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Nepomuk Dunz
Asjad Naqvi
Irene Monasterolo

Climate Transition Risk, Climate Sentiments, and Financial Stability in a Stock-Flow Consistent approach

Working Paper Series
23/2018

Climate Transition Risk, Climate Sentiments, and Financial Stability in a Stock-Flow Consistent Approach[☆]

Nepomuk Dunz^{a,b,*}, Asjad Naqvi^{a,b}, Irene Monasterolo^{a,c}

^a*Vienna University of Economics and Business, Austria*

^b*International Institute for Applied Systems Analysis, Austria*

^c*Boston University, USA*

Abstract

There is growing awareness that aligning the real economy to the climate and sustainability targets requires the introduction of stable policies. In this regard, a global Carbon Tax (*CT*) and a revision of the micro-prudential banking framework via a Green Supporting Factor (*GSF*), have been advocated. However, our understanding of the conditions under which a *GSF* or a *CT* could represent an opportunity to scale up new green investments, or a new source of risk for financial stability, is very poor. In addition, banks' reaction to policies' announcements (their climate sentiments), have not been considered yet but they could affect the policies' outcomes. We contribute to fill this knowledge gap by developing a Stock-Flow Consistent behavioural model of a high income country that embeds banks climate sentiments, modelled as a non-linear, adaptive forecasting function. With the model, we assess the impact of the introduction of a *GSF* and a *CT* on the greening of the real economy and the credit market. We analyse the risk transmission channels from the credit market to the real economy via loans contracts, and the drivers of reinforcing feedbacks leading to cascading macro-financial shocks. Our results suggest that, under the model (and current policy)'s conditions, the *CT* could be more effective than the *GSF* in fostering new bank's green loans and firms' investments. Nevertheless, short-term negative effects on GDP growth and financial stability could emerge according to how the policies are implemented. Finally, stronger bank's climate sentiments could smooth financial instability risks associated to the low-carbon transition.

Keywords: climate sentiments, climate transition risk, loans, green supporting factor, carbon tax, financial stability, Stock-Flow Consistent modelling

1. Introduction

According to the European Commission, achieving the EU2030 climate and energy targets would require EUR 177 billion of new investments per year in renewable energy and energy efficiency in the European

[☆]This project is partially supported by the Austrian Climate Research Program's (ACRP) 10th call project titled "Analysis of Carbon Risks in Financial Markets and Austrian Portfolios" (RiskFinPorto). The usual disclaimer applies.

*Corresponding author: dunz@iiasa.ac.at. All authors contributed equally to this project.

Union (EU) alone (European Commission, 2018; HLEG, 2018). In addition, scholars and practitioners argue that a deep decarbonization of the real economy and of investors' portfolios is needed to avoid the risk of carbon stranded assets (Caldecott, 2018) and their potential implications on price volatility and on financial stability (ESRB, 2016; Battiston et al., 2017; Monasterolo et al., 2017; NGFS, 2018; Dietz et al., 2016; Batten et al., 2016). Indeed, as highlighted by the Governor of the Bank of England, Mark Carney, in his talk about the "Tragedy of the horizons" (Carney, 2015), climate change could affect financial stability via *climate physical risk*, i.e., climate-led extreme events leading to physical capital destruction, and via *climate transition risk*, i.e., an abrupt revaluation of the value of financial contracts. This might lead, in turn, to the revaluation of lenders and investors' portfolios (e.g. via write-offs), in response to a disordered introduction of climate-aligned policies.

Thus, how to fill this green investment gap while avoiding new risks for financial stability is a subject of debate among academics, practitioners, central bankers and financial regulators. In particular, there is emerging consensus that governments alone cannot finance the investments needed to achieve the EU2030 targets and private finance and capital markets are needed for scaling up green investments (Dombrovskis 2018; UNFCCC 2015 Article 2.3).

In this regard, disclosure of climate-related financial information was recommended by the FSB Task Force on Climate Related Financial Disclosure (TCFD, 2017) and by the European Commissions High-Level Experts Group on Sustainable Finance (HLEG, 2018). However, this might not be sufficient to align investments to sustainability. Recent research shows that markets and investors are not adequately pricing climate risks in the value of financial contracts (Delis et al., 2019; Morana & Sbrana, 2018; Monasterolo & De Angelis, 2018).

With the aim to scale up green investments and loans, a revision of microprudential banking framework and governments' implementation of stable climate-aligned policies were advocated. On the one hand, the introduction of a green supporting factor (*GSF*) aimed to lower capital requirements for green investments (Dombrovskis, 2018) raises criticism among central bankers and financial regulators with regard to its potential implications on financial risk and instability (Thomä & Hilke, 2018; Campiglio et al., 2018b; Dafermos et al., 2018). On the other hand, the introduction of a global carbon tax (*CT*), that is, a tax on production activities' contribution to CO2 emissions (Stiglitz et al., 2017), has so far been delayed, also due to its unclear implications on GDP growth, financial stability and inequality (Monasterolo & Raberto, 2018). A *CT* would work by increasing the production costs for carbon-intensive companies thus fostering them to shift to low-carbon productions. However, the transition phase could result in lower demand and lower profits for those companies. This, in turn, would negatively affect their contribution to Gross Value Added and GDP growth, and could feedback on banks' financial stability via Non Performing Loans (*NPL*) and loans contracts revaluation.

