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Price mechanism and endogenous productivity in an open economy stock-flow consistent model

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Abstract
This paper combines a Stock-Flow Consistent open economy two-country model with the Verdoorn-Kaldor law, which posits a positive relationship between the rate of growth of output and productivity growth. The model shows the role of endogenous productivity as a shock magnifier and underlines the limits of the mechanisms of adjustment that rely exclusively on the "buffer" provided by flexible exchange rates. It also provides arguments in support of fiscal policy both in the context of flexible exchange rates and fixed exchange rates. Finally, it challenges the sustainability of austerity measures aimed to achieve external balance.

KEYWORDS
balance of payments, countercyclical fiscal policy, productivity, two-country model

JEL CLASSIFICATION
E12; F32; O47

1 | INTRODUCTION

The paper presents an open economy Stock-Flow Consistent (SFC) model within the theoretical framework set by Godley and Lavoie in their book "Monetary Economics: an integrated approach to credit, money, income, production and wealth" (2007).

The methodology is combined with an approach to the study of productivity which is well established in post-Keynesian tradition, but that so far has not been fully integrated into the dynamics of a SFC open economy model. This approach lies on a vision of productivity not as an exogenous factor driven by external technological progress, but as an endogenous product of the process of economic growth, characterized by progressive specialization of labour, increasing returns to scale, processes of "learning by doing" and diffusion of technologies via capital accumulation. The first empirical study on the relationship between the growth of output and growth of productivity was made by the Dutch economist Petrus Johannes Verdoorn (1949). The principle was later reclaimed by Kaldor (1966): hence the name "Verdoorn-Kaldor's law" that is often used to indicate this relationship. However, we can track the very first insight of the principle to Smith (1776), as it is briefly explained in Section 3.

While most of SFC models assume productivity as a constant, the model built in this paper draws on the aforementioned relationship to study the impact of negative shocks on an open economy and the effectiveness of fiscal policy as a possible response by the government. Computer simulations conducted with the model show that the burden of the adjustment cannot rely just on the "buffer" provided by the mechanism of flexible exchange rates and on the convergence to the long-run external equilibrium that this mechanism guarantees. By contrast, fiscal policies can play an important role as countercyclical measures even in the context of an open economy with flexible exchange rates.

The paper is structured as follows: Section 2 presents the "state of the art" in SFC literature on open economy models. Section 3 deals with the current debate about productivity in Western countries and provides a brief story of the relationship between the growth of productivity and the growth of output in economic literature. Section 4 describes the core features of the model (OPENPROD model). It builds on the benchmark OPENFLEX model (Godley & Lavoie, 2007) and includes a new structure of prices. Furthermore, the equations of productivity for both countries are introduced too. In Sections 5–7, three computer simulations are conducted to test the behaviours of the system following a negative shock, such as a fall in export. In Section 5, the outcomes of the new OPENPROD model are compared with the original OPENFLEX model from Godley and Lavoie (2007). In Section 6, the OPENPROD model is examined in the context of fixed exchange rates instead of flexible exchange rates. In Section 7, different policy responses to the shock are analyzed. Finally, Section 8 contains the conclusions. The Appendix includes the complete list of the variables and the equations of the model.

2 | OPEN ECONOMY MODELS IN THE SFC LITERATURE

SFC models are characterized by a very accurate accounting framework which provides complete integration of both the real and the financial side of the economy.

However, these models are far from "hydraulic" macroeconomic models simply based on accounting identities. The consistency of flows, their interplays with stocks of assets and wealth, and the feedback mechanisms, provide only a "general constraint".

SFC models are grounded on behavioural equations which are inspired by the Post-Keynesian school of thought. Consequently, 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. That is why some authors refer to this strand of macro models as "Post-Keynesian Stock-Flow Consistent" (PK-SFC).

The popularity of the SFC approach has risen in recent years. So much that it is emerging as "an important new way of unifying all heterodox macroeconomists" (Lavoie, 2015, p. 264).

This paper cannot provide an overview of the SFC literature, which can be found in excellent recent surveys such as Caverzasi and Godin (2015) and Nikiforos and Zezza (2017). This section only presents a summary of the latest academic studies concerning (theoretical) open economy SFC models.

Much of the insights of the so-called "first generation" (Nikiforos & Zezza, 2017, p. 1221) of open economy SFC models have culminated benchmark model featured in Godley and Lavoie (2007): the "More Advanced Open Economy Model", which is a two-country model with four different closures (or sub-models): OPENFLEX, with flexible exchange rates; OPENFIX, with fixed exchange rates and endogenous foreign reserves; OPENFIXR, with fixed exchange rates and endogenous interest rates; OPENFIXG, with fixed exchange rates and endogenous government expenditure (chapter 12).

Lavoie and Daigle (2011) have integrated some recent contributions of behavioural finance into the OPENFLEX.

Duwicquet et al. (2012) have focused on the lack of adjustment mechanisms in the euro area using a FEER approach (Fundamental Equilibrium Exchange Rate) to estimate the exchange rate misalignments within the eurozone over the period 1994–2011. They also tested via computer simulations the effectiveness of European public investments funded by Eurobonds. Computer simulations showed that both instruments could play a significant role in tackling asymmetrical shocks and rebalancing the disequilibria that have dogged the single currency project so far.

Mazier and Valdecantos (2015) have pushed forward even more radical solutions for the Euro area. They adapted the basic structure of the "More Advanced" model to represent a four-country bloc including the United States, Germany (the surplus country/area in the eurozone), Spain (the deficit country/area in the eurozone) and the "rest of the world". The scenario in which the surplus country has left the eurozone showed the best performance in computer simulations "compared to a pure fiscal union or a scenario in which Germany finances the bail-out of the deficit countries" (Mazier & Valdecantos, 2015, p. 108).

Imbalances at a world level have been studied by Mazier and Aliti (2012) in a SFC three-country model including three blocs: the United States, the Eurozone and China. It drew on an earlier model developed by Lavoie and Zhao (2010). The authors confirmed the results of Lavoie and Zhao's paper about the negative impact on the eurozone of a strategy of diversification of reserves potentially undertaken by the People's Bank of China in favour of assets denominated in euros.

Valdecantos and Zezza (2015) have developed a model with four blocs—the United States, the Eurozone, China and the "rest of the world"—to investigate the original proposal by John Maynard Keynes for a post-Second World War international monetary system based on the introduction of a new "international currency", the *Bancor*, to be used as means of payment and international reserve.

The effects of Keynes' plan on the European Monetary Union have been tested also by Mazier and Valdecantos (2019), who have developed their previous four-country SFC model (Mazier & Valdecantos, 2015) for this purpose. Their simulation experiments suggested that "the implementation of Keynes" ideas may conduct European countries to a stronger and more sustainable growth cycle' (Mazier & Valdecantos, 2019, p. 8).

Ioannou (2018) has used a SFC open economy model to study the impact of the assessments of the Credit Rating Agencies (CRA) on the dynamic of a recessionary shock.

One of the most recent developments of this strand of academic literature is represented by the use of SFC open economy models to address topics like green finance and climate change. Carnevali, Deleidi, Pariboni, and Veronese Passarella (2019) have built a prototype which introduces the ecosystem into a simplified two-country model. A more advanced two-county model is used in Carnevali, Deleidi, Pariboni, and Veronese Passarella (2020) to analyze the cross-border financial effects of global warming both in a context of flexible exchange rates and in a fixed exchange rates regime.

3 | TOWARDS A MODEL WITH ENDOGENOUS PRODUCTIVITY

The New York Times has recently ranked productivity among the big economic "challenges of our age" (Irwin, May the 26th 2017).

"Productivity puzzles" was also the title of a speech given by Andrew Haldane, chief economist of the Bank of England, at the London School of Economics on May 2017. Haldane borrowed an expression already used in several academic papers (Barnett, Batten, Chiu, Franklin & Sebastia-Barriel, 2014; Barnett, Broadbent, Franklin, & Miller, 2014; Weale, 2014), to introduce "a tale of productivity disappointment, in forecasting and in performance" that "has been extensively debated and analysed over recent years" (Haldane, 2017). Even the (former) President of the European Central Bank, Mario Draghi, has often pointed to productivity as the "culprit" of the unbalances between deficit and surplus countries which have been at the centre of the European sovereign debt crisis (Draghi, 2013, 2014).

Actually, countless examples could be given of the growing attention towards productivity and its determinants that have involved institutions, policymakers and academic scholars in recent years.

In the same context, a revival of empirical studies on the so-called Verdoorn-Kaldor law (Kaldor, 1966; Verdoorn, 1949, 1980) has occurred. In a nutshell, the law links productivity with aggregate demand and scale of production.

The main idea behind this approach dates back to the founder father of political economy, Adam Smith. The division of labour was at the core of the analysis of the "Wealth of Nations" (1776). Productivity—or the "powers of labour", if one wants to recall the original expression used by Smith—was considered the outcome of a more and more sophisticated division of labour and specialization. Yet, the precondition for this process of specialization to take place was the actual possibility of selling the growing quantities of homogenous goods that would be produced: ultimately, the "extent of the market" could be identified as the real determinant of the powers of labour:

"As it is the power of exchanging that gives occasion to the division of labour, so the extent of this division must always be limited by the extent of that power, or, in other words, by the extent of the market. When the market is very small, no person can have any encouragement to dedicate himself entirely to one employment, for want of the power to exchange all that surplus part of the produce of his own labour, which is over and above his own consumption, for such parts of the produce of other men's labour as he has occasion for". (Smith, 1776, p. 121).

The debate on productivity has also been encouraged by a parallel controversy on the policy responses to the Great Recession of 2007–2008 and on the austerity measures that have been implemented in Europe following the sovereign debt crisis.

For many policymakers—especially in central-northern Europe—the best way to rebalance economies affected by government and external deficits was to cut public expenditure and increase taxes. In their vision, economic growth should rely on improvements in productivity, which would make the production system more competitive. Higher levels of productivity could be achieved via the "liberalisation" of labour markets and the corrective power of competition among workers that would follow.

On the other side of the argument, there have been scholars who have pointed out that the disappointing trajectory of productivity in many advanced countries could be the *product* of struggling economies rather than the *cause* of the crisis and the *vindication* of austerity measures. The growing attention towards ideas like the aforementioned Verdoorn-Kaldor law is perfectly in line with this alternative vision. Paolo Sylos Labini's equation of productivity (Sylos Labini, 1984, 1995) and the abundant research related to it also belongs to the same trend. Sylos tried to integrate the principle of the Verdoorn-Kaldor's law with technological innovation and cost of labour; in recent years several empirical studies have provided new evidence to his theory (see, for instance, Carnevali, Godin, Lucarelli, & Veronese Passarella, 2020; Corsi & D'Ippoliti, 2013; Guarini, 2007, 2009).

