavoie 2007b, p. 487).

The only difference between the models that appears in these simulations can be identified in Figure 8. In the OPENSIME the US current account is negative since the occurrence of the shock; by contrast, in the OPENFLEX the same variable is positive in the year of the shock and just after 2021 it becomes negative. Yet the discrepancy is absolutely negligible: in the 'new version' of the OPENSIME model capital gains produced by the depreciation of the pound do not affect immediately UK consumption and therefore do not boost US current account and trade balance in the year of the shock.[21] As soon as the stronger dollar starts to affect the equations of export and import in the OPENFLEX model the US current account and trade balance turn negative and the behaviour of the models is substantially equivalent. The larger value of the external deficit in the OPENSIME model is entirely due to the more direct effect of the currency on the import and export equations that has been explained earlier.

5. AN EXAMPLE OF AN APPLICATION OF THE OPENSIME CLOSURE FOR A LARGE, OPEN SFC MODEL

In the last decade, the climate change emergency has spurred a growing interest in the application of macroeconomic models to study environment-related issues. However, most of ecological SFC models developed so far have been focused on a single-area economy (see Carnevali et al. 2019 for a brief survey of Eco-SFC models). Among others, there is a technical reason behind this choice. Eco-SFC models add to the traditional balance sheet and the transaction flow matrices two further matrices to account for the impact of production and consumption on the ecosystem and the subsequent feedbacks: the physical flow matrix, which is meant to capture the First and Second Law of Thermodynamics; and the physical stock-flow matrix, which account for the change in physical stocks of material reserves, renewable and non-renewable energy reserves,

[21] In equation 14 (UK import) the exchange rate is lagged. If UK nominal import *was* given by real import multiplied by import price, it *would be* higher in value due to the depreciation of the pound. The fact that we ruled out prices from import and export equations – and from the model as a whole – produces a 'neutralisation' of the sterling depreciation on UK current account just after the shock. In other words, no *typical* 'J-Curve alike' phenomenon emerges. That's another reason why the UK current account can turn positive almost *immediately*; consequently, the US external position is in deficit right from the beginning.

atmospheric CO_2 concentration, the socio-economic stock (e.g. stock of capital goods and housing) and other elements affecting human life and well-being.

All this implies that the 'basic structure' of Eco-SFC models starts with a huge number of equations to deal with. Additional building blocks – which account for the private banking sector, productive investment (conventional and 'green'), a variety of financial assets, different patterns of consumption behaviours in different portions of the population – are usually embedded in the basic structure of the model. That's why a very small two-area framework which economises the number of equations requested to take into account the dynamics of the (flexible) exchange rate can play a very useful part. In Carnevali et al. (2020) the OPENSIME closure has been used to study the impact of green investment on climate change through a model in which the world economy is made of two quasi-independent but interacting systems. The study found that policies which are supposed to promote a low-carbon transition can have unexpected side effect due to cross-border financial flows and exchange rate mechanisms. A weaker currency in the areas of the world less engaged in the ecological transition can boost their share in international trade. The upshot is to partially offset the effects of green policies in the more environmentally friendly areas. The conclusions of the paper underlined that international coordination of the efforts to fight against climate change is required to maximise the effectiveness of green policies. However, in Carnevali et al. (2020) the exchange rate mechanism was discussed only briefly and no full explanation of its origin and dynamics was given. The present paper aims to fill that gap and to provide a general framework to be used for further research.

6. CONCLUDING REMARKS

In this paper a new, simplified two-county SFC 'benchmark' model with flexible exchange rates (the OPENSIME model) has been presented.

In the OPENSIME model the symmetry in the equations of the two countries is fully respected, even in the treatment of the financial assets supply.

Section 2 is dedicated to the debate on complexity vs simplicity in macroeconomic modelling. The paper makes an argument in favour of simple macroeconomic models as part of a 'pluralistic toolbox' of macroeconomists.