Given the very short time left for policymakers to implement the low-carbon transition and achieve the

climate targets (IPCC, 2018), understanding the conditions under which a *CT* or a *GSF* could represent an opportunity for scaling up green investments, while preventing trade-offs on risk for financial stability, is crucial. In this context it is fundamental to consider how banks could react to the policies, that is, through their *climate sentiments*. Indeed, banks could trust governments and anticipate the climate-aligned policies, thus revising the lending conditions to green or brown companies, by respectively decreasing the risk associated to green loans and to increase that associated to brown loans. In contrast, if banks' climate sentiments will not play out, that is, the bank decides to adopt on a Business-as-Usual (BAU) behaviour and not to price the introduction of the policy in their contracts, the policy itself might not achieve its goals (CISL, 2015; Trucost & ESG Analysis, 2018; Bank of England, 2018).

However, a formalization of banks' climate sentiments and their interaction with *GSF* and *CT* policies is still missing. Further, the conditions for financial-real economy feedbacks and cascade losses to emerge as a reaction to *GSF* and *CT* under bank's stronger or weaker sentiments, deserve research attention. This represents a main knowledge gap that prevents financial regulators and central banks to assess the conditions for the onset and the mitigation of climate-related financial risk, and banks to better price risks and opportunities related to the low-carbon transition.

We contribute to fill this gap by developing a stylized one country, Stock-Flow Consistent (*SFC*) macroeconomic behavioral model that embeds an adaptive forecasting function of banks' climate sentiments. This allows us to model banks' climate sentiments as a function of expectations of the climate-aligned policy, of firms' past performance, and of future expected profitability and their ability to repay loans. The *SFC* behavioral model represents heterogeneous agents and sectors of the economy and credit market as a network of interconnected balance sheets to assess the generation and transmission of direct and indirect endogenously generated effects of the climate-aligned policies. With the model we analyze the impact of a *GSF* and a *CT* on new green loans and investments in the real economy, and on bank's financial stability through a Capital Adequacy Ratio (*CAR*) aligned to Basel III (BIS, 2011), under banks' strong or weak climate sentiments. In particular, we can identify the macro-financial risk transmission channels and reinforcing feedbacks, and the conditions for cascade losses via loans contracts.

Our approach represents a methodological innovation on the modelling state of the art and allows us to answer three research questions that are relevant for climate-aligned research and policy; (i) to what extent a *CT* or *GSF* could foster green loans and investments in the real economy?, (ii) under which conditions trade-offs for financial stability could occur, and (iii), what role (if any) banks' climate sentiments may play in fostering or hindering the expected effect of the policies on the green economy and on financial stability?

The remaining paper is organized as follows. Section 2 provides a review of the state-of-the-art on climate risks and financial stability, with a focus on investors' climate sentiments and *SFC* models. Section 3 introduces the model, while section 4 lays out three different climate policy scenarios and respective model's transmission channels. The results and their implications are discussed in section 5. Section 6 concludes

and provides avenues for further research.

2. Literature Review

2.1. *Challenges for credit market stability 10 years after Lehman Brothers*

In the aftermath of the Great Financial Crisis (GFC), academics and financial regulators focused on risk transmission channels and measures for financial instability.¹ Since excessive credit growth is considered as an important driver of financial instability (Schularick & Taylor, 2012; Taylor, 2015), the Basel III accords (BIS, 2011) aim to build the foundation of a resilient banking system by setting macroprudential minimum requirements such as capital adequacy ratios (CAR), capital buffers and maximum leverage ratios. Two aspects are of specific interest for academics with respect to Basel III; (i) its role in increasing banks' resilience to shocks, and (ii) its impacts on banks' lending conditions and credit growth and thus on GDP growth.

In this context, the conditions for excessive credit growth that drive credit cycles have been analysed (Aikman et al., 2015; Alessi & Detken, 2018). Fratzscher et al. (2016) analyse the impact of financial regulation and more independent supervision with respect to banks stability and credit provisioning using country panel data, concluding that tighter capital buffers had positive effects on banks stability. Considering the effects on lending, several studies (Ben Naceur et al., 2018; Aiyar et al., 2016; Martynova, 2015) find an inverse relationship between tighter capital regulation and growth in banks lending to the real economy. Similarly, stricter capital requirements could contribute to increase bank's lending rates (King, 2010; Akram, 2014), which transmit to the real economy.

2.2. *Climate-aligned policies and financial regulations: risk or opportunity for financial stability?*

The Paris Agreement signed at the UNFCCC COP21 conference in Paris in 2015 (UNFCCC, 2015) highlighted the role of private investments in financing the low-carbon transition. Since then, the barriers and opportunities for scaling up green investments started to be analyzed (UNEP-FI, 2018), and climate-aligned policies and regulations to overcome the barriers and enable opportunities were discussed.

