Environmental and Labor Policies in a North-South SFC Model

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PRELIMINARY DRAFT

Abstract

This paper presents a stock-flow consistent two region North-South model with aspects of technical change, environment, and employment. The aim of this paper is to build on existing research by Acemoglu et al. (2014) and introduces endogenous finance to understand how government policies directed toward cleaner energy production affect global output, investment behavior, and environmental degradation. Following a report by the European Commission (2013), two policies are conducted: a permanent (policy 1) and a temporary (policy 2) subsidy is granted for clean investment by the North region. Results show a positive impact of the policies on South employment levels and a negative impact on the North. Furthermore the policies induce a temporary change in investment patterns that also affect capital productivity and output. While the policy can not prevent environmental degradation, the conceptualized model framework serves for demonstrating the diversity of feedback effects that accompany environmental policies.

Keywords: SFC modeling, North-South, technology transfers, employment, environment

JEL: E12, E17, E22, Q52, Q55, Q56, Q57

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1 Introduction

While the 200 years of rapid economic development and industrialization have brought the Earth towards its ecological boundaries and recovering capacity (Rockström et al., 2009), humanity is still lacking an adequate and effective answer to cope with these issues. One reason for that is that the field of economics currently faces difficulties to deal with the inherent complexity of ecological crises such as climate change. There are attempts within the field of economics to address these matters by proposing various fundamentally different approaches, ranging from models that treat environmental issues as market externalities and discount the inter-generational value of the environment (Nordhaus and Yang, 1996), to propositions of degrowth (Kallis, 2011) that require a transformation of the current mode of living (Brand and Wissen, 2013). However, what is missing is a conceptual framework that could integrate ecological, social and economic issues to effectively tackle issues like climate change while regarding potential feedback effects on income inequality, employment, and economic throughput.

Nevertheless, a promising conceptualization to tackle the ecological crisis is provided by Ecological Economics, which focuses on the role of institutions, social norms as well as power relations (Fontana and Sawyer, 2016). In contrast to the Neoclassical Economics assumption of perfect substitutability between production factors and the societal, the ecological and the economic sphere (Fontana and Sawyer, 2016; Rezai and Stagl, 2016), Ecological Economics conceives the economy to be embedded within society which itself is embedded within the environment following the concept of Karl Polanyi (1944). The application of this logic considers interdependencies of ecological, economic and social challenges and highlights their complementarity (Rezai and Stagl, 2016). Furthermore, Ecological Economics aims at developing a better-suited and more holistic approach to jointly deal with ecological, social and economic issues on large and small scales. Such a pathway means an apparent progress in the field of economics due to the provided opportunity to cope with societal and ecological complexity in a more holistic way. Nevertheless, also Ecological Economics currently misses a coherent framework that could inform concrete macroeconomic policy advice (Dafermos et al., 2015).

For doing so, a symbiosis of the Ecological Economics perspective and Post-Keynesian macroeconomics could have great potential. This symbiosis would merge the values and considerations of Ecological Economics with the macroeconomic framework of Post-Keynesian Economics with its focus on demand and investment. Nevertheless, Post-Keynesian Economics endorses demand-led growth policies that stay in contrast to the Ecological Economics approach, which criticizes that focus on growth by pointing out that an expansion of demand would increase material throughput and the usage of fossil fuels, which puts even more pressure on the ecosystems (Jackson et al., 2015). However, both approaches share a common understanding of complexity, market imperfections and fundamental uncertainty (Rezai and Stagl, 2016). The Stock-Flow Consistent Model (SFC) framework, often used in Post-Keynesian Economics, could provide an examination of feedback effects and financial flows. The SFC structure is based on a quadruple entry system, meaning that inflows in one sector need to be equal outflows in another sector since a closed financial and physical system is assumed. This accounting scheme, pioneered by Copeland (1949) and enhanced by Tobin (1982) and Godley and Lavoie (2007b), ensures that all transactions have an equal counterpart. Hence, this framework seems to be a good starting point for conceptualizing a holistic ecological macroeconomic framework. Several papers, like Victor and Rosenbluth (2007), Jackson et al. (2015), Jackson and Victor (2015), Naqvi (2015), Dafermos et al. (2015) and Berg et al. (2015) already conceptualized a combined model framework to examine the feedback effects of an output-stabilized economy onto aspects of the ecology, poverty and employment in macroeconomic growth models. Within these models, the financial system, including investments, plays a central role, in contrast to most research within Ecological Economics (Rezai and Stagl, 2016). However, these models do not incorporate an international perspective as well as technical change and innovation.

Technical change and innovation are often considered to be the decisive instruments (Smulders and Maria, 2012) that could enable Green Growth (OECD, 2011) by changing the structural production and consumption patterns. Thereby technical change would allow us to follow a sustainable growth path while staying within the ecological limits. While this reliance on technical change is often criticized and questioned (Brand and Wissen, 2013; Herring and Roy, 2007), it seems, nevertheless, evident that technical change and innovation should play a complementary role (van den Bergh, 2013; Smulders and Maria, 2012; Winter, 2014) in designing an effective environmental policy. Hence, a thorough understanding of the concepts of innovation (Arthur, 2007; Dopfer et al., 2004; Hanusch and Pyka, 2007; Fernandes et al., 2014) and technical change (Acemoglu, 2002; Acemoglu et al., 2012) and their implications for society (Smith and Stirling, 2010; Smith et al., 2005; Geels, 2004) are necessary to incorporate into a holistic model framework. Furthermore, the global character of causes and consequences of many ecological issues, including climate change (Jaffe et al., 2005; Maria and Van Der Werf, 2008; Ploeg, 2013; Aichele and Felbermayr, 2012), requires an inclusion of international trade and the global value chain of goods and services within this modeling framework. Finally, the implications for employment and income inequality are necessary to take into consideration for evaluating environmental policies. While there exists a decent amount of literature that explicitly dealt with the relationship of income distribution and demand (Onaran and Galanis, 2013; Stockhammer and Onaran, 2012; Carvalho and Rezai, 2016), the topic has only recently found its way into an ecological macroeconomic framework (Naqvi, 2015).

While these four aspects, the environment, the international perspective, employment as well as technical change and innovation, already have important implications for the design of effective environmental policies by themselves, it is especially interesting to analyze overall feedback effects that result out of the interdependence and distinct dynamics of these areas. A comprehensive and consistent ecological macroeconomic framework (Rezai et al., 2013; Jackson et al., 2015) is needed that integrates environmental, societal and economic considerations and challenges, thereby being able to inform relevant policy advice. The incorporation of the proposed four elements could help to conceptualize a model framework in which the ecological constraints of a finite planet could be reconciled with financial stability, the maintenance of employment levels as well as reduced income and wealth inequality (Jackson et al., 2015).

Acemoglu et al. (2014) develop a General Equilibrium model that includes aspects of the international perspective, the environment, and technical change while having a distinct ontological and epistemological conceptualization compared to Ecological Economics. Their model of Directed Technical Change in a two economies North-South model (Acemoglu et al., 2014) could function as a starting point for developing a comprehensive and consistent ecological macroeconomic framework. However, this model does not provide a full examination of feedback effects and financial flows. Therefore, this paper attempts to apply their conceptualization of the environment, technical change, employment and the international perspective onto a SFC framework, which can depict financial flows and feedback effects. The literature on SFC models so far only dealt with these essential elements, the international perspective (Godley and Lavoie, 2007a,b; Greenwood-Nimmo, 2014, Chapter 6), the environment (Jackson et al., 2015; Berg et al., 2015; Naqvi, 2015), employment (Godin, 2013) and innovation (Caiani et al., 2014), separately. To fill this gap in the literature, this article aims at adapting and integrating the model by Acemoglu et al. (2014) into a framework that can account for the financial sphere as well as for the dynamic analysis of different sectors of the economy. The so developed model aims for analyzing the possibility of a unilateral environmental policy for directing technical change towards cleaner technology in the absence of a binding international environmental agreement. Similar to Acemoglu et al. (2014), this paper conducts a scenario analysis for evaluating an environmental policy that consists of unilaterally granting a clean investment subsidy, both, for a limited period and over the entire model run, respectively. By doing so, this paper wants to provide a more holistic understanding of impacts of a particular unilateral environmental policy on employment, output, and emissions. Thereby, this article aims at contributing to the research on conceptualizing a comprehensive and consistent ecological macroeconomic model framework.

