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POST GROWTH & THE NORTH-SOUTH DIVIDE

A POST-KEYNESIAN STOCK-FLOW CONSISTENT ANALYSIS

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Abstract

Postgrowth economics has received increased attention in the last decade, in part because economic growth is seen to exacerbate environmental problems and in part because growth rates in advanced economies have been declining for over half a century. It has therefore been argued that the richest economies should deprioritise growth in GDP as a policy objective in order to make room for sustainable development in poorer countries. A key objection to this strategy is that the macroeconomic implications of a postgrowth transition in advanced countries on the economic and environmental conditions in the rest of the world have not yet been rigorously analysed. This working paper addresses that gap. Specifically, we describe a 2-region post-Keynesian stock-flow consistent macroeconomic model and use the model to simulate a unilateral postgrowth transition in one region (the 'North') while the other region (the 'South') pursues economic development. The postgrowth transition is enforced by introducing a cap on resources in the North. This is effective in stopping the growth in resource consumption but comes at the cost of higher inflation in the North and somewhat lower development in the South due to a reduction in international trade. The model is at this stage conceptual, rather than empirically calibrated, so these results must be seen as preliminary insights into the underlying problem. Nonetheless, the findings highlight the potential tension between economic globalisation and this form of postgrowth transition. We discuss the implications of these findings and suggest policies to mitigate adverse impacts on development in the South.

1 Introduction

The state of the environment is a source of increasing concern. Climate change, the depletion of natural resources and the loss of biodiversity are proceeding at an unsustainable pace. They threaten not only the integrity of natural systems but also the viability of the economic system and, consequently, the long-term security of human wellbeing and prosperity. These threats constitute one of the biggest challenges that human societies have ever faced. The scale of technological improvement and societal transformation required to become sustainable is unprecedented in human history and the time frame on which these must take place is alarmingly short.

The strong link between growing ecological deterioration and economic production and consumption has led many scholars to argue that pursuing GDP growth is incompatible with reaching environmental sustainability (Daly, 1974; Victor, 2008; Jackson, 2009; Kallis, 2018). At the global level, carbon emissions, environmental pollution and material consumption all need to decrease in order to remain within ecological boundaries (Rockström et al., 2021) and to avoid an irreversible collapse in ecological integrity. If this assumption is accepted, policies should primarily focus on reducing the material footprint of the economy, particularly in the so-called advanced economies of the global North. The idea that such reductions can be achieved purely through a technological 'decoupling' of material consumption from GDP is not well supported by available data and projections (Haberl et al., 2020; Krausmann et al., 2017; Krausmann et al., 2018; Schandl et al., 2016).

To rely on the assumption that it will be possible in some imagined future to achieve sufficient levels of decoupling to allow growth to continue indefinitely cannot be satisfactory from a scientific perspective. As a consequence, there is an increasing acknowledgment that the possibility of a stationary or even decreasing economy needs be considered. The fact that rates of economic growth have been declining in the advanced economies for over half a century is further reason for questioning the assumption of continued economic growth, particularly as this 'secular stagnation' may not be reversible (Gordon 2016, Storm 2017).

These considerations give rise to what might be called the 'postgrowth challenge' (Jackson 2019): the need to develop a postgrowth economics capable of exploring the macroeconomic, environmental and social implications of a transition to an economy in which it cannot be assumed that GDP grows indefinitely. Van den Bergh (2011) and Raworth (2017) have both argued for a 'growth-agnostic' approach to economic development, in which it is not assumed that GDP growth is a given. Hardt and O'Neill (2017) suggest that consideration of the limits to growth means taking a critical 'postgrowth' stance on economics, particularly in the richest countries of the world. The logical conclusion from these considerations is that we need to do considerably more research on postgrowth economics because the economic, social and environmental consequences of a postgrowth transition are vast, complex and still relatively poorly understood (Victor and Jackson 2020).

Among the many issues related to the postgrowth challenge, one particularly thorny problem stands out, namely: the need to ensure the economic development of low-income countries. A common view within the postgrowth movement is that developed nations should markedly reduce their environmental footprint in order to allow for a sustainable increase in GDP in developing countries (Hickel et al 2022, Jackson, 2017; Althouse et al., 2020). However, the macroeconomic consequences of a postgrowth transition in one area which allows for the rest of the world to keep growing remain mostly unexplored.

The aim of this working paper is to address that task. Specifically, we describe the development of a post-Keynesian stock-flow consistent (SFC) model capable of addressing this gap by simulating a postgrowth transition in a 2-region world. The focus is on the international macroeconomic consequences of a unilateral postgrowth transition in one region—which we refer to as the 'North'—on a second region—which we call the 'South'. It is thus necessary to firstly introduce how postgrowth has been framed in international economic analyses so far and why SFC modelling is a promising methodological approach for this work. The next section is devoted to this task. In Section 3 we describe key features of a two-region, post-Keynesian SFC model capable of simulating a postgrowth transition in one region. Section 4 will discuss how the postgrowth transition is simulated and Section 5 will present the scenario analysis. In Section 6 we reflect on the results of the simulations and highlight some limitations of the model. Finally, Section 7 provides a brief summary of findings and draws conclusions.

2 Towards international ecological macroeconomics

Postgrowth macroeconomics remains at the margin within mainstream academic and political debates. Indeed, conventional economists have generally criticised or ignored postgrowth approaches and systematically favoured growth-oriented solutions to environmental challenges, characterised by the terminology of ‘green growth’ (Hepburn and Bowen, 2013; Jakob and Edenhofer, 2014). In the last decade or so, however, there has been a rise in what has been called ‘ecological macroeconomics’ (Victor and Jackson 2020). This has emerged as a branch of ecological economics, thanks to the work of Victor and Rosenbluth (2007), Harris (2008), Victor (2008) and Jackson (2009). Its recent development stems from two different elements.

First, there was a gap in ecological economics in terms of macro analyses on the complex interplay between finance, the real economy and the environment (Victor and Jackson, 2020). Thus, the focus of ecological macroeconomics is on developing macroeconomic models and theories that embed all these three dimensions in a coherent framework. Although there is still a high degree of heterogeneity in the field, the key insight of ecological economics, namely that the economy is embedded in a social context which is embedded in the ecosystem, is equally important in ecological macroeconomics. Therefore, the study of financial and economic dynamics is usually framed within the context of planetary boundaries.

Second, the mainstream macroeconomic focus and analytical instruments are not adequate to address this research agenda (Victor and Jackson, 2020). Ecological macroeconomists criticise the neoclassical methodological approach to environmental issues, its lack of attention to financial variables and its reliance on economic growth. Indeed, they prefer a different epistemology, usually drawing from the post-Keynesian school of thought (Rezai and Stagl, 2016), and are more concerned with concepts such as progress or prosperity rather than narrow economic growth (Hardt and O’Neill, 2017).

Ecological macroeconomics is the only field where a postgrowth transition has been explicitly studied and analysed from a macroeconomic perspective. Nonetheless, to date, these models tend mainly to explore such a transition in closed economies or in simplified open economies with an exogenous foreign sector. Althouse et al. (2020) have used a post-Keynesian Balance-of-Payments-constrained growth model to simulate several scenarios of the interactions between an advanced and a developing area. Their results show that only a strong degrowth commitment from the developed part of the world is consistent with ecological sustainability, as green growth policies are likely to increase the import of carbon and material intensive goods from the developing country. However, their model also suggests that degrowth could undermine the potential for developing countries to reach higher level of income. This work is an important first step towards the study of postgrowth economics in an international context, but it lacks the comprehensive treatment that could be provided using post-Keynesian SFC models.

SFC models have become popular within ecological macroeconomics thanks to their sound accounting framework, the possibility of embedding several environmental feedback mechanisms and their ability to shed light on conventional macroeconomic variables without overlooking the financial sector. Although increasingly popular, SFC models addressing fully open economies are still missing. Ecological macroeconomists have usually focused on closed economy simulating the entire world (Dafermos et al., 2017; Bovari et al., 2018) or on national economies such as Canada (Jackson and Victor, 2020), France (D'Alessandro et al., 2020; Cieplinski et al., 2021a) and Italy (Cieplinski et al., 2021b) with very simplified exogenous foreign sectors.

Two exceptions are Dunz and Naqvi (2016) and Carnevali et al. (2020). Dunz and Naqvi present a simple 2-country SFC model and carry out different simulations to study the impact of green subsidies to improve the sustainability of production. However, their work is still in a draft version and has never been published in a peer-reviewed journal. Carnevali et al. (2020) show that capital flows can be a crucial variable for international economic equilibria during a green transition. To the best of our knowledge, this is the only (peer-reviewed) work that combines a 2-country SFC model with an ecological macroeconomic perspective. The authors divide the world into two areas: one with greener technologies and one with more carbon-intensive activities. They also model key environmental variables following Dafermos et al. (2017) and introduce damage functions and feedback mechanisms. Their simulations include changes in investors and consumer preferences and increases in green government spending in one or both countries.

Some interesting results emerge from these scenarios. For instance, when preferences for green assets increase among investors, the subsequent capital inflows to the greener country generate a contraction of its economy due to the strengthening of its currency. On the other hand, the carbon-intensive country sees its currency depreciating and experiences a boost in its production, worsening global CO_2 emissions. Conversely, an increase in preferences for green products favours the greener country and the environment. Lastly, Carnevali and his co-authors conclude that only coordinated fiscal policies will have long-term effects on the low carbon transition, although at the risk of fostering growth and thus worsening the impact on the environment. Their overall conclusion is that environmental policies crucially depend on cross-border financial flows and their influence on the exchange rate.

This is an interesting new insight as scarce attention has been devoted to the role of international capital flows in ecological economics. Indeed, environmental and ecological economists have tended to focus on the environmental consequences of foreign direct investment (Demena and Afesorgbor, 2020) but not on the macroeconomic impact of international portfolio investments and capital account dynamics on green policies. Carnevali et al. (2020) demonstrate the usefulness of SFC modelling for the study of financial variables and the importance of considering an international economic perspective when dealing with a green transition.

In the next section, we will present a SFC model that will be used to investigate the macroeconomic consequences of a postgrowth transition in an open context.

3 Model structure

The previous section has presented a rationale for using an SFC model to investigate a postgrowth transition in an open economy. In what follows, we lay out the structure of the model that will be used in this work. In the interests of clarity and brevity, we restrict our attention here to a narrative account of the model. The equations can be found fully described in Appendix A. The balance sheet and transaction flow matrixes can be found in Appendix B.

The SFC modelling tradition has been developed since the 1980s thanks to the contributions of Godley (Godley and Cripps, 1983; Godley, 1996), but has received more attention only in recent years following the publication of 'Monetary Economics' by Godley and Lavoie (2007), which formalised the SFC framework and presented several closed and open models.

Our model builds on the open model described in Godley and Lavoie (2007) but improves it in several ways. Specifically, our theoretical model includes two regions and endogenous growth. The aim of this work is to investigate the macroeconomic implications of a postgrowth transition from an international perspective. Therefore, simulating a growing open economy seems appropriate as we want to understand what happens when growth decreases or disappears and how international dynamics are influenced. Following standard post-Keynesian theory, the growth of aggregate demand is what drives the overall growth of the economy. However, endogenous labour productivity also plays a role in determining the level of growth.

For what concerns the postgrowth transition, the prevalent view in the literature is that the transition should start in the richer developed world rather than the poorer developing world for both ethical and technical reasons. We embed this idea here by modelling two autonomous areas linked together by international trade and capital flows. We call these two areas the North and the South respectively to highlight the fact that the area that will transition should be the North, i.e., the so-called developed world. Figure 3.1 gives a schematic representation of the general structure of the model.

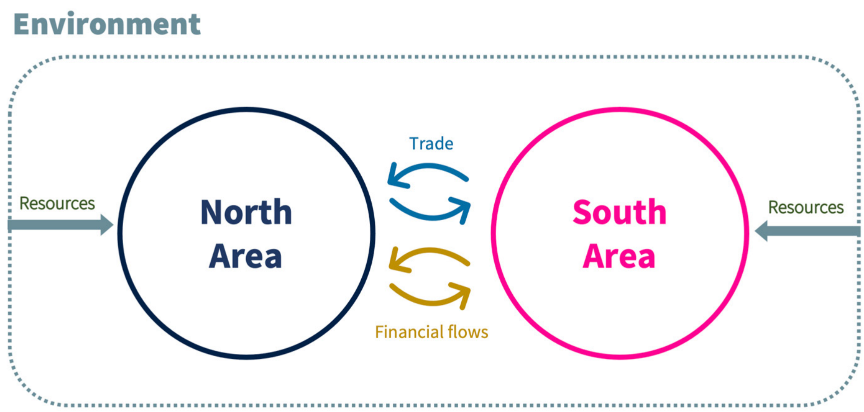

Figure 3.1 | Overview of the model structure.

In line with the ecological economic framework, the economy is embedded in the environment. In this model, the economy-environment interaction is constituted by the extraction of resources by the resource sector. This relatively simplified structure stems from the desire to avoid adding extra complexity to the model. This simple addition is already sufficient to illustrate the crucial point that the economy is constrained by the rate of consumption of natural resources.

Regarding the economic structures of the two areas, in this work we first take these to be identical. The type and number of sectors are the same, as are the values of exogenous parameters, initial stocks and endogenous variables. Having perfect symmetry between the two countries is of course a strong assumption, adopted here because it allows us easily to simulate a steady state from which to begin the analyses that will be proposed later[1]. A more realistic simulation would model the two areas with different economic structures and productivity growth rates. However, once these features are introduced, the macroeconomic dynamics of the two countries tend to diverge, making it extremely difficult to find a steady state. Though it would of course be possible to run simulations from a non-steady state, it is harder to infer causal influences and unravel the precise dynamics of change under more these complex conditions. As a starting point, therefore, we have chosen to prioritise analytical rigour over realism.

Having outlined the general layout of the model, we now focus on the more detailed economic structure of each area. As the two areas are identical, only one of them will be described. Each area is composed of 7 sectors: the household sector, the government sector, the traded sector, the non-traded

1 It is also fairly easy to obtain a steady state where the two areas have different stock and flow levels. For instance, one area could have twice the level of wealth and GDP than the other. But this does not make the results of the model more insightful.

sector, the resource sector, the banking sector and the Central Bank (CB). To make the presentation of the model more straightforward, we will first describe the sectors that can be associated with the real-economy side of the model and then introduce those that play a bigger role in its financial side. The terms real economy and financial will be explained below.

Figure 3.2 is a schematic representation of the real economy, by which we mean consumption, production and the associated income and expenditure flows.

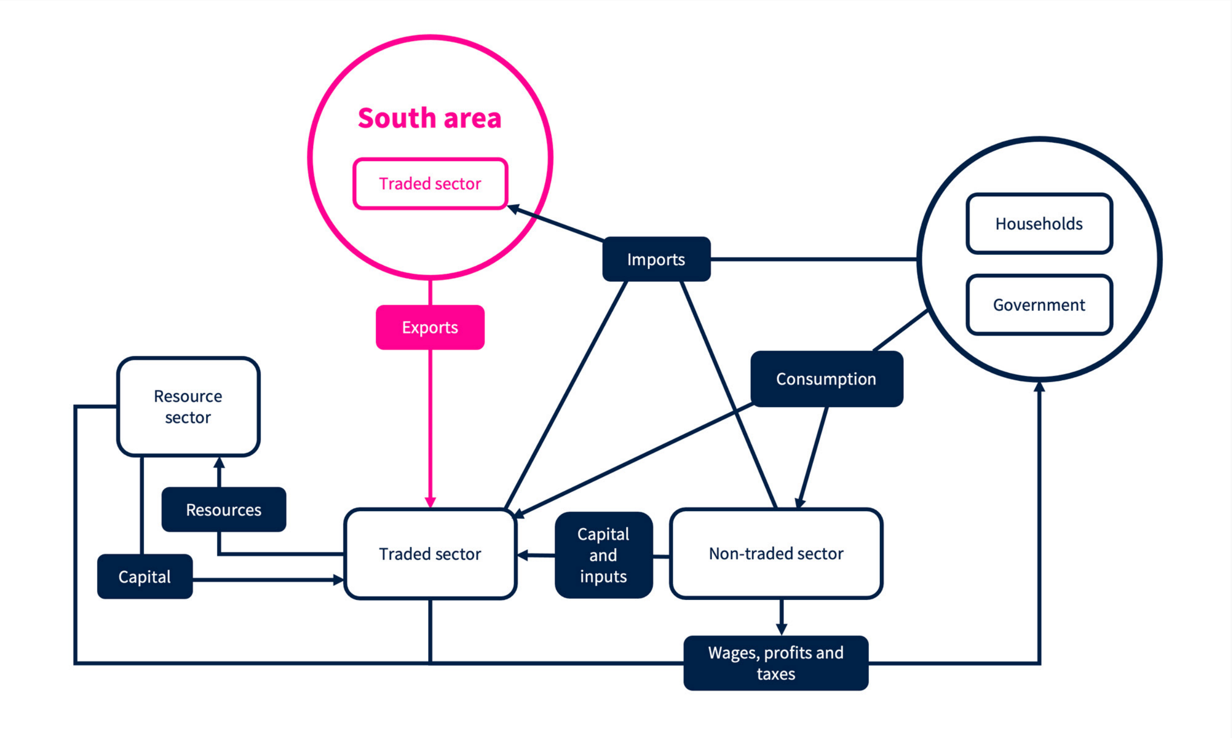

Figure 3.2 | Monetary flows associated with production and consumption in one area. The direction of the arrows indicates the direction of the income flow. For instance, the traded sector purchases resources from the resource sector and sells capital to it.

Two sectors account for most of the consumption of goods and services in the model, namely: households and government. The former is divided between two classes of household that we refer to as 'workers' and 'capitalists': workers receive income in the form of wages, while capitalists are the recipient of income from the return on capital. Wages are provided in exchange for labour, whereas capital income is constituted by firms and banks' distributed profits and interest payments on household deposits. Households use the majority of their after-tax income to purchase three different goods produced by the traded sector, the foreign traded sector and the domestic non-traded sector respectively. The allocation of nominal household income to the different goods is partially exogenous. In addition, relative prices of goods affect the real consumption of households. For instance, if the price of one good increases, the real consumption of that good decreases relative to the others. The share of disposable income that is not consumed is saved. More specifically, workers spend all their income in consumption while capitalists divide their income between consumption and savings.

The government sector receives income through the collection of taxes on wages, profits and imports. It consumes the same goods as the household sector. The consumption function of government is similar to that of households in the sense that it starts from an exogenous share of nominal expenditure and then relative prices affect the real allocation of income to the different goods. The government also devotes an exogenous share of its revenues to financing R&D activities. Lastly, it provides unemployment insurance to unemployed workers. When expenditure is higher than the income collected through taxes, the government issues bonds to cover its deficit.