In this regard, the discussion has focused on market-based solutions to climate change, including a carbon tax, the revision of microprudential regulations and the role of new green financial instruments (for example, green bonds), which could be eventually used as a tool to greening central banks' monetary policies. The

¹See for instance the special issue in this journal on "Challenges for financial stability in Europe" (Galuscak & Horvath, 2018), see also Silva et al. (2017) for a literature review on systemic financial risk, and the JFS special issue on "Network models, stress testing and other tools for financial stability monitoring and macroprudential policy design and implementation" for a proposition of new research avenues with respect to systemic risk analysis and financial stability implications (Battiston & Martinez-Jaramillo, 2018).

new policies and regulations are expected to contribute to overcome the current mispricing of climate risks by signaling investors in the real economy and financial markets.

The introduction of a global carbon tax is the most debated market-based solution to climate change (Stiglitz et al., 2017; Lagarde & Kim, 2015), aimed to make polluters pay by pricing carbon. However, the political challenges related to its implementation led scholars to discuss about what role central banks and financial regulators could play in the low-carbon transition. Central banks started to look at climate-related risks (including climate transition risks (Batten et al., 2016)), in the context of financial stability, which is the main focus of their mandate. Indeed, a disordered introduction of climate-aligned policies could lead to price volatility (for both green and brown assets). This could eventually affect financial stability if large asset classes and systemic financial actors are involved (Monasterolo et al., 2017). Several central banks and financial regulators joined in the Network for Greening the Financial System (NGFS) with the aim to identify and disclose the climate-related risks for the stability of the financial system (NGFS, 2017), also via forward-looking climate stress-tests for their and of financial actors portfolios (NGFS, 2018).

In addition, the role of central banks' monetary policies in signaling the market in the low-carbon transition (for example, the assets' purchases under the Quantitative Easing, (Matikainen et al., 2017) gained scholars' and practitioners' attention. In the EU, the discussion focused on the European Central Bank's (mis)alignment to the EU2030 targets and the Paris Agreement, and its role in steering the allocation of assets and collateral towards low-carbon sectors to reduce the cost of capital for these sectors. The conditions for greening monetary policies (Schoenmaker, 2019), for example, via the preferential purchase of green bonds (Monasterolo & Raberto, 2017) and by exploiting synergies with the European Investment Bank (EIB) (Monasterolo & Raberto, 2018) started to be analyzed. Nevertheless, the lack of a standardized green taxonomy and green bonds' standards, the limited market share of green bonds on the bonds' market, the partial disclosure of climate-related financial information (Battiston & Monasterolo, 2019), and the lack of understanding of banks' climate sentiments, could weaken central banks' intervention, with unknown effects on financial stability.

Finally, the EC has proposed to revise the microprudential banking framework in order to foster green investments and loans by lowering capital requirements for green investments, the so called "green supporting factor" (GSF). This is expected to foster banks to assign lower risk weights to green loans (Thomä & Hilke, 2018; Campiglio et al., 2018a,b), thus decreasing their risk perception of green investments and improving the green lending conditions. Dafermos & Nikolaidi (2018) analyze the implications of differentiated capital requirements on carbon emissions and on financial stability but they don't find significant effects on the reduction of carbon emissions.

However, understanding the conditions under which a reform of financial regulation could contribute to foster green investments while minimizing trade-offs for financial stability and inequality is still at an infant stage, but it is crucial to inform effective policies.

2.3. Climate sentiments in credit markets

The role for investors' expectations of future profitability under climate physical and transition scenarios, is gaining research and policy attention. This point is relevant because banks could alter their lending conditions for green and brown sectors with implications on firms' performance and economic growth, particularly in the green sector. By building on the financial instability hypothesis by Hyman Minsky (1977), concepts such as investors' sentiments (Barberis et al., 1998; Greenwood & Shleifer, 2014), diagnostic expectations (Bordalo et al., 2018), or credit-market sentiments (Lopez-Salido et al., 2017) contribute to explain endogenous credit cycles.

In particular, Greenwood et al. (2016), Bordalo et al. (2018), and Lopez-Salido et al. (2017) model credit cycles with extrapolative beliefs of investors. The resulting time-varying credit sentiments of investors can explain several empirical findings with respect to credit cycles without the assertion of financial frictions. Further, Lopez-Salido et al. (2017) show that a predictable component of changes in credit spreads can be associated with unwinding past investor sentiment, that is, their dynamic beliefs about default probabilities. However, the magnitude of impacts of climate-aligned policies on bank's financial stability could depend on bank's climate sentiments, for example, on banks' perceptions and reactions regarding the likelihood and scale of climate change and climate-aligned policies (CISL, 2015; Trucost & ESG Analysis, 2018). CISL (2015) and Trucost & ESG Analysis (2018) use experts' elicitation to provide qualitative insights about current investors' climate sentiments and their implications on smoothing financial stability impacts stemming from climate transition risk.