The idea of "endogenous productivity", namely the idea that the productivity is at the same time a trigger and a *product* of economic development, is a concept that cannot be confined just in a particular school of economic thought.

In the aftermath of the Second World War, growth models developed within the so-called neoclassical synthesis were dominated by the idea of exogenous technological progress (Solow, 1956; Swan, 1956). Neoclassical theory parted company with this way of modelling technological progress when it started to "endogenise" technical changes in the new generation of endogenous growth models: increasing return to scale can be the outcome of externalities linked with capital accumulation (Romer, 1986) and with the investments in research and development and in education that accompany the process of economic growth (Lucas, 1988; Romer, 1990).

However—as explained by Magacho and McCombie in a recent paper about the empirical evidence of Verdoorn's law—even in the new scheme "productivity growth is ultimately constrained by the growth of the supply side and, in these models, the latter is determined exogenously" (Magacho & McCombie, 2017, p. 2; see also Dutt, 2006; McCombie, 2002).

An alternative "tradition" which has looked at the evolution of productivity as an essential feature of the process of economic growth can be identified from a Keynesian-Kaldorian perspective. The starting point of what has been subsequently labelled as the Verdoorn-Kaldor's law was an article written by the Dutch economist Petrus J. Verdoorn and published in 1949 in the Italian journal *L'Industria* (the original title was: "Fattori che regolano lo sviluppo della produttività del lavoro"—"Factors which determine the development of labour productivity"[1]). Verdoorn used statistical data of the period 1870–1930 (available for a series of industrial countries such as the United Kingdom, the United States, Germany, Italy, Japan) to estimate the elasticity of labour productivity with respect to industrial production. The average value found was 0.45 (in a log-log equation). The Dutch economist explained the relationship via the "increased level of labour specialisation that is prompted by a higher level of industrial production"; at the same time "the expansion of the production creates the opportunity of further rationalisation via the effect of increased mechanisation"[2] (Verdoorn, 1949). As it is evident, the argument was very similar to the one proposed by Smith in the quotation reported previously in this section.

It is true that—as Anthony Philip Thirlwall pointed out—"nowadays, most economists like to think of the Verdoorn relationship in more 'dynamic' terms related to the extent to which capital accumulation is induced by output growth and technical progress is embodied in capital (as well as 'learning by doing')" (in McCombie, Pugno, & Soro, 2002, p. X). Yet, not only Verdoorn's main intuition remains still valid, but also the empirical estimation of the coefficient he proposed in his 1949 article (around 0.5) has been substantially confirmed via several different econometric techniques in a very large number of successive empirical studies on data across countries, across regions within a single country, across branches of industries within a single country, across branches of industries across countries, across branches of industries across regions (for examples of recent research see Alexiadis & Tsagdis, 2010; Fazio, Maltese, & Piacentino, 2013; Magacho & McCombie, 2017; Millemaci & Ofria, 2014, 2016).

Despite the long-lasting popularity of the Verdoorn's law and the blossoming literature it has generated, few economists noticed that contribution just after the publication of the original article. We owe to Kaldor—who had worked with Verdoorn at the Research and Planning Division of the Economic Commission for Europe in Geneva—the "re-discovery" of this relationship. In his famous inaugural lecture held in Cambridge on November the 2nd 1966 and entitled "Causes of the Slow Rate of Economic Growth of the United Kingdom" (Kaldor, 1966), Kaldor set the Verdoorn law at the centre of his diagnosis of British economic malaise. From this moment onwards the law, rebranded as Verdoorn-Kaldor law or Kaldor's "second law", gathered increasing attention in the debate about productivity and economic growth.

[1]My translation from Italian.

[2]My translation from Italian.

Stock-Flow Consistent models developed so far have mainly assumed productivity as constant (or as characterized by a fixed, exogenous rate of growth: see, for instance, the growth model prototype in chapter 11 of Godley & Lavoie, 2007). One of the few exceptions is Mazier and Aliti (2012): a version of the model presented in that paper featured an equation of productivity in line with the Verdoorn-Kaldor law. However, the implications of this specific choice were not discussed in that work, which was mainly focused on the effects and implications of different exchange rates regimes (see also Section 2).

This paper tries to fill the gap. On the one hand a realistic representation of an open economy cannot overlook proper scrutiny of productivity and its effects on the competitiveness of a country. On the other hand, the relationship discovered by Verdoorn could "benefit" from being part of a broader "network" of equations with the aim of offering an effective account of the dynamics of a modern, open economic system.

4 | THE OPENPROD MODEL

The OPENPROD model presented in this paper is a development of the "More Advanced open economy model" described in Godley and Lavoie (2007).[3] The changes in the model required by the analysis of the new topic have been focused on a limited number of equations rather than on its assets' structure. Therefore, the new model can easily rely on the matrices of the original OPENFLEX model that are featured in the Appendix (Tables A1 and A2).

The OPENFLEX model consists of a system of two countries. Godley and Lavoie named them as the United States and the United Kingdom. For sake of continuity of the notation—and to provide some "historical narrative" to the experiments (in particular for experiment 2)—the same denomination will be kept here too.

In this simplified economy, goods are produced without fixed capital and there are no inventories. The equivalence between the supply and demand of goods is guaranteed via a so-called "quantity adjustment mechanism" (Godley & Lavoie, 2007, p. 65): the driver of the level of production is the

[3]The code of the benchmark OPENFLEX model and of the computer simulations shown in Godley and Lavoie (2007) can be found here: http://gennaro.zezza.it/software/eviews/gl2006.php. This is a "translation" in *Eviews* made by Gennaro Zezza of the original code written by Godley in *Modler*. "Zezza's code" was "officially endorsed" by Godley and Lavoie in the preface of their book. It has been used as the base of the OPENPROD model too. However, some typos have been corrected. Equations (12.1) and (12.4) (regular nominal disposable income in the United Kingdom and United States) refer in fact to the Haig-Simons nominal income since capital gains are added. This implies that the equations of Haig-Simons nominal income (12.2 and 12.5) end up to be wrong, because they take into account capital gains twice.

Equation 12.25 includes current relative prices instead of prices with one lag. In the OPENPROD model the original formula of the book (OPENFLEX 12.25 with lags) has been reinstated to compare the new model with the original OPENFLEX model.

The "paper version" of the model presented in Godley and Lavoie's book contains some other typos. The "residual variables" of the portfolio equations should not be the demand for money (H_d) (see Equations OPENFLEX 12.79 and 12.72 in the book)—but the *actual holding of money*. This hypothesis is validated by Equations OPENFLEX 12.77 and 12.80, which match the supply of money (H_s) with households' money holding (H_h). Without this amendment, the model *would not close*, and it *would not run,* since there would not be any equation determining H_h. The "official code" is not affected by the typo because equations 12.77 and 12.80 are modified so that on the right-hand side the demand for money appear.

In the code of the OPENPROD model it has been preferred to scrap the variable H_d—and to use H_h—to make more transparent the "residual nature" of the balance of money.

aggregate demand and firms can satisfy whichever level of demand coming from the consumers. In other words, there are no supply constraints.

Each country comprises three sectors: households, firms and government (the latter including the central bank). Given the fact that there are no capital goods or inventories, firms do not need to borrow and there is no bank sector and credit money.

The governments finance their budget deficits issuing short-term obligations (bills), which can be purchased by households and yield an interest. Their price is fixed at one unit of the country's currency (a price that does not change during the duration of a bill's life, which is assumed to be one period).

Households of each country hold bills denominated both in their own currency and in the foreign currency. By contrast, they keep only cash in domestic currency.

A list with all the variables (and the corresponding symbols) used in the paper—together with all the equations of the OPENPROD model—is included in the Appendix. With respect to the notation, two conventions must be born in mind: (a) quotations of exchange rates are always in indirect, or "European", terms (the sterling exchange rate, $xr^{£}$, defines how many dollars can be bought with one pound); (b) The superscript of a variable always denotes the country which issued the asset (i.e., \$ for United States and £ for the United Kingdom). The subscript, the country where the asset is held. Assets are always denominated in the currency of the country which issued them. The only exception to this rule is given by the demand of assets, which is denominated in the currency of the country of the agent that expresses that demand.

The OPENPROD model builds on the OPENFLEX model[4] to take into account the productivity as an "endogenous" variable of the system and to study the consequences of this change on the dynamics of the economy.

Intuitively it is not difficult to argue that a higher level of productivity—given a specific value of the exchange rate—will allow a country to produce with lower costs; the prices of its "homemade" goods will be lower and the country will be more competitive. Its trade balance will improve.

The following equation makes use of a simple mark-up rule on unit costs to represent price level of the goods "made in Britain" or "made in USA" ($p^{£}_{madeUK}$; from now on, only the equations of the United Kingdom will be shown since the United States ones follow by symmetry):

$$p^{£}_{madeUK} = \left(1+\varphi^{£}\right) UC^{£} = \left(1+\varphi^{£}\right) \frac{W^{£}N^{£}}{y^{£}} = \left(1+\varphi^{£}\right) \frac{W^{£}N^{£}}{s^{£}-im^{\$}} \tag{41}$$

From Equation (41)[5] it is possible to calculate a weighted average of the price of all sales by merely summing up the price of made in Britain goods (multiplied by the share of made in Britain goods on the total of sales), the price of imported goods (multiplied by the share of imported goods on the total

[4]Of course, the reference here is to the "amended version" of the OPENFLEX model as described in note 4, meaning once that all the typos have been fixed. The "amended benchmark" is made of 82 equations and 82 unknowns. According to the equations' numbering in Godley and Lavoie (2007), the OPENFLEX model should have 91 equations. Yet there are some gaps in the numbering (Equations OPENFLEX 12.73 and 12.74 do not exist); furthermore, some equations have just a "definition function" such as the ones for the expected changes in the exchange rates, which are assumed to be zero to simplify the model (equations OPENFLEX 12.75 and 12.76 are consequently dropped in the simulations presented in http://gennariozezza.it/software/eviews/gl2006.php). Equation OPENFLEX 12.91Fl merely defines the reserves denominated in dollars held by the U.K. central bank as a constant: it is better to classify it as an exogenous variable (as the "official code" does). Equations OPENFLEX 12.9, 12.10, 12.63A and 12.64A refer to the same unknowns respectively of Equations 12.53, 12.54, 12.7 and 12.8: they must be dropped. After the new calculation, the total of equations ends up to be 82 (=91–9).