The model is made of 36 equations (presented in section 3), whereas the benchmark OPENNFLEX model by Godley and Lavoie is made of roughly 90 equations.
In fact, the core of the OPENSIME model is made only of 18 equations, given its perfect symmetry and disregarding identical equations across countries. Some of these 18 equations are accounting identities (equations 1-6, 15-16, 23-26, 29-30, 36). At the end, the OPENISIME is made of a handful of fundamental equations, just like similar 'mainstream' textbook models used in undergraduate courses.
The simplified version of the model implies some sacrifices of the building blocks of the original one. Yet the OPENSIME model can carry out the same experiments (on fiscal policy, change in liquidity preferences, and change in the international competitiveness of a country) with which Godley and Lavoie have initially tested their model (in Godley and Lavoie 2007b).
Both models are set in a pure flexible exchange regime. However, the OPENSIME model is based on a different closure than the OPENFLEX.
The specific advantages of the OPENSIME are twofold: 1) The mechanism to determine the exchange rate is 'transparent', because it is directly and explicitly linked to the balance of payments position of a country: the 'new value' of the exchange rate is the one that brings the system to a 'new equilibrium' of the balance of payments. The comprehension of the drivers of the adjustment when a 'disequilibrium' of the external position occurs is very simple. Consequently, the model reveals itself easily 'readable' when it is shocked and allows grasping the economic dynamics which follow straightforwardly. Indeed, as long as the current account position of a country has not settled in a new equilibrium (which must be zero, whereas the trade balance can be negative, positive or zero) the exchange rate is expected to move from period to period. The Harrodian open economy tradition which is implicitly behind the closure of Godley and Lavoie's OPENFLEX model, here is explicitly captured by equation 35.
2) The behaviour of the OPENSIME model is qualitatively the same as the OPENFLEX model presented in Godley and Lavoie (2007 b): same reactions after the same kind of shock (simulations are conducted in section 4). These results are obtained despite a considerable reduction in the number of equations and variables in the OPENSIME model in comparison to the OPENFLEX.

The simplicity and the flexibility of the new benchmark can prove itself very useful both for didactic purposes and to address complex issues from an SFC open economy perspective via the incremental addition of theme-specific building blocks.

Although the code of the model has been developed in *Eviews*, it is simple enough to be easily translated and run with an *Excel* spreadsheet. *Excel* is widely used in educational institutions and this would facilitate further the use of the model.

The paper has also shown an example of this 'modular approach' in Section 5, where a large, ecological SFC model based on the OPENSIME's closure has been presented, with a summary of its policy implications.

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REFERENCES

Álvarez, M. C. Ehnts, D. 2015. 'The Roads Not Taken: Graph Theory and Macroeconomic Regimes in Stock-Flow Consistent Modeling'. *Levy Institute working paper* no. 854, 32 pp.

Berg, M. Hartley, B. and Richters, O. 2015. 'A Stock-Flow Consistent Input-Output Model with Applications to Energy Price Shocks, Interest Rates, and Heat Emissions'. *New journal of physics* 17(1): 1-21.

Bernanke, B. 2016. 'Federal Reserve Policy in an International Context'. *IMF Economic Review* 65(1): 5-36.

Blanchard, O. 2018. 'On the Future of Macroeconomic Models'. *Oxford Review of Economic Policy* 34(1-2): 43-54.

Botta, A. Caverzasi, E. Russo, A. Gallegati, M. Stiglitz, J. E. 2021. 'Inequality and Finance in a Rent Economy'. *Journal of Economic Behavior & Organization* 183: 998-1029.

Bovari, E. Giraud, G. and Mc Isaac, F. 2018. 'Carbon Pricing and Global Warming: A Stock-Flow Consistent Macro-Dynamic Approach'. *AFD Research Papers Series*, No. 2018-65 (January), 29 pp.

Burgess, S. Burrows O. Godin, A. Kinsella, S. and Millard, S. 2016. 'A Dynamic Model of Financial Balances for The United Kingdom'. *Bank of England Staff Working Paper No. 614*, 37 pp.