A formalization of climate sentiments in the context of the impacts of climate transition risks on banks financial stability via loan contracts is still missing. This information is crucial both for financial regulators and Central Banks to identify sources of potential risk for financial stability stemming from banks' loans contracts. Further, it would help banks to better manage their portfolios in anticipation to climate shocks, and thus to make their portfolios more climate-resilient.

Overall, the implications of greening fiscal policies (for example, via a carbon tax (CT)) or greening financial regulation (for example, via a green supporting factor (GSF)) on the stability of the credit market and its implications on loans contracts, green and brown companies' performance and composition of GDP have just started to be analyzed in the literature and more modelling research is needed. In particular, three points deserve attention; (i) bank's reaction to the policies based on their expectations on the same policy and their risk pricing, (ii) the risk transmission channels from changes in policies and regulations on the credit market and from here to the real economy agents, and (iii), the conditions for the onset of credit market instability (or resilience) via loans contracts.

3. Model

In this section we present the stock-flow consistent (SFC) model structure, the behavioral equations of sectors, and the non-linear adaptive forecasting function that represents banks' climate sentiments.

Model overview

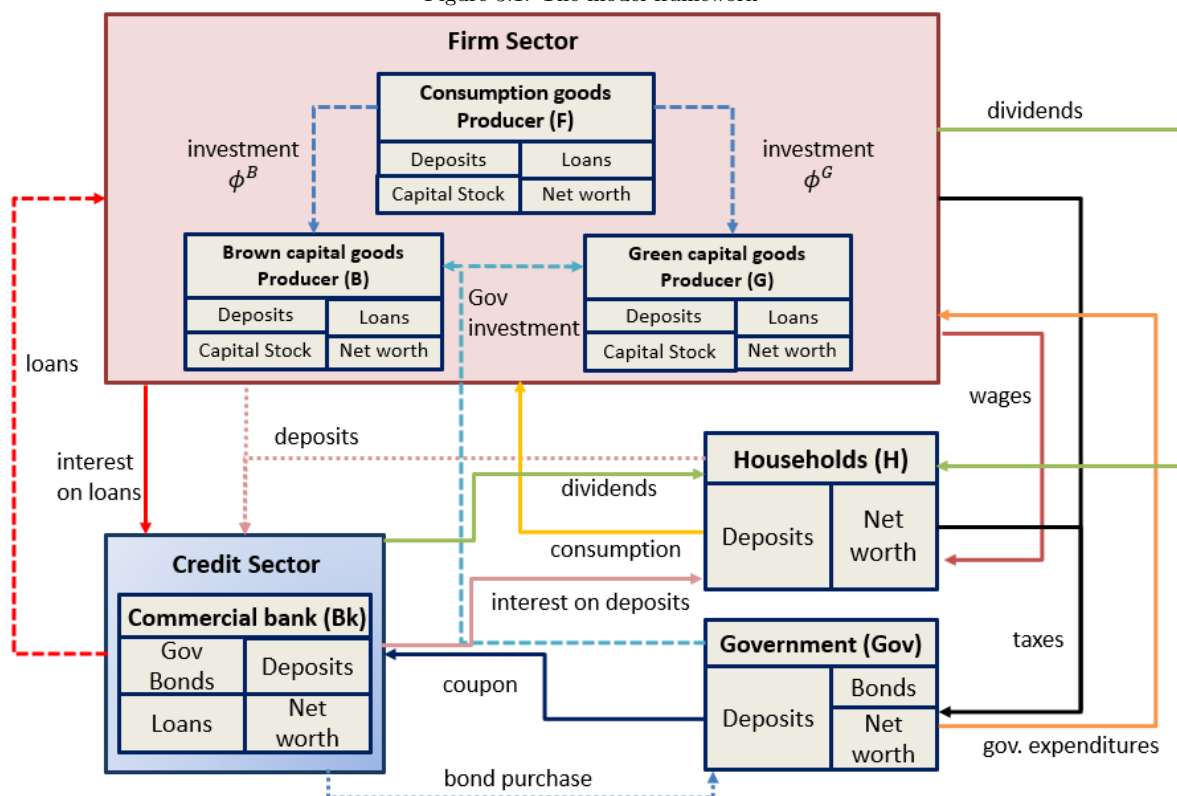
We present a stylized model of a high-income one country economy composed of six sectors – households (H), government (Gov), commercial banks (Bk), a consumption good producer (F), a brown capital good producer (B), and a green capital good producer (G). Sectors are represented as a network of interconnected balance-sheets where their interactions shape a circular flow economy via capital and current account flows. The model is roughly calibrated to a high income economy (see [Appendix C](#) for parameter values).

These relationships are summarized in [Figure 3.1](#). For each sector, a balance sheet representation in terms of assets and liabilities is provided. Dotted lines represent capital account flows, whereas solid lines represent current account flows. Households purchase and consume consumption goods and receive income from wages and dividends from the firm sector. Households also earn deposit interests and bank's dividends. Both the firm sector and households pay taxes to the government, which uses them for consumption expenditures and for supporting investments in brown or green capital goods. In addition, the government can issue sovereign bonds to finance a deficit. The sovereign bonds are purchased by the bank in return of interests. The firm sector is composed of brown and green capital goods producers (based on the emissions' intensity of their production, which is lower for the green capital goods producer) and by a consumption good producer that could decide to use either green or brown capital goods (see [Monasterolo & Raberto 2018](#)).