[5]The equation numbering in the paper follows the numbering of the complete list of equations featured in the Appendix.

of sales) and the price of exported good (multiplied by the share of exported goods on the total of sales):

$$p_s^{£} = p_{madeUK}^{£} * \left(\frac{s^{£} - im^{£} - x^{£}}{s^{£}}\right) + p_m^{£} * \left(\frac{im^{£}}{s^{£}}\right) + p_x^{£} * \left(\frac{x^{£}}{s^{£}}\right) \tag{43}$$

Equation (43) differs from the one proposed by Godley and Lavoie, namely OPENFLEX 12.45:

$$p_s^{£} = \frac{\left(1+\varphi^{£}\right) * (W^{£}N^{£} + IM^{£})}{s^{£}} \text{ (OPENFLEX 12.45)}$$

OPENFLEX 12.45, whose dependent variables enters many other equations, does not takes into account that the "made in Britain" goods are not sold abroad at their original price. Export prices are influenced by several factors. In the OPENFLEX model (as in the OPENPROD), it is assumed they are affected by the exchange rate, the domestic inflation, the domestic inflation of the country which is importing and the exchange rate pass-through coefficient to export prices. That is why export should be considered separately in the equation of sales' prices.

Not only is Equation (41) useful to determine the price level of all sales (via Equation 43), but it also appears to be a more effective indicator of the homemade products' inflation than the deflator of the GDP. The latter is the variable used by Godley and Lavoie as a measure of changes in domestic prices and it is included in import and export price Equations (OPENFLEX 12.21 and 12.22). That represents a quite standard approach. However, the GDP deflator is obtained by dividing nominal GDP (nominal export included) by real GDP (real export included). Since it takes into account exported goods and their prices—which are affected, as we have just seen, by many other factors, like the exchange rate—it is not a measure of the absolute and "original" competitiveness of the economy as accurate as the "original price" of made in Britain goods is. When the deflator of GDP is used in OPENFLEX 12.21 and 12.22, the impact of the exchange rate is actually inputted *two times*, and the parameters of the equations run the risk of losing any empirical and even any logical link with what they are supposed to represent.

The same reasoning could be applied to equations of import and export volumes (OPENFLEX 12.25 and 12.26).

For all these reasons, the OPENPROD model gets rid of the deflators of GDP (Equations OPENFLEX 12.57 and 12.58 are dropped) and in their place it uses the price level of the made in United Kingdom and made in U.S. goods ($p_{madeUK}^{£}$ and $p_{madeUS}^{£}$). Therefore, Equations OPENFLEX 12.21, 12.22, 12.25 and 12.26 are replaced by the following:

$$log(p_m^{£}) = v_0 - v_1 \log(xr^{£}) + \left(1 - v_1\right) \log\left(p_{madeUK}^{£}\right) + v_1 \log\left(p_{madeUS}^{\$}\right) \tag{17}$$

$$log\left(p_x^{£}\right) = u_0 - u_1 \log\left(xr^{£}\right) + \left(1 - u_1\right) \log\left(p_{madeUK}^{£}\right) + u_1 \log\left(p_{madeUS}^{\$}\right) \tag{18}$$

$$log(x^{£}) = \varepsilon_0 - \varepsilon_1 \left(\log\left(\frac{p_{m-1}^{\$}}{p_{madeUS-1}^{\$}}\right)\right) + \varepsilon_2 \log\left(y^{\$}\right) \tag{19}$$

$$log(im^{£}) = \mu_0 - \mu_1 \left(\log\left(\frac{p_{m-1}^{£}}{p_{madeUK-1}^{£}}\right)\right) + \mu_{2\log}\left(y^{£}\right) \tag{20}$$

The parameters of Equations (17)–(20) in the OPENPROD model are set in accordance with the condition that assures so that the trade balance would improve following a devaluation of the currency[6] (Carnevali, Fontana, & Veronese Passarella, 2020; Lavoie, 2015).

Once that it has been identified a price variable ($p^{£}_{madeUK}$) directly affected by changes in costs of production, but not by changes in the exchange rate,[7] the problem of productivity can be addressed too. Indeed, now it is possible to study how a change in productivity can influence the "basic competitiveness" of a country which depends on the "real" conditions of production and not on the value of the domestic currency.

In the OPENPROD model, the productivity is an endogenous variable of the system and it is determined via the Verdoorn-Kaldor law:

$$\log(pr^{£}) = prbase + sm * \log\left(y^{£}_{-1}\right) \tag{61}$$

sm is the so-called Smith parameter, which set the sensitivity of productivity with respect to real GDP, being the latter a measure of the size of the economy; *prbase* is a constant.

Equation (61)—which sets the real output as the "right-hand side" variable and the productivity as the "left-hand side variable"—captures the primary causal relationship between y and pr as the theorists of Kaldor-Verdoorn's law hypothesize it. Then, the value of productivity affects the level of internal prices via Equation (41) (and its equivalent for the United States). Indeed, Equation (41) contains the variable N which expresses the level of employment; N itself is given by the real output divided by productivity (OPENFLEX 12.65 and OPENFLEX 12.66). When a higher level of output prompts a higher level of productivity, the costs for every unit of product fall. If the mark-up is fixed—$\left(1+\varphi^{£}\right)$ in Equation (41)—the drop of unit costs implies a decrease in the price level of "homemade goods" and therefore, an improvement of the competitiveness of a country.

Note that the output enters Equation (61) with a one period (year) lag. This is to account for the long-term relationship between the two variables. There is also a short-term relationship between output and productivity. In a downturn, firms may be reluctant to make workers redundant, first of all not to lose their "knowhow"; productivity will fall as less output is produced with the same number of workers. During an upswing, firms may be reluctant to hire new workers until they are sure that the higher level of demand is going to last; productivity could rise, as more output is produced with the same number of workers. However, if prices are assumed to be sticky in the very short-run, these changes in productivity will mainly affect the level of the mark-up. The OPENPROD model—as the OPENFLEX model—represents a pure labour economy, which does not account for different consumption behaviours between wage recipients and profit recipients. A change in the distribution of income between profits and wages would not impact the dynamics of the system. That is why the short-term relationship between output and productivity has not been properly embedded in the system of equations. And that is why the assumption of "rigid wages" included in the OPENFLEX model has been kept also in the OPENPROD model. More generally, distributional issues are not addressed in the paper. We acknowledge this can be regarded as a limitation of the model. The choice aims to avoid the addition of further complexity to the model and to the analysis of the experiments carried out with it.

[6] $\varepsilon_1\left(1-u_1\right)+\mu_1 v_1 > v_1 - u_1$. More precisely, the actual values of the parameters of the model used for the simulations in the second part of this chapter are: 0.7*(1 − 0.5) + 0.7*0.7 > 0.7 − 0.5. This implies 0.84 > 0.2: the condition holds.

[7] In spite of its more complex price structure, the OPENPROD model retains some of the simplifying assumptions of the OPENFLEX model: the production is carried out by labour alone with no fixed or working capital and no intermediate costs of production. Therefore, the exchange rate can affect the price of imported goods, but the latter cannot affect the cost of production.

5 | COMPUTER SIMULATION, EXPERIMENT 1. A COMPARISON BETWEEN OPENPROD AND OPENFLEX MODELS

In the following sections, the main characteristics of the OPENPROD model are analyzed via computer simulations.

As the purpose of this research is mainly theoretical, the values of the parameters and exogenous variables that OPENPROD shares with OPENFLEX are borrowed from the original model. The elasticity of productivity with respect to output (*sm*) is set at the original value estimated by Verdoorn (0.45). The constant of the productivity equation (*prbase*) is set at a level which allows the equation to returns an initial level of productivity (1.286143) pretty close to the constant used in the original OPENFLEX model (1.3333). However, far from being a purely "symbolic homage" to Verdoorn, *sm* roughly reflects the empirical evidence on the "Smith effect" that can be found in the most recent literature (Carnevali, Godin, Lucarelli, & Veronese Passarella, 2020; Magacho & McCombie, 2017). Indeed, as it has been already said in Section 3, recent estimates tend to confirm the first estimate made by Verdoorn, who noted that a change in the volume of production by 10% tends to be followed by an average increase of the productivity of nearly 4.5% (Verdoorn, 1949). Given the fact that productivity is expressed via a log-log specification (see Equation 61), that is exactly the effect produced by the OPENPROD model.

All the experiments are conducted starting from the stationary state of the OPENPROD model, which is very similar to the "original stationary state" reached by the OPENFLEX model (for instance real GDP of the United Kingdom in 1952 is 97.3918 in the OPENFLEX model and is 97.3972 in the OPENPROD). This simplifies—when needed—the comparison between the behaviour of the two models.

The first experiment consists in a step fall in U.K. exports. The shock takes the form of a change in the constant ε_0 of Equation (19). Factors like the costs of production are already encompassed in the price level of made in Britain goods—which affects British export prices and consequently United States import prices; therefore, ε_0 can be considered as a "residual variable" that captures all the other characteristics of an economic system responsible for the international competitiveness of an economy: for example, the reputation of its brands, the quality of its products, but also the tariff regime that the system faces. Therefore, shocks to the parameter ε_0 can take the form, for instance, of a scandal that engulfs a domestic firm/industry or tariffs that are imposed against a country/sector.

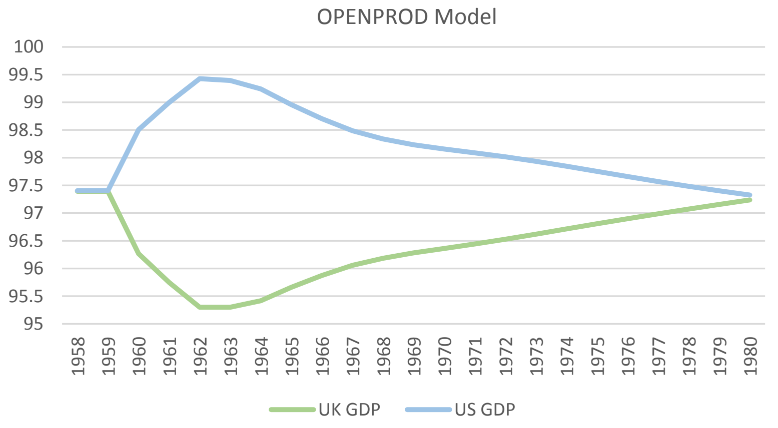
Experiment 1 simulates the scenario in which the United Kingdom suffers a drop in ε_0 from −2.1 to −2.2 (since 1960 onwards ε_0).

Graph 1 shows the U.K. and U.S. GDP following the shock. As it is evident, while British GDP plunges, a symmetrical gain is experienced by the U.S. total income. Indeed, a lower level of U.K. export means an equivalent decrease of U.S. import: American consumers redirect their consumption patterns towards made in USA goods and this boosts the American economy. What is striking in Graph 1 is the steepness of the British economy downturn (and consequently of the American boom).