The production side of the model is constituted by three sectors: the traded, non-traded and resource sector. The resource sector is very simple and has been developed following Naqvi and Stockhammer (2018)[2]. It extracts resources and sells them to the traded sector. It does not employ workers, but it purchases capital from the traded sector. This latter is the only sector that exports goods to the other area. It also produces capital for all the other productive sectors. The decision to split the firms' sector between a traded and non-traded sector stems from the literature on postgrowth, which highlights the importance of transitioning from manufacturing to service sectors in order to reduce the ecological footprint of the economy and address some of the imbalances that might arise in a postgrowth economy (Jackson, 2017, Jackson et al., 2023). Conventionally, services are less open to trade than manufacturing (Mano and Castillo; 2015), thus here they are proxied by the non-traded sector. Moreover, services are generally associated with labour-intensive and resource-light production (Hardt et al., 2021). Though this is a simplification[3], these stylised facts are replicated in this model. Concerning their production requirements, both the traded and non-traded sectors need labour and intermediate inputs to produce their output. However, only the former needs resources, while the latter uses intermediate goods produced by the traded sectors of the two areas. Thus, the traded sector is more resource intensive. In contrast, the labour requirement and the labour-capital ratio of the non-traded sector are higher than those of the traded sector, thus making it more labour intensive.

The investment decisions of both sectors are similar to those of conventional SFC models. Specifically, firms target a level of capital based on desired or expected sales and then invest in order to reach that capital target. The only difference between this model and the traditional SFC

2 Although simplified, the resource sector in this work is more sophisticated than that modelled in their work.

3 For instance, sectors such as construction are resource-intensive and labour-intensive but also rarely open to trade. Conversely, there are sectors such as IT services that are resource-light and labour-light and also prone to trade (Mano and Castillo, 2015; Hardt et al., 2021).

investment function is that desired output also depends on expected profits[4]. Part of investment is funded through an exogenous share of retained profits while the rest is financed by borrowing from the banking sector. Moreover, an exogenous share of gross profits is spent in R&D activities. Lastly, remaining profits are distributed to the capitalist class.

For what concerns the financial side, it is first worth mentioning that every sector is involved in the financial dynamics of the model. Nonetheless, we refer here to the sectors that are primarily involved in lending, selling and purchasing financial assets and determining the interest rates on those, namely the banking sector and the central bank. Figure 3.3 shows a graphical illustration of this part of the model.

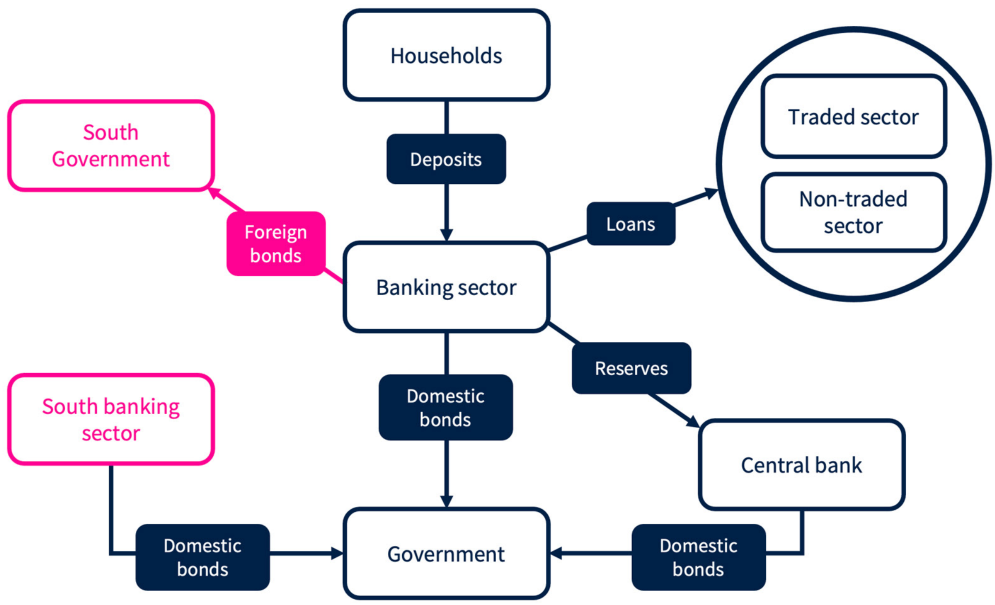

Figure 3.3 | Financial assets and related sectors.

As can be seen, the banking sector is at the centre of the financial network. On the liability side of its balance sheet, banks hold equity and the savings of the household sector in the form of deposits. On the asset side, it has 4 different financial assets: domestic government bonds, foreign government bonds, central bank's reserves and firms' loans. Financial assets only last one period. Therefore, in each new period the debtor has to pay the interest rate on the principal and repay the principal itself. Government bonds are the only type of asset that is traded internationally. Following the endogenous money theory, commercial banks do not need households' deposits in order

4 The reason and justification for this can be found in Appendix A in the section named "Traded sector".

to lend to the other sectors. However, they need to keep a certain level of reserves in order to guarantee their ability to meet their liquidity requirements. Banks then decide how to allocate credit to the government and firm sectors following an exogenous process. The Central Bank provides reserves to the banking sector in exchange for government bonds.

The interest rates on the different assets are endogenous. The only interest rate that is set by the Central Bank is that on reserves, the so-called policy rate. This is the base for the determination of all the other interest rates in the economy. Indeed, the interest rate on government bonds is specified as a mark-up over the policy rate. Moreover, the banking sector sets an exogenous mark-up over the policy rate to determine the interest rate that they pay on deposits. Lastly, banks charge a higher fixed mark-up (again based on the policy rate) for loans to the traded and non-traded sectors.

Having concluded the description of the financial side, it is worth mentioning one last feature of the model that plays a crucial role for its overall dynamics. This is the way in which technological development is endogenously determined. In the context of this model, technology refers to the level of efficiency in the use of productive inputs such as resources, labour and intermediate goods. Endogeneity is modelled following Naqvi and Stockhammer (2018) and, more broadly, a simplified version of the cost-induced technological change theory. Specifically, technological change depends on the levels of R&D funding allocated to different input-saving technologies, which in turn partly depend on the relative prices of inputs. R&D is financed both by private companies and the government, while households supply the necessary labour to carry out the research activities. This part of the model is of crucial importance for the objectives of this work because post growth will be induced here by imposing a cap on resources in the North. The general idea behind a cap-and-trade system (regardless of whether it is framed in a postgrowth context) is that of changing the relative prices of resources compared to labour in order to stimulate resource-saving technologies. If this model did not have an endogenous technological change, introducing this policy would not be very insightful.

Having broadly defined the structure of the model, we will now present how the postgrowth transition will be generated and the characteristics of the resource cap.

4 A resource cap to simulate a postgrowth transition

The aim of this work is to investigate a postgrowth transition in an international context. The first problem that arises when choosing this topic is to understand how the transition can happen. The scientific literature addressing this issue can be roughly divided into discursive works that suggest different pathways based on specific policies and institutions (see for instance Daly, 1977; Victor, 2008; Jackson, 2009; Lawn, 2011; Kallis, 2018) and modelling works that add numerical simulations to the narrative approach (for instance Victor, 2012; D'Alessandro et al., 2020; Jackson and Victor, 2020; Nieto et al., 2020).

These latter works have proposed several different ways in which a postgrowth transition can be simulated. For instance, D'Alessandro et al. (2020) assume a voluntary reduction in consumption to achieve a degrowth scenario. Nieto et al. (2020) obtain a postgrowth scenario by exogenously assuming a decrease in GDP per capita. Jackson and Victor (2020) model the transition in part through the endogenous impacts of a partly policy-driven shift in investment and in part through shifts in working hours. Non-SFC models such as that of Victor and Rosenbluth (2007) achieve post growth by exogenously changing the assumption on the growth rate of various macroeconomic variables, while a Kaleckian model developed in Rosenbaum (2015) requires capital depreciation to be equal to gross investment.

To provide a novel contribution in this field and expand the range of options for simulating post growth, we propose here a resource cap as the policy through which the transition is obtained. This policy is very consistent with the idea that post growth should not target GDP itself, but rather focus on a steady state in resource and environmental terms (Daly 1977). Indeed, a cap on resources is a very straightforward way to tackle environmental degradation because it directly sets the maximum quantity of resources that can be produced without adopting any position towards whether GDP should grow or not. Moreover, modelling a resource cap within a growth model allows us to simulate the transition without imposing a non-growing steady state on the model.

Our approach here differs from the common modelling approach used in the literature, namely, to obtain a postgrowth economy by modifying the model to reach a stationary GDP. This standard approach produces very ordinated transitions, which is a somewhat unsatisfactory outcome as it is arguably unrealistic to imagine that a postgrowth economy would be realised smoothly. In this model, the constraint introduced by the cap is at odds with the growing nature of the economy. Thus, the transition brings about tensions within the model as the frustrated growth of GDP puts growing pressure on other variables. This produces a more dynamic and unstable transition, which better reflects the nature of economic systems.

However, it must be stressed that this type of analysis can only work for short-to-medium run scenarios. Indeed, two problems affect a simulation of this type in the long run. From a theoretical perspective, it would be tantamount to assume that there is a growth imperative within the economy, which remains a highly contested assumption (Cahen-Fourot, 2022). From a technical perspective, the model crashes as a constant reduction of the cap leads to extreme outcomes (such as an economy that uses almost zero resources to produce goods). To obtain a steady state again, the cap must be stopped. Here, we chose to avoid presenting the long-run implications of stopping the cap as the analysis would have become too lengthy for the scope of this paper. Therefore, this work only covers the short-to-medium run.

To sum up, both the type of policy and the way it is modelled provide novel contributions to the postgrowth and post-Keynesian literature and allow us to deepen our understanding of the transition.

The way in which the cap is modelled in this work requires some further explanations.

First of all, it is worth describing the core features of a cap-and-trade scheme in order to shed light on the rationale behind some of the simulations that will be presented in this work. A cap-and-trade scheme is a policy that aims to constrain the amount of aggregate production of a given resource or pollutant to a certain pre-defined level. In order to implement the cap, in any given period a limited number of allowances are issued by the regulatory authority and distributed to different economic actors depending on the authority's priorities. Producers of the resource can then trade the allowances in order to obtain a number of allowances equal to the quantity of resource that they want to produce. At the end of the period, allowances are handed over to the regulatory authority and a new round of issuance follows. The decision concerning the distribution of the allowances does not affect the results of the policy, but it has relevant consequences in terms of distributional effects (Stavins, 2008). Indeed, if the government decides to auction the allowances, the revenue collected through the auctioning can be spent for other purposes. Conversely, giving free allowances to certain industries can be seen as a form of compensation for the negative effects that the cap might have on them.

In this model, the cap is implemented both on domestic resource consumption in the North and on imports to the North from the South. The cap on resources embedded in imports is crucial to avoid inconsistencies in the policy goal. Indeed, without controlling for imports, the introduction of a cap on domestic resource consumption alone would have the perverse effect of leading to an increased outsourcing of resource extraction in the other area. A further feature of the cap is that it becomes smaller every year. This choice stems from the evidence that, in the real world, the consumption of resources in the Global North far exceeds sustainable levels (Bringezu, 2015). Therefore, fixing the level of resource consumption in wealthy countries is not enough; it has to decrease rapidly.

The level of aggregation of this model does not allow for in-depth modelling of the trade side of the policy. Thus, what happens is that after the introduction of the cap, the price of resources increases until the demand for them is reduced enough to match the capped supply. This happens both for domestic resource production and for imports. The price of allowances is obtained as the difference between the original price of resources and the new price needed to equilibrate demand and supply. Once this difference is multiplied by the quantity of resources produced and purchased through import, we obtain the revenue generated by the introduction of the policy. If all this revenue is allocated to the government, then we can say that the allowances have been auctioned. If the revenue is allocated to a specific sector, then allowances have been freely distributed to that sector. The various combinations of auctioning and free allocation to different sectors are potentially endless. In the simulations that will be presented in the next section, we will examine two interesting cases.

5 Scenario analysis

This section will present two scenarios where the resource cap is introduced. The first one is dubbed *Baseline* and simulates the introduction of a declining cap which is imposed on the North from period 5 onwards. All the allowances are auctioned by the government and the income collected is used to repay public debt. This is the simplest possible way to model the cap and will allow us to fully grasp the fundamental dynamics triggered by it. A second scenario which aims to reflect a more coherent postgrowth strategy in the north (hereafter dubbed *Coherent*) will introduce additional policies implemented in the North to address some of the imbalances created by the cap. Specifically, these additional policies are:

1. A change in public R&D spending. A higher share of money is allocated to resource and import-saving technologies relatively to labour-saving ones, while part of the income collected through the auctioning of the allowances is added to the current R&D budget, thus effectively increasing overall public R&D spending.
2. A second policy compensates firms for the impact that the cap has on them. Specifically, the government does not auction all allowances but freely distributes a share of them to the traded sector, which is the most affected of the three production sectors.
3. The third policy is a shift in government sectoral consumption. The government slowly increases the consumption of non-traded sector goods, which are less material intensive, and reduces consumption of traded goods, thus reducing the pressure on resource and import prices.

In both scenarios, the South remains passive and (for the purposes of this paper) no policies are implemented in this area. Though this assumption is unrealistic, it is necessary to avoid over-complicating the analysis at this point. These two scenarios already introduce a lot of dynamics, adding a reaction in the South would confound the effects of the cap, reducing the clarity of the modelling exercise. The Southern reaction will be explored in a future work.

The analysis will focus on the medium run, that is, it will stop 20 periods after the introduction of the cap. The reasons for this stem from the nature of the simulation and the purpose of this work (and have been partly discussed in the previous section). The former means that simulating the cap poses a real, shrinking constraint on the economy, which inevitably makes it impossible to reach a new steady state. The simulation can go on for other 60-70 periods, but then the cap becomes so small that the model crashes. A steady state could be reached again only if the cap stops declining, which leads to the latter reason, namely, that the simulations focuses on the impact of the policy and its reactions to it. Including the analysis of the stop of the cap and its consequences would require a new description of the impact of this new change in the economic environment as well as a discussion of the different reactions that the economic actors could have regarding it. This would make the analysis very lengthy and include further arbitrariness. In other words, the longer the time span considered, the weaker the analysis becomes. Therefore, it is sensible to find a compromise.

A 20-period time span is chosen here because it allows us to discuss the transitioning phase towards a postgrowth economy while also showing all the relevant dynamics between the main variables. Longer time spans simply show the same dynamics playing out for longer, which does not add much to the analysis.

To start the presentation of the results, we will focus on the core dynamic of the model, which can be illustrated by looking at inflation, real GDP and technological change. We will firstly look at what happens in the Northern area and will discuss the Southern dynamics later. The *Baseline* is presented with solid lines and the *Coherent* scenario is represented with dotted lines in the following graphs.

As soon as the cap on resources and on (resources embedded in) imports is introduced in the North, the inflation rate of resource and imports increases (Figure 5.1). This happens because higher prices are needed to reduce the desired demand for both goods and make them match the new capped supplies. As a general principle of this model, higher inflation has two major effects on the economy. Firstly, it shrinks real GDP as aggregate demand is overall lower. Secondly, it reshapes the pattern of technological development as the costs of inputs change. In both scenarios, the higher resource and import prices in the North lead exactly to these two outcomes, which are shown in the next two figures.

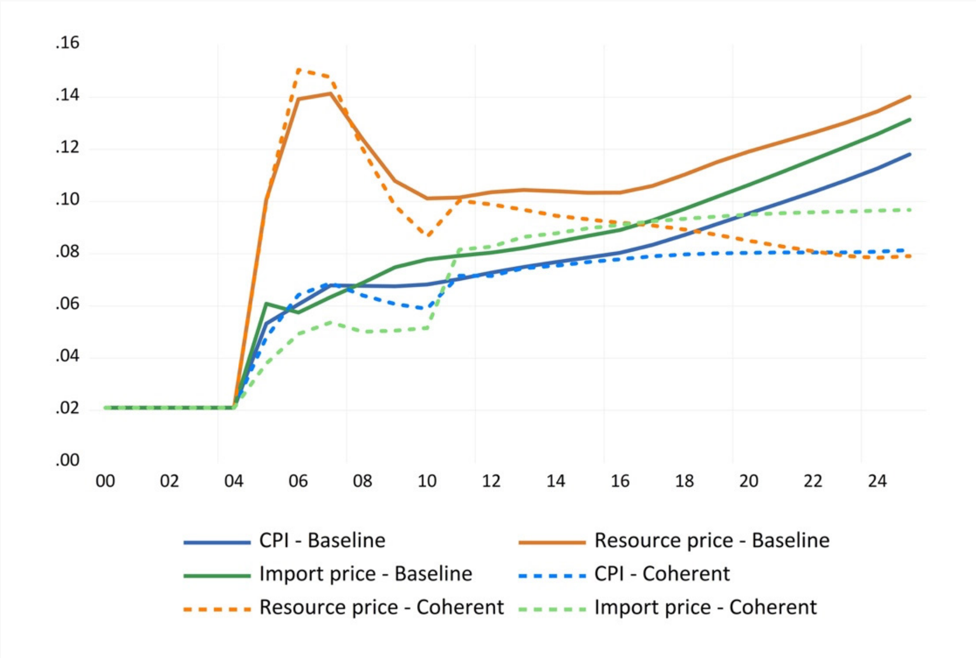

Figure 5.1 | Inflation rates – North

Figure 5.2 shows the reduction in the growth rate of real GDP for the North. The negative impact of inflation is much stronger for the *Baseline* scenario as the Northern government does not implement any other policies to protect the economy from the impact of the cap. The result is a sort of degrowth transition. The *Coherent* scenario shows a better outcome thanks to higher public investment in R&D, which lowers the pressure of the resource constraint on the economy, and the structural shift in government consumption towards the non-traded sector, which is not resource intensive.