The remaining article is structured as follows: Section 2 gives an overview of the developed model framework and Section 3 presents the related behavioral equations in detail. Section 4 conducts two different policy experiments and compares them to a Baseline Scenario. Section 5 discusses the resulting implications and concludes by highlighting the contribution of this model to the literature.

2 Model Framework

The here presented model framework aims to contribute towards the conceptualization of a comprehensive and consistent ecological macroeconomic framework. As such, four essential elements, namely the environment, the international perspective, employment as well as innovation and technical change that constitute to economic, social and ecological changes have been identified and are incorporated into a Stock-Flow Consistent (SFC) Model Framework. This framework has been chosen because of its ability to portray and analyze societal, economic and ecological feedback effects and track financial flows between various sectors.

The model framework conceptualizes two economies, North and South, that are embedded in the environmental sphere. Figure 1 demonstrates the various relationships between eight entities, namely Firms, Commercial Banks, Households and the Government in the North and South, respectively. If not stated differently, it is assumed that the entities within both economies have the same behavioral patterns and relationships. However, as a crucial difference, the South acts as an imitator of the North's technology and cannot come up with innovations, following the assumption by Acemoglu et al. (2014). The two economies interact with each other only via firms that either produce a Clean good or a Dirty good in each economy, respectively. This assumption of inter-company trade follows the approach by

Godley and Lavoie (2007b, Chapter 6), who assume an intermediary function of companies for the households that want to consume the imported goods. Since the exchange rate is exogenously given and fixed over time, the model abstracts from the implementation of a Central Bank.

Furthermore, the interaction with the environment is provided by the emission of greenhouse gases as a by-product of Dirty good production in both economies that constitutes to a deterioration of the environment. Clean good production is assumed to have no impact on the environment. So far, there is no reverse feedback of the environment onto the economic sphere incorporated into the model.

Moreover, firms need to decide whether to invest in Clean or Dirty good production capital. Similar to Dafermos et al. (2015), the investment decision is based on individual incentives for the firms, besides accounting for depreciation. In this model framework, these incentives consist of capital utilization, relative capital productivity and relative interest rates that determine whether the companies invest in dirty or clean investment, thereby adding up to the respective capital stock. The amount of investment in the individual sector influences capital productivity, thereby following the logic of Acemoglu et al. (2014), who assume the innovation rate and thus sectoral productivity to be dependent on the number of scientists employed in each sector. Nevertheless, the innovation that feeds back into capital productivity can only happen in the North and is property protected for one period. After one period, the South is able to imitate the North's innovation and hence climbs on the same level of capital productivity.

Both, the government and households demand the goods produced by the companies. To finance its expenditures, the government raises household taxes and has the possibility to fund deficits by issuing government bonds that are held by commercial banks. The government has to pay interest on these bonds in order to compensate the banks for lending money.

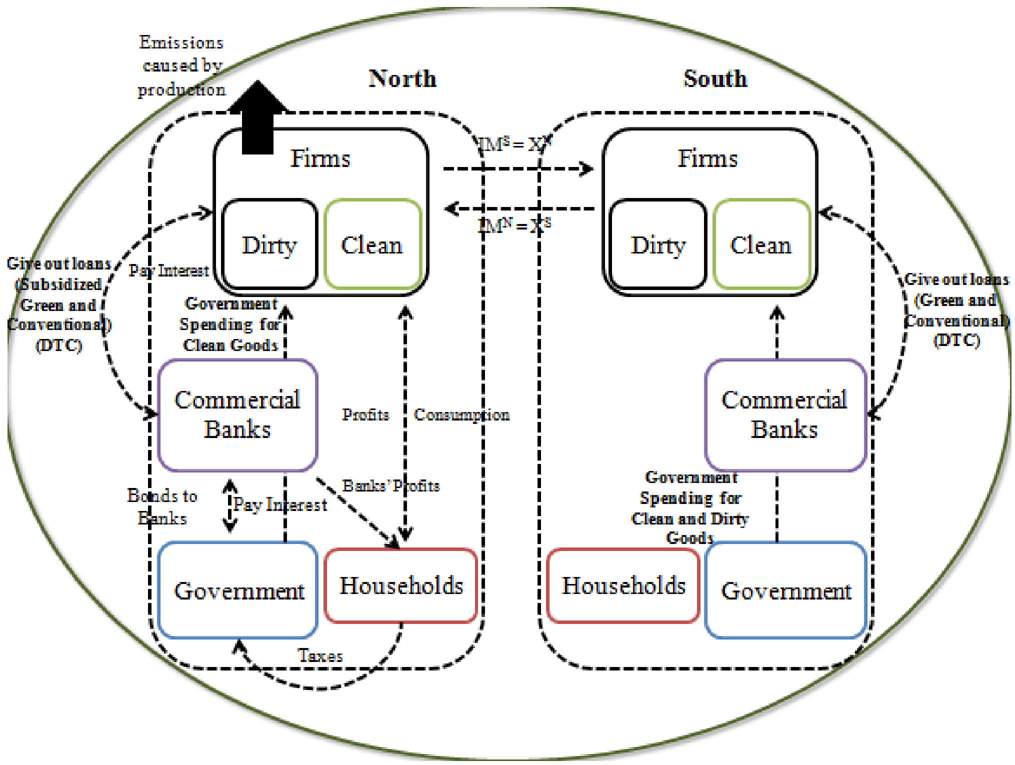
Households are offering their labor to the companies to receive income that Households use for consumption, paying taxes and accumulating wealth. Furthermore, Households are assumed to be the owners of Firms and Commercial Banks who distribute their profits to the Households.

The role of Commercial Banks in this framework is twofold. On the on hand, they finance the governmental deficit by lending money to the government. On the other hand, Commercial Banks give out loans to companies to enable Clean or Dirty investments. As such, banks have the role of financial entrepreneurs in the sense of Perez (2007) because their credit granting decision for a particular sector shapes the technological environment by establishing a certain production technology (Caiani et al., 2014). As pointed out by Fontana and Sawyer (2016), investment decisions and credit creation are connected and provide banks with the opportunity to decide about the pathway of investments. Thereby, governments can make use of this link by setting the external political conditions that direct investments towards cleaner production capital. As has been indicated by Jackson et al. (2015), the transition towards a low-growth society necessitates governmental steering of investment choices. Moreover, the Banks set distinct interest rates for the respective sector or economy that demonstrate an implicit risk assessment. In fact, this means that interest rates for Dirty good investments in the North are lower than Clean good investments in the North or investments in general in the South.

Being interested in the implications and feedback effects of a unilaterally implemented environmental policy, the North government can intervene in this model via two channels. First, an interest rate subsidy for clean investments can lower its opportunity costs, which raise investment incentives in that sector. These higher Clean investments increase clean capital productivity that feeds back on to investments, thereby initiating a virtuous circle. Second, the North government can increase Clean good purchases by providing a larger market for Clean goods. This government decision affects the target capital stock that is based on capital utilization. Because of the assumed important role of capital utilization for the investment decisions of firms, higher government Clean good consumption also affects capital productivity. Hence, it is evident that the government can stimulate technical change and thereby induce a structural change in production patterns.