Firms produce based on the demand coming from households and government, investing in capital stock with share ϕ_t^B in brown and the remaining share, $\phi_t^G = 1 - \phi_t^B$, in green capital stock. Firms finance their investments by partially relying on retained earnings and partially by borrowing from the bank through interest-bearing loans.

The model framework follows the accounting logic of stock-flow consistent (SFC) models ([Godley & Lavoie, 2012](#); [Caverzasi & Godin, 2015](#); [Nikiforos & Zezza, 2017](#)) implying that all transactions between sectors or economies are captured by a Balance Sheet (see [Table A.2](#)) and a Transaction Flow Matrix (see [Table A.3](#)). All further relationships and dependencies between different sectors are determined by a set of behavioral equations that are presented below. It is important to notice that the SFC structure allows us to display agents and sectors in terms of accounting relations that hold irrespective of the behavioral rules. The SFC logic requires that all entities have specific budget constraints and all transactions within the economy are zero-sum. Thus our model structure allows to understand, (i) the transmission channels through which either the GSF or a CT could affect low-carbon transition in the economy, and (ii) the conditions for GSF or CT to generate risks leading to bank's financial instability via loan contracts.

Figure 3.1: The model framework



Note: Flows of the model economy. For each sector, a balance sheet representation in terms of assets and liabilities is provided. Dotted lines represent capital account flows, whereas solid lines represent current account flows.

The formalization of the model is supported by the following set of notations. The firm sector is represented by n goods where $n = \{F, B, G\}$ and $m = \{B, G\}$ represent the subset of brown and green capital good firms. Capital letters depict nominal values in current prices (for example, Y_t is nominal GDP), while lowercase letters stand for real values, or stocks (y_t , is real GDP). The subscript t denotes time and Δ represents first order time differences, for example, $\Delta r_t = r_t - r_{t-1}$. Parameters are represented by Greek symbols where the endogenous parameters are explicitly stated and indexed with the time t subscript.

3.1. The Firm Sector

The firm sector produces all the goods consumed in the economy. This is represented by the general identity for GDP or total nominal output as:

$$Y_t = C_t^H + I_t + C_t^{Gov} \quad (1)$$

where C_t^H and C_t^{Gov} are total household and government expenditures on goods produced by the consumption good firm (F). The total investment, I_t , comprises of brown and green capital stock, produced by brown capital good firm (B) and green capital good firm (G) respectively. The demand for investment comes from three sources; (i) the consumption good firm (I_t^F) that want to increase production capacity, (ii), from the government sector which invests in infrastructure (I_t^{Gov}); and (iii) brown and green capital good sector (I_t^B, I_t^G) that builds up their own capital stock. Formally, this can be defined as:

$$I_t = \sum_n I_t^n + I_t^{Gov} \quad (2)$$

For this categorization, the demand for output of each firm sector can be derived as follows:

$$\begin{aligned} Y_t^F &= C_t^H + C_t^{Gov} \\ Y_t^B &= I_t^B + \phi_t^B (I_t^F + I_t^{Gov}) \\ Y_t^G &= I_t^G + \phi_t^G (I_t^F + I_t^{Gov}) \end{aligned} \quad (3)$$

where $\{\phi_t^B, \phi_t^G\}$ are shares of private and public investment demand for brown and green capital stock respectively (see Equations 5–7). By definition, $\phi_t^G = 1 - \phi_t^B$, implying that if one is estimated, the other can be derived as a residual.

The production function of the firm sector requires two complementary inputs; Labor (N) and capital stock (K), where the total input demand is defined as:

$$Y_t^n = Min[N_t^n, K_t^n] \quad (4)$$

Labor demand, N_t^n , and capital demand, $K_t^n = \phi_t^B K_t^B + \phi_t^G K_t^G$, are determined by their respective productivities ϵ^N , and ϵ_t^m .

To keep the model tractable, we make several simplifying assumptions. First, we assume that labor productivity (ϵ^N) and consumption good productivity (ϵ^F) are constant, while the productivity of green and brown capital good firms are evolving over time (see Eq. 7 below). Second, we assume that only the consumption good firm (F) and the government (Gov) decide between green and brown capital stock. Green (G) and Brown (B) capital good firms use only the capital they produce themselves.²