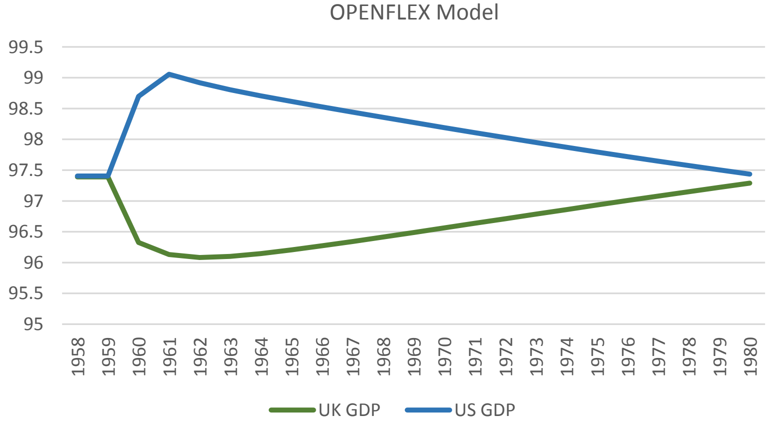
If an identical shock is triggered in the OPENFLEX model the effect on the GDP of the two countries is far less marked.

In Graph 2, U.K. GDP never goes beneath 96 and U.S. GDP barely overcomes 99.

The reason for the discrepancy between the models lies in the role played by the endogenous productivity, which widens the scale of the fluctuation in the OPENPROD model. When the U.K. "propensity to export" drops, British economy shrinks. (Labour) productivity decreases and costs of production increase (Graph 3 and 4). This results in higher prices for made in Britain goods and higher prices for U.K. exports, despite the fact that price variables enter import and export equations with a one-period lag. The lag accounts for the so-called "J-Curve effect".



GRAPH 1 U.S. and U.K. GDP following a step fall in the U.K. export (OPENPROD model) [Colour figure can be viewed at wileyonlinelibrary.com]

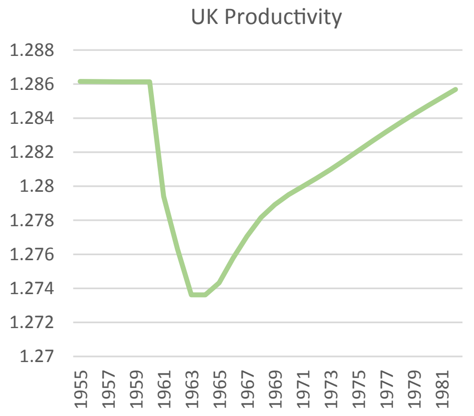


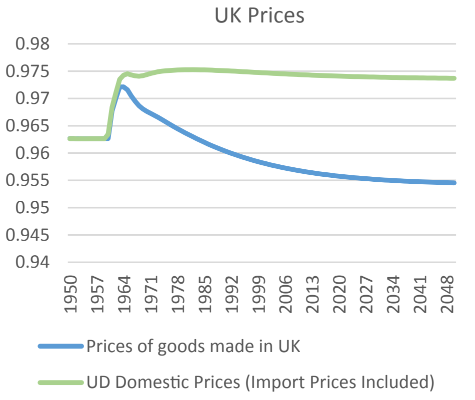
GRAPH 2 U.S. and U.K. GDP following a step fall in the U.K. exports (OPENFLEX model) [Colour figure can be viewed at wileyonlinelibrary.com]

While in the OPENFLEX model British exports rebound quickly and stem the recession thanks to the fall in the value of the pound, in the OPENPROD model the positive effect of the devaluation of the currency on U.S. import prices is partially offset by the increase in the "basic price" of U.K. "homemade" goods due to this loss of productivity. U.K. export is also undermined by the decrease in the price level of American goods which is linked to the productivity gains enjoyed by the United States.

In the meantime, U.K. import decreases due to the increase in import prices caused by the devaluation of the pound. However, since the "basic prices" of U.S. goods are decreasing too, the drop in U.K. export outpaces the drop in U.K. import, notwithstanding the dip in U.K. GDP, which should help to reduce import. U.K. trade balance and current account balance record a wide deficit position.

In addition, higher inflation of domestic prices in the United Kingdom undermines real disposable income and real wealth of households, despite capital gains associated with the devaluation of the currency: as a result, United Kingdom overall consumption dips in the periods following the shock.





GRAPH 3 AND 4 Productivity in the United Kingdom following a step fall in the U.K. exports; Prices of made in Britain goods and U.K. domestic prices following a step fall in the U.K. exports (OPENPROD model) [Colour figure can be viewed at wileyonlinelibrary.com]

Experiment 1 shows that a system with endogenous productivity is more unstable than a system with exogenous productivity. When an exogenous shock hits the economy, the effects of the shock are magnified by the fact that the recession affects productivity and the latter deepens the recession. This result is less trivial then it appears at first sight. In fact, alternative scenarios could *in theory* be envisaged within the framework of the model. Here is an example: lower productivity means higher "homemade goods" prices, which mean larger current account deficits, which in turn mean steeper depreciation of the currency. Greater capital gains follow and therefore, greater (Haig-Simons) disposable income, wealth and consumption. Only via computer simulations is possible to put together the multiple forces at play in the model and verify which are the prevailing ones, as far as the results are not dependent on a particular set of ad hoc parameters. That is why the results of experiment 1 presented above have been checked against different parameters which imply a higher propensity to consume out of Haig-Simons disposable income and wealth, higher price elasticity of import and export and higher pass-through from exchange rate to import and export prices. In all these cases, the negative impact of the shock is higher in the model with endogenous productivity than in the original OPENFLEX model (see the Appendix at the end of the chapter).

The outcome shown by OPENPROD model can have significant consequences on the debate on how public institutions should react to an external shock similar to the one described in experiment 1. In the next sections, the topic will be analyzed with the use of two slightly different versions of the OPENPROD model.

6 | COMPUTER SIMULATION, EXPERIMENT 2. OPENPROD MODEL WITH FIXED EXCHANGE RATES

In the scenario described by experiment 1, the drop of ε_0 generates a severe recession in the U.K. (GDP slumps by over 2% two periods after the shock). An even more dramatic crisis can be observed in case of a fixed exchange rate between the two countries. The recovery in experiment 1 is activated and pushed forward by two factors: the devaluation of the pound, which helps export to recover, restricts U.K. import and sustains British incomes with capital gains on American securities denominated in dollars and held by U.K. households; and the growing level of productivity following the first bounce of recovery prompted by the devaluation. This virtuous circle cannot take place in the context of fixed exchange rates. Some other mechanisms must lead the system to a stable solution where the current account balance is back to zero (as no country is assumed to have an infinite amount of international reserves, no country can run a current account deficit forever[8]).

Austerity measures can be one of the responses deployed by the deficit country's institutions to tackle this kind of balance of payment crisis. And from a historical point of view, this has actually been one of the major tools used by British governments to deal with the problem in the "Bretton Woods era".

For instance, the Labour government led by Harold Wilson in the Sixties tried to rebalance the British current account deficit with increases in taxes and temporary import surcharge. Yet, eventually, on November the 18th 1967, it had to resort to the devaluation of the pound: the scale of the adjustment needed to rebalance the external position of the country turned out to be far greater than expected. The sacrifices in terms of GDP would have been too high to be imposed, especially by a Labour government.

Experiment 2 helps to shed light on this issue. The OPENPROD model has been adapted to a system with fixed exchange rates, following the closure of the OPENFIXG model presented in Godley and Lavoie (2007). This closure assumes that the U.K. government funds itself only with bills it is able to sell in capital markets (U.K. central bank does not operate as a lender of last resort). In case of a shock similar to the one presented in experiment 1, U.K. private wealth slumps due to consumption overcoming income. A lower level of U.K. bills is demanded by U.K. households. U.S. households may buy more U.K. bills, but they cannot offset the disinvestment of U.K. private sector insofar as the propensity to buy foreign bills is lower than the propensity to buy domestic bills. Therefore, the British government's real expenditure decreases. This helps to rebalance the current account deficit, but the result comes with a high price: a much lower level of GDP both in the short and in the long-run.

Graph 5 allows comparing the behaviour of the OPENPROD and the OPENFIXG model following a drop in U.K. export since 1960 onwards (like in experiment 1, ε_0 is lowered by 0.1 and set at -2.2).

The consequences of the crisis are much graver in the model with endogenous productivity. Not only is the dip in the GDP figures much steeper, but even the long-run stationary state is at a lower level. The simulation confirms that if the effects of a recession on productivity are taken into account, the sacrifice in terms of GDP which a country has to undergo if it wants to rebalance its external position is much higher than expected given a model with exogenous and fixed productivity. This could help to explain why, for instance, the Labour government in the Sixties had to give up the strategy of an adjustment conducted via austerity measures and resorted to a devaluation of the pound. At the end of the decade, British current account was back in surplus.

The following graph shows the consequences of a devaluation of the currency the year after the shock in U.K. exports.[9] In 1967, the pound is devalued by 14% against the U.S. dollar, exactly the

[8]Naturally, an inflow of capitals from abroad can offset the deficit in the current account. However, that cannot be considered a 'structural' solution, in particular if one gets rid of the assumption of perfect asset substitutability. The exceptional role of the dollar as a global reserve currency and the related privilege enjoyed by the United States in managing their current account deficit, is not considered here.

[9]This time the shock is triggered in 1966.

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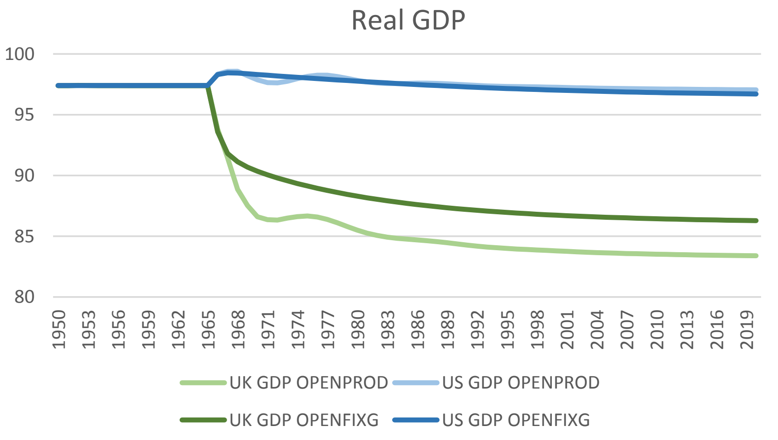
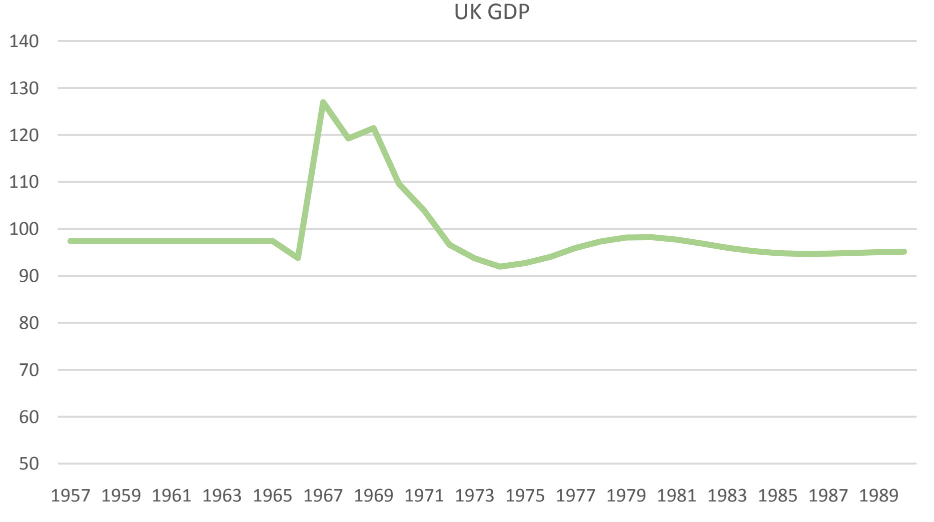