The model framework follows the accounting logic for SFC Models by Godley and Lavoie (2007b), implying that all transactions between sectors or economies are captured by a Balance Sheet (Appendix B) and a Transaction Flow Matrix (Appendix C). All further relationships and dependencies between different sectors are determined by a set of behavioral equations that are presented in the following section. As mentioned above, the SFC logic requires that all entities have to stick to their respective budget constraints and all transactions within the economy add up to zero. In that sense, a decision for a particular good or investment automatically implies a non-decision for its counterpart as a consequence of limited financial resources.

Figure 1: Model Framework



3 Behavioral Equations

This section presents the behavioral equations that determine the transactions, interdependencies and feedback effects of the agents. For the equations, the following notation system is applied: Subscript D expresses Dirty Good production, while subscript C stands for Clean production goods. Furthermore, superscript N presents the North economy, superscript S expresses the South economy. Moreover, if j and i are stated, it applies that $j = \{N, S\}$ and $i = \{C, D\}$, being the same character for the entire equation. Capital letters depict nominal values in current prices, while lowercase letters stand for real values or stocks. Additionally, subscript CB stands for commercial banks and subscript "-1" portrays the previous period's value. Furthermore, exogenous parameters will be explicitly pointed out and only change their values during the model run, if explicitly stated.

The standard behavioral equations of this model, namely consumption behavior, disposable income, tax setting and output, lean on Godley and Lavoie (2007b, Chapter 6) and are applied to the specific needs of this model. Demand decisions of agents drive output and output related variables, thereby following the Post-Keynesian understanding of a demand driven economy. Nevertheless, demand is constrained by the budget limit of the agents and the production capacities of the specific sector.

3.1 Firms

Output and Trade

Firm's total nominal output for the respective sector and country is calculated by household consumption, firm investment, government spending and the difference between imports and exports. Following the Post-Keynesian assumption, all goods that are demanded are produced with the constraint of maximum capital utilization for that period.

$$Y_i^j = C_i^j + I_i^j + G_i^j + X_i^j - IM_i^j \tag{1}$$

Furthermore, the approach by Godley and Lavoie (2007b, Chapter 6) is applied, meaning that all imports are defined as an exogenously fixed share μ^j of nominal output Y_i^j . Exports of the North are the counterparts of the other country's imports divided by the exogenously fixed exchange rate κ, while exports of the South are the imports of the North times the exchange rate κ.

$$IM_i^j = \mu^j Y_i^j \tag{2}$$

$$\begin{aligned} X_i^N &= \frac{IM_i^S}{\kappa} \\ X_i^S &= IM^N \cdot \kappa \end{aligned} \tag{3}$$

Wages

As an essential share of the production costs, firms have to pay the wage bill wb_i^j that consists of the employed labor force n_i^j and the real wage w_i^j for the respective sector and country. WB_i^j is the nominal real wage adjusted to the actual price level p_i^j.

$$wb_i^j = w_i^j n_i^j \tag{4}$$

$$WB_i^j = wb_i^j p_i^j \tag{5}$$

Respective feedback effects endogenously determine both, the employed labor force n_i^j, as well as the real wage w_i^j. As expressed in equation 6, the employed labor force depends on the utilization of labor, which is given by the relation of real output y_i^j to the exogenously set labor productivity λ^j.

$$n_i^j = \frac{y_i^j}{\lambda^j} \tag{6}$$

Furthermore, the real wage w_i^j is a function of the previous period real wage and a certain share $\Omega_{1,2}$ of labor productivity λ^j and the rate of the difference between expectation of future output y_i^{je} and the previous period's realized output y_{i-1}^j, applying some features of Godley and Lavoie (2007b, Chapter 11). This relationship implies that if the sectoral economy is growing, the real wage also slowly grows over time. Thereby the function for the real wage represents a redistribution of economic achievements to the workers.

$$w_i^j = w_{i-1}^j + \Omega_1 \lambda^j + \Omega_2 \frac{y_i^{ej} - y_{i-1}^j}{y_{i-1}^j} \tag{7}$$

Similar to Godley and Lavoie (2007b, Chapter 10), expected output y_i^{je} consists of a share γ of past realized real output and of last period's expected output y_{i-1}^{je} multiplied by an exogenously assumed growth rate ϵ. The underlying logic of this equation is that agents form their expectations by relying, on the one hand, on past realized observations and on the other hand, consider an assumed long-run growth path based on historical patterns.

$$y_i^{je} = \gamma y_{i-1}^j + (1-\gamma) y_{i-1}^{e,j}(1+\epsilon) \tag{8}$$

Capital Stock

New investments i_i^j add up to the previous real capital stock k_{i-1}^j, while capital depreciation δk_{i-1}^j diminishes it. The difference between these two flow variables determines the new real capital stock k_i^j. The depreciation rate δ is fixed and exogenously determined. Additionally, the nominal capital stock K_i^j is given by applying the real capital stock to the current price level.

$$k_i^j = k_{i-1}^j + i_i^j - \delta k_{i-1}^j \tag{9}$$

$$K_i^j = k_i^j p_i^j \tag{10}$$

Prices and Unit Costs

Prices p_i^j are determined by an exogenous mark-up υ that is put on top of the endogenously adapting unit costs UC_i^j of an unit of output.

$$p_i^j = (1+\upsilon) UC_i^j \tag{11}$$

Moreover, the real output y_i^j is determined by the nominal output Y_i^j divided through the price level p_i^j.

$$y_i^j = \frac{Y_i^j}{p_i^j} \tag{12}$$

The real wage bill wb_i^j and real costs for holding and adding capital r_i^j determine the overall costs firms face when producing goods. Divided by real output y_i^j, the sum of the overall costs is broken down to the costs of one unit of output UC_i^j.

$$UC_i^j = \frac{wb_i^j + r_i^j}{y_i^j} \tag{13}$$

Capital Costs

Furthermore, it is assumed that all investments that add up to the capital stock are debt-financed. Thereby, the costs for holding capital are determined by the exogenously given share of repayment ψ of the granted loans L_i^j.

$$R_i^j = \psi L_{i-1}^j \tag{14}$$

In order to express the costs for capital in real terms, the nominal capital costs R_i^j are divided by the price level.

$$r_i^j = \frac{(\psi L_{i-1}^j)}{p_i^j} \tag{15}$$

Profits

Furthermore, the profits of firms are composed of the total output minus the interest payments for outstanding loans $int_i^j \cdot L_j^i$, the costs for employing labor WB_i^j and the depreciation of capital δK_{j-1}^i. Each type of good in the particular country faces an individual interest rate that is exogenously set and kept fix by an assumed monetary authority.

$$\Pi_i^j = Y_i^j - int_i^j L_{i-1}^j - WB_i^j - \delta \cdot K_{i-1}^j \tag{16}$$

However, a slight exemption portrays the case of Clean good profits in the North economy. In that case, the profits are higher than they would be otherwise because of a government subsidy χ that is provided for decreasing the Clean good lending rate for investments.

$$\Pi_C^N = Y_C^N - \chi(int_C^N L_{C-1}^N) - WB_C^N - \delta K_{C-1}^N \tag{17}$$

Investment Decision of Firms

Similar to the logic of Dafermos et al. (2015), the investment decision of firms, whether to invest in Clean or Dirty production capital i_i^j , depends on several incentives. First, the firm needs to replace depreciated capital. In addition to that, firms follow a certain capital target k_i^{jT} and compare their target with the previous period's realized capital stock k_{i-1}^j. The difference between these two variables adds to or diminishes the investment of the period. Furthermore, the relative capital productivity $\frac{\phi_{D-1}^N}{\phi_{C-1}^N}$ adds to the investment function, implying that the more productive the capital of the respective type of production is, the more will be invested in that type of capital. The model is conceptualized as such that capital productivity signifies the current stage of technology, which influences the investment decision. Because the South is assumed to not innovate but only imitate the North's technology, the capital productivity of the South is lagging one period behind. Finally, the assumption that a higher interest rate increases the amortization period of the investment expresses the fact that the relative interest rates affect the sector for the investment decision. To promote Clean investment, the government in the North subsidized the interest rate for Clean production loans in the North by a factor χ. Hereby, the initially assumed higher Clean production interest rate is lowered, which lowers the amortization period of the investment. The nominal investment amount is given by adapting to the price level.