Cardaci, A., Saraceno, F. 2016. 'Inequality, Financialization and Credit Booms: a Model of Two Crises'. *SEP Working Papers 2016/2*, 26 pp.

Carnevali, E. Deleidi, M. Pariboni, R. Veronese Passarella, M. 2019. 'SFC Dynamic Models: Features, Limitations and Developments'. In P. Arestis and M. Sawyer (eds.): *Frontiers of Heterodox Economics, Series: International Papers in Political Economy*. *16.* Basingstoke (UK) & New York (US): Palgrave Macmillan.

Carnevali, E. Deleidi, M. Pariboni, R. Veronese Passarella, M. 2020. 'Cross-Border Financial Effects of Global Warming in a Two-Area Ecological SFC Model'. *Socio-Economic Planning Sciences*. In Press.

Caverzasi, E. Godin, A. 2015. 'Post-Keynesian Stock-Flow-Consistent Modelling: a Survey'. *Cambridge Journal of Economics* 39(1): 157–87.

Dafermos, Y. Nikolaidi, M. Galanis, G. 2017. 'A Stock-Flow-Fund Ecological Macroeconomic Model'. *Ecological Economics* 131: 191-207.

Dafermos, Y. Nikolaidi, M. Galanis, G. 2018. 'Climate Change, Financial Stability and Monetary Policy'. *Ecological Economics* 152: 219-234.

Ehnts, D. H. 2013. 'Macroeconomic Imbalances in an Open Economy Stock-Flow Consistent Model'. Unpublished manuscript.

Fleming, J. M. 1962. 'Domestic Financial Policies under Fixed and Floating Exchange Rates'. *IMF Staff Papers* 9: 369–379

Godley, W. 1996. 'Money, Finance and National Income Determination: An Integrated Approach'. *Levy Institute Working Paper 167*, 31 pp.

Godley, W. 1999. 'Seven Unsustainable Processes: Medium-Term Prospects and Policies for the United States and the World'. *Levy Institute Strategic Analysis* (January), pp. 28.

Godley, W. and Lavoie, M. 2003. 'Two-Country Stock-Flow Consistent Macroeconomics using a Closed Model within a Dollar Exchange Regime'. *Working paper 10, Cambridge Endowment for Research in Finance*, 33 pp.

Godley, W. and Lavoie, M. 2007a. 'A Simple Model of Three Economies with Two Currencies: The Eurozone and the USA'. *Cambridge Journal of Economics* 31(1): 1-23.

Godley, W. and Lavoie, M. 2007b. *Monetary Economics: an Integrated Approach to Credit, Money, Income, Production and Wealth*. London (UK): Palgrave MacMillan.

Ioannou, S. 2018. 'Sovereign Ratings, Macroeconomic Dynamics, and Fiscal Policy. Interactions within a Stock Flow Consistent Framework'. *Metroeconomica* 69(1): 151-177.

Jackson, T. Victor, P.A. 2015. 'Does Credit Create a 'Growth Imperative? A Quasi-Stationary Economy with Interest-Bearing Debt'. *Ecological Economics.* 120: 32–48.

Jonáš, J. and Komínek, O. 2017. 'Sectoral Balances and Stock-Flow Consistent Models'. *Journal of Economic Integration* 32(3): 689-722.

Lavoie, M. 2015. *Post-Keynesian Economics. New foundations*. Cheltenham (UK): Edward Elgar.

Lavoie, M. and Daigle, G. 2011. 'A Behavioural Finance Model of Exchange Rate Expectations within a Stock-Flow Consistent Framework'. *Metroeconomica* 62(3): 434–458.

Lavoie, M. and J. Zhao. 2010. 'A Study of the Diversification of China's Foreign Reserves within a Three-Country Stock-Flow Consistent Model'. *Metroeconomica* 61(3): 558-592.

Mazier, J. and Valdecantos, S. 2015. 'A Multi-Speed Europe: is it Viable? A Stock-Flow Consistent Approach'. *European Journal of Economics and Economic Policies: Intervention* 12(1): 93–112.