GRAPH 5 U.S. and U.K. GDP following a step fall in the U.K. exports (OPENPROD and OPENFIXG model) [Colour figure can be viewed at wileyonlinelibrary.com]

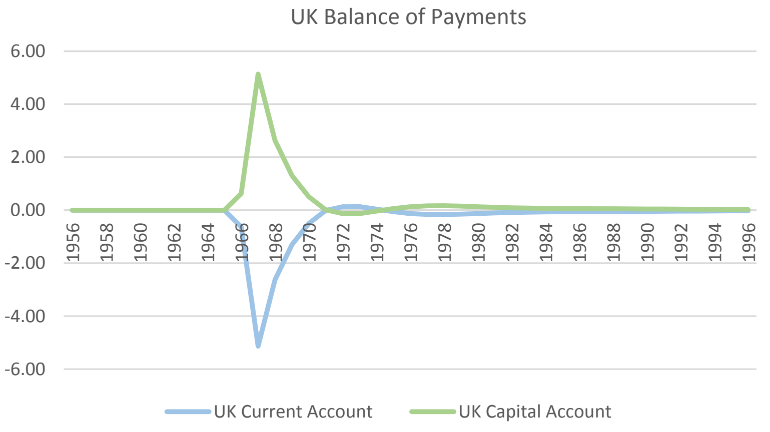


GRAPH 6 U.K. GDP following a step fall in the U.K. exports in 1966 and the devaluation of the pound in 1967 [Colour figure can be viewed at wileyonlinelibrary.com]

same amount of the “actual” devaluation announced by Wilson with his famous “pound in your pocket” speech.[10]

[10]The size of the change in the exchange rate has been chosen just to provide a “historical narrative” to the experiment. However, it is necessary to bear in mind that the initial values of the variables of the model *do not* represent real historical values. Furthermore, it is evident that the parameters of the original version of the OPENFIXR model tend to overestimate the effect of capital gains on consumption: this leads to unrealistic values of the GDP immediately after the devaluation of the currency (it is worth to notice that picture 12.4B of Godley and Lavoie (2007) has the wrong values on the vertical axes. The real values are far higher and as unrealistic as the one that results from the simulation with the OPENPROD model shown below).

Said that, the simulation can help to grasp what Wilson's government tried to achieve via its intervention on the value of the currency.



GRAPH 7 U.K. Balance of payments following a step fall in the U.K. exports in 1966 and a devaluation of the pound in 1967 [Colour figure can be viewed at wileyonlinelibrary.com]

Graph 6 shows how the devaluation of the pound brings about the adjustment of the economy that was earlier (Graph 5) provided by austerity measures. Thanks to a weaker currency, British current account improves very quickly after the initial shock, as it is shown in Graph 7.

The same reasoning can be applied to the European sovereign debt crisis started in 2009. The eurozone is a de facto fixed exchange regime area. European institutions have tried to mend the internal imbalances which characterized the eurozone via the imposition of austerity measures to Southern deficit countries. The social costs of this operation in terms of lower income and a higher level of unemployment have been much greater than expected.

7 | COMPUTER SIMULATION, EXPERIMENT 3. OPENPROD MODEL AND POLICY RESPONSES TO A NEGATIVE SHOCK

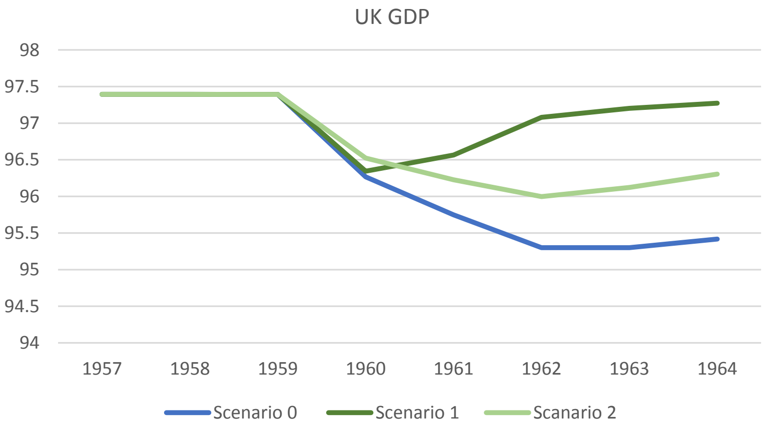
Within a flexible exchange rate regime, the recession suffered by the United Kingdom after the shock is deeper in the OPENPROD than in the OPENFLEX model (experiment 1). However, both scenarios/models display a long period—roughly 20 years in the simulations—in which the GDP remains under its pre-crisis level. The slowness of the recovery in the OPENFLEX is due to the fact that it has to rely entirely on the effects of the depreciation of the currency on the trade balance. In the OPENPROD model, the improvement of productivity accompanies and speeds up the recovery, yet, the initial depth of the trough represents a heavy burden for the British economy for many years after the shock. Different parameters of the models in the equations defining the terms of trade would alter the time necessary to come back to the pre-crisis levels, but still the economy would face the consequences of the recession and the uncertainty due to rebalancing mechanisms entirely based on market forces.

Experiment 3 tests if some forms of economic policy can be effective in dealing with this kind of situations in the context of the OPENPROD model.

A new version of the model is used. It includes a more advanced equation of productivity (from which follows an amended equation of total level of government spending too):

$$\log(pr^{£}) = prbase + sm * \log\left(y^{£}_{-1}\right) + crs^{£} * \log\left(prs^{£}_{-1}\right) \quad (61\ \text{bis})$$

$$g^{£} = gbase^{£} + prs^{£} \quad (83)$$



GRAPH 8 U.K. GDP following a step fall in the U.K. exports: three scenarios of political response [Colour figure can be viewed at wileyonlinelibrary.com]

Equation (61 bis) defines U.K. productivity. In comparison to Equation (61), it features an additional variable: public investment in R&D (*prs*). Public expenditure on R&D carries out a double function. On the one hand, it helps to boost productivity along with a typical pattern of industrial policy. On the other hand, it represents a net increase of total public expenditure which affects the economy via the traditional Keynesian multiplier. For this reason, *prs* is also included in Equation (83), which "endogenizes" real government expenditure as a sum of a basic level (*baseg*) and an industrial policy component.

The parameter $crs^{£}$ is set at 0.17. It implies that an increase by 1% in government expenditure on R&D prompts a productivity increase of 0.17%. The reason for the choice of this particular value is twofold: it is consistent with empirical evidence[11]; and it brings about plausible values for the other variables when a shock hits the model. $gbase^{£}$ is the exogenous and "generic" public expenditure.

As usual, the system is shocked in 1960 with a fall in U.K. export: ε_0 drops from −2.1 to −2.2. However, this time, the U.K. government reacts with a countercyclical policy.

Graph 8 shows the outcome of the intertwined effects of three different forces on U.K. GDP. Indeed, the total level of income tends to go down due to the drop in the propensity to export, but at the same time it is pushed up by the fiscal stimulus and the boost in productivity.

Moreover, the graph outlines three different scenarios: scenario 0 describes the effect of a drop of propensity to export without any response by the government. In scenario 2, public institutions react via a "raw" fiscal stimulus of 0.2 pounds (+1.25% of the total level of real expenditure). Scenario 1 displays the effect of the stimulus when the extra-expenditure is concentrated on R&D.

[11]In the simplified world of the OPENPROD model, where no capital is taken into account, it is pretty tricky to mechanically introduce parameters that have been estimated in economic literature using real data and complex production functions. However, in Guellec, Pottelsberghe, and de la Potterie (2004)—a study conducted on 16 major OECD countries with data from 1980 to 1998—the variables of the regression are sufficiently aggregated to provide some useful insights for the purpose of the OPENPROD model too. The elasticity of (total factors) productivity with respect to public expenditure on R&D is estimated at around 0.17. Therefore, in a pure labour economy like the one represented by the model it does not seem unreasonable to assume that an increase by 1% of public expenditure concentrated on R&D would prompt an increase by 0.17% of productivity.

In scenario 1, R&D grow by 10%, which corresponds to an increase in total real public expenditure of 0.1 pounds or 0.6%. To summarize, the R&D intervention costs around half of the traditional fiscal stimulus.

The OPENPROD model turns out to demonstrate the effectiveness of fiscal policy even in the context of flexible exchange rates. This important feature pits the model against the core system of beliefs of most "mainstream" open economy models. "A permanent change in fiscal policy has no net effect on output. Instead, it causes an immediate and permanent exchange rate jump that offsets exactly the fiscal policy's direct effect on aggregate demand. A fall in net export demand counteracts the rise in government demand"[12] (Krugman, Obstfeld, & Melitz, 2015, p. 509). In the OPENPROD model, the exchange rate supports fiscal policy: the devaluation of the currency caused by the current account deficit—which is the real driver of the value of the currency and is inevitably linked with any expansionary fiscal policy that increases import—helps to boost export and GDP.

Scenario 0 (blue line) in graph 3.9 is absolutely identical to the path of the British economy featured in Graph 1. Scenario 1 (dark green) and 2 (light green) show that a fiscal stimulus manages to mitigate the depth of the recession *regardless of how government funds are spent*. Thanks to the stimulus, not only is the recession far less steep, but it is also short-lived. The economy is back to the pre-shock level around 10 periods (years) before it would have been without intervention.