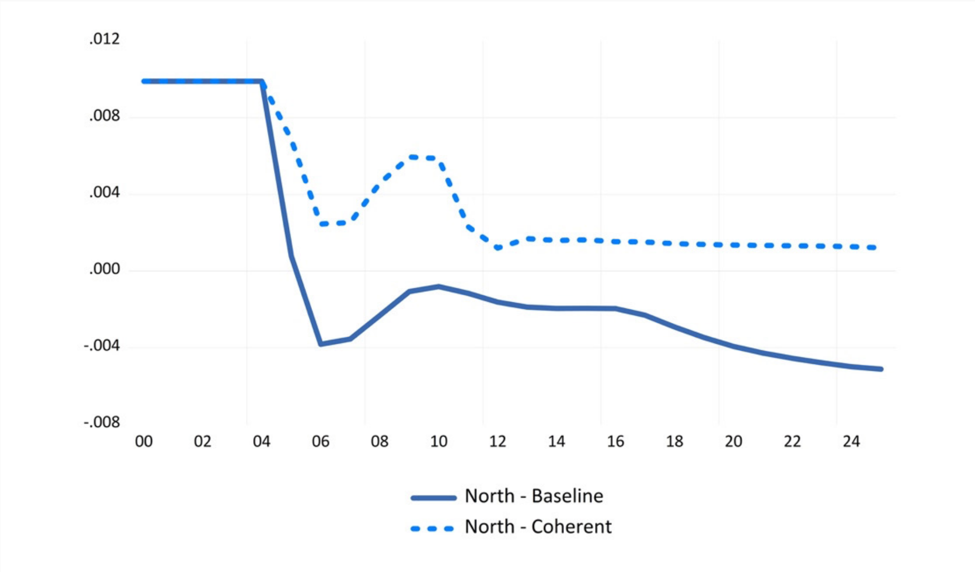

Figure 5.2 | Real GDP growth rate – North

Figure 5.3 shows the other important dynamic triggered by the change in inflationary patterns. Technological change now moves towards resource and import-saving technologies rather than labour-saving ones. Again, the *Baseline* scenario tends to show a more moderate restructuring of technological development because the government keeps constant its allocation of R&D funding to different technologies and does not increase the overall R&D investment. The *Coherent* scenario addresses these inconsistencies and show a much bigger movement in technological change. It is important to notice that in this latter scenario labour productivity growth becomes negative by the end of the simulation. This has important implications for the unemployment rate in the North.

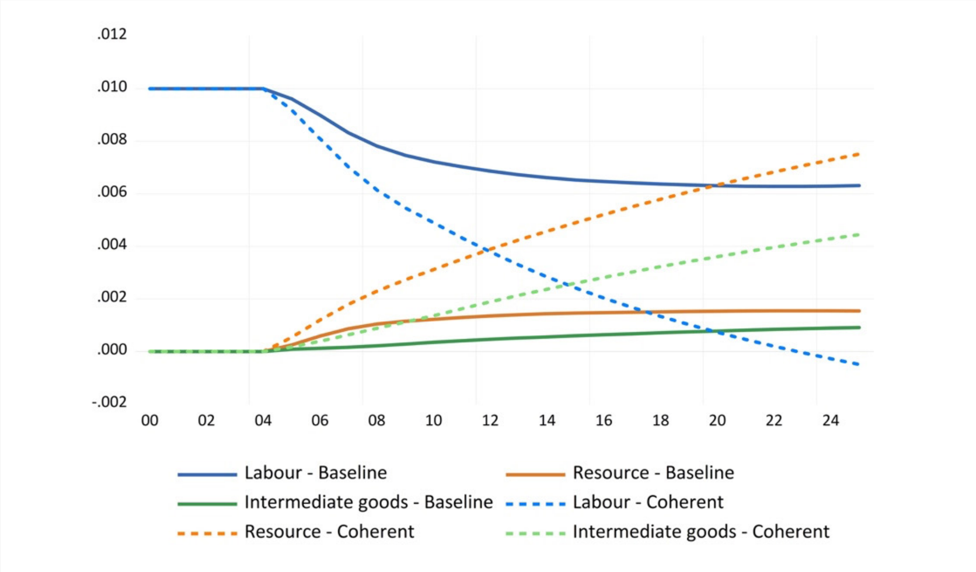

Figure 5.3 | Productivity growth rates – Traded Sector – North

To recap, we have seen that the introduction of the cap alters the structure of relative prices. This has two major implications. GDP is depressed as aggregate demand is reduced by higher inflation and the direction of technological progress shifts following the increased costs of resources and imports. These core dynamics subsequently impact all the other variables in the economy, which in turn have feedback effects on the former. Before discussing some of these effects, we will describe what happens in the South in terms of these three core variables, i.e., inflation, GDP and technological change.

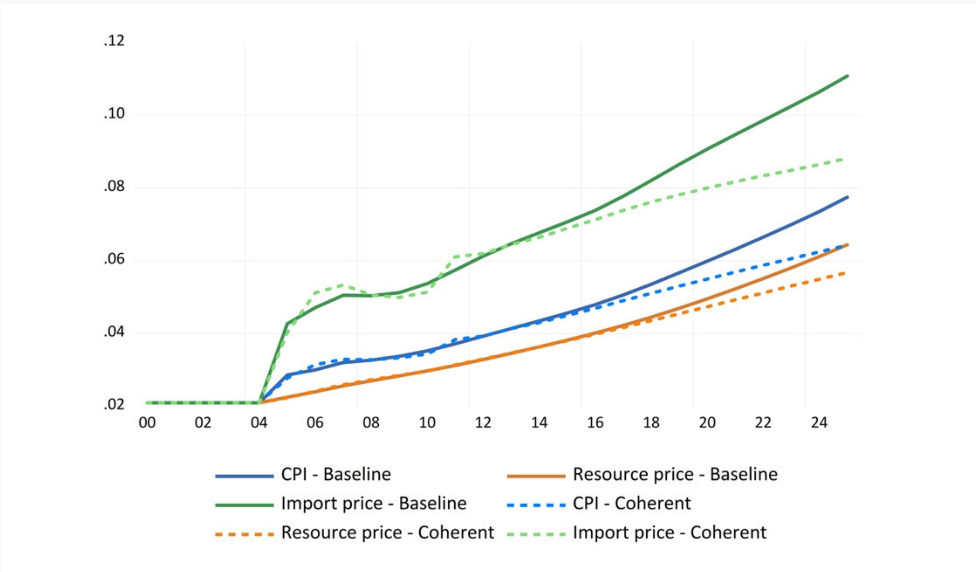

Figure 5.4 | Inflation rates – South

By construction, the South does not implement any policies in reaction to the changes in the North. However, its inflation rate starts to increase as a result of the introduction of the cap in the North (Figure 5.4). This is mainly driven by the price of imports, which becomes higher due to two main factors: the price of exports in the North increases due to the higher cost of resources; and the Southern currency depreciates. As can be seen in Figure 5.4, the *Coherent* scenario has the positive effect of lowering imported inflation in the South at the end of the simulation.

The higher inflation rate has a negative impact on real GDP growth in the South (Figure 5.5). This is generally lower as the overall inflation is more modest, but by the end of the simulation it starts to become substantial. Interestingly, the alternative scenario makes the North more internationally competitive and this has a negative impact on the Southern economy. The real GDP of the South is not only affected by higher inflation. Indeed, the Northern cap on imports limits the ability of the South to export to the North. Therefore, a contraction of exports is also partly responsible for the general slowdown in real GDP growth of the South.

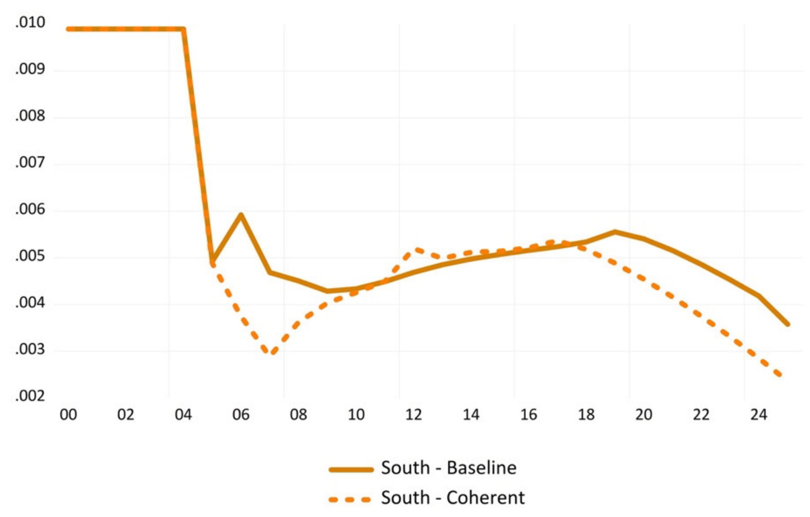

Figure 5.5 | Real GDP growth rate – South

Lastly, the change in inflation rates affects the technological development of the South. Figure 5.6 shows that there is more investment in import-saving technologies. However, it remains fairly modest as the overall change in inflation of the different productive inputs is not as marked as in the North. Moreover, there is little incentive in investing in resource-saving technologies as the price of resources is not altered in the South. This could be considered unrealistic as the South would still have an incentive to make its production more resource-efficient in order to be able to trade more with the North. This is a limitation of the model that can be addressed by simulating a reaction by the South to these changing circumstances. This will be the subject of future work. However, it goes beyond the scope of the present work.

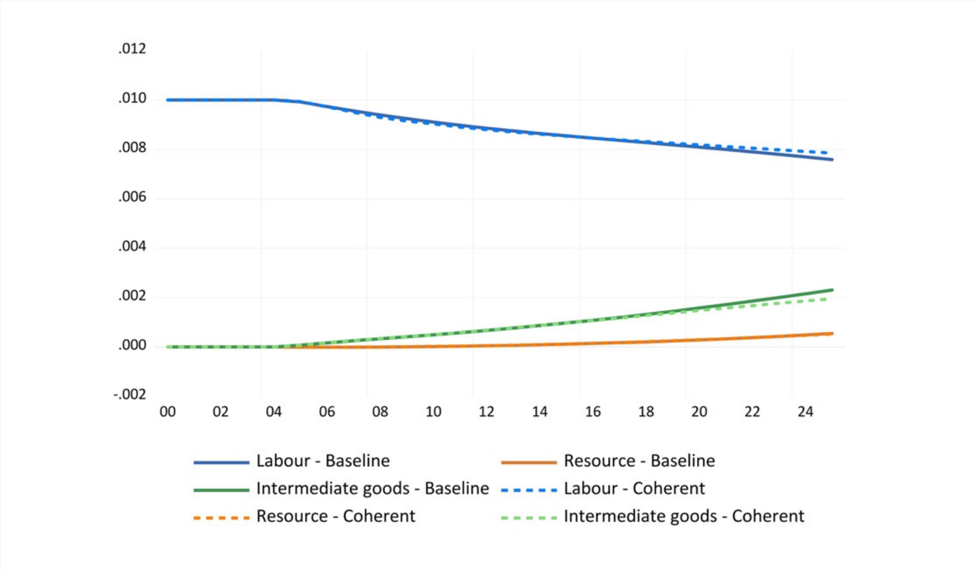

Figure 5.6 | Productivity growth rates – Traded sector – South

Having shown how the core dynamics of the model play out in both areas, it is worth discussing the major implications for the international dimension of the model and how these in return affect the two areas.

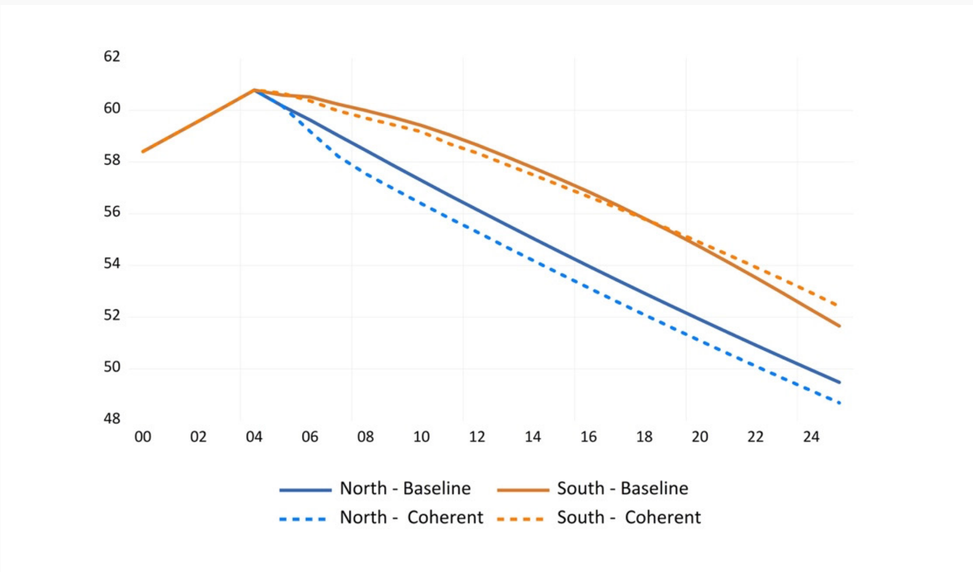

Figure 5.7 | Real imports

Figure 5.7 shows the impact of the cap on real imports of the two areas, which is one way to represent the dynamics of international trade. The cap limits the amount of goods that the South can sell to the North, whereas Southern imports from the North are not so directly constrained. This explains why Southern real imports are higher than the Northern ones. The *Coherent* scenario shows an even bigger difference because the North becomes more resource efficient, thus can sell more goods to the South, while simultaneously decreasing its reliance on imports as it invests more in import-saving technologies and shifts government consumption away from foreign goods.

Unsurprisingly, these dynamics lead to a trade surplus in the North (Figure 5.8). Consequently, the South becomes a net recipient of capital inflows. International financial flows in this first version of the model are kept very simple and tend to behave passively. A more sophisticated specification of the equations that govern the behaviour of international investors can produce more complex results. However, this is beyond the scope of the present paper.

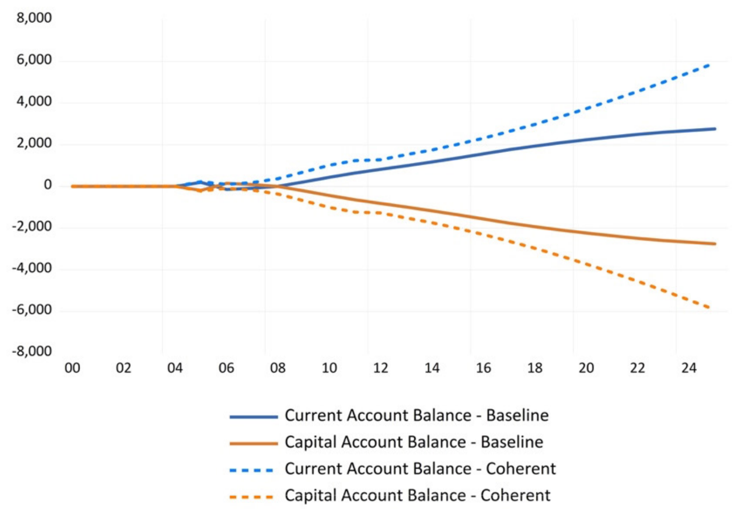

Figure 5.8 | Balance of payments – North

The consequences of the Northern trade surplus on the movement of the exchange rate are shown in Figure 5.9. After five or six periods of (relative) stability, the Southern currency starts to steadily depreciate. However, the loss of value in the Southern currency is not enough to offset the trade imbalance, thus the movement of the exchange rate is not able to stabilise the balance of payments. In this work, trade is the main driver of currency movements. This has long been debated in economics (Harvey, 2009). Some scholars argue that international financial flows play a bigger role than real flows in determining exchange rate conditions. In this model, it is possible to model financial flows so that they become the major determinant of exchange rate movements. However, this analysis has not been included to simplify the exposition of the results.

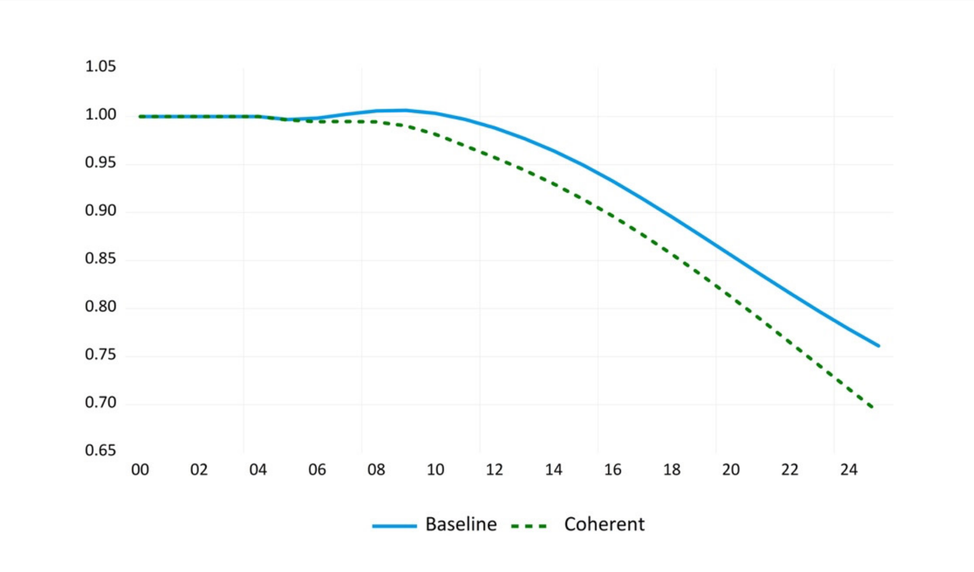

Figure 5.9 | Exchange rate (South currency / North currency)

The effects of the cap on the international economy have repercussion on several variables in both areas. The most important of these are the impacts on the profits of the traded sector. These are partly driven by the pricing behaviour of exporters. Indeed, when exporters decide the price of their goods, they can follow two strategies. They can set their export price either based on the other country price level and the movements of the exchange rate or based on the price of the same good sold on their domestic market. In both scenarios, we assume that they equally weigh the two strategies so that all three variables are considered in the final export price[5].

However, this leads to a somewhat inconsistent behaviour. For instance, Northern exporters see their currency appreciating, so that the actual price of their exports becomes higher for Southern customers. If Northern exporters reacted more to exchange rate movements than to their own domestic price, they would cut down their export price so that the Southern import price (Northern exports denominated in Southern currency) would be relatively lower. However, there is little economic sense in trying to preserve export sales when the actual production is limited by the cap. Therefore, the most rational behaviour of Northern exporters would be to let the price of Southern imports increase as much as the exchange rate movement allows (full pass through), so that they maximise their profits. Similarly, Southern exporters must decide whether to exploit the depreciation of their currency to charge a lower price for Northern

5 Equation 150 and its description in the Appendix section 'Trade and exchange rate' can be helpful to better understand the argument.

customers or keep the Northern import price (Southern exports denominated in Northern currency) stable and enjoy extra profits. The first strategy could expand the market share of Southern exporters, but it does not make economic sense in a context where Northern imports are capped. Therefore, the most rational pricing behaviour of Southern exporters would be to earn extra profits by increasing the price of their exports at the same rate of the depreciation of their exchange rate (no pass through).

As mentioned above, in these two simulations exporters maintain a balanced behaviour. Therefore, Northern exporters partly reduce the price of their exports and thus accept a shrinking of their real profits (Figure 5.10). In the *Baseline* scenario, the reduction is substantial. One of the biggest negative consequences is that private R&D investment depends on profits, thus this fall in the real profit of the traded sector leads to less investment in technological development, which is crucial for the transition. In the *Coherent* scenario, this dynamic is partially offset by freely allocating a share of allowances to the traded sector. As can be seen in Figure 5.10, this policy is effective in stabilising real profits of the traded sector.

For what concerns the South, Figure 5.11 shows that Southern exporters make substantial profits due to the cap. However, if they had fully adopted the strategy of increasing the export price as much as the depreciation of their currency allowed, they would have made even higher profits.