Capital demand and productivity

Consumption goods firms (F) can use both the green and the brown capital goods for production. The demand for green or brown capital follows a portfolio choice-like problem determined by two variables, price and productivity. Formally, this is represented as:

$$\Phi = \Lambda_0 + \Lambda_m \mathbf{Q} \quad (5)$$

where $\Phi = \{\phi_t^m\}$ is a vector of shares of brown and green capital goods. $\Lambda_0 = \{\lambda_0^m\}$ is the baseline exogenously given demand for the two capital goods. $\Lambda_m = \{\lambda_{ij}\}$ is a $m \times m$ matrix of sensitivity coefficients for $\mathbf{Q} = \{p_t^m, \epsilon_t^m\}$, the price and capital productivity vectors for green and brown capital stocks respectively. The sensitivity parameters Λ_m capture qualitative preferences, institutional conditions (that is, quality of governance) as well as opportunities for substitution between green and brown capital goods. By definition, the column of Λ_0 sums up to 1, and the rows and columns of Λ_m sum up to 0 (Tobin, 1982). Assuming the total capital stock requirement is K_t , then the shares of green and brown capital stock would be derived by the following equations:

$$\begin{aligned} \phi_t^B &= \frac{K_t^B}{K_t} = \lambda_0^B + \lambda_{11} p_t^B + \lambda_{12} \epsilon_t^B \\ \phi_t^G &= \frac{K_t^G}{K_t} = \lambda_0^G + \lambda_{12} p_t^G + \lambda_{22} \epsilon_t^G \end{aligned} \quad (6)$$

Due to symmetry conditions, $\phi_t^G = 1 - \phi_t^B$. Using the standard accelerator principle from literature, capital productivity ϵ_t^m evolves with respect to change in investments (Δi_t^m) (McCombie, 2002; Acemoglu, 2002; Acemoglu et al., 2012; Romer, 1990), such that:

$$\epsilon_t^m = \epsilon_{t-1}^m (1 + \gamma_\epsilon^m \Delta i_t^m) \quad (7)$$

²If these assumptions are relaxed, one would need to introduce aspects of technological change (see Naqvi & Stockhammer 2018), and input-output (I-O) structures (see Berg et al. 2015), that will further increase the complexity of the outputs.

where γ_ϵ^m is the adjustment parameter. We assume that the brown capital good producer has an initially higher productivity than the green capital good producer ($\epsilon_0^B > \epsilon_0^G$) based on economies of scale for the brown sector and higher cost of capital for green investments (HLEG, 2018). However, we also assume that productivity growth is higher for green relative to brown ($\gamma_\epsilon^G > \gamma_\epsilon^B$), owing to the fact that green capital goods have higher potential of efficiency gains allowing them to catch-up to the brown sector (Lazard, 2018; Acemoglu, 2002; Popp et al., 2010; McCombie, 2002).³ The final good sector buys capital stock from capital good firms. Thus, we estimate its capital productivity as a weighted average of the productivity of the green and brown sectors.

Investment, Loans, and Defaults

Changes in demand results in changes in capital stock requirements. Capital stock accumulation equals new investments net of depreciation (Eq. 8). Investments are determined by a target capital stock and firms preference for slack production capacity to adjust to short-run changes in demand (Lavoie, 2014). Indeed, data from the manufacturing industry of the EU shows that the rate of capacity utilization in the EU28 is around 80% (FRED Economic Data, 2019; Eurostat, 2019) and capacity utilization is an important indicator, both for price stability (ECB, 2007, 2010, 2019) and business cycles (Greenwood et al., 1988; Dergiades & Tsoulfidis, 2007) considerations. We model this feature by assuming a target capacity utilization rate \bar{u} , while the actual sector-specific utilization rate is estimated as $u_t^n = y_t^n / (\epsilon_t^n k_t^n)$ (see Lavoie (2014); Godley & Lavoie (2012)).

$$k_t^n = k_{t-1}^n(1 - \delta) + i_t^n \quad (8)$$

$$i_t^n = \gamma_i(u_t^n - \bar{u})k_{t-1}^n + \delta k_{t-1}^n \quad (9)$$

Equation 9 represents the investment function. If firm products are in high demand, then the utilization rate goes up, implying firms approach full capacity. Therefore in order to maintain their target utilization rate, additional investments in capital stock are required. In contrast, if demand goes down, firms might decide to replace only the depreciated capital stock, or might decide not to engage in new investments. This would result in firms lowering their “functional” capital. This can also result in stranded assets through large scale divestment (Caldecott & McDaniels, 2014; Caldecott, 2018; Campiglio et al., 2018a). In particular, the parameter γ_i implies that desired investment targets are met over several time periods. In nominal terms, investment requirement equals $I_t^n = i_t^n p_t^n$.

³This is in line with several EU and national level policies which plan higher green R&D investment, and feed-in-tariff’s (FITs) to boost the productivity of the green sector (European Commission, 2010, 2008; EC, 2014; Official Journal of the European Union, 2013, 2009).

The firm sector finances investments via retained earnings RE_t^n and via banks' loans L_t^n . Thus, the loans stock at a point in time is defined as:

$$L_t^n = L_{t-1}^n(1 - \rho) + I_t^n - \eta RE_t^n \quad (10)$$

where ρ is the repayment rate of loans, and η is the share of retained earnings utilized for capital stock accumulation.

Firms facing deteriorating economic conditions might not be able to meet their debt service obligations to the bank, which could then incur in non-performing loans (NPL). In case of firms' inability to repay the principal, the bank is affected via two channels; (i) it faces reduced interest payments for the share of loans that are non-performing, and (ii), it has to adjust its balance sheet, by taking non-performing loans off its books.