$$\begin{aligned} i_D^N &= \delta k_{D-1}^N + (k_D^{NT} - k_{D-1}^N) + \frac{\phi_{D-1}^N}{\phi_{C-1}^N} - \frac{int_D^N}{\chi int_C^N} \\ i_D^S &= \delta k_{D-1}^S + (k_D^{ST} - k_{D-1}^S) + \frac{\phi_{D-2}^N}{\phi_{C-2}^N} - \frac{int_D^S}{int_C^S} \end{aligned} \tag{18}$$

$$\begin{aligned} i_C^N &= \delta k_{C-1}^N + (k_C^{NT} - k_{C-1}^N) + \frac{\phi_{C-1}^N}{\phi_{D-1}^N} - \frac{\chi \cdot int_C^N}{int_D^N} \\ i_C^S &= \delta k_{C-1}^S + (k_C^{ST} - k_{C-1}^S) + \frac{\phi_{C-2}^N}{\phi_{D-2}^N} - \frac{int_C^S}{int_D^S} \end{aligned} \tag{19}$$

$$I_i^j = i_i^j \cdot p_i^j \tag{20}$$

Target Capital Stock

The target capital stock k_i^{jT} constitutes the utilization rate of capital. Thus, the capital utilization rate consists of the previous period's real output divided by the capital productivity ϕ_i^N of the previous period. Capital productivity for the South, simply is the North's capital productivity of the previous period, thereby accounting for the role of the South an an imitator of the North's technology.

$$
\begin{aligned}
k_i^{NT} &= \frac{y_{i-1}^N}{\phi_{i-1}^N} \\
k_i^{ST} &= \frac{y_{i-1}^S}{\phi_{i-2}^N}
\end{aligned}
\tag{21}
$$

Credit Level

Furthermore, the accumulated sum of granted and outstanding loans L_i^j, determines the credit level of firms. While the repayment of loans ψL_i^j diminishes the outstanding credit level, new investment I_i^j adds up to the previous amount of loans L_i^j.

$$
L_i^j = (1-\psi)L_{i-1}^j + I_i^j \tag{22}
$$

3.2 Households

It is assumed that households have a twofold role of being owners of capital and workers at the same time. Households use their generated income for consuming goods to satisfy their needs or saving for future consumption by accumulating wealth. Their consumption decision for Clean or Dirty goods depends on the disposable income that is generated in the particular sector. It follows from that assumption that households who earn their income from Clean goods manufacturing also tend to consume Clean goods. However, if households consume out of accumulated wealth both types of goods are equally chosen. The underlying intuition of this consumption pattern is that people who own cleaner production capital or work in the cleaner manufacturing sector, usually also tend to be more environmentally aware than other people and thus prefer the consumption of Clean goods. However, owing to the fact that it proofs difficult to exclusively consume Clean goods, the propensity to consume out of non sector-specific wealth addresses that issue by adding a mixed consumption feature.

Disposable Income and Taxes

In general, the number of goods that can be consumed or the amount of money that can be added to the wealth stock depends on the disposable income of households YD_i^j. To receive an income in the form of a wage bill WB_i^j, households offer their labor force to companies. Since the role of households is twofold, they also receive profits Π_i^j and $(int_i^j L_{i-1}^j) + (\beta r B_{i-1}^j)$ that increase their disposable income, owing to their function as owners of both, firms and banks. Nevertheless, households have to pay a particular amount of taxes βT^j to finance government expenditures and the infrastructure in the economy. The amount of taxes depends on the disposable income and is determined by the exogenous tax rate θ^j. The exogenous parameter β has the function of a weighing factor to assign the not sector specific taxes T^j and government bills B_{CB-1}^j to the sector specific disposable income YD_i^j.

$$\begin{aligned} YD_D^N &= -(\beta T^N) + int_D^N L_{D-1}^N + (\beta r B_{CB-1}^N) + \Pi_D^N + WB_D^N \\ YD_D^S &= -(\beta T^S) + int_D^S L_{D-1}^S + (\beta r B_{CB-1}^S) + \Pi_D^S + WB_D^S \end{aligned} \tag{23}$$

$$\begin{aligned} YD_C^N &= -((1-\beta) T^N) + \chi(int_C^N L_{C-1}^N) + ((1-\beta) r B_{CB-1}^N) + \Pi_C^N + WB_C^N \\ YD_C^S &= -((1-\beta) T^S) + int_C^S L_{C-1}^S + ((1-\beta) r B_{CB-1}^S) + \Pi_C^S + WB_C^S \end{aligned} \tag{24}$$

$$\begin{aligned} T^N &= \theta^N(\chi(int_C^N L_{C-1}^N) + int_D^N L_{D-1}^N + r B_{CB-1}^N + \Pi_C^N + \Pi_D^N + WB_C^N + WB_D^N) \\ T^S &= \theta^S(int_C^S L_C^S + int_D^S L_D^S + r B_{CB-1}^S + \Pi_C^S + \Pi_D^S + WB_C^S + WB_D^S) \end{aligned} \tag{25}$$

$$0 < \theta^N, \theta^S < 1$$

Household Consumption

The entire consumption of households consists of a certain exogenous propensity α_1^j to consume out of disposable income YD_i^j and a certain exogenous propensity α_2^j to rely on their accumulated wealth V_{-1}^j.

$$\begin{aligned} C_D^j &= \alpha_1^j YD_D^j + \beta(\alpha_2^j V_{-1}^j) \\ C_C^j &= \alpha_1^j YD_C^j + (1-\beta)(\alpha_2^j V_{-1}^j) \end{aligned} \tag{26}$$

The cumulative wealth from last period V_{-1} split between dirty and clean consumption defined a parameter β.

$$0 < \alpha_2 < \alpha_1 < 1$$

Household Wealth

The difference between the disposable income YD_i^j and consumption C_i^j as well as the previous period's stock of wealth V_{-1}^j constitute the actual stock of wealth.

$$V^j = V_{-1}^j + (YD_i^j - C_i^j) \tag{27}$$

3.3 Government

As described above, the government collects taxes T^j to fund its exogenously determined government spending G_i^j. As an additional expenditure, the North government also subsidizes the lending rate of Clean investment. The government deficit, defined as the difference between government income (taxes) and government spending, is financed by issuing government bonds B_{CB}^j that are entirely held by commercial banks of the same country. At this stage of the model, commercial banks can only acquire their own country's bonds and no North-South bond purchases are possible. The incorporation of an international bond market could be pursued by a further model since in the real world a lot of government debt is internationally owned, e.g China owns a significant share of US/EU debt. To incentivize government bond purchases by the commercial banks, the government has to pay interest r, exogenously set, for the outstanding government bills. These interest payments contribute to commercial banks' profits.

$$\begin{aligned} B^N_{CB} &= B^N_{CB-1} + G^N_C + G^N_D + rB^N_{CB-1} + (int^N_C L^N_C - \chi int^N_C L^N_C) - T^N \\ B^S_{CB} &= B^S_{CB-1} + G^S_C + G^N_D + rB^S_{CB-1} - T^S \end{aligned} \tag{28}$$

3.4 Environment

The damage function (equation 29), similar to Acemoglu et al. (2014), describes the relationship between Dirty goods production and the environmental sphere. Hereby, the assumption is that higher Dirty goods manufacturing harms the stage of the environment σ. The environment has a particular recovery capacity, expressed by the exogenous parameter ρ, but Dirty good production deteriorates the environment by the exogenous factor ξ. If σ is reaching its lower bound of 0, the environment is assumed to break down and the economy is doomed to crash. Therefore, a continuous high Dirty good manufacturing eventually leads to an economic collapse. For this model, the relationship between the environment and the economy is one-sided. So far, there is no counter-effect of a deterioration of the environment on particular economic parameters.

$$\sigma = 1 + Min[(1+\rho)\sigma_{-1} - \xi(Y^N_{D-1} + Y^S_{D-1}), 0] \tag{29}$$

3.5 Capital Productivity

The notion of technical change enters the model via capital productivity ϕ^N_i. Capital productivity ϕ^N_i is a function of the previous period's capital productivity and the change in investment. Higher investments increase capital productivity, thereby incorporating Acemoglu et al. (2014)'s approach that more scientists employed in research in a particular sector, meaning higher investments are conducted in that sector, increase the probability of technical change. In reverse, the higher capital productivity influences the investment decision as well, which accounts for Acemoglu et al. (2014)'s assumption of preferring research in the more advanced sector by benefiting from the "shoulder of giants effect". Because the South economy is assumed to imitate the North's technology, the South economy has no own explicit capital productivity function. The imitator effect is integrated by the fact that the South just adopts the current North's capital productivity one period later.