Mazier, J. and Valdecantos, S. 2019. 'From the European Monetary Union to a Euro-Bancor: a Stock-Flow Consistent Assessment'. *European Journal of Economics and Economic Policies: Intervention* 16(1): 8-26.

Mazier, J. Tiou-Tagba Aliti, G. 2012. 'World Imbalances and Macroeconomic Adjustments: a Three-Country Stock-Flow Consistent Model with Fixed or Flexible Prices'. *Metroeconomica* 63(2): 358–388.

Modigliani, F. 1966. 'The Life Cycle Hypothesis of Saving, the Demand for Wealth and the Supply of Capital'. *Social Research* 33(2): 160–217.

Monasterolo, I. and Raberto, M. 2018. 'The EIRIN Flow-of-Funds Behavioural Model of Green Fiscal Policies and Green Sovereign Bonds'. *Ecological Economics* 144: 228-243.

Mundell, R. 1961. 'Flexible Exchange Rates and Employment Policy'. *Canadian Journal of Economics and Political Science* 27(4): 509-517.

Mundell, R. A. 1963. 'Capital Mobility and Stabilization Policy under Fixed and Flexible Exchange Rates'. *Canadian Journal of Economic and Political Science* 29(4): 475-485.

Naqvi, A. 2015. 'Modeling Growth, Distribution, and the Environment in a Stock-Flow Consistent Framework'. *Institute for Ecological Economics Working Paper* 2/2015, 30 pp.

Nikiforos, M. Zezza, G. 2017. 'Stock-Flow-Consistent Macroeconomic Models: a Survey'. *Journal of Economic Surveys* 31(5): 1204-1239.

Tobin, J. 1969, 'A General Equilibrium Approach to Monetary Theory'. *Journal of Money, Credit and Banking* 1(1): pp. 15-29.

Tobin, J. 1982. 'Money and Finance in the Macroeconomic Process'. *Journal of Money, Credit and Banking* 14(2): 171-204.

Veronese Passarella, M. 2019. 'From Abstract to Concrete: Some Tips for Developing an Empirical Stock–Flow Consistent Model'. *European Journal of Economics and Economic Policies: Intervention* 16(1): 55-93.

Wren-Lewis, S. 2018. 'Ending the Microfoundations Hegemony'. *Oxford Review of Economic Policy* 34(1-2): 55-69.

Zezza, G. and Zezza, F. 2019. 'On the Design of Empirical Stock–Flow Consistent Models'. *European Journal of Economics and Economic Policies: Intervention* 16(1): 134-158.

APPENDIX A

Table 1A: OPENSIME balance sheet matrix

	UK Households	UK Firms	UK Government	UK Central Bank		US Households	US Firms	US Government	US Central Bank	Sum
	all in £				Ex. rate	all in \$				
Money	$+H^{£}$			$-H^{£}$		$+H^{\$}$			$-H^{\$}$	0
£ Bills	$+B^{£}_{£}$			$+B^{£}_{cb£}$	$xr^{£}$	$+B^{£}_{\$}\,xr^{£}$				0
\$ Bills	$+B^{\$}_{£}\,xr^{\$}$		$-B^{£}$		$xr^{£}$	$+B^{\$}_{\$}$		$-B^{\$}$	$+B^{\$}_{cb\$}$	0
Balance	$-V^{£}$		$-NW^{£}_{g}$		$xr^{£}$	$-V^{\$}$		$-NW^{£}_{g}$		0
Sum	0		0	0	$xr^{£}$	0		0	0	0