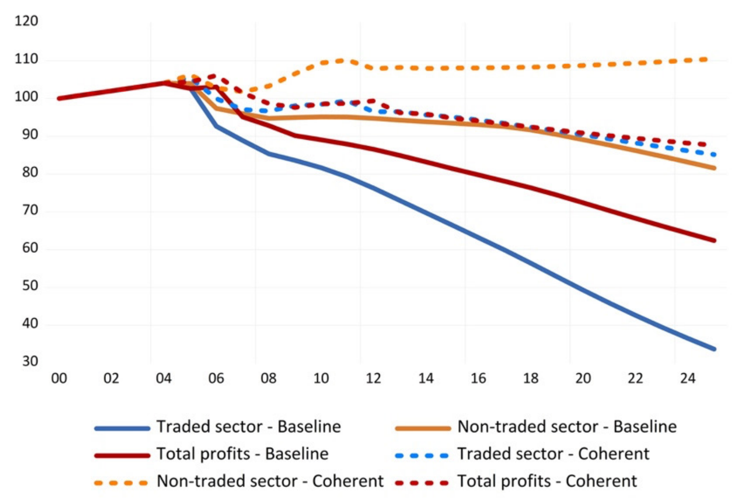

Figure 5.10 | Real net profit index (Base year = 00) – North

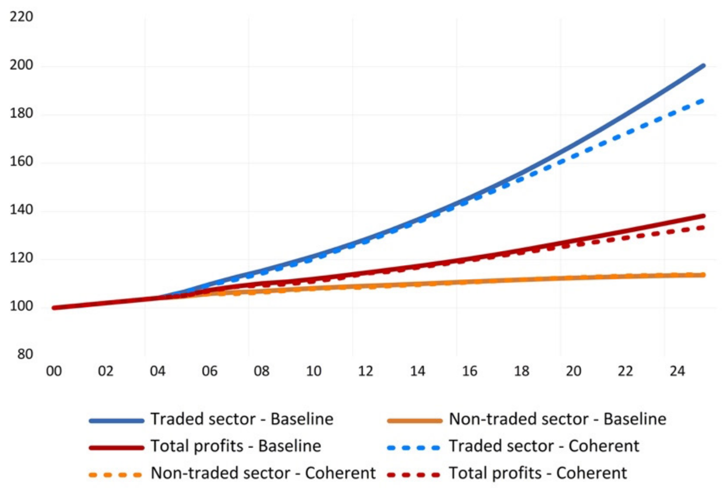

Figure 5.11 | Real net profit index (Base year = 00) – South

The dynamics of profits have important consequences for the income distribution of the two areas. In the North, workers experience a reduction in real wages but this is lower than the reduction in real profits. Therefore, the share of disposable income going to worker becomes slightly higher (Figure 5.12). Conversely, the boom in Southern profits leads to a dramatic increase in the income of the capitalist class, worsening income inequality (Figure 5.13). This is only partly offset in the *Coherent* scenario.

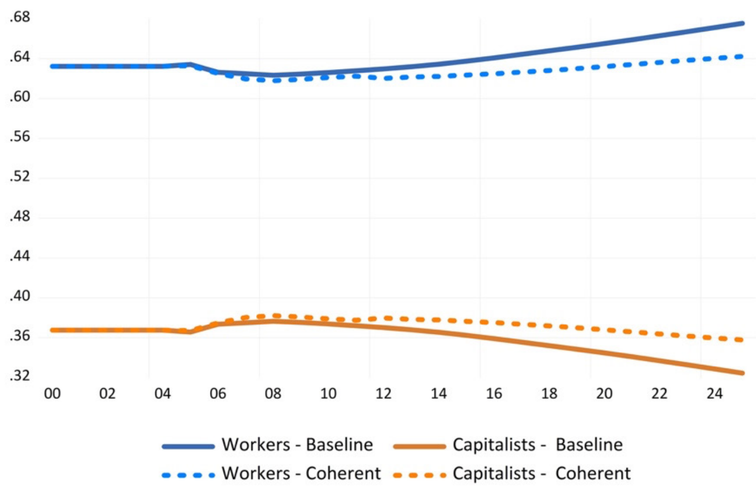

Figure 5.12 | Share of disposable income over total disposable income – North

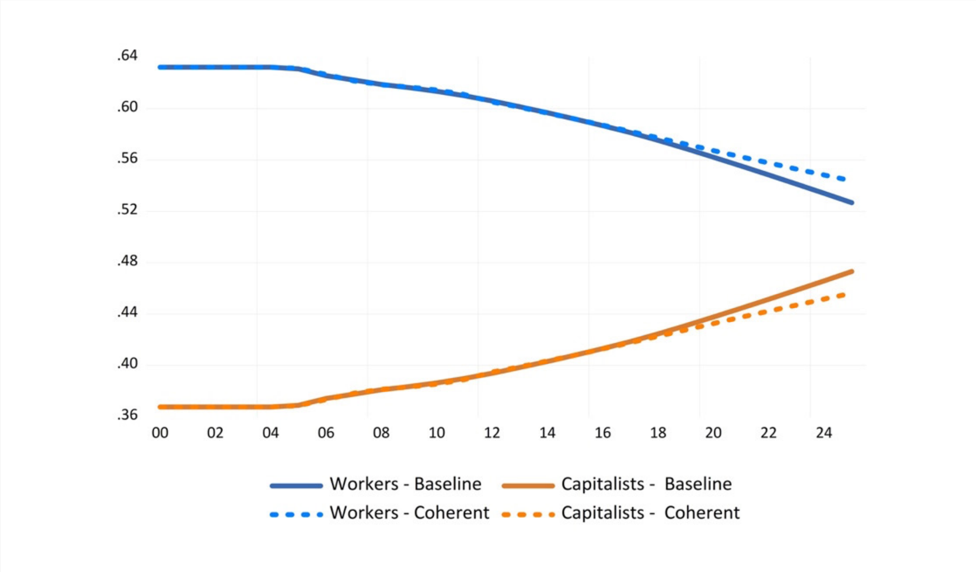

Figure 5.13 | Share of disposable income over total disposable income – South

Lastly, it is worth highlighting how technological change impacts on the unemployment rate in the North.

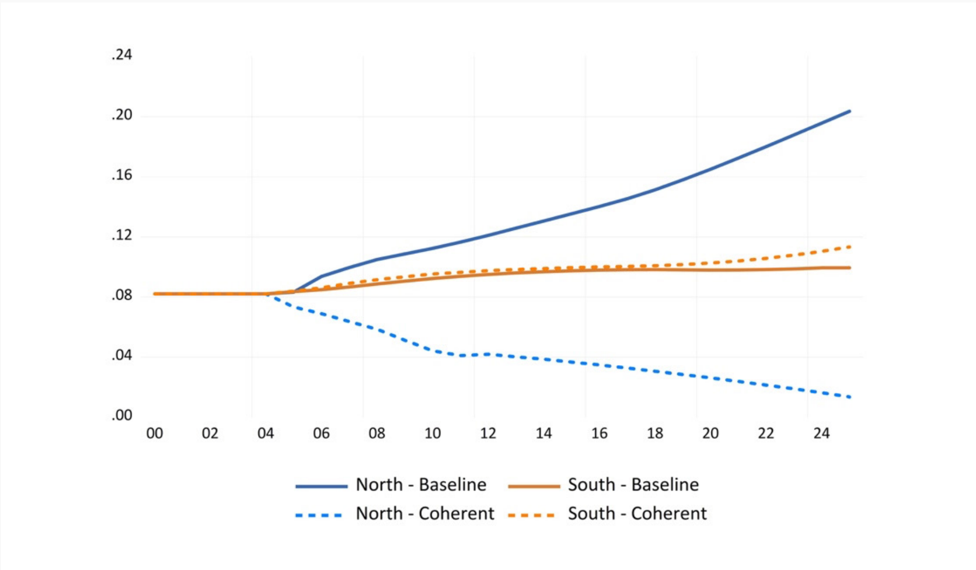

Figure 5.14 | Unemployment rate

Figure 5.14 shows the dramatically different results for the *Baseline* and *Coherent* scenario. In the former, unemployment skyrockets, reaching unsustainably high levels, because of the sharp reduction in real GDP coupled with a positive labour productivity growth rate. In the latter, full employment is reached thanks to the massive shift in the direction of technological progress and the government increasing consumption of non-traded goods (which are more labour intensive). Clearly, this result partly rests on the assumption that improvements in the efficient use of one productive input have to be offset with relative reductions in the efficiency of another one. However, it shows that the common concern that a postgrowth economy would lead to high levels of unemployment might be partially mitigated when endogenous technological change is taken into account.

6 Discussion

This subsection will provide an assessment of the results and discuss the main limitations of this work. Before doing so, however, it is useful to understand how effective the cap has been. Figure 6.1 shows the trajectory of real GDP and material consumption at the global level. Material consumption decreases quite substantially in both scenarios and by the end of the simulation it is 10% lower compared to the year when the cap is introduced. Conversely, global GDP at the end of the *Baseline* simulation is only few percentage points higher than in period 05. However, this aggregate measure conceals the redistribution of income that has occurred between the two areas. Indeed, the share of global GDP owned by the South changes from 50% to 55%, which would be a desirable outcome from a real-world perspective. In the *Coherent* scenario, global GDP performs more strongly, showing moderate absolute decoupling from resource consumption.

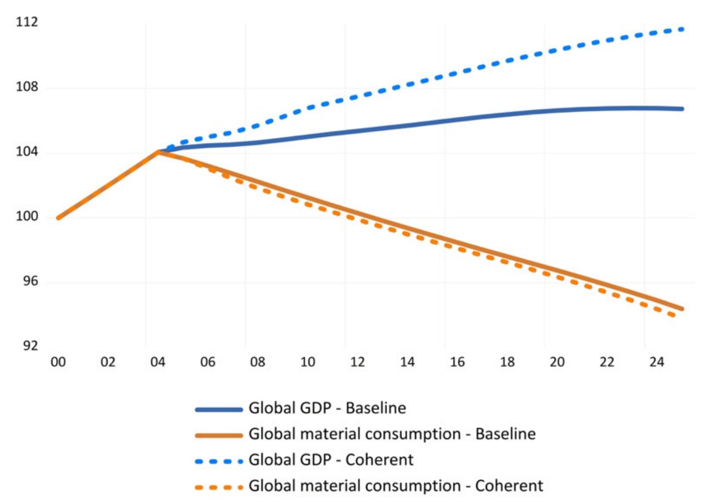

Figure 6.1 | GDP and material consumption index (Base year = 00) – World level

Overall, it can be concluded that the cap is effective in bringing down resource consumption (and by implication environmental damage) though the economic cost of the policy is high especially when not supported by other policies. It is also worth remarking however, that resource cuts of this magnitude are not necessarily sufficient to put the world on a sustainable path in the long term.

As regards the macroeconomic implications of a postgrowth transition, it is worth remarking on several dimensions of the current economic system which are likely to be profoundly impacted. First of all, the model shows a rapid increase in inflation. This raises the question of how to deal with it in a postgrowth world. On one hand, high inflation is detrimental to the economic environment. On the other hand, it could be argued that in the first phases of a postgrowth transition, it would be a necessary evil. Indeed, it is important for stimulating technological progress towards improvement in resource efficiency. More importantly, it signals that aggregate real income is too high and needs to be reduced to reach ecological sustainability. In this sense, a broader shift in how inflation is perceived is probably needed in a postgrowth world. For instance, the main role of monetary policy might have to change. Indeed, higher interest rates would only negatively affect an economy that is already in a stagnant or even decreasing trajectory. Moreover, in this model at least, higher interest rates affect investment, reducing the speed of adoption of new, greener technologies.

A further complicating issue might be generated by the capital losses incurred by the banking sectors as rising interest rates shrink the market value of their assets. Thus, the mandate of central banks would need to be linked more closely to financial sustainability.[6] High inflation combined with low interest rates would erode the profits of finance, leading to a dangerously unstable financial environment. At the same time, increasing interest rates too much (and too quickly) might lead to big capital losses of the banking sector. The central bank could thus target indicators representing the soundness of the financial sector, balancing increases and decreases in the policy rate to ensure its stability.

Secondly, a transition can have a strong effect on the distribution of income and employment, which is one of the most discussed topics in the postgrowth literature (Cosme et al., 2017). However, much depends on the evolution of technological change. The assumption that a lower use of resources will have to be paired with a higher use of labour seems sensible, but the uncertainty regarding this topic remains high. Regardless of this, there is a significant likelihood that a constraint on consumption and higher inflation will have their most negative impact on low-income households. Policies that redistribute income are thus essential under postgrowth conditions. However, this has to be done very carefully. For example, a fairer distribution of income could stimulate consumption, which, given the cap, would just create more inflation. Policymakers would have to find a delicate

6 A discussion on the mandate of central banks in the ecological transition can be found in Campiglio (2016) and Campiglio et al. (2018) among the others, though a change in how inflation is perceived is not explicitly discussed. See also Jackson and Jackson (forthcoming).

balance between protecting the weakest parts of society while avoiding a strong increase in aggregate nominal demand.

This leads to a broader reflection regarding the need for rethinking the role and functioning of fiscal policies. In a postgrowth economy, the typical post-Keynesian recommendation of expansionary government spending cannot be seen as a standard solution. Indeed, this would probably imply higher resource consumption and thus be at odds with the pursuit of environmental sustainability. More specifically, if a cap was in place, it would be tantamount to exacerbating inflation. Therefore, the role of the government should shift towards ensuring that the transition is as smooth and painless as possible. The main strategies that it can adopt are investing in R&D to foster the improvement in resource efficiency and thus reduce the constraint imposed by the cap, promoting a structural shift towards labour-intensive and resource-light economic sectors (such as the care economy (Jackson, 2017)), or using tax (or allowances) income to compensate the most vulnerable parts of the economy.

Lastly, international trade will be severely affected by the transition. This has long been acknowledged in ecological economics (Muradian and Martinez-Alier, 2001). However, it is unclear what the consequences of a regionalisation of the world economy are. The model shows that the reduction in Southern exports implies some loss of one of the major drivers of economic development for lower-income countries. Moreover, a more regionally oriented economic system might lead to losses in production efficiency and a slower adoption of modern, resource-efficient capital in the developing world. On the other side, we know that trade also exacerbates the degradation of environment in the global South, as extensively shown in the ecologically unequal exchange literature (Dorninger et al., 2021). One possible way to reduce the negative consequences of deglobalisation is to improve international cooperation for what concerns the spreading and diffusion of novel technological developments. These would allow developing countries to rapidly implement more efficient productive processes and avoid remaining locked into trade patterns that consistently worsen the quality of their environment. Financial flows could be also redirected to help the South pay for the investment needed to increase its ecological sustainability.

Even in this context, post-Keynesian economics has not much to say in terms of policies to implement and how to deal with the international effects of the transition. Althouse et al. (2020) correctly point out that expansionary coordinated fiscal policies, a typical post-Keynesian recommendation for solving balance of payment issues, cannot be considered in the context of a postgrowth economy. However, as shown in this work, trade imbalances are very likely to continue and even worsen throughout the transition. Therefore, more research is urgently needed to address these gaps.

There are several limitations regarding the work presented above. Specifically, this model is not designed to replicate the existing trade structure between the global North and the global South. Thus, our analysis has abstracted from showing the uneven distribution of ecological burden of the current global production patterns. However, it is a feature that should be implemented, as it is likely to significantly affect the results of the simulations.

Moreover, international financial flows remain in the background of the analysis and are modelled in a very simplified way. This is mainly due to our desire to avoid further arbitrary assumptions on the behaviour of financial actors. Some instances of more realistic financial features include the important role that expectations play in determining exchange rate movements, the ability of international investors to trigger financial and economic crisis once they change their view on the macroeconomic fundamentals of a country, the tendency in many developing countries to borrow in foreign currency. Modelling these behaviours would lead to relevant dynamics but would also require making many assumptions on how expectations and behaviours are formed, which add a lot of arbitrariness and complicate substantially the results of the model.

Abstracting from these complications has been necessary to simplify the analysis and obtain a stable and robust model. However, future work will try to relax these limitations.

Lastly, a major caveat of this analysis is the absence of strategic behaviours of the different sectors. Once a policy is announced by the government, the rest of the economy does not always adapt to the changing environment.[7] For instance, the Southern government does not—in this version of the model—change its trade and R&D policies after the Northern government introduces the cap on imports. Banks are passive agents. Exporters do not change their pricing strategy. Being able to simulate adaptive, strategic behaviours would greatly improve the realism of this work. However, it comes at the cost of more arbitrary choices on what is the right (or reasonable) strategy that should be pursued by the different actors. Although the endeavour would be complicated, it could provide a rich ground for further analyses and is the focus of ongoing work.

7 Conclusion

In summary, this working paper has addressed the global issues raised by a transition to a postgrowth economy in the advanced economies. To our knowledge, it is the first post-Keynesian SFC model to have addressed these questions. Specifically, we have explored a significant open question in macroeconomic research on postgrowth transitions: namely the impact that a unilateral postgrowth transition in the North might have on trade and development in the South. Specifically, we developed a SFC model capable of simulating such a transition in the context of a 2-country regionalisation of the global economy. Our approach to the transition was to impose a declining resource cap on the North. This is one of the most direct ways to target environmental sustainability without imposing some form of

7 This argument is close to the famous Lucas critique. However, we reject the idea that microfoundations could be considered a solution to the issue.

exogenous cap on GDP itself, in keeping with the philosophy of postgrowth economics.

We have demonstrated through simulations of the model that the cap is effective in stopping resource consumption growth in the North and also reduces the global rate of resource consumption significantly. However, our simulations also highlight the danger of potentially negative impacts on the development of the South in the absence of appropriate policies. We have not simulated such policies here, focusing instead on policies which might be implemented in the North, to create a more coherent postgrowth transition. These policies are found to improve economic outcomes in the North, but could lead to worse outcomes in the South. Inflation, inequality and trade surplus all improve in the North under the *Coherent* scenario but worsen several macroeconomic outcomes in the South.

However, it is clear that there are potential policy responses, both in the North and the South, which could offset these perverse impacts on development in the South. Responses in the South might include a reform of the tax system to address the growth in income inequality and more investment in domestic R&D to reduce the dependency on imports from the North. Responses from the North could include the free transfer of technological knowledge or financial capital to foster investment in resource and labour productivity in the South. The model therefore supports wider calls for North to South transfers, in line both with historical responsibility for environmental damage in the North (UN, 2022) and the need for faster technological innovation to improve both economic and environmental outcomes in the South (Pigato et al., 2020). Future work will explore these policy suggestions.

References

Agarwal, S., Qian, W. and Tan, R. (2020) *Household Finance*, Springer Singapore.

Agarwal, S., Chomsisengphet, S., Yildirim, Y. and Zhang, J. (2021) Interest Rate Pass-Through and Consumption Response: The Deposit Channel. *The Review of Economics and Statistics*; 103 (5): 922–938.