If NPL exceed the expected levels that the banking sector has already priced into its credit conditions (and displayed via the interest rate on the loan), the NPL might affect bank's financial stability (Nkusu, 2011; Kaminsky & Reinhart, 1999).

$$\Delta NPL_t^n = \Delta \xi_t^n L_t^n \quad (11)$$

$$\xi_t^n = \xi_{t-1}^n \left(1 - \frac{\Pi_t^n - \Pi_{t-1}^n}{\Pi_{t-1}^n} \right) \quad (12)$$

The share of NPL in total loans is determined by an endogenous parameter ξ_t^n (Eq. 12). We assume this parameter to evolve inversely relative to the rate of firm's profitability (Eq. 12) implying that firms are able to meet repayment targets if their profits are growing and the country's macroeconomic conditions are favorable (Klein, 2013; Jakubik & Reininger, 2013; Nkusu, 2011; Beck et al., 2015). This specifications allows us to proxy firm-specific and country-specific macroeconomic determinants of $NPLs$, as identified by Ghosh (2015).

Costs, Prices, and Profits

Firms use markup pricing (Eq. 16) over unit costs (Eq. 15) to determine the price of their products. As firms have two input factors for production, firms have two sources of costs that is, the wage bill WB_t^n and the costs of borrowing that we define as capital bill KB_t^n :

$$WB_t^n = \omega \frac{y_t^n}{\epsilon^N} \quad (13)$$

$$KB_t^n = r_t^n(L_{t-1}^n - NPL_t^n) + \rho L_{t-1}^n \quad (14)$$

Equation 13 displays the wage bill which equals sector-specific real output over labor productivity ϵ^N times the wage rate ω . For simplicity, we assume labor productivity and wage rates to be constant.⁴

Similarly, KB_t represents the cost of investment in capital. This can be defined as the interest paid on active loans (L_t^n) minus non-performing loans (NPL_t^n) plus the repayment of loans at rate ρ . We assume that in case of (NPL_t^n) firms don't pay interest on that, thus reducing bank's expected profits. Nevertheless, their loan level is not reduced since NPL 's cannot be taken off their books.

$$UC_t^n = \frac{WB_t^n + KB_t^n + T_t^{CT}}{y_t^n} \quad (15)$$

$$p_t^n = UC_t^n(1 + \theta)(1 + \tau^n) \quad (16)$$

$$\Pi_t^n = Y_t^n - T_t^n - T_t^{CT} - WB_t^n - KB_t^n + r_t^v S_{t-1}^n \quad (17)$$

where the tax T_t^n is a profit tax such that $T_t^n = (Y_t^n - WB_t^n - KB_t^n)\tau^n$. Firms' profits (Eq. 17) are calculated as their income plus interest payments on firms' savings, minus their labor and capital costs as well as tax payments to the government.

Profits are split into dividends ($Div_t^n = \pi\Pi_t^n$) and into retained earnings ($RE_t^n = (1 - \pi)\Pi_t^n$). Dividends are passed onto households as capital income, while a fraction ηRE_t^n of retained earnings is used for investments. The remaining $(1 - \eta)RE_t^n$ adds to firm's savings in the bank.

The Carbon Tax (CT)

The carbon tax (Eq. 18) as a climate-aligned policy scenario is raised on sector B and sector F 's nominal output, with the aim to increase production costs for brown capital goods and brown capital-based consumption goods. F only has to pay a carbon tax on its production using brown capital as an input factor K_t^B/K_t . The carbon tax adds to firms' unit costs (Eq. 15) and reduces firms' profits (Eq. 17). Via mark-up pricing (Eq. 16), the higher unit costs are passed on to customers.

$$T_t^{CT} = \sum_{j=\{F,B\}} \tau^{CT} Y_t^j \quad (18)$$

3.2. Household sector

Households are owners of capital and represent also the model's workers. They use their income for consuming goods (Eq. 20) or for saving for future consumption, thus accumulating wealth (Eq. 21).

⁴The model structure allows to relax both assumptions by increasing wage and productivity growth endogenously. In this paper, we did not opt for this solutions because it would result in additional level of complexity which does not directly affect the results. For an endogenous treatment of both these factors, see [Naqvi & Stockhammer \(2018\)](#).

$$YD_t = \sum_n WB_t^n + \sum_n Div_t^n + Div_t^{Bk} + r_t^v V_{t-1}^H - T_t^H \quad (19)$$

$$C_t^H = \alpha_1 YD_t + \alpha_2 V_{t-1}^H \quad (20)$$

$$\Delta V_t = YD_t - C_t \quad (21)$$

Disposable income YD_t consists of the wages that are paid to workers from each of the firm sectors. Furthermore, all households receive dividends from the firm and the banking sector. Additional income for households is generated through interest payments on their bank deposits. Households pay income tax (τ^H) on their total income, where the disposable income is calculated as an income net of taxes (Eq. 19).

3.3. Government sector

The government is in charge of the fiscal policy that consists of (i) collecting taxes from households and firms, and (ii), introducing a CT to make brown firms pay for their higher contribution to emissions in comparison to green firms, and collecting the carbon tax CT revenues (Eq. 22).