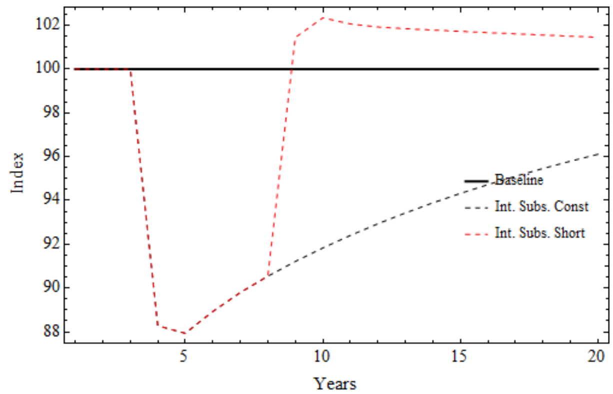
$$\phi_i^N = \phi_{i-1}^N + (i_i^N - i_{i-1}^N) \tag{30}$$

4 Policy Experiments

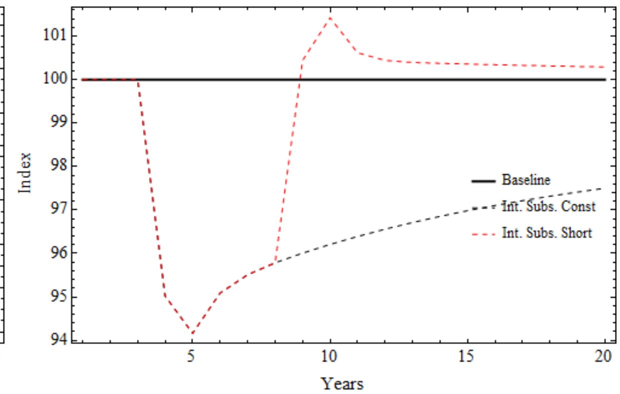
In this section, two policy experiments are conducted. The two experiments are a unilateral lending rate subsidy for Clean investments by the North economy. In the first scenario, a permanent subsidy is introduced in year three. In contrast to that, in the second scenario, a lending rate subsidy is introduced for five years and set back to the initial value. The purpose of the specific experiments of the interest rate subsidy is to demonstrate the effect of this policy and analyze how long that effect lasts if the environmental policy is stopped. In the optimal case, shown in the model by Acemoglu et al. (2014), the limited period of the environmental policy would bring the model onto a sustainable growth path that induces structural changes in production patterns. Optimally, these patterns would persist even when the lending rate subsidy for Clean goods is not in place anymore. The results could provide valuable insights if a unilateral policy, in the absence of an effective international treaty, could be sufficient to prevent an ecological catastrophe, while still ensuring a stable employment level.

Figure 2: Output

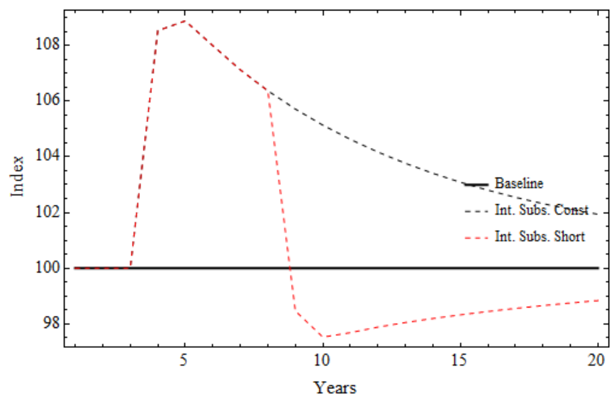
(a) Dirty North



(b) Dirty South



(c) Clean North



(d) Clean South

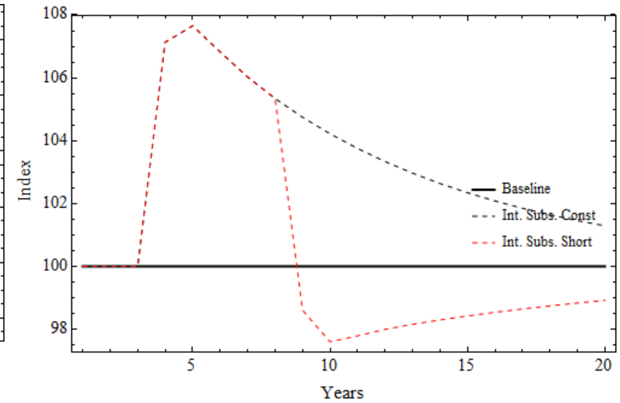
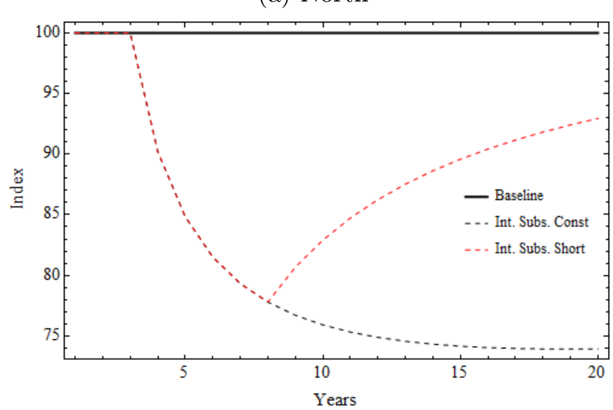