Althouse, J., Guarini, G. and Porcile, J.G. (2020) Ecological macroeconomics in the open economy: Sustainability, unequal exchange and policy coordination in a center-periphery model, *Ecological Economics*, Volume 172.

Bond, S.R., Klemm, A., Newton-Smith, R., Syed, M. and Vlieghe, G.W. (2004) "The Roles of Expected Profitability, Tobin's Q and Cash Flow in Econometric Models of Company Investment." Institute for Fiscal Studies, *IFS Working Papers*: No. W04/12.

Bovari, E., Giraud, G. and Mc Isaac, F. (2018) "Coping with Collapse: A Stock-Flow Consistent Monetary Macrodynamics of Global Warming", *Ecological Economics*, 147: 383-98.

Bringezu, S. (2015) Possible Target Corridor for Sustainable Use of Global Material Resources, *Resources* 4, 25–54.

Cahen-Fourot, L., 2022 Looking for growth imperatives under capitalism: money, wage labour, and market exchange (No. 01/2022). Working Paper Series.

Campiglio, E. (2016) Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecological economics*, *121*, p. 220-230.

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G. and Tanaka, M. (2018) Climate change challenges for central banks and financial regulators. *Nature climate change*, *8*(6), p. 462-468.

Carnevali, E., Deleidi, M., Pariboni, R. and Veronese Passarella, M. (2020) "Cross-Border Financial Flows and Global Warming in a Two-Area Ecological SFC Model", *Socio-Economic Planning Sciences*. 2020, 100819, ISSN 0038-0121, https://doi.org/10.1016/j.seps.2020.100819.

Carruth, A., Dickerson, A. and Henley, A. (2000) "Econometric modelling of UK aggregate investment: the role of profits and uncertainty", *The Manchester School*, 68(3), pp. 276-300.

Castro, V. (2011) "Can central banks' monetary policy be described by a linear (augmented) Taylor rule or by a nonlinear rule?", *Journal of Financial Stability*, *7*(4), p. 228-246.

Chirinko, R. (1993) Business fixed investment spending, *Journal of Economic Literature*, vol. 21, no. 4, 1875-1911.

Cieplinski, A., D'Alessandro, S., Distefano, T. and Guarnieri, P. (2021b) "Coupling environmental transition and social prosperity: a scenario-analysis of the Italian case", Structural Change and Economic Dynamics, 57, 265-278.

Cieplinski, A., D'Alessandro, S. and Guarnieri, P. (2021a) Environmental impacts of productivity-led working time reduction, *Ecological Economics*, Volume 179, SSN 0921-8009, https://doi.org/10.1016/j.ecolecon.2020.106822.

Cosme, I., Santos, R. and O'Neill, D. W. (2017) "Assessing the degrowth discourse: A review and analysis of academic degrowth policy proposals", *Journal of Cleaner Production*, 149: 321–34.

Cummins, J.G., Hassett, K.A. and Oliner, S.D. (2006) "Investment behaviour, observable expectations, and internal funds", *American Economic Review*, 96(3), pp. 796-810.

Daly, H. E. (1974) "The Economics of the Steady State", The American Economic Review, 64(2), 15–21.

Daly, H.E. (1977) *Steady-State Economics*, Washington DC: Island Press.

D'Alessandro, S., Cieplinski, A., Distefano, T. Dittmer, K. (2020) Feasible alternatives to green growth. *Nat Sustain* 3, 329–335.

Dafermos, Y., Nikolaidi, M. and Galanis, G. (2017) "A stock-flow-fund ecological macroeconomic model", Ecological Economics, 131: 191–207.

Demena, B.A. and Afesorgbor, S.K. (2020) "The effect of FDI on environmental emissions: Evidence from a meta-analysis", *Energy Policy*, Volume 138, 111192.

Dorninger, C., Hornborg, a., Abson, D.J., von Wehrden, H., Schaffartzik, A., Giljum, S., Engler, J., Feller, R.L., Hubacek, K., Wieland, H. (2021) Global patterns of ecologically unequal exchange: Implications for sustainability in the 21st century, *Ecological Economics*, Volume 179.

Dunz, N. and Naqvi, A. (2016) “Environmental and Labor Policies in a North-South SFC Model”, draft (ONLINE)
https://www.boeckler.de/pdf/v_2016_10_21_dunz.pdf

Ekins, P., Meyer, B., Schmidt-Bleek, F. and Schneider, F. (2014) “Reducing Resource Consumption–A Proposal for Global Resource and Environmental Policy”, *Factor X* (pp. 249-273). Springer, Dordrecht.

Gennaioli, N., Ma, Y. and Shleifer, A. (2016) “Expectations and investment”, *NBER Macroeconomics Annual*, 30(1), pp. 379-431.

Glyn, A. (1997) “Does aggregate profitability *really* matter?”, *Cambridge Journal of Economics*, Volume 21, Issue 5, Pages 593–619.

Godley, W. (1996), Money, Finance and National Income Determination: An Integrated Approach, Economics Working Paper Archive, Levy Economics Institute. Online at:
https://EconPapers.repec.org/RePEc:lev:wrkpap:wp_167.

Godley, W. and F. Cripps (1983) *Macroeconomics* (London: Fontana).

Godley, W. and Lavoie, M. (2007) *Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth*, Palgrave Macmillan, Basingstoke, UK.

Gordon, R (2016) *The Rise and Fall of American Growth*. Princeton: Princeton University Press.

Gropp, R., Kok, C. and Lichtenberger, J.D. (2014) “The dynamics of bank spreads and financial structure”, The Quarterly Journal of Finance, 4 (04).

Haberl, W. et al. (2020) A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights. *Environmental Research Letters*, 15(6).

Hardt, L. and O’Neill, D.W. (2017) “Ecological Macroeconomic Models: Assessing Current Developments”, *Ecological Economics*, 134: 198-211

Hardt, L., Barrett, J., Taylor, P.G. and Foxon, T.J. (2021) What structural change is needed for a post-growth economy: A framework of analysis and empirical evidence. *Ecological Economics*, *179*, p.106845.

Harris, J.M. (2008) “Ecological macroeconomics: consumption, investment, and climate change”, *Global Development and Environment Institute Working Paper*, No. 08-02.

Hartwig, J. (2011) “Testing the Baumol–Nordhaus model with EU KLEMS data”, *Review of Income and Wealth*, 57(3), p. 471-489.

Harvey, J.T., (2009) *Currencies, capital flows and crises: A post Keynesian analysis of exchange rate determination*. Routledge.

Hein, E. (2018) “Autonomous government expenditure growth, deficits, debt, and distribution in a neo-Kaleckian growth model”, Journal of Post Keynesian Economics, 41(2), 316-338.

Hepburn, C. J., and Bowen. A. (2013) ‘Prosperity with Growth: Economic Growth, Climate Change and Environmental Limits’, ch. 29 in R. Fouquet (ed.), *Handbook of Energy and Climate Change*, Cheltenham, Edward Elgar.

Hickel J, Kallis G, Jackson T, O’Neill D, Schor J B, Steinberger J K, Victor PA and D Ürge-Vorsatz 2022. Degrowth can work—here’s how science can help. In: *Nature* 612, 400-403 (2022).
Doi: https://doi.org/10.1038/d41586-022-04412-x

Horváth, R. and Podpiera, A., (2012) “Heterogeneity in bank pricing policies: The Czech evidence”, *Economic Systems*, 36(1), pp. 87-108.

Jackson, A. and Jackson, T. (2021) Modelling energy transition risk: The impact of declining energy return on investment (EROI), *Ecological Economics* 185: 107023.

Jackson, A. and Jackson, T. (2023) Something's got to give: Fiscal and monetary policy in the post pandemic era. Submitted to *Cambridge Journal of Economics*. Forthcoming.

Jackson, T. (2009) *Prosperity without Growth—Economics for a Finite Planet*, London: Routledge.

Jackson, T. (2017) *Prosperity without growth: Foundations for the economy of tomorrow*. London: Routledge.

Jackson, T. (2019) The Post-Growth Challenge: Secular Stagnation, Inequality and the Limits to Growth. *Ecological Economics* 156: 236-246. https://doi.org/10.1016/j.ecolecon.2018.10.010.

Jackson T, Gallant B and S Mair (2023) Towards a Model of Baumol's Cost Disease in a Postgrowth Economy—developments of the FALSTAFF stock-flow consistent (SFC) model. *CUSP Working Paper* No. 37. Guildford: Centre for the Understanding of Sustainable Prosperity. Online: https://cusp.ac.uk/wp-content/uploads/WP-37.pdf

Jackson, T. and Victor, P. (2020) The Transition to a Sustainable Prosperity—A Stock-Flow-Consistent Ecological Macroeconomic Model for Canada, *Ecological Economics*, Volume 177, https://doi.org/10.1016/j.ecolecon.2020.106787.

Kalecki, M. (1965) Theory of Economic Dynamics, 2nd edition, Allen and Unwin, London

Kallis, G. (2018) *Degrowth*, Newcastle upon Tyne: Agenda Publishing.

Krausmann, F., Lauk, C., Haas, W., Wiedenhofer, D. (2018) From resource extraction to outflows of wastes and emissions: The socioeconomic metabolism of the global economy, 1900–2015, *Global Environmental Change*, 52, 131–140.

Krausmann, F., Schandl, H., Eisenmenger, N., Giljum, S. and Jackson, T. (2017) 'Material Flow Accounting: Measuring Global Material Use for Sustainable Development', *Annual Review of Environment and Resources*, 42(1), pp. 647-675.

Jakob, M. and Edenhofer, O. (2014) Green growth, degrowth, and the commons, *Oxford Review of Economic Policy*, 30(3), pp.447-468.

Lavoie, M. (2014) *Post-Keynesian Economics: New Foundations*, Cheltenham: Edward Elgar.

Lawn, P. (2011) Is steady-state capitalism viable? A review of the issues and an answer in the affirmative, *Annals of the New York Academy of Sciences*, 1219(1), pp. 1-25.

Mano, R. and Castillo, M. (2015) The level of productivity in traded and non-traded sectors for a large panel of countries, *International Monetary Fund Working Paper*, WP/15/48.

Martin, C. and Milas, C. (2004) Modelling monetary policy: inflation targeting in practice, *Economica*, *71* (282), p. 209-221.

Muradian, R. and Martinez-Alier, J. (2001) Trade and the environment: From a 'Southern' perspective, *Ecological Economics*, 36, 281-297.

Naqvi, A. and Stockhammer, E. (2018) Directed technological change in a post-Keynesian ecological macromodel, *Ecological Economics*, 154, p. 168-188.

Nieto, J., Carpintero, Ó., Miguel, L.J. and de Blas, I. (2020) Macroeconomic modelling under energy constraints: Global low carbon transition scenarios, *Energy Policy*, 137, p.111090.

Nordhaus, W.D. (2008) Baumol's diseases: a macroeconomic perspective. *The BE Journal of Macroeconomics*, *8*(1).

Pigato, M., Black, S., Dussaux, D., Mao, Z., McKenna, M., Rafaty, R., Touboul, S., (2020) Technology Transfer and Innovation for Low-Carbon Development; Washington, DC: World Bank. Online at: https://openknowledge.worldbank.org/entities/publication/ba95cb2c-6db5-5a29-bcad-36d97cb988ac

Rezai, A. and Stagl, S. (2016) Ecological macroeconomics: Introduction and review, *Ecological Economics*, 121: 181-85.

Rockström, J., Gupta, J., Lenton, T.M., Qin, D., Lade, S.J., Abrams, J.F., Jacobson, L., Rocha, J.C., Zimm, C., Bai, X., Bala, G., Bringezu, S., Broadgate, W., Bunn, S.E., Declerck, F., Ebi, K.L., Gong, P., Gordon, C., Kanie, N., Liverman, D.M., Nakicenovic, N., Obura, D., Ramanathan, V., Verburg, P.H., Van Vuuren, D.P., Winkelmann, R., (2021) Identifying a safe and just corridor for people and the planet. *Earth's Future*, 9 (4).

Rosenbaum, E. (2015) Zero growth and structural change in a post Keynesian growth model, *Journal of Post Keynesian Economics*, 37: 623-47.

Schandl, H., Hatfield-Dodds, S., Wiedmann, T., Geschke, A., Cai, Y., West, J., Newth, D., Baynes, T., Lenzen, M., Owen, A. (2016) Decoupling global environmental pressure and economic growth: scenarios for energy use, materials use and carbon emissions. *Journal of Cleaner Production*. 13245–56.

Stavins, R.N. (2008) Addressing climate change with a comprehensive US cap-and-trade system. *Oxford Review of Economic Policy*, p. 298-321.

Storm, S. (2017) The New Normal: Demand, Secular Stagnation and the Vanishing Middle-Class. *INET Working Paper* No 55, May 2017. Online: https://www.ineteconomics.org/uploads/papers/WP_55-Storm-The-New-Normal.pdf.

Sue Wing, I., (2006) Representing induced technological change in models for climate policy analysis. *Energy Economics*, 28 (5-6), p. 539-562.

Sue Wing, I., and Eckaus, R. S. (2004). Explaining long-run changes in the energy intensity of the us economy, MIT Joint Program on the Science and Policy of Global Change, report 116.

UN (2022) Loss and Damage—a moral imperative to Act. United Nations. Climate Action Blog by Adelle Thomas. Online at: https://www.un.org/en/climatechange/adelle-thomas-loss-and-damage

Van den Bergh, J. C. (2011) Environment versus growth—A criticism of "degrowth" and a plea for "a-growth", *Ecological economics*, 70(5), 881-890.

Vandeventer, J.S., Cattaneo, C. and Zografos, C. (2019) A Degrowth Transition: Pathways for the Degrowth Niche to Replace the Capitalist-Growth Regime, *Ecological Economics*, 156: 272-86.

Victor, P. (2008) *Managing Without Growth: Slower by Design, Not Disaster*, Cheltenham: Edward Elgar.

Victor, P.A. (2012) Growth, degrowth and climate change: A scenario analysis. *Ecological Economics*, 84, p. 206-212.

Victor, P. A., and Jackson, T. (2020) A research agenda for ecological macroeconomics. In Sustainable Wellbeing Futures. Cheltenham, UK: Edward Elgar Publishing

Victor, P. and Rosenbluth, G. (2007) Managing without growth, *Ecological Economics*, 61: 492– 504.

Weiss, M. and Cattaneo, C. (2017) Degrowth—Taking Stock and Reviewing an Emerging Academic Paradigm, *Ecological Economics*, 137: 220-30.

Appendix A. Description of the model

This appendix is devoted to a detailed presentation of the model including the model equations. As the two areas are identical, there is no need to describe the equations of both areas. From now on, we present only the equations of the North. When variables belonging to the South will appear, they will be defined by the superscript S.

Household sector

In this model, households are divided into two groups: workers and capitalists. The first group provides labour to the productive sectors and to R&D activities in exchange for wages. Moreover, unemployed workers receive unemployment benefits from the government. In line with many post-Keynesian models and the empirical evidence (Lavoie, 2014), workers have higher propensity to consume than capitalists. In this model, we follow the traditional Kaleckian assumption (Kalecki, 1965; Rosenbaum, 2015; Hein, 2018) that wage earners spend all their income and make no savings. Conversely, the capitalist group receives profits from the banking and firm sectors and interest payments on deposits. Capitalists divide their income between consumption and savings, though they can invest their savings only in deposits which pay a minimum interest rate. Adding a more sophisticated portfolio approach as in traditional SFC models is possible but does not significantly improve the results of the model.

We now present the equations of this sector. Firstly, we introduce how households' income is determined, then we describe the consumption function and lastly discuss how savings are obtained. As indicated above, households' nominal disposable income is divided between income from wages YD_w and from capital YD_c:

$$YD_w = (NW + \mho) * (1 - t_w) + G_{ws} \tag{1}$$

$$YD_c = (F_H^f + F_H^B + i_{d_{-1}} D_{H_{-1}}) * (1 - t_c) \tag{2}$$

Where NW is the wage bill, $\mho$ is the income received for R&D activities, G_{ws} is the unemployment insurance paid by the government, F_H^f and F_H^B are distributed profits from the firm[8] and banking sectors and $i_{d_{-1}} D_{H_{-1}}$ is interest payments on deposits. t_w and t_c are the exogenous tax rates on wages and capital income. Once disposable income is specified, consumption can be determined as:

$$CONS_H = \theta_0 YD_w + \theta_1 YD_c + \theta_2 V_{-1} \tag{3}$$

Where V_{-1} is nominal wealth in the previous period. $\theta_0, \theta_1, \theta_2$ are consumption coefficients and their values are attributed respecting this simple rule: $\theta_0 > \theta_1 > \theta_2$. In other words, the propensity to consume out of income of the capitalists is lower than that of workers, while the propensity to consume out of wealth is the lowest of the three. While θ_0 and θ_2 are

8 $F_H^f = F_H^T + F_H^D + F_H^R$. The profits of each specific sector will be presented later.

exogenous, θ_1 is endogenous and dependant on the change in the interest rate on deposits:

$$\theta_1 = \theta_{1_{-1}} - \nu_0 \Delta i_d \tag{4}$$

ν_0 is the exogenous sensitivity of the propensity to consume of capitalists to the interest rate on deposits. The choice of using the interest rate on deposits as the interest rate of reference for capitalists stems from the fact that they can only invest their savings in deposits. Overall, empirical works show mixed evidence on whether and how interest rates affect households' consumption and saving (Agarwal et al., 2020). This ambiguity might be due to the heterogeneity of households. Agarwal et al. (2021) show that interest-sensitive households react quite strongly to changes in interest rates. In this model, capitalists are the only type of household that is affected by changes in interest rates, thus only their propensity to consume is endogenised.