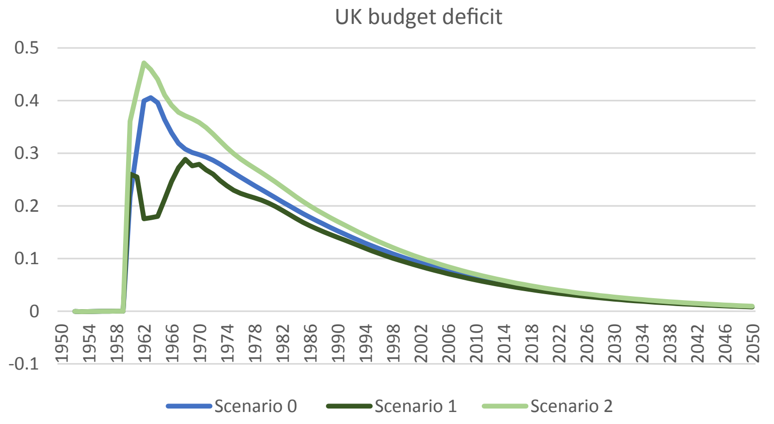
Furthermore, if the government expenditure is focused on R&D the downturn is actually minimal and very short lived. The dark green line (scenario 1) goes slightly down for a while, but GDP never goes below 96.34 from a pre-shock stable value of 97.39 (−1%). In this case, the productivity increase triggered by R&D expenditure offsets the decrease in productivity caused by the Smith effect. A slowly increasing productivity props up exports and keeps down domestic prices despite the fall of the pound and the steep increase in import prices (Graph 10 and 11). British income and wealth are not eroded in real terms thanks to the stability of prices.

Obviously, with a more substantial stimulus the recession could even be shunned: higher levels of productivity prompted by R&D funds would be bolstered by the Smith effect linked with the expansion of the scale of production; lower domestic prices would boost real income and wealth, which in turn would affect consumption.

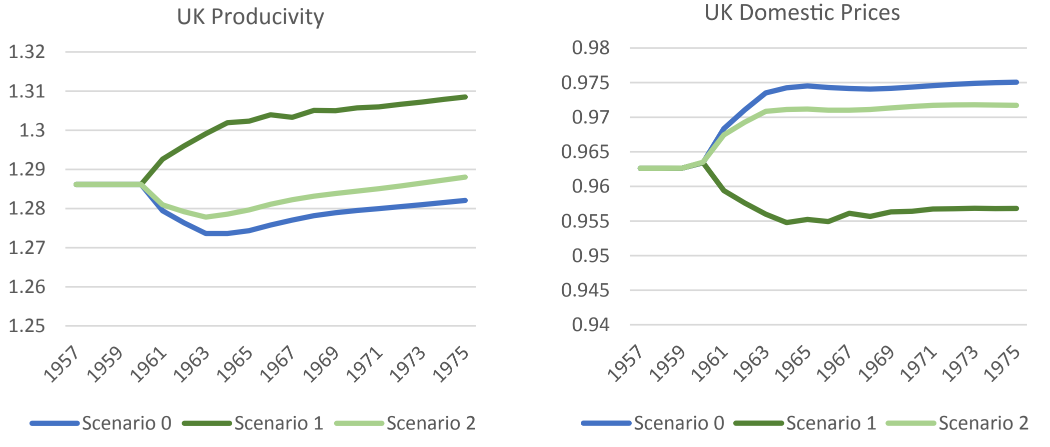
By contrast, when the stimulus is not directed to R&D (light green line, scenario 2) the effects of fiscal policy are less powerful: GDP comes back to the pre-shock level in roughly the same interval of time, but the recession is deeper.

In addition, a fiscal stimulus focused on R&D expenditure is followed by a lower level of budget deficit (see Graph 9): a milder recession curbs the losses in revenues linked to a lower level of income and partly offsets the negative effect of the stimulus on the government balance sheet. In addition, the policy is far less expansive than the "generic" fiscal sitimulus. This result can support the "political viability" of a fiscal stimulus focused on industrial policy. Indeed, it is worth to underline that in the short-run the government deficit in scenario 1 is even lower than the value there would be without any fiscal stimulus (scenario 0).

[12]The textbook from which the quotation is taken is based on a revised version of the classical Mundell-Fleming model (Fleming, 1962; Mundell, 1960, 1961a, 1961b, 1963). Despite the long evolution of macroeconomic theory from the "old times" of the Neoclassical Synthesis, when it comes to the analysis of open economies the departure from the main theoretical assumptions and policy conclusions of the Mundell-Fleming model has often been very limited among "mainstream" economists (see, for instance, Bernanke, 2016).



GRAPH 9 U.K. budget deficit following a step fall in the U.K. exports: three scenarios of political response [Colour figure can be viewed at wileyonlinelibrary.com]



GRAPH 10 AND 11 U.K. productivity following a step fall in the U.K. exports; U.K. domestic prices following a step fall in the U.K. exports. Three scenarios of political response [Colour figure can be viewed at wileyonlinelibrary.com]

8 | CONCLUSIONS

After a brief description of the "state of the art" of the SFC open economy literature and a summary of the current debate on productivity, this paper has presented a model (OPENPROD model) that combines the SFC methodology and the so-called Verdoorn-Kaldor law.

In comparison to the benchmark OPENFLEX model (Godley & Lavoie, 2007), the OPENPROD model features a new and more consistent system of prices, which allows studying the role played by endogenous productivity as captured by the Verdoorn-Kaldor law to the dynamics of an open economy.

In the new model, negative shocks to the external position of a country appear to bring about graver consequences. Despite a system of flexible exchange rates that provides a mechanism of adjustment, recessions can be very deep even with "middle size" shocks.

The situation is even worse when exchange rates are fixed and austerity measures are the only tools at the disposal of the deficit country to rebalance its current account. In Section 6, the OPENPROD model has been amended in order to study exactly this kind of dynamics. This institutional framework can be regarded as a good proxy of British and American economies in the "Bretton Woods era". The current arrangements within the Euro Area work on the basis of the same principles too.

However, the role of productivity as an endogenous variable is not just a source of increased instability. In fact, it allows us to broaden the set of political tools at the disposal of policymakers.

The OPENPROD model shares with the benchmark OPENFLEX model an important characteristic: the effectiveness of fiscal policy even in the context of flexible exchange rates. Indeed, the policy implications of OPENPROD model are clearly at odds with the scepticism about fiscal policy which characterizes "mainstream" open economy models. In Experiment 3, two additional equations have been introduced. This amended version of the model has been pretty useful to distinguish between the impact of a "raw" fiscal stimulus—that is to say a generic extension of government expenditures—and of an "industrial policy" fiscal stimulus—namely a use of government money for projects aimed to increase the level of productivity of workers. The results showed by experiment 3 suggest that industrial policy can be a far more powerful tool than "generic" fiscal policy to address negative shocks in the context of flexible exchange rates. Furthermore, industrial policy presents an advantage in terms of "political feasibility" because its impact on short-term government budget deficit is minimal.

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APPENDIX A

TABLE A1 OPENPROD balance sheet matrix

	All in £					All in $				
	UK households	UK firms	UK Government	UK C. B.	Ex. rate	US households	US firms	US Government	US C. B.	Sum
Money	$+H^{£}$			$-H^{£}$		$+H^{\$}$			$-H^{\$}$	0
£ Bills	$+B^{£}_{£}$			$+B^{£}_{cb£}$	$xr^{£}$	$+B^{£}_{\$}\, xr^{£}$				0
$ Bills	$+B^{\$}_{£}\, xr^{\$}$		$-B^{£}$	$+B^{\$}_{cb£}\, xr^{\$}$	$xr^{£}$	$+B^{\$}_{\$}$		$-B^{\$}$	$+B^{\$}_{cb\$}$	0
Gold				$+or^{£}p^{£}_{g}$	$xr^{£}$				$+or^{\$}p^{\$}_{g}$	$\sum \mathrm{or}p^{£}_{g}$
Balance	$-V^{£}$		$-NW^{£}_{g}$	$-NW^{£}_{cb}$	$xr^{£}$	$-V^{\$}$		$-NW^{£}_{g}$	0	$-\sum \mathrm{or}p^{\$}_{g}$
Sum	0		0	0	$xr^{£}$	0		0	0	0

TABLE A2 OPENPROD transaction-flow matrix

	All in £					All in $				
	UK house	UK firms	UK Gov.	UK C.B.	Exch. rate	US house	US firms	US Gov.	US C. B.	Sum
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
	$+r^{£}B^{\$}_{\$}xr^{\$}$			$+r^{\$}B^{\$}_{cb£}xr^{\$}$	$xr^{£}$	$+r^{\$}B^{\$}_{\$}$		$-r^{\$}B^{\$}$	$-r^{\$}B^{\$}_{cb\$}$	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	$-\Delta B^{\$}_{£}xr^{\$}$			$-\Delta B^{\$}_{cb£}xr^{\$}$	$xr^{£}$	$-\Delta B^{\$}_{\$}$		$+\Delta B^{\$}$	$-\Delta B^{\$}_{cb\$}$	0
Gold				$-\Delta or^{£}p^{£}_{g}$	$xr^{£}$				$-\Delta or^{\$}p^{\$}_{g}$	
Sum	0	0	0	0		0	0	0	0	0

APPENDIX B

EQUATION OF THE OPENPROD MODEL

Macroeconomic variables

$YD_r^{£}$ = Regular disposable income U.K.
$YD_r^{\$}$ = Regular disposable income U.S.
$Y^{£}$ = National U.K. income at current prices
$Y^{\$}$ = National U.K. income at current prices
$r^{£}$ = Interest rate on U.K. bills
$r^{\$}$ = Interest rate on U.S. bills
$B_{£s}^{£}$ = U.K. bills held by U.K. households
$B_{£s}^{\$}$ = U.S. bills held by U.K. households
$B_{\$s}^{\$}$ = U.S. bills held by U.S. households
$B_{\$s}^{£}$ = U.K. bills held by U.S. households
$xr^{£}$ = U.K. exchange rate (value of the pound in U.S. dollars)
$xr^{\$}$ = U.S. exchange rate (value of the dollar in pounds)
$T^{£}$ = U.K. tax revenues
$T^{\$}$ = U.S. tax revenues
$YD_{hs}^{£}$ = U.K. households Haig-Simons disposable income (nominal terms)
$YD_{hs}^{\$}$ = U.S. households Haig-Simons disposable income (nominal terms)
$V^{£}$ = U.K. households' private wealth
$V^{\$}$ = U.S. households' private wealth
$T^{£}$ = Taxes paid by U.K. households
$T^{£}$ = Taxes paid by U.S. households
$F_{cb}^{£}$ = U.K. Central Bank's profits
$F_{cb}^{\$}$ = U.S. Central Bank's profits
$B_s^{£}$ = U.K. public debt (total U.K. bills issued)
$B_s^{\$}$ = U.S. public debt (total U.S. bills issued)
$CAB^{£}$ = U.K. current account balance
$CAB^{£}$ = U.S. current account balance
$X^{£}$ = U.K. exports (nominal terms)
$X^{\$}$ = U.S. exports (nominal terms)
$IM^{£}$ = U.K. imports (nominal terms)
$IM^{\$}$ = U.S. imports (nominal terms)
$CABOSA^{£}$ = U.K. financial account balance
$CABOSA^{\$}$ = U.S. financial account balance
$or^{£}$ = U.K. gold reserves
$or^{\$}$ = U.S. gold reserves
$p_g^{£}$ = Price of gold in United Kingdom
$p_g^{£}$ = Price of gold in United States
$p_m^{£}$ = U.K. import prices
$p_x^{£}$ = U.K. export prices
$p_m^{\$}$ = U.S. import prices
$p_x^{\$}$ = U.S. export prices
$p_{madeUK}^{£}$ = Original price of made in U.K. goods