Table 2A: OPENSIME Transactions-Flow Matrix

	UK House.	UK Firms	UK Gov.	UK C.B.		US House.	US Firms	US Gov.	US C. B.	Sum
	all in £				Exch. rate	all in $				
Consumption	$-C^{£}$	$+C^{£}$				$-C^{\$}$	$+C^{\$}$			0
Gov. Expend.		$+G^{£}$	$-G^{£}$				$+G^{\$}$	$-G^{\$}$		0
Trade		$-IM^{£}$			$xr^{£}$		$-IM^{\$}$			0
		$+X^{£}$			$xr^{£}$		$+X^{\$}$			0
GDP/Income	$+Y^{£}$	$-Y^{£}$				$+Y^{£}$	$-Y^{\$}$			0
Taxes	$-T^{£}$		$+T^{£}$			$-T^{\$}$		$+T^{\$}$		0
Interes paym.	$+r^{£}B_{£}^{£}$		$-r^{£}B^{£}$	$+r^{£}B_{cb£}^{£}$	$xr^{£}$	$+r^{£}B_{\$}^{£}xr^{£}$				0
	$+r^{\$}B_{£}^{\$}xr^{\$}$				$xr^{£}$	$+r^{\$}B_{\$}^{\$}$		$-r^{\$}B^{\$}$	$+r^{\$}B_{cb\$}^{\$}$	0
CB profits			$+F_{cb}^{£}$	$-F_{cb}^{£}$				$+F_{cb}^{\$}$	$-F_{cb}^{\$}$	0
Flows of funds (changes in assets)										
Money	$-\Delta H^{£}$			$+\Delta H^{£}$		$-\Delta H^{\$}$			$+\Delta H^{\$}$	0
£ Bills	$-\Delta B_{£}^{£}$		$+\Delta B^{£}$	$-\Delta B_{cb£}^{£}$	$xr^{£}$	$-\Delta B_{\$}^{£}\ xr^{£}$				0
$ Bills	$-\Delta B_{£}^{\$}\ xr^{\$}$				$xr^{£}$	$-\Delta B_{\$}^{\$}$		$+\Delta B^{\$}$	$-\Delta B_{cb\$}^{\$}$	0
Sum	0	0	0	0		0		0	0	0

APPENDIX B

VARIABLES, EQUATIONS AND INITIAL VALUES OF MODEL OPENSIME

Macroeconomic Variables

$YD_r^£$ = Regular disposable income UK
$YD_r^\$$ = Regular disposable income US
$YD_{hs}^£$ = UK households Haig-Simons disposable income
$YD_{hs}^\$$ = US households Haig-Simons disposable income
$V^£$ = UK households' private wealth
$V^\$$ = US households' private wealth
$T^£$ = Taxes paid by UK households
$T^£$ = Taxes paid by US households
$Y^£$ = UK GDP
$Y^\$$ = US GDP
$C^£$ = Value of consumption in the UK
$C^\$$ = Value of consumption in US
$X^£$ = UK exports
$X^\$$ = US exports
$IM^£$ = UK imports
$IM^\$$ = US imports
$B_{£d}^£$= Demand for UK bills by UK households
$B_{£d}^\$$= Demand for US bills by UK households
$B_{\$d}^\$$= Demand for US bills by US households
$B_{\$d}^£$= Demand for UK bills by US households
$H_h^£$ = Money held by UK households
$H_h^\$$ = Money held by US households
$B_{£s}^£$ = UK bills held by UK households
$B_{£s}^\$$ = US bills held by UK households
$B_{\$s}^\$$ = US bills held by US households
$B_{\$s}^£$ = UK bills held by US households
$B_{cb£s}^£$ = UK bills held by UK central bank
$B_{cb\$s}^\$$ = US bills held by US central bank
$H_s^£$ = UK money supply
$H_s^\$$ = US money supply
$F_{cb}^£$ = UK Central Bank's profits
$F_{cb}^\$$ = US Central Bank's profits
$B_s^£$ = UK public debt (total UK bills issued)
$B_s^\$$ = US public debt (total US bills issued)
$xr^£$ = UK exchange rate (value of the pound in US dollars)
$xr^\$$ = US exchange rate (value of the dollar in the UK)

Variables not in the model, but used for the demonstrations in the paper

$CAB^£$ = UK current account balance

$CAB^{£}$ = US current account balance
$FA^{£}$ = UK financial account balance
$FA^{\$}$ = US financial account balance