Nominal consumption is divided into three parts to account for the purchase of non-traded goods $CONS_H^D$, domestically produced traded goods $CONS_H^T$ and imports $CONS_H^m$:

$$CONS_H^D = \alpha_H * CONS_H \tag{5}$$

$$CONS_H^T = (1 - \alpha_H) * \beta_H * CONS_H \tag{6}$$

$$CONS_H^m = (1 - \alpha_H) * (1 - \beta_H) * CONS_H \tag{7}$$

Real consumption $cons_H$ is:

$$cons_H = \ cons_H^D + cons_H^T + \ cons_H^m \tag{8}$$

Where real consumption for each good is determined as:

$$cons_H^D = \frac{CONS_H^D}{p_D} \tag{9}$$

$$cons_H^T = \frac{CONS_H^T}{p_T} \tag{10}$$

$$cons_H^m = \frac{CONS_H^m}{p_m} \tag{11}$$

Where p_D, p_T, p_m are the price of non-traded, traded and imported goods respectively. In other words, households choose a fixed proportion of nominal income to allocate to the different goods, then real quantities of each good are determined based on their actual price. This formulation of the consumption function might seem odd as real consumption in SFC models is generally determined using equation 3. Namely, households decide their real consumption and then nominal consumption is determined by multiplying real consumption times prices. The results are not particularly different between these two versions. However, in the formulation used in this model, the price elasticity of each good tends to be higher than in the standard approach. Moreover, growing divergences between the prices of two goods might lead to an unrealistically low level of real consumption of a given good. In order to avoid this undesirable outcome, the coefficients α_H and β_H are subject to simple real target consumption constraints $\bar{\alpha}_H$ and $\bar{\beta}_H$. This means that when the real consumption of the non-traded goods becomes higher than the threshold $\bar{\alpha}_H$, the parameter α_H becomes smaller. Similarly, when the real consumption of the imported good becomes smaller than a certain threshold $\bar{\beta}_H$, the parameter β_H starts to grow. This is represented in the model using the following two equations:

$$\alpha_H = \alpha_{H_{-1}} + z_{cons_0}\alpha_0\left(\bar{\alpha}_H - \frac{cons_H^D}{cons_H}\right) \tag{11}$$

$$\beta_H = \beta_{H_{-1}} + z_{cons_1}\beta_0\left(\frac{cons_H^m}{cons_H} - \bar{\beta}_H\right) \tag{12}$$

α_0 and β_0 are exogenous parameters while z_{cons_0} and z_{cons_1} are conditional operators that have value 0 unless a certain condition occurs:

$$z_{cons_0} = 1 \;\; if \;\; \frac{cons_H^D}{cons_H} > \bar{\alpha}_H$$

$$z_{cons_1} = 1 \;\; if \;\; \frac{cons_H^m}{cons_H} < \bar{\beta}_H$$

The rationale for adopting a consumption function that starts from nominal values stems from the desire of simulating the introduction of a cap on resources in order to start a postgrowth transition. This formulation of consumption is necessary for allowing the modelling of the cap.

Once consumption has been determined, capitalists save the remaining part of their income. This is shown in the equation for nominal wealth V, which is:

$$V = V_{-1} + YD_w + YD_c - CONS_H + \Delta OF_B \tag{13}$$

Where ΔOF_B is the change in banks' own funds, which will be explained in subsection 0. Most of wealth is invested in deposits. This wealth is called financial wealth V_{fin} and is derived as:

$$V_{fin} = V - OF_B \tag{14}$$

In other words, the funds of the banking sector OF_B, i.e., banks' capital, still account as wealth of the capitalists, but cannot be considered as investible wealth as they are used as capital cushion by the banking sector.

As said above, financial wealth can only be invested in deposits D, thus:

$$D_H = V_{fin} \tag{15}$$

Deposits pay an interest rate i_d which will be described later.

Government sector

The government sector has a central role in this model. It collects taxes from wages, imports, capital income and firms' gross profits. Moreover, it has three types of expenditure: consumption of traded, non-traded and imported goods, R&D expenditure and social transfers. When expenditure is higher than the income collected through taxes, the government issues bonds to cover its deficit. However, what really makes this sector important is the way in which its expenditure is specified. Indeed, public spending grows following an exogenous growth rate, which plays a fundamental role in driving the growth rate of the whole model. The dynamics between labour productivity growth and real wages are also important for the determination of the growth rate of real GDP in this model. Indeed, a positive labour productivity growth rate would be sufficient to generate a growth model if the government sector was not introduced. However, once taxes are added to the model, they drag down growth in the long run (and thus a steady state is impossible to reach) unless government expenditure grows in line with the growth of labour productivity[9]. This condition is important to reach a stable steady state.

The description of the government sector starts from the equation that determines its target real expenditure $\bar{g}$:

$$\bar{g} = \bar{g}_{-1}(1 + \varsigma) \tag{16}$$

Where ς is its growth rate, which depends on an exogenous parameter and one specific condition, that is, that the level of public debt over nominal GDP does not overcome a certain threshold. Regardless of whether targeting the debt-to-GDP ratio is a sensible policy choice for a government, this is a common approach to public finances. The equation expressing this is:

$$\varsigma = \varsigma_0 + z_{g_0}\varsigma_1\left(\overline{Debt} - Debt_{-1}\right) \tag{17}$$

Where $Debt = \frac{B^s}{Y}$ is the public-debt-to-GDP ratio, $\overline{Debt}$ is the exogenous target threshold, ς_0 and ς_1 are exogenous parameters and z_{g_0} is a conditional operator that has value zero unless the threshold is overcome:

$$z_{g_0} = 1 \ if \ Debt > \overline{Debt}$$

From this first equation, nominal expenditure G can be written as:

$$G = p_{ds} * \bar{g} \tag{18}$$

Where p_{ds} is the price index for domestic sales.

It is necessary to first introduce nominal expenditure because, as for the household sector, the government plans its consumption starting from nominal values. Part of the nominal government budget G is allocated to R&D expenditure $\mho_G$:

9 It is also possible to have government expenditure growing at a lower (higher) rate than labour productivity growth. However, this would create a model with a constantly growing (decreasing) unemployment rate.

$$\mho_G = \Theta_G G \tag{19}$$

Θ_G is exogenously set. Then, nominal government consumption for the three available goods is:

$$G^D = \alpha_G * (G - \mho_G) \tag{20}$$

$$G^T = (1 - \alpha_G) * \beta_G * (G - \mho_G) \tag{21}$$

$$G^m = (1 - \alpha_G) * (1 - \beta_G) * (G - \mho_G) \tag{22}$$

Real government consumption is then obtained again by dividing nominal consumption of each good by their respective prices:

$$g^D = \frac{G^D}{p_D} \tag{23}$$

$$g^T = \frac{G^T}{p_T} \tag{24}$$

$$g^m = \frac{G^m}{p_m} \tag{25}$$

$$g = g^D + g^T + g^m \tag{26}$$

As for the household sector, the government starts its consumption decision with nominal values. As explained above, in order to avoid that long lasting divergences in prices lead to unrealistically low level of real consumption of a specific good, the parameter α_G and β_G are subject to a real target consumption level. The equations for the parameters of the government sector mirror those of the household sector:

$$\alpha_G = \alpha_{G_{-1}} + z_{g_1}\alpha_0 \left(\bar{\alpha}_G - \frac{g^D}{g}\right) \tag{27}$$

$$\beta_H = \beta_{H_{-1}} + z_{g_2}\beta_0 \left(\frac{g^m}{g} - \bar{\beta}_H\right) \tag{28}$$

α_0 and β_0 are exogenous parameters while z_{g_1} and z_{g_2} are conditional operators that have value 0 unless a certain condition occurs:

$$z_{g_1} = 1 \;\; if \;\; \frac{g^D}{g} > \bar{\alpha}_G$$

$$z_{g_2} = 1 \;\; if \;\; \frac{g^m}{g} < \bar{\beta}_G$$

Lastly, the government pays an exogenous share φ of average nominal wages W_{av} to all unemployed workers U:

$$G_{ws} = \varphi W_{av} U \tag{29}$$

Where the subscript ws stands for 'welfare state'. Given the way in which wages are determined, wages of the two sectors are identical, thus $W_{av} =$

$W_D = W_T$. Unemployed workers are total labour force minus employed workers $U = Q - N$.

Total nominal expenditure of the government before interest payments on public debt is:

$$G_{tot} = G + G_{ws} \tag{30}$$

It is worth highlighting that only G contributes to GDP, whereas G_{ws} is effectively a transfer.

Having described the government's main outflows, we now focus on its inflows, that is, the tax revenue. Total tax income T is the sum of taxes collected on wages T_w, capital income T_c, firms' profits T_f, imports T_m and cap allowances T_r:

$$T_w = t_w(NW + \mho) \tag{31}$$

$$T_c = t_c(F_H^f + F_H^B + i_{d_{-1}} D_{H_{-1}}) \tag{32}$$

$$T_f = t_f(F_T + F_D + F_R) \tag{33}$$

$$T_m = (t_m - 1)M \tag{34}$$

$$T = T_w + T_c + T_f + T_m + T_r \tag{35}$$

In line with what happens in many countries, firm profits are taxed twice, both at the firm level t_f and when distributed to households t_c. t_m is equal to 1 in the base model, thus effectively the tariff rate and tariff income are equal to zero. However, the introduction of a cap on resources will require making the tariff rate higher than 1. Lastly, the government issues bonds in order to cover its deficit:

$$B^s = \left(G_{tot} + B_{-1}^s + i_{g_{-1}} B_{-1}^s\right) - (T + F_{CB}) \tag{36}$$

F_{CB} is the profit of the central bank. The interest rate on government bonds i_g is endogenous. The supply of bonds is divided between the domestic central bank B_{CB}^s and domestic and foreign banks (B_B^s and B_{BS}^{Ns} respectively):

$$B_{CB}^s = B_{CB}^d \tag{37}$$

$$B_B^s = B_B^d \tag{38}$$

$$B_{BS}^{Ns} = B^s - (B_{CB}^s + B_B^s) \tag{39}$$

The supply of bonds to the central bank and the domestic banking sector are equals to their demands B_{CB}^d and B_B^d. The supply to the other area's banks B_{BS}^{Ns} is the residual. These equations conclude the description of the government sector.

Traded sector

We start by presenting the equations of the traded industry as it is the most important of the three sectors. Indeed, it produces the only good that can be traded across the two areas and it is also the only sector that produces capital for itself and the other industries. Moreover, only the traded sector uses natural resources to produce its output. The other two inputs used in production of the traded good are labour and imported goods from the other area's traded sector.

Technological development is represented by the dynamics of input productivities, i.e., how efficiently inputs are employed to produce the traded good. The productivity growth rate of each input depends on the amount of R&D funding devoted to it, while the allocation of R&D funding to the different input-saving technologies is partly exogenous and partly depends on the inflation rate of the specific input price. This formulation is inspired by the work of Naqvi and Stockhammer (2018) and will be thoroughly described in this section.

Lastly, profits are partly retained for financing investment and R&D activities and partly distributed. The amount of investment that is not covered by retained profits is financed through borrowing from the banking sector.

We will start the description of the traded sector by outlining how real sales and gross value added are determined. Real sales are the sum of all goods and capital sold in the economy:

$$s_T = cons_H^T + g^T + ic_D^T + inv_T + inv_D + inv_R + x_T \qquad (40)$$

ic_D^T is intermediate consumption of the non-traded sector. inv_T, inv_D and inv_R stand for real investment of the traded, non-traded and resource sector respectively. x_T are real exports. In other words, the goods produced by the traded sector are purchased for consumption by households and the government, as an input for production by the non-traded sector, as capital by all the three productive sectors in the North and are also exported to the other area.

Nominal sales are:

$$S_T = p_T(cons_H^T + g^T + ic_D^T + inv_T + inv_D + inv_R) + p_x x_T \qquad (41)$$

Where p_T is the price for the domestic economy, whereas p_x is the export price.

Real gross value added is real sales minus intermediate consumption of the traded sector. Thus:

$$y_T = s_T - ic_T^m - r_T \qquad (42)$$

That is, intermediate consumption of the traded sector is constituted by imported goods from the other area ic_T^m and resources r_T purchased from the domestic resource sector. Nominal gross value added is:

$$Y_T = S_T - IC_T^m - R_T \qquad (43)$$

Where $IC_T^m = p_m ic_T^m$ and $R_T = p_R r_T$, i.e., real inputs times their prices.

In order to produce its output, the traded sector needs capital and the other three productive inputs. we will first describe how capital and investment are determined. The formulation here is similar to those of conventional stock-flow consistent models (Godley and Lavoie, 2007). Firms target a specific level of capital $\bar{k}_T$ based on an exogenous output-to-capital ratio κ. However, the output that they target to determine the target capital is not lagged output as in Godley and Lavoie (2007), but rather their desired (target) output $\bar{s}_T$ for the next period, which is based on expected sales and expected profits. This choice is motivated by the desire of making the investment function slightly more realistic. Indeed, although the evidence that investment depends on sales is robust (Chirinko, 1993), the common formulation used in SFC models tends to generate very stable investment, which is rather unrealistic as this is one of the most volatile components of GDP. Adding expected profits allows to obtain more volatile investment and also makes it indirectly dependant on the interest rate. From a theoretical perspective, expected profits have been traditionally considered a crucial variable for the determination of investment. Empirical evidence seems to support this view (Bond et al., 2003; Cummins et al., 2006; Gennaioli et al., 2016). For the sake of simplicity, expectations here are adaptive, thus they are represented by lagged real sales and lagged real profits respectively. However, adaptive expectation could be questioned as an appropriate proxy for profit expectations. In this regard, two arguments can be advanced. Firstly, recent empirical work shows that CFOs' expectations regarding future profits can be consistently predicted by relying on publicly available information such as past profitability (Gennaioli et al., 2016). Thus, expectations are not perfectly rational and can be approximated by an adaptive function. Moreover, it has to be noted that there is also sufficient, though admittedly inconclusive, evidence that investment depends on past profits (Glyn, 1997; Carruth et al., 2000). Overall, the specification that will be presented below seems fairly robust.

Target sales are:

$$\bar{s}_T = \kappa_0 s_{T_{-1}} + \kappa_1 \frac{F_{T_{-1}}}{p_{ds_{-1}}} \tag{44}$$

Where κ_0 and κ_1 are exogenous parameters that weight the importance of one variable over the other. $\frac{F_{T_{-1}}}{p_{ds_{-1}}}$ is lagged real profits.

The target capital is then derived by dividing target sales by the exogenous technical coefficient κ, which represents the output-to-capital ratio:

$$\bar{k}_T = \frac{\bar{s}_T}{\kappa} \tag{45}$$

Real investment is then determined by a standard partial adjustment function:

$$inv_T = \mu_T\left(\bar{k}_T - k_{T_{-1}}\right) + \delta k_{T_{-1}} \tag{46}$$

$\delta k_{T_{-1}}$ is depreciated capital (δ is exogenously determined) and $\mu_T < 1$ is the exogenous partial adjustment coefficient. Real investment then adds to the real capital stock as follows:

$$k_T = (1-\delta)k_{T_{-1}} + inv_T \tag{47}$$

Nominal gross investment and nominal capital stock are:

$$INV_T = p_T inv_T \tag{48}$$

$$K_T = (1-\delta)K_{T_{-1}} + INV_T \tag{49}$$

This concludes the description of the equations that determine investment and the accumulation of the capital stock.

We next describe the way in which the quantity of the three inputs used in production are obtained. Firms start with a target level of input that they would like to employ given the real sales of the period. Thus:

$$\bar{N}_T = \frac{s_T}{\lambda_T} \tag{50}$$

$$\bar{ic}_T^m = \frac{s_T}{\xi_T} \tag{51}$$

$$\bar{r}_T = \frac{s_T}{\pi_T} \tag{52}$$

Where $\bar{N}_T, \bar{ic}_T^m$ and $\bar{r}_T$ are the target levels for labour, imported goods and resources while λ_T, ξ_T and π_T are their respective productivities. Before moving to the actual level of inputs employed, we will describe how productivities are specified and determined. All productivities are embedded in the capital stock as in Jackson and Jackson (2021)[10]. Each new capital vintage, i.e., new investment, embeds different levels of productivity compared to previous capital. Thus, productivities in every period are determined as follows:

$$\lambda_T = \frac{\lambda_{T_{-1}}\left(k_{T_{-1}} - \delta k_{T_{-1}}\right) + \lambda_T^{new}(inv_T)}{k_T} \tag{53}$$

$$\xi_T = \frac{\xi_{T_{-1}}\left(k_{T_{-1}} - \delta k_{T_{-1}}\right) + \xi_T^{new}(inv_T)}{k_T} \tag{54}$$

$$\pi_T = \frac{\pi_{T_{-1}}\left(k_{T_{-1}} - \delta k_{T_{-1}}\right) + \pi_T^{new}(inv_T)}{k_T} \tag{55}$$

Where $\lambda_T^{new}, \xi_T^{new}$ and π_T^{new} are the new productivity levels. The term $\lambda_{T_{-1}}\left(k_{T_{-1}} - \delta k_{T_{-1}}\right)$ indicates that the scrapping of depreciated capital replaces previous levels of productivity that were embedded in the old capital stock. In other words, the productivity levels in each period for the different inputs are a weighted average of the past productivity attached to

10 However, in this model the tracking of the different levels of productivity in the different period is much more simplified than in their work.

the remaining capital stock and the new productivity embedded in investment. New productivities $\lambda_T^{new}, \xi_T^{new}$ and π_T^{new} are determined as:

$$\lambda_T^{new} = \lambda_{T_{-1}}^{new}\left(1 + \lambda_T^{gt}\right) \tag{56}$$

$$\xi_T^{new} = \xi_{T_{-1}}^{new}\left(1 + \xi_T^{gt}\right) \tag{57}$$

$$\pi_T^{new} = \pi_{T_{-1}}^{new}\left(1 + \pi_T^{gt}\right) \tag{58}$$

Where λ_T^{gt}, $\xi_T^{gt}$and π_T^{gt} are endogenous growth rates (superscript gt) and depend on the level of R&D funds allocated to that specific input-saving technology $\left(\frac{\mho_T^n}{\mho_T^{tot}}, \frac{\mho_T^{ic}}{\mho_T^{tot}}, \frac{\mho_T^r}{\mho_T^{tot}}\right)$ and the R&D-to-GDP ratio of the overall economy $\frac{y_{R\&D}}{y}$ (Naqvi and Stockhammer, 2018):

$$\lambda_T^{gt} = \lambda_0\left(\frac{\mho_T^n}{\mho_T^{tot}} + \frac{y_{R\&D}}{y}\right) \tag{59}$$

$$\xi_T^{gt} = \xi_0\left(\frac{\mho_T^{ic}}{\mho_T^{tot}} + \frac{y_{R\&D}}{y}\right) \tag{60}$$

$$\pi_T^{gt} = \pi_0\left(\frac{\mho_T^r}{\mho_T^{tot}} + \frac{y_{R\&D}}{y}\right) \tag{61}$$

λ_0, ξ_0 and π_0 are exogenous parameters. $y_{R\&D}$ is the real output of all the R&D activities performed in one period, which depends on the total amount of R&D spending in the economy, the number of researchers available and their productivity. The term $\frac{y_{R\&D}}{y}$ reflects the idea that more R&D spending relative to total output increases the general level of productivity of the economy. It could be argued that this capture the spill-over effects typical of R&D activities.