Figure 3: Employment

(a) North



(b) South

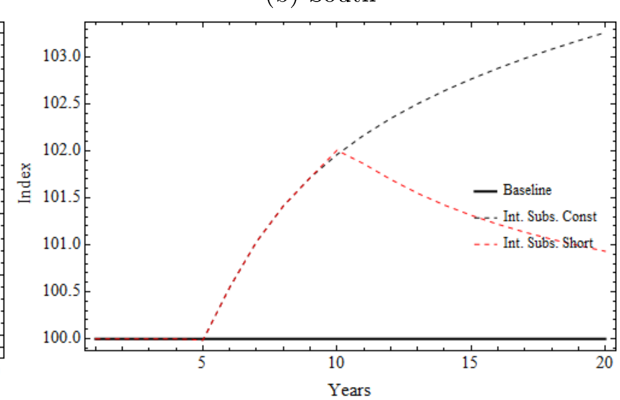


Figure 4: Investment

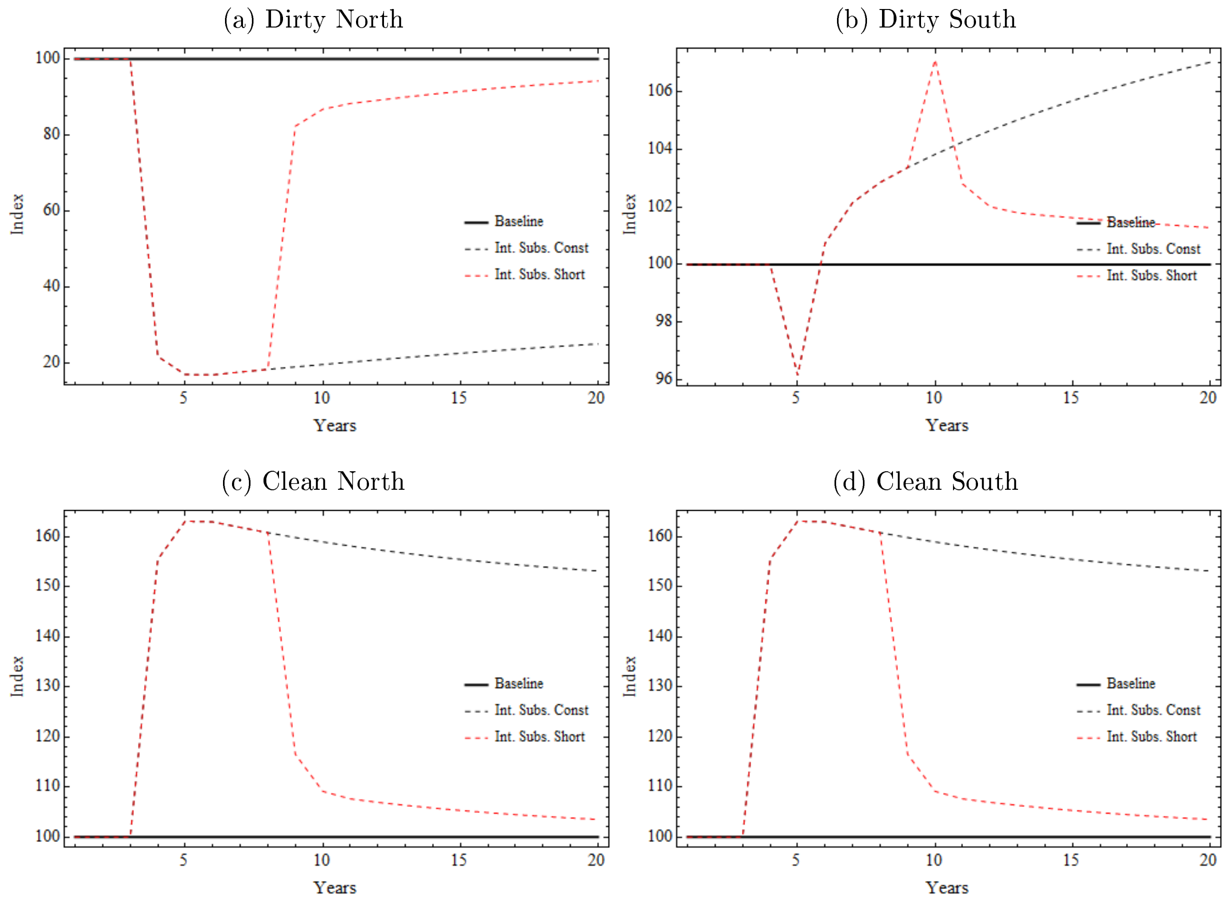


Figure 5: Capital productivity

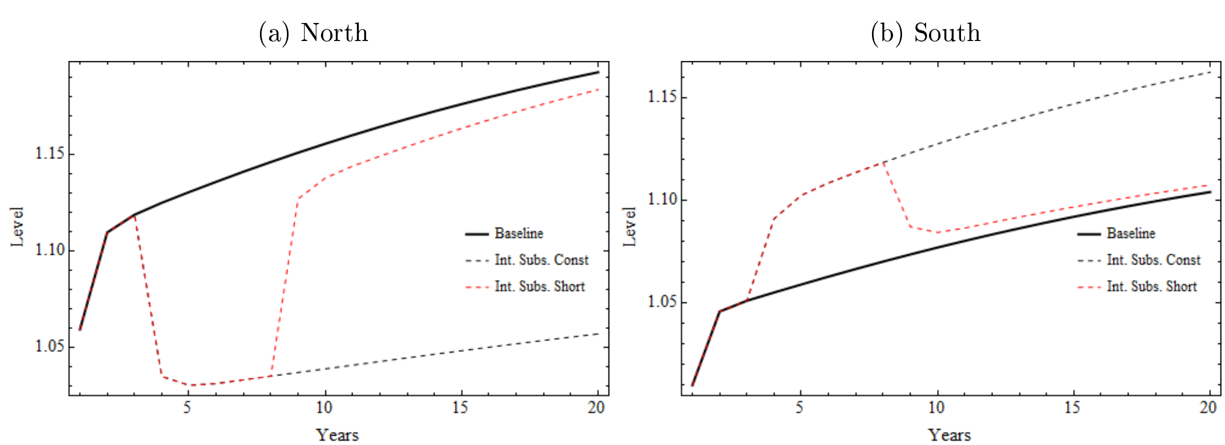
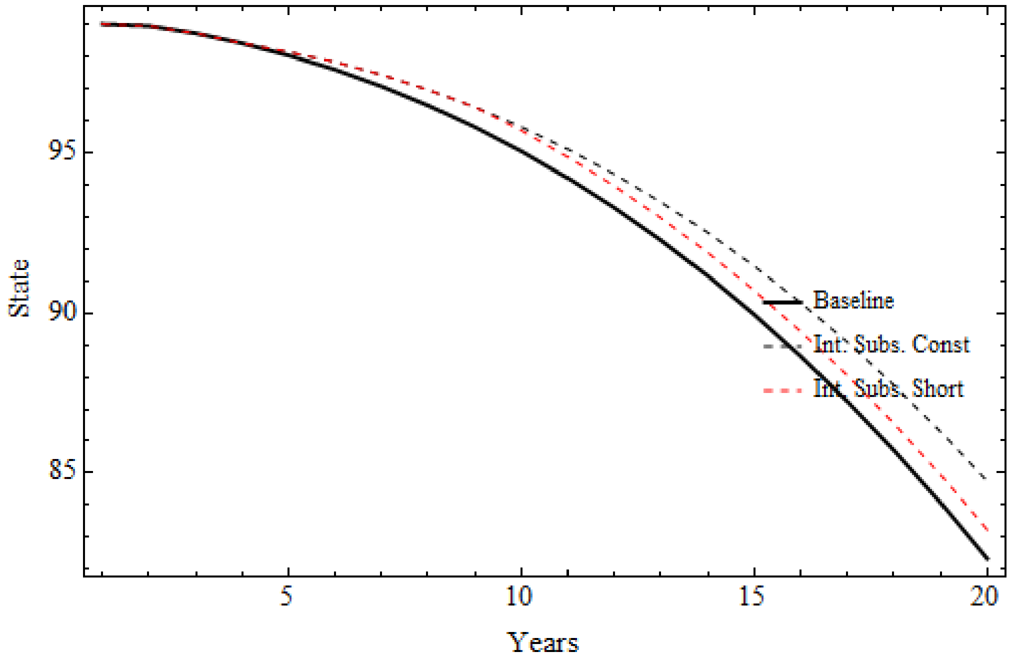


Figure 6: Environmental damage



The explicit values that are assumed for the Baseline-Scenario are provided in the Appendix Section A. In general, the parameter values are set such that the North pays higher wages, has a higher price level and higher labor costs. Furthermore, Cleaner goods are assumed to be more expensive in the first place because of lower capital productivity and higher production costs that their manufacturing faces. Moreover, since they have higher unit costs and can build less on previous research, Clean goods are not as productive as Dirty goods. Initially, investments in Clean capital are riskier, reflected by a higher interest rate. Additionally, initial output is assumed to be equal for all sectors and countries. The North has a lower propensity to consume out of disposable income but a higher propensity to consume out of accumulated wealth than the South, which reflects the more elaborated financial institutions in North countries. Furthermore, to account for the different risk assessments of banks, the exogenous set interest rates for investments differ in each sector and country. In that sense, the Dirty North production industry faces the lowest interest rate, followed from equal interest rates, both for Clean North and Dirty South sectors, and finally, the Clean South sector has to pay the highest interest rate. Moreover, it is assumed in the Baseline Scenario that interest rates are not subsidized by the North government. This changes in the two conducted scenarios that are always depicted in relation to the Baseline Scenario.