Exogenous variables

$G^{£}$ = UK government expenditure
$G^{£}$ = UK pure government expenditure
$r^{£}$ = Interest rate on UK bills
$r^{\$}$ = Interest rate on US bills

Model Parameters

$\theta^{£}$ = US Tax rate
$\theta^{\$}$ = US Tax rate
ε_0 = Constant of the UK export equation
ε_1= Elasticity of UK exports with respect to UK exchange rate
ε_2 = Elasticity of UK export with respect to US output
μ_0 = Constant of UK import equation
μ_1 = Elasticity of UK imports with respect to UK exchange rate
μ_2 = Elasticity of UK import with respect to UK output
$\alpha_1^{£}$ = UK propensity to consume out of income
$\alpha_1^{\$}$ = US propensity to consume out of income
$\alpha_2^{£}$ = UK propensity to consume out of wealth
$\alpha_2^{\$}$ = US propensity to consume out of wealth
λ_{ij}= Portfolio equations parameters

Equations of the model

$$YD_r^{£} = Y^{£} + r_{-1}^{£} B_{£s-1}^{£} + r_{-1}^{\$} B_{£s-1}^{\$} xr^{\$} - T^{\$} \quad (1)$$

$$YD_{hs}^{£} = YD_r^{£} + \left(\Delta xr^{\$}\right) B_{£s-1}^{\$} \quad (2)$$

$$\Delta V^{£} = YD_{hs}^{£} - C^{£} \quad (3)$$

$$YD_r^{\$} = Y^{\$} + r_{-1}^{\$} B_{\$s-1}^{\$} + r_{-1}^{£} B_{\$s-1}^{£} xr^{£} - T^{£} \quad (4)$$

$$YD_{hs}^{\$} = YD_r^{\$} + (\Delta xr^{£}) B_{\$s-1}^{£} \quad (5)$$

$$\Delta V^{\$} = YD_{hs}^{\$} - C^{\$} \quad (6)$$

$$T^{£} = \theta^{£}\left(Y^{£} + r_{-1}^{£} B_{£s-1}^{£} + r_{-1}^{\$} B_{£s-1}^{\$} xr^{\$}\right) \quad (7)$$

$$T^{\$} = \theta^{\$}\left(Y^{\$} + r_{-1}^{\$} B_{\$s-1}^{\$} + r_{-1}^{£} B_{£s-1}^{£} xr^{£}\right) \quad (8)$$

$$Y^{£} = C^{£} + G^{£} + X^{£} - IM^{£} \quad (9)$$

$$Y^{\$} = C^{\$} + G^{\$} + X^{\$} - IM^{\$} \quad (10)$$

$$C^{£} = \alpha_1^{£} YD_{hs}^{£} + \alpha_2^{£} V_{-1}^{£} \quad (11)$$

$$C^{\$} = \alpha_1^{\$} YD_{hs}^{\$} + \alpha_2^{\$} V_{-1}^{\$} \quad (12)$$

$$\ln(X^{£}) = \varepsilon_0 - \varepsilon_1 \ln(xr_{-1}^{£}) + \varepsilon_2 \ln(Y^{\$}) \quad (13)$$

$$\ln(IM^{£}) = \mu_0 + \mu_1 \ln(xr_{-1}^{£}) + \mu_2 \ln(Y^{£}) \quad (14)$$

$$X^{\$} = IM^{£} xr^{£} \quad (15)$$

$$IM^{\$} = X^{£} xr^{£} \quad (16)$$

$$B_{£d}^{£} = V^{£}(\lambda_{10} + \lambda_{11} r^{£} - \lambda_{12} r^{\$}) \quad (17)$$

$$B_{£d}^{\$} = V^{£}(\lambda_{20} - \lambda_{21} r^{£} + \lambda_{22} r^{\$}) \quad (18)$$

$$B_{\$d}^{\$} = V^{\$}(\lambda_{40} + \lambda_{41} r^{\$} - \lambda_{42} r^{£}) \quad (19)$$

$$B_{\$d}^{£} = V^{\$}(\lambda_{50} - \lambda_{51} r^{\$} + \lambda_{52} r^{£}) \quad (20)$$