$\mho_T^{tot}$ is the sum of R&D funding devoted to the traded sector by the sector itself and by the government:

$$\mho_T^{tot} = \mho_T + \left(\varrho_n^{GT} + \varrho_{ic}^{GT} + \varrho_r^{GT}\right)\mho_G \tag{62}$$

The second term of this equation will become clear with the next equation. Following Naqvi and Stockhammer (2018), the allocation of research funds to the different productivities of the traded sector ($\mho_T^n, \mho_T^{ic}, \mho_T^r$) is partly made through a portfolio approach *à la* Tobin:

$$\begin{pmatrix} \mho_T^n \\ \mho_T^{ic} \\ \mho_T^r \end{pmatrix} = \begin{pmatrix} \varrho_n^{GT} \\ \varrho_{ic}^{GT} \\ \varrho_r^{GT} \end{pmatrix}\mho_G + \left[\begin{pmatrix} \varrho_0^T \\ \varrho_1^T \\ \varrho_2^T \end{pmatrix} + \begin{pmatrix} \varrho_{00}^T & \varrho_{01}^T & \varrho_{02}^T \\ \varrho_{10}^T & \varrho_{11}^T & \varrho_{12}^T \\ \varrho_{20}^T & \varrho_{21}^T & \varrho_{22}^T \end{pmatrix}\begin{pmatrix} \dot{W}_T \\ \dot{p}_m \\ \dot{p}_R \end{pmatrix}\right]\mho_T \tag{63}$$

ϱ_n^{GT}, ϱ_{ic}^{GT} and ϱ_r^{GT} determine the shares of government R&D expenditure $\mho_G$ allocated to the different input-saving technologies for the traded sector and are exogenously set based on government's priorities. The sum of their values is $\varrho_n^{GT} + \varrho_{ic}^{GT} + \varrho_r^{GT} = 0.5$ as the other half of public R&D expenditure is used by the government to fund R&D activities of the non-traded sector. ϱ_0^T, ϱ_1^T and ϱ_2^T shape the distribution of firms' R&D funding $\mho_T$ and are standard exogenous parameters of a portfolio approach. Clearly, their value must sum to 1. However, firms' allocation of funding is partly endogenous as it reacts to the inflationary dynamics of input prices $\dot{W}_T, \dot{p}_m$ and $\dot{p}_R$. This follows from the well-established idea in the induced technological change (ITC) literature that technological change is driven by the relative price of input costs. The values of the parameter in matrix $\begin{pmatrix} \varrho_{00}^T & \varrho_{01}^T & \varrho_{02}^T \\ \varrho_{10}^T & \varrho_{11}^T & \varrho_{12}^T \\ \varrho_{20}^T & \varrho_{21}^T & \varrho_{22}^T \end{pmatrix}$ follow the standard rules of portfolio allocation presented in Godley and Lavoie (2007). Thus, each row and each column sums to zero.

To sum up, the allocation of R&D funding determines the level of productivity growth of the different inputs. This allocation is partly exogenous and partly endogenised through the dynamics of the rates of inflation of input prices. Once the new levels of inputs productivity are determined, they are embedded in new capital vintages, which are equal to investment, and added to the existing capital stock. The weighted average of new and past productivities determines the current productivity levels. These are then used to estimate target input requirements given firms' real sales in the period.

Once target inputs are determined, actual inputs are employed depending on the inflation rate of the specific input price:

$$N_T = \frac{\overline{N}_T}{1 + \epsilon_0 \Delta \dot{W}_T - \epsilon_1 \Delta \dot{p}_m - \epsilon_1 \Delta \dot{p}_R} \tag{64}$$

$$ic_T^m = \frac{\overline{ic}_T^m}{1 + \epsilon_0 \Delta \dot{p}_m - \epsilon_1 \Delta \dot{W}_T - \epsilon_1 \Delta \dot{p}_R} \tag{65}$$

$$r_T = \frac{\bar{r}_T}{1 + \epsilon_0 \Delta \dot{p}_R - \epsilon_1 \Delta \dot{W}_T - \epsilon_1 \Delta \dot{p}_m} \tag{66}$$

This means that in the short run firms are able to reduce the use of a specific input if there is a spike in its price by employing more of the other inputs. ϵ_0 and ϵ_1 are exogenous parameters that regulate the sensitivity of substitution between inputs. However, in the long run the increase in efficiency will come from higher productivities embedded in new capital vintages. The rationale for this formulation stems from the difference between substitutability and technological change (Sue Wing, 2006). Indeed, in the short run, changes in relative prices allow for modest degrees of substitution between productive inputs without requiring new technology. However, in the long run, only new technologies stimulated by R&D can bring about a steady increase in production efficiency. This has been empirically demonstrated for the energy intensity of the US economy by Sue Wing and Eckaus (2004).

Given the level of input requested, it is possible to derive the price of the traded good. Prices in this model follow the standard post-Keynesian approach (Lavoie, 2014), i.e., they are obtained as a mark-up over unit costs. Thus, the price p_T for this sector is:

$$p_T = (1+\eta_T)\left(\frac{W_T N_T + IC_T^m + R_T}{s_T}\right) \quad (67)$$

η_T is the exogenous mark-up.

Having defined how production and prices are determined, we now turn to the financial side of the sector. Starting from firms' revenue, which is nominal sales S_T, profits before taxes can be derived as follows:

$$F_T = S_T - W_T N_T - IC_T^m - R_T - i_{T_{-1}} L_{T_{-1}} \quad (68)$$

Where $i_{T_{-1}} L_{T_{-1}}$ is the cost of debt, i.e., the sector-specific interest rate times the stock of loans borrowed by the traded sector.

Gross profits are then allocated to different uses. Part of them has to be paid to the government in the form of corporate taxes $T_T = t_f F_T$. Then firms retain a share of profit F_T^u equal to an exogenous share ϑ_T of nominal investment INV_T:

$$F_T^u = \vartheta_T INV_T \quad (69)$$

Another part of profits is devoted to R&D:

$$\mho_T = \Theta_T F_T \quad (70)$$

Here Θ_T is an exogenous share. The residual part of profits is distributed:

$$F_H^T = F_T - \mho_T - T_T - F_T^u \quad (71)$$

Lastly, firms finance the investment not covered by undistributed profits by borrowing from banks:

$$L_T = INV_T + L_{T_{-1}} - F_T^u \quad (72)$$

Non-traded sector

The non-traded sector behaves very similarly to the traded sector. The main differences are that the non-traded sector purchases capital from the traded sector, it only sells to the domestic economy and its productive inputs are labour and intermediate goods purchased from the traded sectors of the two countries. The idea of adding a non-traded sector reflects the attempt to model a proxy of the service sector. This choice stems from the emphasis given on structural transition in the literature on post growth. Indeed, postgrowth scholars (Jackson, 2017) argue that a sustainable economy will necessarily invest more in sectors that are not resource intensive and still provide important services for human welfare. Having this sector in the model allows for simulating this structural transition and reflecting on its macroeconomic implications both at the domestic and international level.

We now list the equations of the non-traded sector in the same order as the previous subsection. Thus, we will first start by showing how production and required inputs are determined. A description will be added only when an equation substantially differs from that in the traded sector. This would allow us to save some space.

$$s_D = cons^D + g^D \tag{73}$$

$$S_D = p_D y_D \tag{74}$$

$$y_D = s_D - ic_D^T - ic_D^m \tag{75}$$

$$Y_D = S_D - IC_D^T - IC_D^m \tag{76}$$

$$\bar{k}_D = \frac{\bar{s}_D}{\kappa} \tag{77}$$

$$\bar{s}_D = \kappa_0 s_{D_{-1}} + \kappa_1 \frac{F_{D_{-1}}}{p_{ds_{-1}}} \tag{78}$$

$$inv_D = \mu_D\left(\bar{k}_D - k_{D_{-1}}\right) + \delta k_{D_{-1}} \tag{79}$$

$$k_D = (1-\delta)k_{D_{-1}} + inv_D \tag{80}$$

$$INV_D = p_T inv_D$$

$$K_D = (1-\delta)K_{D_{-1}} + INV_D \tag{81}$$

For what concerns its production function, the non-traded sector employs three different inputs: labour, imported goods and domestic traded goods. The overall determination of each input is the same as in the traded sector:

$$\bar{N}_D = \frac{s_D}{\lambda_D} \tag{82}$$

$$\bar{ic}_D^m = \frac{s_D}{\xi_D^S} \tag{83}$$

$$\bar{ic}_D^T = \frac{s_D}{\xi_D^T} \tag{84}$$

Where $\bar{N}_D, \bar{ic}_D^m$ and $\bar{ic}_D^T$ are the target levels of labour, imported goods and domestic traded goods required for production. λ_D, ξ_D^m and ξ_D^T are the respective productivities of these inputs.

$$\lambda_D = \frac{\lambda_{D_{-1}}\left(k_{D_{-1}} - \delta k_{D_{-1}}\right) + \lambda_D^{new}(inv_D)}{k_D} \tag{85}$$

$$\xi_D^m = \frac{\xi_{D_{-1}}^m\left(k_{D_{-1}} - \delta k_{D_{-1}}\right) + \xi_D^{mnew}(inv_D)}{k_D} \tag{86}$$

$$\xi_D^T = \frac{\xi_{D_{-1}}\left(k_{D_{-1}} - \delta k_{D_{-1}}\right) + \xi_D^{Tnew}(inv_D)}{k_D} \tag{87}$$

$$\lambda_D^{new} = \lambda_{D_{-1}}^{new}\left(1 + \lambda_D^{gt}\right) \tag{88}$$

$$\xi_D^{mnew} = \xi_{D_{-1}}^{mnew}\left(1 + \xi_D^{mgt}\right) \tag{89}$$

$$\xi_D^{Tnew} = \xi_{D_{-1}}^{Tnew}\left(1 + \xi_D^{Tgt}\right) \tag{90}$$

$$\lambda_D^{gt} = \lambda_0 \left(\frac{\mho_D^n}{\mho_D^{tot}} + \frac{y_{R\&D}}{y} \right) \tag{91}$$

$$\xi_D^{mgt} = \xi_0^m \left(\frac{\mho_D^m}{\mho_D^{tot}} + \frac{y_{R\&D}}{y} \right) \tag{92}$$

$$\xi_D^{Tgt} = \xi_0^T \left(\frac{\mho_D^T}{\mho_D^{tot}} + \frac{y_{R\&D}}{y} \right) \tag{93}$$

$$\mho_D^{tot} = \mho_D + (\varrho_n^{GD} + \varrho_m^{GD} + \varrho_{ic}^{GD})\mho_G \tag{94}$$

$$\begin{pmatrix} \mho_D^n \\ \mho_D^m \\ \mho_D^T \end{pmatrix} = \begin{pmatrix} \varrho_n^{GD} \\ \varrho_m^{GD} \\ \varrho_{ic}^{GD} \end{pmatrix} \mho_G + \left[\begin{pmatrix} \varrho_0^D \\ \varrho_1^D \\ \varrho_2^D \end{pmatrix} + \begin{pmatrix} \varrho_{00}^D & \varrho_{01}^D & \varrho_{02}^D \\ \varrho_{10}^D & \varrho_{11}^D & \varrho_{12}^D \\ \varrho_{20}^D & \varrho_{21}^D & \varrho_{22}^D \end{pmatrix} \begin{pmatrix} \dot{W}_D \\ \dot{p}_m \\ \dot{p}_T \end{pmatrix} \right] \mho_D \tag{95}$$

$$N_D = \frac{\overline{N}_D}{1 + \epsilon_0 \Delta \dot{W}_D - \epsilon_1 \Delta \dot{p}_m - \epsilon_1 \Delta \dot{p}_T} \tag{96}$$

$$ic_D^m = \frac{\overline{ic}_D^m}{1 + \epsilon_0 \Delta \dot{p}_m - \epsilon_1 \Delta \dot{W}_D - \epsilon_1 \Delta \dot{p}_T} \tag{97}$$

$$ic_D^T = \frac{\overline{ic}_D^T}{1 + \epsilon_0 \Delta \dot{p}_T - \epsilon_1 \Delta \dot{W}_D - \epsilon_1 \Delta \dot{p}_m} \tag{98}$$

$$p_D = (1 + \eta_D) \frac{(W_D N_D + IC_D^T + IC_D^m)}{s_D} \tag{99}$$

$$F_D = S_D - W_D N_D - IC_D^T - IC_D^m - i_{D_{-1}} L_{D_{-1}} \tag{100}$$

$$F_D^u = \vartheta_D INV_D \tag{101}$$

$$\mho_D = \Theta_D F_D \tag{102}$$

$$F_H^D = F_D - T_D - F_D^u - \mho_D \tag{103}$$

$$L_D = INV_D + L_{D_{-1}} - F_D^u \tag{104}$$

Resource sector

The resource sector is a slightly more sophisticated version of that in Naqvi and Stockhammer (2018). In line with their work, we simplified its structure to improve the tractability of the model. Resources are extracted using capital bought from the traded sector. The resource sector does not have productive inputs such as labour or intermediate goods and does not borrow money from the banking sector. Its investments are completely self-financed. Real and nominal resource sales are:

$$r_R = r_T \tag{105}$$

$$R = p_R r_R \tag{106}$$

p_R is the price of resources. The resource sector does not use labour or intermediate inputs, thus its price is determined as an exogenous mark-up η_R over an internal unitary cost Φ:

$$p_R = (1 + \eta_R)(1 + t_r)\Phi_{\mathrm{R}} \tag{107}$$

t_r is the variable that is used in the model to introduce the cap on resources. When the cap is active, t_r becomes positive and is endogenised so that it always enforce the equality between the demand for resources and the capped supply. Φ_{R} starts as an exogenous value as in Naqvi and Stockhammer (2018). However, in this model its growth rate follows an adjustment process based on the inflation rate of the domestic price index:

$$\dot{\Phi}_R = \dot{\Phi}_{R_{-1}} + \Psi_{\mathrm{R}}\left(\dot{p}_{ds} - \dot{\Phi}_{R_{-1}}\right) \tag{108}$$

$\Psi_{\mathrm{R}} < 1$ is the exogenous adjustment parameter.

The modelling of investment and capital accumulation is identical to that of the standard SFC models (Godley and Lavoie, 2007). The target capital is not dependant on profits as in the traded and non-traded sectors. Indeed, adding profits as a determinant of the resource sector does not really affect the results of the model, for this reason we have preferred to keep the sector simpler and with less exogenous parameters. Target capital and investment are thus:

$$\bar{k}_R = \frac{r_{-1}}{\kappa} \tag{109}$$

$$inv_R = \mu_k\left(\bar{k}_R - k_{R_{-1}}\right) + \delta k_{R_{-1}} \tag{110}$$

$$k_R = (1 - \delta)k_{R_{-1}} + inv_R \tag{111}$$

New capital is bought from the traded sector, thus nominal gross investment and nominal capital stock are:

$$INV_R = p_T inv_R \tag{112}$$

$$K_R = (1 - \delta)K_{R_{-1}} + INV_R \tag{113}$$

It is worth noticing that the resource sector itself cannot become more or less productive. Its only ‘productivity’ is the output-capital ratio κ, which is exogenous. Thus, it does not play a role in improving resource efficiency, which mainly relies on improvement in the resource use of the traded sector.

The resource sector finances its investment entirely with own funds F_R^u. It does not have other costs apart from taxes on its gross profits T_R and, only when introduced, the costs of the cap allowances $T_r = t_r(1 + \eta_R)\Phi_{\mathrm{R}} r_R$. The remaining part of its profits is distributed to households F_H^R. Therefore:

$$F_R^u = INV_R \tag{114}$$

$$T_R = t_f R \tag{115}$$

$$F_H^R = R - F_R^u - T_R - T_r \tag{116}$$

Banking sector

In this model, the banking sector plays the crucial role of providing credit to the productive sectors and the government. It also holds the accumulated wealth of households in the form of deposits. To meet its liquidity requirement, it keeps a certain level of reserves at the central bank account. The banking sector purchases bonds from the foreign government, thus it is the only sector which deals with international financial flows.

Banks here are simplified in their cost structure if compared to the traded and non-traded firms. Indeed, banks do not employ workers, other inputs or capital. Their only costs are constituted by interest payments on deposits. They save part of their profits as a capital buffer. The remaining profits are distributed to households.

We firstly introduce the balance-sheet side of the banking sector. As said above, the financial wealth of households is held in the form of deposits D on the liability side of banks. Thus:

$$D_B = D_H \tag{117}$$

On their asset side, banks requires a certain level of reserves HH_B to ensure that they have enough liquidity for their customers, this is determined as an exogenous share ρ over deposits:

$$HH_B = \rho D_B \tag{118}$$

Reserves are provided by the central bank and will be described below.

Another category of assets that banks hold on their balance sheet is loans to firms. By assumption, banks always accommodate firms' needs for new loans, thus the total supply L_B^s is equal to:

$$L_B^s = L_T + L_D \tag{119}$$

Moreover, banks purchase domestic and foreign government bonds. This latter variable is particularly difficult to model. Indeed, international capital flows are influenced by many different socioeconomic factors. Here, the demand for foreign bonds is simply modelled as an exogenous share ϕ of their lagged total assets:

$$B_{BN}^{Sd} = \phi ASSETS_{-1} \tag{120}$$

where $ASSETS_{-1} = L_{B_{-1}}^s + HH_{B_{-1}} + B_{B_{-1}}^d + B_{BN_{-1}}^{Sd}$. This is not a realistic specification of demand for international assets, but it is useful as a starting point. More sophisticated formulations can be easily developed but would complicate the analysis and make the core dynamics of the model less clear.

The demand for domestic government bond is determined as a residual to ensure the consistency of the banking sector's balance sheet:

$$B_B^d = B_{B_{-1}}^d + \Delta D_B^s + \Delta OF_B - (\Delta L_B^s + \Delta HH_B + \varepsilon_N \Delta B_{BN}^{Sd}) \tag{121}$$

where OF_b is banks' own funds. First differences must be used to account for potential capital gains due to fluctuations of the Northern exchange rate $\varepsilon_N = \frac{North\ currency}{South\ currency}$ and thus ensure the stock-flow consistency of the model (Godley and Lavoie, 2007).

Having described the balance sheet of the banking sector, we now turn to its financial flows. Banks' profits are the difference between all interest payments received on their assets and interest payments on their liabilities:

$$F_b = i_{g_{-1}} B^s_{B_{-1}} + \varepsilon * i^S_{g_{-1}} B^{Ss}_{BN_{-1}} + i_{T_{-1}} L_{T_{-1}} + i_{D_{-1}} L_{D_{-1}} + i_{hh_{-1}} HH_{B_{-1}} - i_{d_{-1}} D_{B_{-1}} \quad (122)$$

All interest rates are endogenous. Banks control the interest rates on deposits i_d and firms' loans (i_T, i_D). The former is determined as a simple exogenous mark-up η_d over the lagged interest rate on reserves:

$$i_d = i_{hh_{-1}} + \eta_d \quad (123)$$

The lag is due to the robust finding that banks sluggishly adjust the deposit rate to changes in monetary policy (Horváth and Podpiera, 2012; Gropp et al., 2014).

The interest rates on loans are obtained by adding a mark-up over the policy rate. The equations for firms' interest rates are:

$$i_T = i_{hh} + \eta^T_B \quad (124)$$

$$i_D = i_{hh} + \eta^D_B \quad (125)$$

Though it would be more logically consistent to use the deposit rate as the base of the mark-up, we have chosen the policy rate given that empirical evidence shows that mark-up on loans tend to react more quickly than mark-up on deposits when the policy rate changes (Gropp et al., 2014). η^T_B and η^D_B are exogenous.