The following shortcuts are applied in the following scenario description: Dirty North for the dirty production sector in the North economy; Dirty South for the dirty production sector in the South economy; Clean North for the clean production sector in the North economy, Clean South for the clean production sector in the South economy.

An European Commission report (European Commission, 2013, p.11) promotes upfront investment support in the form of grants, preferential loans and tax reductions to overcome the limited availability for short-term financial resources for funding large-scale energy investments. In that sense, the two scenarios want to examine the impact of such investment subsidies and are conceptualized as follows:

- Scenario 1 - A unilateral lending rate subsidy for Clean investments is introduced by the North country in period 3 *until the end of the model run*
- Scenario 2 - A unilateral lending rate subsidy for Clean investments is introduced by the North country in period 3 *for a duration of 5 periods*

As can be drawn from the scenario analyses, the interest subsidy seems to have an impact on output, investment patterns and employment in both economies. Figure 2 indicates that as soon as the subsidy is in place, Dirty output in the North sharply falls and also the South economy faces a drop in Dirty production. In the second scenario, Dirty output slightly recovers in both economies and even reaches the baseline output level in the South after some period of time. However, as soon as the subsidy is not granted anymore (Scenario 2), Dirty output goes back upwards and even overshoots compared to the Baseline level.

For Clean output, the picture is reversed (Figure 2). The subsidy encourages Clean investment in both economies (Figure 4) that feeds back into higher Clean output. However, over time, the effect of the subsidy diminishes (Scenario 1) and Clean output continuously falls in both economies. If the subsidy is stopped (Scenario 2), Clean output immediately drops and even goes beyond the Baseline Scenario, also demonstrating an overshoot-effect.

An unexpected pattern can be observed for the employment level in both economies (Figure 3). While in the North economy employment falls as a consequence of the lending rate subsidy, it goes sharply upwards in the South economy and stays at the higher level over the run of the model. Interestingly, even after the subsidy has been stopped (Scenario 2), employment in the South does not fall sharply but only decreases slightly. The reason for that pattern could be twofold: First, as can be seen in figure 4, Dirty and Clean investment rises in the South, while only Clean investment rises in the North and Dirty investment falls sharply. Hence the increase in investment creates new jobs, which significantly raise the employment level in the South. Second, the one period advantage in Clean capital productivity of the North cannot make up for the lower production costs in the South, which attract firms and consumers and result in higher output 2.

As for the environment (Figure 6), the subsidy does not prevent a continuous deterioration. However, with the subsidies in place, the degradation happens slightly slower than in the Baseline Scenario. The reason for that is that the investment subsidy stimulates Clean output, while diminishing Dirty output but is not sufficient in order to crowd out Dirty output entirely.

The investment patterns look similar to the output developments after the implementation of the Clean interest subsidy. For the Dirty North investments fall sharply, and for Clean North and South investments increase strongly. However, interesting is the level at which investment patterns change. For both, Clean and Dirty, they fall or rise by far stronger than output does. Nevertheless, as soon as the subsidy is not granted anymore (Scenario 2), investment sharply moves to the Baseline Scenario patterns. Notwithstanding, this indicates the higher flexibility and sensitivity of investment compared to output that is less volatile and needs longer to adapt due to path dependency and capital utilization. Another astonishing exemption is the Dirty South investment case (Figure 4). In that case, the subsidy also encourages Dirty investment in the South that continuously increases over time and when the subsidy is stopped (Scenario 2), it even goes further up for a short period of time, falls sharply down and then slightly decreases over time, however at an higher level than in the Baseline Scenario.

Lastly, capital productivity is worth to take a look at (Figure 5). For Dirty capital productivity, the subsidy induces a sharp decline and a continuously lower level over the run of the model because of lower investment in the North. However, as soon as the subsidy is taken out, capital productivity comes close to its previous level and follows the patterns of the Baseline Scenario. In the case of Clean Capital Productivity, the effect is reversed. The subsidy causes Clean capital productivity to go upwards and stay at a higher level as long as the subsidy is granted.

5 Discussion of Results and Conclusions

The model serves as a first step towards a comprehensive and consistent ecological stock-flow consistent two-region macroeconomic model that includes aspects of the environment and trade as well as technical change and innovation. The model follows the approach by Acemoglu et al. (2014), who include these elements into a General Equilibrium model to examine the role of a unilaterally implemented environmental policy. Being a good starting point for the development of a holistic ecological macroeconomic framework, the Acemoglu et al. (2014) framework faces weaknesses in demonstrating environmental, economic and societal feedback effects. However, these feedback effects are essential since they can provide insights where to invest, which sectors to promote and which power alliances (between firms, NGOs, citizens, etc.) could emerge. The here presented model deviates from the Acemoglu et al. (2014) model by bringing the elements of technical change, the environment, and the international perspective into a SFC framework that allows for analyzing feedback effects and financial flows. To design effective environmental policies and steer technology into the desired direction, an understanding of ecological and social feedback effects, as well as financial flows is substantial. Hence, a holistic ecological macroeconomic framework should incorporate these elements and be able to analyze the resulting feedback effects. In that sense, the here presented model can provide a valuable contribution in providing a starting point for further research by including these elements into a SFC framework as a first step towards a comprehensive and consistent ecological macroeconomic framework.

Taking a look at the scenario analysis of the previous section, it is evident that a unilaterally granted Clean investment subsidy by the North economy is not sufficient to prevent an ecological catastrophe. Nevertheless, the experiments provide some valuable insights that can be taken into account for designing an effective environmental policy. The model substantially concentrates on the decision-making and investment behavior of firms, which is conceptualized in great detail. Exogenous events, such as the stylized intervention of the government sector through a lending rate subsidy, influence the firms' decision-making and can induce significant changes in output. The chain of effects works that way that, first, the subsidy causes a sharp increase in Clean investments in both economies and a slight increase in Dirty investments in the South. On the contrary, North investments are crowded out and fall sharply. Interestingly, the investments change to a far greater extent than the amount of the granted subsidy, which indicates the existence of a multiplicator effect that induces a virtuous investment circle, in response to capital productivity. Because investment effects feed back, on the one hand, onto capital productivity, they increase Clean capital productivity and decrease Dirty capital productivity. On the other hand, the changes investment patterns stimulate output, both Clean and Dirty, but in a diluted form. Second, employment in the North is negatively affected in the North and positively impacted in the South. This is especially astonishing since the subsidy was granted for Clean investments in the North. A possible explanation could be the higher cost structure and higher prices in the North economy. Higher wages make production in the North unattractive, and the one-period lasting capital productivity advantage of the North country cannot compensate for that advantage of the South. However, similar to Acemoglu et al. (2014), this insight could inform an international property rights discussion by pointing out the potential for developing countries for changing their production patterns by relatively fast and cheap adapting the North's technology. This understanding could support the attempts for a valid international agreement since it could help to overcome the deadlocked positions of Industrialized and Developing countries.

Nevertheless, the model clearly indicates that the North is losing from the implementation of a unilateral lending rate subsidy for Clean investments. It can be taken from the experiment results of this model that either a subsidy is not the right tool for a policy that aims for cleaner production patterns while maintaining high employment levels and overall output growth. This could mean that a mixture of various environmental policies could be an effective way to pursue those goals. A combination of different policies is also preferred by Aalbers et al. (2013), who point out that a more specific and narrow government policy focusing on one channel increases the risk of failure or undesired outcomes of that policy. In contrast, a broader set of policies could reduce this risk of failure and also enable a wide set of societal actors favoring the desired changes since different policies might favor different interest groups. However, the results of this model could also imply a general impossibility to reconcile these three separate goals of maintaining high employment levels, continuing to grow and becoming sustainable. This would imply that we have to sacrifice some of these elements to maintain the others. If that should be the case, it is a normative question for society to evaluate the value of each of these sectors and to decide, which of these to pursue.