$p^{\$}_{madeUS}$ = Original price of made in U.S. goods
$x^{£}$ = U.K. exports (real terms)
$im^{£}$ = U.K. imports (real terms)
$x^{\$}$ = U.S. exports (real terms)
$im^{\$}$ = U.S. imports (real terms)
$v^{£}$ = U.K. households private wealth (real terms)
$v^{\$}$ = U.S. households private wealth (real terms)
$p^{£}_{ds}$ = U.K. price of domestic sales
$p^{\$}_{ds}$ = U.S. price of domestic sales
$yd^{£}_{hs}$ = U.K. households Haig-Simons disposable income (real terms)
$yd^{\$}_{hs}$ = U.S. households Haig-Simons disposable income (real terms)
$c^{£}$ = U.K. real consumption
$c^{\$}$ = U.S. real consumption
$yd^{£}_{hse}$ = U.K. households Haig-Simons expected disposable income (real terms)
$yd^{\$}_{hse}$ = U.K. households Haig-Simons expected disposable income (real terms)
$s^{£}$ = Total volume of sales in United Kingdom
$s^{\$}$ = Total volume of sales in United States
$g^{£}$ = U.K. pure government expenditure (real terms)
$g^{\$}$ = U.K. pure government expenditure (real terms)
$S^{£}$ = Value of sales in United Kingdom
$S^{\$}$ = Value of sales in United States
$p^{£}_{s}$ = Average price of all sales in United Kingdom
$p^{\$}_{s}$ = Average price of all sales in United States
$p^{£}_{madeUK}$ = Original price goods made in United Kingdom
$p^{£}_{madeUS}$ = Original price goods made in United States
$N^{£}$ = Employment level in United Kingdom
$N^{\$}$ = Employment level in United States
$DS^{£}$ = U.K. domestic sales value
$DS^{\$}$ = U.S. domestic sales value
$ds^{£}$ = U.K. domestic sales volume
$ds^{\$}$ = U.S. domestic sales volume
$Y^{£}$ = Nominal U.K. GDP
$Y^{\$}$ = Nominal U.S. GDP
$y^{£}$ = Real U.K. GDP
$y^{\$}$ = Real U.S. GDP
$C^{£}$ = Value of consumption in United Kingdom
$C^{\$}$ = Value of consumption in United States
$pr^{£}$ = U.K. productivity (output per worker)
$pr^{\$}$ = U.S. productivity (output per worker)
$B^{£}_{£d}$ = Demand for U.K. bills by U.K. households
$B^{\$}_{£d}$ = Demand for U.S. bills by U.K. households
$B^{\$}_{\$d}$ = Demand for U.S. bills by U.S. households
$B^{£}_{\$d}$ = Demand for U.K. bills by U.S. households
$H^{£}_{h}$ = Money held by U.K. households
$H^{\$}_{h}$ = Money held by U.S. households
$H^{£}_{s}$ = U.K. money supply

$H^{\$}_{s}$ = U.S. money supply
$B^{£}_{cb£s}$ = U.K. bills held by U.K. central bank
$B^{\$}_{cb\$s}$ = U.S. bills held by U.S. central bank
$B^{£}_{cb£d}$ = Demand for U.K. bills by U.K. central bank
$B^{\$}_{cb\$d}$ = Demand for U.S. bills by U.S. central bank
$B^{\$}_{cb£d}$ = Demand for U.S. bills by U.K. central bank
$G^{£}$ = U.K. pure government expenditure (nominal terms)
$G^{£}$ = U.K. pure government expenditure (nominal terms)
$W^{£}$ = Wage rate in United Kingdom
$W^{\$}$ = Wage rate in United States
$r^{£}$ = Interest rate on U.K. bills
$r^{\$}$ = Interest rate on U.S. bills
$B^{\$}_{cb£s}$ = U.S. bills held by U.K. central bank

Model parameters

$\theta^{£}$ = U.S. Tax rate
$\theta^{\$}$ = U.S. Tax rate
v_0 = First parameter of U.K. import prices equation
v_1 = Second parameter of U.K. import prices equation
u_0 = First parameter of U.K. export prices equation
u_1 = Second parameter of U.K. export prices equation
ε_0 = Constant of the U.K. exports equation
ε_1 = Elasticity of U.K. exports with respect to U.S. import prices relative to prices of made in U.S. goods
ε_2 = Elasticity of U.K. export with respect to U.S. output
μ_0 = Constant of U.K. import equation
μ_1 = Elasticity of U.K. imports with respect to U.K. import prices relative to prices of made in U.K. goods
μ_2 = Elasticity of U.K. import with respect to U.K. output
$\alpha^{£}_{1}$ = U.K. propensity to consume out of income
$\alpha^{\$}_{1}$ = U.S. propensity to consume out of income
$\alpha^{£}_{2}$ = U.K. propensity to consume out of wealth
$\alpha^{\$}_{2}$ = U.S. propensity to consume out of wealth
$\varphi^{£}$ = Mark-up on unit cost in United Kingdom
$\varphi^{\$}$ = Mark-up on unit cost in United States
λ_{ij} = Portfolio equations parameters
prbase = Constant of productivity equations
sm = Smith parameter of productivity equations

Equations

$$YD^{£}_{r} = Y^{£} + r^{£}_{-1} B^{£}_{£s-1} + r^{\$}_{-1} B^{\$}_{£s-1} xr^{\$} - T^{\$} \tag{1}$$

$$YD^{£}_{hs} = YD^{£}_{r} + \left(\Delta xr^{\$}\right) B^{\$}_{£s-1} \tag{2}$$

$$\Delta V^{£} = (YD_r^{£} - C^{£}) + \left(\Delta xr^{\$}\right) B_{£s-1}^{\$} \tag{3}$$

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

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

$$\Delta V^{\$} = (YD_r^{\$} - C^{\$}) + \left(\Delta xr^{£}\right) B_{\$s-1}^{£} \tag{6}$$

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

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

$$F_{cb}^{£} = r_{-1}^{£} B_{cb£s-1}^{£} + r_{-1}^{\$} B_{cb£s-1}^{\$} xr^{\$} \tag{9}$$

$$F_{cb}^{\$} = r_{-1}^{\$} B_{cb\$s-1}^{\$} \tag{10}$$

$$\Delta B_s^{£} = G^{£} - T^{£} + r_{-1}^{£} B_{£s-1}^{£} - F_{cb}^{£} \tag{11}$$

$$\Delta B_s^{\$} = G^{\$} - T^{\$} + r_{-1}^{\$} B_{\$s-1}^{\$} - F_{cb}^{\$} \tag{12}$$

$$CAB^{£} = X^{£} - IM^{£} + r_{-1}^{\$} B_{£s-1}^{\$} xr^{\$} - r_{-1}^{£} B_{\$s-1}^{£} + r_{-1}^{\$} B_{cb£s-1}^{\$} xr^{\$} \tag{13}$$

$$CAB^{\$} = X^{\$} - IM^{\$} + r_{-1}^{£} B_{\$s-1}^{£} xr^{£} - r_{-1}^{\$} B_{£s-1}^{\$} - r_{-1}^{\$} B_{cb£s-1}^{\$} \tag{14}$$

$$CABOSA^{£} = \Delta B^{£}_{\$s} - \Delta B^{\$}_{£s} xr^{\$} - \left\{ \Delta B^{\$}_{cb£s-1} xr^{\$} + \Delta or^{£} p^{£}_{g} \right\} \tag{15}$$

$$CABOSA^{\$} = \Delta B^{\$}_{£s} - \Delta B^{£}_{\$s} xr^{£} - \left\{ \Delta or^{\$} p^{\$}_{g} \right\} \tag{16}$$

$$log(p^{£}_{m}) = v_0 - v_1 \log(xr^{£}) + (1 - v_1) \log\left(p^{£}_{madeUK}\right) + v_1 \log\left(p^{\$}_{madeUS}\right) \tag{17}$$

$$log\left(p^{£}_{x}\right) = u_0 - u_1 \log\left(xr^{£}\right) + (1 - u_1) \log\left(p^{£}_{madeUK}\right) + u_1 \log\left(p^{\$}_{madeUS}\right) \tag{18}$$

$$log(x^{£}) = \varepsilon_0 - \varepsilon_1 \left(\log\left(\frac{p^{\$}_{m-1}}{p^{\$}_{madeUS-1}} \right) \right) + \varepsilon_2 \log\left(y^{\$}\right) \tag{19}$$

$$log(im^{£}) = \mu_0 - \mu_1 \left(\log\left(\frac{p^{£}_{m-1}}{p^{£}_{madeUK-1}} \right) \right) + \mu_{2\log}\left(y^{£}\right) \tag{20}$$

$$p^{\$}_{x} = p^{£}_{m} + xr^{£} \tag{21}$$

$$p^{\$}_{m} = p^{£}_{x} + xr^{£} \tag{22}$$

$$x^{\$} = im^{£} \tag{23}$$

$$im^{\$} = x^{£} \tag{24}$$

$$X^{£} = x^{£} p^{£}_{x} \tag{25}$$

$$X^{\$} = x^{\$} p^{\$}_{x} \tag{26}$$

$$IM^{£} = im^{£} p^{£}_{m} \tag{27}$$

$$IM^{\$} = im^{\$} p_m^{\$} \tag{28}$$

$$v^{£} = \frac{V^{£}}{p_{ds}^{£}} \tag{29}$$

$$v^{\$} = \frac{V^{\$}}{p_{ds}^{\$}} \tag{30}$$

$$yd_{hs}^{£} = \frac{YD_r^{£}}{p_{ds}^{£}} - v_{-1}^{£} \frac{\Delta p_{ds}^{£}}{p_{ds}^{£}} + \frac{\Delta xr^{\$} B_{£s-1}^{\$}}{p_{ds}^{£}} = \frac{YD_{hs}^{£}}{p_{ds}^{£}} - v_{-1}^{£} \frac{\Delta p_{ds}^{£}}{p_{ds}^{£}} \tag{31}$$

$$yd_{hs}^{\$} = \frac{YD_r^{\$}}{p_{ds}^{\$}} - v_{-1}^{\$} \frac{\Delta p_{ds}^{\$}}{p_{ds}^{\$}} + \frac{\Delta xr^{£} B_{\$s-1}^{£}}{p_{ds}^{\$}} = \frac{YD_{hs}^{\$}}{p_{ds}^{\$}} - v_{-1}^{\$} \frac{\Delta p_{ds}^{\$}}{p_{ds}^{\$}} \tag{32}$$