Once banks' profits F_B are determined, banks allocate a share of them to their own capital, called own funds here. Banks have a target level of own funds $\overline{OF}$ that they want to reach, which is an exogenous share τ of loans:

$$\overline{OF} = \tau L^s_B \quad (126)$$

Their actual own funds are then:

$$OF_B = F^u_B + OF_{B_{-1}} \quad (127)$$

Where F_{ub} are undistributed profits:

$$F^u_B = \overline{OF} - OF_{B_{-1}} \quad (128)$$

The remaining profits are distributed to households:

$$F^B_H = F_B - F^u_B \quad (129)$$

The Central bank

The central bank is the last sector that will be described in the model. It has two functions: providing reserves to the banking sector and setting the interest rate on them. This interest rate serves as direct or indirect foundation for the other interest rates in the economy. Reserves are introduced into the system by purchasing government bonds. Thus, the balance sheet of the central bank has reserves on the liability side:

$$HH_{CB} = HH_B \quad (130)$$

The supply of reserves is equal to its demand coming from the banking sector. An equal amount of domestic government bonds is purchased and held on the asset side:

$$B^d_{CB} = HH_{CB} \quad (131)$$

In this way, the consistency of central bank's balance sheet is guaranteed.

Lastly, the central bank sets the interest rate on reserves following a heuristic similar to a Taylor rule:

$$i_{hh} = i_{hh_{-1}} + z_3(\iota_0 * \Delta\dot{p}_{ds}) + z_4(\iota_1 * \Delta\dot{p}_{ds}) \quad (132)$$

Where ι_0 and ι_1 are exogenous parameters that represent the sensitivity of the central bank when inflation rate goes above or below its target respectively. The bigger the change, the more vigorously the CB changes the interest rate to tame inflation. z_3 and z_4 are logical operators which have value zero unless the following condition occurs:

$$z_3 = 1 \; if \; \dot{p}_{ds} > 3\%$$

$$z_4 = 1 \; if \; \dot{p}_{ds} < 1.5\%$$

The idea is that the CB has a corridor of acceptable values for the inflation rate (Martin and Milas, 2004; Castro, 2011). As long as inflation is within those values, the CB does not change the interest rate on reserves. It is worth reflecting here on what is the role of interest rates in this model and how effective monetary policy can be in targeting inflation. It is usually assumed that changes in interest rate impact aggregate demand. In this model, interest rates affect consumption through equation (4) and investment through their impact on firms' profits (equations (44) and (78)). Thus, aggregate demand is negatively affected by a rise in the policy rate. However, the effect is limited to the short run and in the long run the inflation rate is not determined by interest rates. Interest rates here play a much bigger role in shaping the dynamics of income distribution rather than directly influencing aggregate demand. Overall, it could be argued that the standard view that monetary policy can control inflation is not replicated in this model. Indeed, the central bank can use the interest rate to smooth the impact of a shock to the economy but cannot really bring inflation to a specific target level.

The remaining interest rate that needs to be described is that on government bonds. In this model the mark-up over the policy rate is determined by an exogenous mark-up η_g:

$$i_g = i_{hh} + \eta_g \tag{133}$$

The last equation of the Central Bank sector regards its profits F_{CB}. These are the difference between the interest rate inflows and outflows:

$$F_{CB} = i_{g_{-1}} B^S_{CB_{-1}} - i_{hh_{-1}} HH_{CB_{-1}} \tag{134}$$

F_{CB} is distributed to the government. This concludes the section.

Labour market

In this subsection we describe how employment and wages are determined. There are two employers in the economy, the traded and the non-traded sectors. Their demand for labour has been described above (equations (64) and (96)). The maximum amount of available labour FE depends on the number of workers Q and the exogenously determined working hours wh:

$$FE = whQ \tag{135}$$

The supply of labour Q and the employment rate are:

$$Q = Q_{-1}\left(1 + z_{N_1}\frac{N}{E^{up}wh} + z_{N_2}\frac{N}{E^{low}wh}\right) \tag{136}$$

$$E = \frac{N}{Q} \tag{137}$$

ζ_1 and ζ_2 are exogenous parameters, $N = N_T + N_D$ and z_{N_1} and z_{N_2} are conditional operators which have value 0 unless a specific condition occurs. For z_{N_1} this is:

$$z_{N_1} = 1 \quad if \quad E > E^{up}$$

Whereas for z_{N_2} is:

$$z_{N_2} = 1 \quad if \quad E < E^{low}$$

In other words, more workers enter the workforce when the employment rate is above its exogenous upper limit E^{up}. Conversely, workers leave the workforce when the employment rate is below its exogenous lower limit E^{low}.

The employment rate has a strong influence on real wages. Indeed, workers have a real wage target $\bar{w}$ that depends on the *average* level of labour productivity $\lambda_{av} = \frac{s_T + s_D}{N_T + N_D}$ and on the employment rate:

$$\ln(\bar{w}) = \varpi_0 + \varpi_1 \ln(\lambda_{av}) + \varpi_2 \ln(E) \tag{138}$$

This formulation is taken from Jackson and Jackson (2021), who have slightly modified the equation proposed by Godley and Lavoie (2007) in chapter 11 of their textbook. The choice of using the *average* level of labour productivity instead of labour productivity at the sector level is in line with empirical findings (Nordhaus, 2008; Hartwig 2011), although conclusive evidence is still missing. The employment rate plays the role of a proxy for workers' bargaining power.

Nominal wages are then derived using a partial adjustment function:

$$W_D = W_{D_{-1}} + \varpi_3\left(\overline{w} * p_{ds} - W_{D_{-1}}\right) \qquad (139)$$

$$W_T = W_{T_{-1}} + \varpi_3\left(\overline{w} * p_{ds} - W_{T_{-1}}\right) \qquad (140)$$

p_{ds} is a price index that will be described in the next subsection. $\varpi_3 < 1$ is an exogenous parameter.

R&D module

For what concerns the wage and employment level in the R&D sector, these are modelled in a simplified fashion. The rationale behind the formulation that will be described stems from a problem that affected the model when R&D income was not linked to real resources. Indeed, in certain simulations the government could have ended up spending an unrealistically large fraction of its budget in R&D activities, creating very high levels of productivity growth for all inputs. This was clearly problematic. Thus, the decision of linking R&D expenditure to real variables. Indeed, once all researchers are employed, adding more income to R&D will simply trigger inflation of researchers' wages without increasing R&D output. The supply of researchers will adapt to higher demand for R&D, but this will happen following a slow process of adjustment. This reflects a more realistic scenario where highly skilled workers are scarce and the training process for increasing their supply takes time.

Wages in the R&D module follow the inflation rate of the average wage in the economy, unless there is a shortage of researchers:

$$W_{R\&D} = W_{R\&D_{-1}}\left(1 + \dot{W}_{av}\right)\left(1 - z_{R\&D_0}\right) + z_{R\&D_0}\left(\frac{\mho}{Q_{R\&D}}\right) \qquad (141)$$

$z_{R\&D_0}$ is a conditional operator which takes value 0 unless the following condition occurs:

$$z_{R\&D_0} = 1 \quad if \quad \frac{N_{R\&D}}{Q_{R\&D}} > 1$$

Where $N_{R\&D}$ is the number of researchers employed and $Q_{R\&D}$ is the total labour force for the R&D sector. In other words, when there is full employment in the R&D sector, the wage $W_{R\&D}$ increases until the demand for workers matches the labour force.

$Q_{R\&D}$ is constant unless full employment is reached, in which case it grows following the growth rate of R&D funding $\dot{\mho}$:

$$Q_{R\&D} = Q_{R\&D_{-1}}\left(1 + z_{R\&D_1}\Psi_{R\&D}\dot{\mho}\right) \tag{142}$$

$\Psi_{R\&D}$ is an exogenous parameter and $z_{R\&D_1}$ is again a conditional operator of value 0 unless the following condition occurs:

$$z_{R\&D_1} = 1 \quad if \quad \dot{W}_{R\&D} > \dot{W}_{av}$$

$\dot{W}_{R\&D} > \dot{W}_{av}$ is another way to say that $Q_{R\&D}$ increases when full employment is reached. This alternative formulation is needed to avoid a circular argument in the model. The idea behind equation (142) is that when there is a shortage of researchers, R&D wages increase more than the average wage growth and this attracts more workers, allowing for an expansion of R&D activities.

The number of people employed $N_{R\&D}$ is equal to the total R&D funds divided by the R&D wage:

$$N_{R\&D} = \frac{\mho}{W_{R\&D}} \tag{143}$$

Thus, it becomes clear what happens when full employment is reached, i.e., $\frac{N_{R\&D}}{Q_{R\&D}} > 1$. Indeed, $W_{R\&D}$ becomes $W_{R\&D} = \frac{\mho}{Q_{R\&D}}$ which, once substituted in the above equation, yields $N_{R\&D} = \frac{\mho}{\frac{\mho}{Q_{R\&D}}} = Q_{R\&D}$.

Lastly, once the number of workers employed has been determined, we can derive the real R&D output. This depends on researchers' productivity, thus:

$$y_{R\&D} = \lambda_{R\&D}N_{R\&D} \tag{144}$$

Where researchers' productivity is growing at an exogenous growth rate $\lambda_{R\&D}$:

$$\lambda_{R\&D} = \lambda_{R\&D_{-1}}\left(1 + \lambda_{R\&D}^{gt}\right) \tag{145}$$

Trade and exchange rate

In this subsection, we describe how the variables that represent international trade have been specified. We first present the equations of imports and exports. Next, we show how export and import prices are specified. Lastly, we outline how the exchange rate and the balance of payments are determined.

Real imports are derived as the sum of imported consumption and intermediate good requirements:

$$m = cons_H^m + g_H^m + ic_T^m + ic_D^m \tag{146}$$

Real exports are constituted by the same variables but of the other area. In this case, we just use the superscript x to identify them, but clearly from the perspective of the other area they are imports. Exports are produced by the traded sector, thus the subscript T:

$$x_T = cons_H^x + g_H^x + ic_T^x + ic_D^x \tag{147}$$

It is worth mentioning that capital is not traded in this model.

Nominal imports and exports are obtained by multiplying their real values by their respective prices:

$$M = p_m m \tag{148}$$

$$X = p_x x_T \tag{149}$$

Regarding prices, the export price p_x is different from its base price p_T as the former is partly determined by the other country price p_T^S and by the foreign exchange rate $\varepsilon_S = \frac{1}{\varepsilon} = \frac{South\ currency}{North\ currency}$. This formulation is taken from Godley and Lavoie (2007):

$$\ln(p_x) = -\sigma_1 \ln(\varepsilon_S) + (1 - \sigma_1)\ln(p_T) + \sigma_1 \ln\left(p_T^S\right) \tag{150}$$

σ_1 is an exogenous coefficient that has a crucial role in the model. Suppose there is a depreciation of the foreign currency, thus ε_S increases. If $\sigma_1 = 0$, exporters do not take into account the exchange rate movement and any change in the foreign price. They maintain the price equal to p_T. In this way, they favour profits over market share. Conversely, if $\sigma_1 = 1$, exporters prefer to focus on their sales and thus decrease their export price of the same amount of the increase in the exchange rate. In this way, no matter what the original value of p_T is, they will always change the export price to accommodate the fluctuations in the exchange rate.

The import price is the export price of the foreign country multiplied by the domestic exchange rate ε and the tariff rate t_m:

$$p_m = \varepsilon_N\, p_x^S t_m \tag{151}$$

p_x^S is specified in the same way as p_x, but clearly the variables are now related to the South:

$$p_x^S = -\sigma_1^S \ln(\varepsilon_N) + \left(1 - \sigma_1^S\right)\ln\left(p_T^S\right) + \sigma_1^S \ln(p_T) \tag{152}$$

Lastly, the exchange rate is determined as:

$$\varepsilon_N = \frac{B_{BS}^{Ns}}{B_{BS}^{Nd}} \tag{153}$$

B_{BS}^{Ns} is the supply of Northern area's government bonds to foreign banks. B_{BS}^{Nd} is foreign banks' demand for the Northern area's government bonds, which is the same, but from the other area's perspective[11]. Although it might seem that the exchange rate is only determined in this market, the

11 $B_{BS}^{Nd} = \phi_0(ASSETS_{-1}^S)$

interconnections of the SFC framework makes this determination entirely identical to more intuitive equations. For instance, the exchange rate could be derived as the ratio between the supply and demand of the domestic currency. Such formulation yields exactly the same results but introduces much more simultaneity in the determination of the exchange rate, which increases the likelihood of model crashes.

For what concerns the balance of payment, the following two equations represent the current account balance (CAB) and the capital account balance (KAB) of the developed area:

$$CAB = \left(X + \varepsilon_N r_{g-1}^S B_{BN}^{Ss}\right) - \left(M + r_{g-1} B_{BS}^{Ns}\right) \quad (154)$$

$$KAB = \Delta B_{BS}^{Ns} - \varepsilon \Delta B_{BN}^{Ss} \quad (155)$$

Where B_{BN}^{Ss} is the supply of South bonds to the banks in the North.

Macroeconomic aggregates

This last subsection will conclude the description of the model by presenting few equations that are used to compute aggregate values such as GDP at the country level and the price index. Some of these variables might not play a role in the dynamics of the model but will be used when presenting its results, so it is worth mentioning how they are derived.

Real and nominal total output of one area are:

$$s = s_T + s_D + r_R \quad (156)$$

$$S = S_T + S_D + R_R \quad (157)$$

Real and nominal GDP can be computed from a production perspective and are:

$$y = s - ic_T^S - ic_D^S - ic_D^T - r_T \quad (158)$$

$$Y = S - IC_T^S - IC_D^S - IC_D^T - R_T \quad (159)$$

Total resource consumption in one area is:

$$r_{cons} = r_R - \frac{x}{\frac{s_T}{r_T}} + \frac{m}{\frac{s_{TS}}{r_{TS}}} \quad (160)$$

Namely, resource extracted minus resource exported plus resource imported. $\frac{s_{TS}}{r_{TS}}$ is the actual resource productivity in the South, while $\frac{s_T}{r_T}$ is that in the North.

Lastly, we have defined all the prices in the economy, thus we can now describe the price index p_{ds} used to keep track of the price dynamics of domestic sales. This is a simple weighted average of the prices in one area for all the goods that are consumed or used by the different sectors:

$$p_{ds} = \frac{S_D + (S_T - X) + M + R}{s + m - x} \quad (161)$$

It is neither a GDP deflator nor a consumer price index (CPI). Indeed, it does not include prices of exports as the former, but it includes prices of investment goods and productive sectors' intermediate consumption, which are not included in the CPI. However, this is the most accurate index for what concerns the average prices that the economy faces at a given period.

Appendix B. Balance sheet and transaction-flow matrixes

	North							Exchange rate	South		
	Household (h)	Traded (t)	Non-traded (d)	Resource (r)	Government (g)	Banking (b)	Central Bank (cb)	(xr)	Government (g)	Banking (b)	Σ
Reserves (HH)						+HH	-HH			+HH	0
Deposit (D)	+D					-D				-D	0
Bonds N (Bn)					-Bn	+Bnb	+Bncb	xr		+Bnb	0
Bonds S (Bs)						+Bsb		xr	-Bs	+Bsb	0
Loans (L)		-Lt	-Ld			+L				+L	0
Own Funds (OF)	+OF					-OF				-OF	0
Capital (K)		+Kt	+Kd	+Kr							Kn + Ks
Balance	-Vh	-Vt	-Vd	-Vr	-Vg	0	0		-Vg	0	-Kn - Ks
Σ	0	0	0	0	0	0	0			0	0

	North										
	Households (h)	Non-traded sector (d) (1)	Non-traded sector (d) (2)	Resource sector (r) (1)	Resource sector (r) (2)	Traded sector (t) (1)	Traded sector (t) (2)	Government (g)	Banks (b)	CB (cb)	Exchange rate
Consumption (C)	-C	+Cd				+Ct					
Government Consumption (G)		+Gd				+Gt		-G			
Intermediate consumption (IC)		-IC				+IC					
Resource consumption (R)				+R		-R					
Imports N (Mn)/Exports S (Xs)	-Mnh	-Mnd				-Mnt		-Mng			xr
Exports N (Xn)/Imports S (Ms)						+Xn					xr
Investment (INV)			-INVd		-INVr	+INV	-INVt				
Wage (W)	+W	-Wd				-Wt					
Research and development (R&D)	+R&D	-R&Dd				-R&Dt		-R&Dg			
Unemployment insurance (Ψ)	+Ψ							-Ψ			
Retained profits (Fu)		-Fud	+Fud	-Fur	+Fur	-Fut	+Fut				
Firm profits (F)	+F	-Fd		-Fr		-Ft					
Bank profits (Fb)	+Fb								-Fb		
Taxes (T)	-Th	-Td		-Tr		-Tt		+T			
Interest rate on deposits (iD)	+iD								-iD		
Interest rate on bond N (iBn)	+iBnh							-iBn	+iBnb	+iBncb	xr
Interest rate on bond S (iBs)									+iBsb		xr
Interest rate on loans (iL)		-iLd				-iLt			+iL		
Central Bank profits (Fcb)								+Fcb		-Fcb	
Changes in stocks											
Changes in deposit (D)	-ΔD								+ΔD		
Changes in reserve (HH)									-ΔHH	+ΔHH	
Changes in bonds N (Bn)								+ΔBn	-ΔBnb	-ΔBncb	xr
Changes in bonds S (Bs)									-ΔBsb·xr		xr
Changes in own funds (OF)	-ΔOF								+ΔOF		
Changes in loans (L)			+ΔLd				+ΔLt		-ΔL		
Σ	0		0		0		0	0	0	0	

	South										
Exchange rate	Households (h)	Non-traded sector (d)		Resource sector (r)		Traded sector (t)		Government (g)	Banks (b)	CB (cb)	Σ
	-C	+Cd				+Ct					0
		+Gd				+Gt		-G			0
		-IC				+IC					0
				+R		-R					0
xr						Xs					0
xr	-Msh	-Msd				-Mst		-Msg			0
			-INVd		-INVr	+INV	-INVt				0
	+W	-Wd				-Wt					0
	+R&D	-R&Dd				-R&Dt		-R&Dg			0
	+Ψ							-Ψ			0
		-Fud	+Fud	-Fur	+Fur	-Fut	+Fut				0
	+F	-Fd		-Fr		-Ft					0
	+Fb								-Fb		0
	-Th	-Td		-Tr		-Tt		+T			0
	+iD								-iD		0
xr									+iBnb		0
xr	+iBsh							-iBs	+iBsb	+iBscb	0
		-iLd				-iLt			+iL		0
								+Fcb		-Fcb	0
Changes in stocks											
	-ΔD								+ΔD		0
									-ΔHH	+ΔHH	0
xr									-ΔBnb·xr		0
xr								+ΔBs	-ΔBsb	-ΔBscb	0
	-ΔOF								+ΔOF		0
			+ΔLd				+ΔLt		-ΔL		0
	0	0		0		0		0	0	0	0