$$H_h^{£} = V^{£} - B_{£s}^{£} - B_{£s}^{\$} xr^{\$} \quad (21)$$

$$H_h^{\$} = V^{\$} - B_{\$s}^{\$} - B_{\$S}^{£} xr^{£} \quad (22)$$

$$B_{£s}^{£} = B_{£d}^{£} \quad (23)$$

$$B_{£s}^{\$} = B_{£d}^{\$} xr^{£} \quad (24)$$

$$B_{\$s}^{\$} = B_{\$d}^{\$} \quad (25)$$

$$B_{\$s}^{£} = B_{\$d}^{£} xr^{\$} \quad (26)$$

$$B_{cb£s}^{£} = B_s^{£} - B_{£s}^{£} - B_{\$s}^{£} \quad (27)$$

$$B_{cb\$s}^{\$} = B_s^{\$} - B_{£s}^{\$} - B_{\$s}^{\$} \quad (28)$$

$$H_s^{£} = B_{cb£s}^{£} \quad (29)$$

$$H_s^{\$} = B_{cb\$s}^{\$} \quad (30)$$

$$F_{cb}^{£} = r_{-1}^{£} B_{cb£s-1}^{£} \quad (31)$$

$$F_{cb}^{\$} = r_{-1}^{\$} B_{cb\$s-1}^{\$} \quad (32)$$

$$\Delta B_s^{£} = G^{£} - T^{£} + r_{-1}^{£} B_{£s-1}^{£} - F_{cb}^{£} \quad (33)$$

$$\Delta B_s^{\$} = G^{\$} - T^{\$} + r_{-1}^{\$} B_{\$s-1}^{\$} - F_{cb}^{\$} \quad (34)$$

$$xr^{\$} = \frac{-X^{£} + IM^{£} + r_{-1}^{£} B_{\$s-1}^{£} - \Delta B_{\$s}^{£}}{r_{-1}^{£} B_{£s-1}^{\$} - \Delta B_{£s}^{\$}} \quad (35)$$

$$xr^{£} = \frac{1}{xr^{\$}} \quad (36)$$

redundant equations:

$$H_h^{£} = H_s^{£} \quad (37)$$

$$H_h^{\$} = H_s^{£} \quad (38)$$

Initial values of stocks

$V^{£} = 0$
$V^{\$} = 0$
$B_{£d}^{£} = 0$
$B_{£d}^{\$} = 0$
$B_{\$d}^{\$} = 0$
$B_{\$d}^{£} = 0$
$B_{£s}^{£} = 0$
$B_{£s}^{\$} = 0$
$B_{\$s}^{\$} = 0$
$B_{\$s}^{£} = 0$
$B_{cb£s}^{£} = 0$
$B_{cb\$s}^{\$} = 0$
$H_s^{£} = 0$
$H_s^{\$} = 0$
$B_s^{£} = 0$
$B_s^{\$} = 0$

Initial values for lagged endogenous variables

$xr^{£} = 1$
$xr^{\$} = 1$

Initial values for exogenous variables

$G^{£} = 16$
$G^{£} = 16$
$r^{£} = 0.03$
$r^{\$} = 0.03$

Model Parameters

$\theta^{£}$ = 0.2
$\theta^{\$}$ = 0.2
ε_0 = -2.1
ε_1= 0.7
ε_2 = 1.228
μ_0 = -2.1
μ_1 = 0.7
μ_2 = 1.228
$\alpha_1^{£}$ = 0.75
$\alpha_1^{\$}$ = 0.75
$\alpha_2^{£}$ = 0.13333
$\alpha_2^{\$}$ = 0.13333
λ_{10}= 0.7
λ_{11}= 5
λ_{12}= 5
λ_{20}= 0.25
λ_{21}= 5
λ_{22}= 5
λ_{40}= 0.7
λ_{41}= 5
λ_{42}= 5
λ_{50}= 0.25
λ_{51}= 5
λ_{52}= 5