$$c^{£} = \alpha_1^{£} yd_{hse}^{£} + \alpha_2^{£} v_{-1}^{£} \tag{33}$$

$$c^{\$} = \alpha_1^{\$} yd_{hse}^{\$} + \alpha_2^{\$} v_{-1}^{\$} \tag{34}$$

$$yd_{hse}^{£} = \frac{\left(yd_{hs}^{£} + yd_{hs-1}^{£}\right)}{2} \tag{35}$$

$$yd_{hse}^{\$} = \frac{\left(yd_{hs}^{\$} + yd_{hs-1}^{\$}\right)}{2} \tag{36}$$

$$s^{£} = c^{£} + g^{£} + x^{£} \tag{37}$$

$$s^{\$} = c^{\$} + g^{\$} + x^{\$} \tag{38}$$

$$S^{£} = s^{£} p_s^{£} \tag{39}$$

$$S^{\$}=s^{\$}p_s^{\$} \tag{40}$$

$$p_{madeUK}^{£}=\left(1+\varphi^{£}\right)UC^{£}=\left(1+\varphi^{£}\right)\frac{W^{£}N^{£}}{y^{£}}=\left(1+\varphi^{£}\right)\frac{W^{£}N^{£}}{s^{£}-im^{\$}} \tag{41}$$

$$p_{madeUS}^{\$}=\left(1+\varphi^{\$}\right)UC^{\$}=\left(1+\varphi^{\$}\right)\frac{W^{\$}N^{\$}}{y^{\$}}=\left(1+\varphi^{\$}\right)\frac{W^{\$}N^{\$}}{s^{\$}-im^{\$}} \tag{42}$$

$$p_s^{£}=p_{madeUK}^{£}*\left(\frac{s^{£}-im^{£}-x^{£}}{s^{£}}\right)+p_m^{£}*\left(\frac{im^{£}}{s^{£}}\right)+p_x^{£}*\left(\frac{x^{£}}{s^{£}}\right) \tag{43}$$

$$p_s^{\$}=p_{madeUS}^{\$}\left(\frac{s^{\$}-im^{\$}-x^{\$}}{s^{\$}}\right)+p_m^{\$}\left(\frac{im^{\$}}{s^{\$}}\right)+p_x^{\$}\left(\frac{x^{\$}}{s^{\$}}\right) \tag{44}$$

$$p_{ds}^{£}=\frac{S^{£}-X^{£}}{s^{£}-x^{£}} \tag{45}$$

$$p_{ds}^{\$}=\frac{S^{\$}-X^{\$}}{s^{\$}-x^{\$}} \tag{46}$$

$$DS^{£}=S^{£}-X^{£} \tag{47}$$

$$DS^{\$}=S^{\$}-X^{\$} \tag{48}$$

$$ds^{£}=s^{£}-x^{£} \tag{49}$$

$$ds^{\$}=s^{\$}-x^{\$} \tag{50}$$

$$Y^{£}=S^{£}-IM^{£} \tag{51}$$

$$Y^{\$}=S^{\$}-IM^{\$} \tag{52}$$

$$y^{£}=s^{£}-im^{£} \tag{53}$$

$$y^{\$} = s^{\$} - im^{\$} \tag{54}$$

$$C^{£} = c^{£} p^{£}_{ds} \tag{55}$$

$$C^{\$} = c^{\$} p^{\$}_{ds} \tag{56}$$

$$G^{£} = g^{£} p^{£}_{ds} \tag{57}$$

$$G^{\$} = g^{\$} p^{\$}_{ds} \tag{58}$$

$$N^{£} = \frac{y^{£}}{pr^{£}} \tag{59}$$

$$N^{\$} = \frac{y^{\$}}{pr^{\$}} \tag{60}$$

$$\log(pr^{£}) = prbase + sm * \log\left(y^{£}_{-1}\right) \tag{61}$$

$$\log\left(pr^{£}\right) = prbase + sm * \log\left(y^{£}_{-1}\right) + crs^{£} * \log\left(prs^{£}_{-1}\right) \quad (61\ bis)$$

$$\log(pr^{\$}) = prbase + sm * \log\left(y^{\$}_{-1}\right) \tag{62}$$

$$B^{£}_{£d} = V^{£}\left(\lambda_{10} + \lambda_{11} r^{£} - \lambda_{12} r^{\$}\right) \tag{63}$$

$$B^{\$}_{£d} = V^{£}\left(\lambda_{20} + \lambda_{21} r^{£} - \lambda_{22} r^{\$}\right) \tag{64}$$

$$B^{\$}_{\$d} = V^{\$}\left(\lambda_{40} + \lambda_{41} r^{\$} - \lambda_{42} r^{£}\right) \tag{65}$$

$$B^{£}_{\$d} = V^{\$}\left(\lambda_{50} + \lambda_{51} r^{\$} - \lambda_{52} r^{£}\right) \tag{66}$$

$$H^{£}_{h} = V^{£} - B^{£}_{£s} - B^{\$}_{£s} xr^{\$} \tag{67}$$

$$H^{\$}_{h} = V^{\$} - B^{\$}_{\$s} - B^{£}_{\$S} xr^{£} \tag{68}$$

$$H^{£}_{s} = H^{£}_{h} \tag{69}$$

$$B^{£}_{£s} = B^{£}_{£d} \tag{70}$$

$$B^{£}_{cb£s} = B^{£}_{cb£d} \tag{71}$$

$$H^{\$}_{s} = H^{£}_{h} \tag{72}$$

$$B^{\$}_{\$s} = B^{\$}_{\$d} \tag{73}$$

$$B^{\$}_{cb\$s} = B^{\$}_{cb\$d} \tag{74}$$

$$\Delta B^{£}_{cb£d} = \Delta H^{£}_{s} - \Delta B^{£}_{cb£s} - \Delta or^{£} p^{£}_{g} \tag{75}$$

$$B^{\$}_{cb£d} = H^{\$}_{s} - or^{\$} p^{\$}_{g} \tag{76}$$

$$p^{£}_{g} = p^{\$}_{g} xr^{\$} \tag{77}$$

$$xr^{\$} = \frac{1}{xr^{£}} \tag{78}$$

$$B^{£}_{\$s} = B^{£}_{\$d} xr^{\$} \tag{79}$$

$$B^{\$}_{cb£d} = B^{\$}_{cb£s} xr^{\$} \tag{80}$$

$$xr^{£} = \frac{B^{\$}_{£s}}{B^{\$}_{£d}} \tag{81}$$

$$B^{\$}_{£s} = B^{\$}_{s} - B^{\$}_{\$s} - B^{\$}_{cb\$s} - B^{\$}_{cb£s} \tag{82}$$

$$g^{£} = gbase^{£} + prs^{£} \tag{83}$$

Redundant equation

$$B^{£}_{cb£s} = B^{£}_{s} - B^{£}_{£s} - B^{£}_{\$s} \tag{84}$$

Initial values of stocks

$B^{£}_{cb£s} = 0.3271126$
$B^{£}_{cb£d} = 0.3271126$
$B^{\$}_{cb£d} = 0.02031$
$B^{£}_{£d} = 102.8436$
$B^{\$}_{£d} = 36.73843$
$B^{\$}_{\$d} = 102.8532$
$B^{£}_{\$d} = 36.733289$
$B^{£}_{£s} = 102.8436$
$B^{\$}_{£s} = 36.73843$
$B^{\$}_{\$s} = 102.8532$
$B^{£}_{\$s} = 36.733289$
$B^{\$}_{cb\$s} = 0.3455884$
$B^{\$}_{cb\$d} = 0.3455884$
$H^{£}_{s} = 7.345973$
$H^{£}_{h} = 7.345973$
$H^{\$}_{s} = 7.346658$
$H^{\$}_{h} = 7.346658$
$B^{£}_{s} = 139.8939$
$B^{\$}_{s} = 139.9575$
$V^{£} = 146.9195$
$V^{\$} = 146.9195$

$v^{£} = 152.6205$
$v^{\$} = 152.6356$

Initial values for lagged endogenous variables

$xr^{£} = 1.000233$
$xr^{\$} = 0.9997667$
$p_m^{£} = 0.9624716$
$p_x^{£} = 0.9625255$
$p_m^{\$} = 0.9627501$
$p_x^{\$} = 0.9626961$
$p_{madeUK}^{£} = 0.9626701$
$p_{madeUS}^{\$} = 0.9626248$
$p_{ds}^{£} = 0.9626458$
$p_{ds}^{\$} = 0.9626401$
$yd_{hs}^{£} = 81.39556$
$yd_{hs}^{\$} = 81.40363000000001$

Initial values for exogenous variables

$g^{£} = 16$ (15 in model with equation 61 bis)
$g^{\$} = 16$ (15 in model with equation 61 bis)
$prs^{£} = 1$ (only in equation 61 bis)
$W^{£} = 1$
$W^{\$} = 1$
$r^{£} = 0.03$
$r^{\$} = 0.03$
$or^{£} = 7$
$or^{\$} = 7$
$p_g^{\$} = 1$
$B_{cb£s}^{\$} = 0.02031$

Model's parameters

$\theta^{£} = 0.2$
$\theta^{\$} = 0.2$
$\varepsilon_0 = -2.1$
$\varepsilon_1 = 0.7$
$\varepsilon_2 = 1$
$\mu_0 = -2.1$
$\mu_1 = 0.7$
$\mu_2 = 1$
$\alpha_1^{£} = 0.75$
$\alpha_1^{\$} = 0.75$
$\alpha_2^{£} = 0.13333$
$\alpha_2^{\$} = 0.13333$
$\lambda_{10} = 0.7$
$\lambda_{11} = 5$
$\lambda_{12} = 5$
$\lambda_{20} = 0.25$

$\lambda_{21} = 5$
$\lambda_{22} = 5$
$\lambda_{40} = 0.7$
$\lambda_{41} = 5$
$\lambda_{42} = 5$
$\lambda_{50} = 0.25$
$\lambda_{51} = 5$
$\lambda_{52} = 5$
$v_0 = -0.00001$
$v_1 = 0.7$
$u_0 = -0.00001$
$u_1 = 0.5$
$\varphi^{£} = 0.2381$
$\varphi^{\$} = 0.2381$
$prbase = 1.808$
$sm = 0.14$
$crs^{£} = 0.17$

APPENDIX C

TABLE C1 Sensitivity test experiment 1

Experiment 1: drop in U.K. GDP				
5 periods after the shock				
Model	alpha1_uk = 0.77	alpha2_uk = 0.14	eps1 = 0.9	nu1m = 0.8
	alpha1_us = 0.77	alpha2_us = 0.14	mu1 = 0.9	nu1x = 0.4
OPENPROD	−2.15%	−2.11%	−2.09%	−2.16%
OPENFLEX	−1.33%	−1.32%	−1.24%	−1.37%