The aim of this model is to contribute to the development of a comprehensive and consistent ecological macroeconomic model by pointing out its necessity and developing a framework that incorporates the crucial aspects of the environment, the international perspective and the role of technical change and innovation. Its contribution to the literature is by applying a Post-Keynesian SFC framework onto the environment, technical innovation and a multiregion setting and thereby depicting feedback effects on different sectors of the economy and society that could inform an environmental policy. The conducted scenario analysis demonstrated the effect of a clean investment subsidy aimed at avoiding an ecological catastrophe. While the unilateral clean investment subsidy proofs to be insufficient to prevent an environmental disaster, it, nevertheless, demonstrates the feedback effects of such a policy on investment, capital productivity, employment, and output. Therefore, this model can make a valuable contribution to the long way to develop a comprehensive and consistent ecological macroeconomic model by guiding further research and function as a starting point. Although some researchers question this proposed combination of Post-Keynesianism and Ecological Economics at this stage (Cahen-Fourot and Lavoie, 2016), other scholars are convinced of the possibility of a symbiosis of an Ecological Economics perspective with a Post-Keynesian Macroeconomic framework and conceptualized models and frameworks that make use of that combination (Fontana and Sawyer, 2016; Guarini and Porcile, 2016; Jackson and Victor, 2015; Dafermos et al., 2015). This article follows the view that a combination of both schools of thought is possible and can contribute to a mutually enrichment of their inherent ontology and epistemology. A continuation of that field of research and the further specification of the model assumptions could provide more explicit and problem-oriented advice for effective environmental policies.

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A Baseline Scenario Values and Parameters

Table 1: Baseline Scenario Values and Parameters

Parameter	Value	Description
α_1^N	0.7	Distribution Parameter for Consumption out of Disposable Income
α_2^N	0.1	Distribution Parameter for Consumption out of Wealth
α_1^S	0.8	Distribution Parameter for Consumption out of Disposable Income
α_2^S	0.05	Distribution Parameter for Consumption out of Wealth
$\mu^{N,S}$	0.18781	Import share of total Income
θ^N	0.2	Tax Rate - North
θ^S	0.1	Tax Rate - South
$G_{C,D}^{N,S}$	50	Government Spending
r	0.01	Government Bill Interest Rate
κ	1.2	Exchange Rate
ρ	0.05	Environmental Regeneration Rate
ξ	0.0035	Pollution Rate of Dirty Input
λ^N	1.2	Labor Productivity per Unit of Output - North
λ^S	1	Labor Productivity per Unit of Output -South
Ω_1	0.1	Weighing Factor for Real Wage
Ω_2	0.1	Weighing Factor for Real Wage
int_D^N	0.01	Interest Rate -North - Dirty
int_C^N	0.02	Interest Rate -North - Clean
int_D^S	0.02	Interest Rate -South - Dirty
int_C^S	0.03	Interest Rate -South - Clean
υ	0.1	Price Mark-up of Firms
χ	1	Government Subsidy to lower banks' interest rates for clean capital loans ($0<\chi<1$)
ψ	0.05	Fraction of Loans repaid to the Banks
β	0.5	Weighing Factor for Disposable Income and Consumption Distribution
γ	0.1	Weighing Factor for Expected Output
ϵ	0.03	Assumed 'Natural' Growth Rate
δ	0.1	Capital Depreciation Rate

B Balance Sheet

Figure 7: Balance Sheet of Two-Region Economy

	North Region					**South Region**					$\sum$
	Households	**Firms**		**Government**	**Commercial Banks**	**Households**	**Firms**		**Government**	**Commercial Banks**	
		Clean	Dirty				Clean	Dirty			
Government Bills				$-B^N_{CB}$	$+B^N_{CB}$				$-B^S_{CB}$	$+B^S_{CB}$	0
Loan Amount		$-L^N_C$	$-L^N_D$		$+L^N_{C,D}$		$-L^S_C$	$-L^S_D$		$+L^S_{C,D}$	0
Capital Stock		$+K^N_C$	$+K^N_D$				$+K^S_C$	$+K^S_D$			$+K^{N,S}_C + K^{N,S}_D$
Wealth	$+V^N_H$				$-V^N_H$	$+V^S_H$				$-V^S_H$	0
$\sum$	$+V^N_H$	0	0	$-B^N_{CB}$	0	$+V^S_H$	0	0	$-B^S_{CB}$	0	$+NV$

C Transaction-Flow Matrix

Figure 8: Transaction-Flow Matrix

	North Region						South Region					
	Households	**Firms**		**Government**	**Commercial Banks**		**Households**	**Firms**		**Government**	**Commercial Banks**	$\sum$
		Clean	Dirty					Clean	Dirty			
Consumption	$-C^N_{C,D}$	$+C^N_C$	$+C^N_D$				$-C^S_{C,D}$	$+C^S_C$	$+C^S_D$			0
Government Expenditures		$+G^N_C$		$-G^N_C$				$+G^S_C$	$+G^S_D$	$-G^S_{C,D}$		0
Northern Exports		$+X^N_C$	$+X^N_D$			$*\kappa$		$-IM^S_C$	$-IM^S_D$			0
Southern Exports		$-IM^N_C$	$-IM^N_D$			$*\kappa$		$+X^S_C$	$+X^S_D$			0
Wages	$+WB^N_{C,D}$	$-WB^N_C$	$-WB^N_D$				$+WB^S_{C,D}$	$-WB^S_C$	$-WB^S_D$			0
Firms' Profits	$+\Pi^N_{C,D}$	$-\Pi^N_C$	$-\Pi^N_D$				$+\Pi^S_{C,D}$	$-\Pi^S_C$	$-\Pi^S_D$			0
Interest Payment Gvt. Bills				$-r^N_{-1}B^N_{CB,H-1}$	$+r^N_{-1}B^N_{CB-1}$					$-r^S_{-1}B^S_{CB,H-1}$	$+r^S_{-1} \times B^S_{CB-1}$	0
Taxes	$-T^N$			$+T^N$			$-T^S$			$+T^S$		0
Interest Payment Bank Loans		$-\chi(int^N_C L^N_C)$	$-(int^N_D L^N_D)$		$+\chi(int^N_C L^N_C) + (int^N_D L^N_D)$			$-(int^S_C L^S_C)$	$-(int^S_D L^S_D)$		$+(int^S_C L^S_C) + (int^S_D L^S_D)$	0
Banks' Profits	$+\chi(int^N_C L^N_C)$ $+(int^N_D L^N_D)$ $+(r^N_{-1}B^N_{CB-1})$				$-\chi(int^N_C L^N_C)$ $-(int^N_D L^N_D)$ $-(r^N_{-1}B^N_{CB-1})$		$+(int^S_C L^S_C)$ $+(int^S_D L^S_D)$ $+(r^S_{-1}B^S_{CB-1})$				$-(int^S_C L^S_C)$ $-(int^S_D L^S_D)$ $-(r^S_{-1}B^S_{CB-1})$	0
ΔBills				$+\Delta B^N_{CB,H}$	$-\Delta B^N_{CB}$					$+\Delta B^S_{CB,H}$	$-\Delta B^S_{CB}$	0
ΔLoans		$+\Delta L^N_C$	$+\Delta L^N_D$		$-\Delta L^N_{C,D}$			$+\Delta L^S_C$	$+\Delta L^S_D$		$-\Delta L^S_{C,D}$	0
ΔCapital		$-\Delta K^N_C$	$-\Delta K^N_D$					$-\Delta K^S_C$	$-\Delta K^S_D$			0
ΔWealth	$-\Delta V_N$				$+\Delta V_N$		$-\Delta V_S$				$+\Delta V_S$	0
$\sum$	0	0	0	0	0		0	0	0	0	0	0