In general, fiscal revenues are used for covering government's running costs (Eq. 23) and government's investment (Eq. 24) aimed to maintain public capital stock (Eq. 25).

$$T_t = T_t^H + T_t^{Bk} + T_t^{CT} + \sum_n T_t^n \quad (22)$$

$$C_t^{Gov} = g_0 + g_1 T_t \quad (23)$$

$$I_t^{Gov} = \sum_m \phi_t^m \left(\delta K_{t-1}^{Gov,m} + g_2 T_t \right) \quad (24)$$

$$K_t^{Gov} = \sum_m K_{t-1}^{Gov,m} (1 - \delta) + I_t^{Gov,m} \quad (25)$$

$$\Delta GBond_t = C_t^{Gov} + \sum_m I_t^{Gov,m} + r^{gov} GBond_{t-1} - T_t \quad (26)$$

The demand decision for green or brown capital stock is also based on price and productivity criteria defined by Equation 5. In case government's expenditures exceed its tax income, the government can issue bonds, which are entirely purchased by the banking sector (Eq. 26). The parameters g_1 and g_2 are kept relatively small and makes government spending pro-cyclical.

3.4. Banking Sector

The banking sector holds private sector's deposits and gives out loans to firms. The Bank only operates via the credit market in the model, implying that bank's profits next of taxes stem only from the spread between interest paid out on deposits and received for outstanding loans:

$$\Pi_t^{Bk} = r_t^v \left(V_t^H + \sum_n V_t^n \right) - r_t^l \sum_n L_t^n - T_t^{Bk} \quad (27)$$

Bank's profits are split into household dividends, $Div_t^{Bk} = \pi \Pi_t^{Bk}$, and bank savings or equity, $V_t^{Bk} = (1 - \pi) \Pi_t^{Bk}$.

The bank is not a simple intermediary between borrowers and savers but engages in endogenous money creation (McLeay et al., 2014) and is endowed with targets aimed to avoid excessive exposure to financial risks and thus to ensure financial stability. We introduce this as the Capital Adequacy Ratio in our model (BIS, 2011). Risk enters into the bank's balance sheet through loans contracts to the firms. The bank assesses the risk related to each loan contract to a firm based on its credit worthiness, which is reflected in a specific interest rate. Recent research shows that on the one hand, banks tend to consider loans to the green sector as riskier than loans to the brown sector (Dhruba, 2018; Zuckerman et al., 2016; Volz et al., 2015; Dombret & Le Lorier, 2017; Nick Robins & McDaniels, 2016) thus applying a higher interest rate, while on the other hand, banks are not yet pricing climate risk in their loans contracts adequately (Delis et al., 2019). In line with this literature, we assume that the green sector is perceived as riskier compared to the brown sector and thus is subject to a higher initial base interest rate.

Capital Adequacy Ratio

The Basel III framework, that was formulated after the great financial crisis of 2007–08, puts specific emphasis on bank's liquidity, risk exposure and capital buffers within the objective of preserving banks' financial stability (BIS, 2011). By adopting Basel III's regulatory framework, the banking sector has to fulfill capital requirements and loan-loss provisioning, depending on quality and level of bank's assets (Pérez Montes et al., 2016) and to comply with a minimum Capital Adequacy Ratio (CAR_t). The CAR_t is defined as bank equity over risk-weighted loans and indicates the liquidity of banks with respect to loans that are considered as safe.

The bank achieves the target CAR through interest rate adjustments (King, 2010; Martynova, 2015), which also incorporate sector-specific credit conditions. This feature represents a proxy for limiting bank's credit supply to the real economy.

$$CAR_t = \frac{V_t^{Bk}}{\sum_n \chi^n L_t^n} \quad (28)$$

Equation 28 defines the bank's CAR as bank's savings over risk weighted loans, where χ^n is the sector specific risk weight.

Interest rates

The bank sets two interest rates. First, the interest rate on deposits (r_t^v) is determined by bank's CAR level. This is estimated in Equation 29 as a moving average determined by the percentage difference between

actual CAR_t and the target CAR^T adjusted at a rate γ_r .

$$\Delta r_t^v = \kappa_0 \left(\frac{CAR_t - CAR^T}{CAR^T} \right) \quad (29)$$

Second, the banking sector sets sector-specific interest rates for all firms (r_t^n). The interest rates depend on the bank's deposit base interest rate r_t^v plus the exogenously-defined central bank interest rate \bar{r} , the share of sector-specific NPL to loans ratio, the expected profits, $\tilde{\Pi}_{t+q}$, up to q periods in the future, the corrections for forecasts for the current time period relative to actual profitability (see Section 3.5 for technical details), and the potential impact of macro-prudential policies that affect the risk-weighting of loans for green and brown firms.

In this framework, we introduce bank's climate sentiments, which are related to the bank's pricing of the CT and GSF in the value of the loans contracts, that is, by revising the interest rate for sectors accordingly (see Section 3.5).

$$r_t^n = \underbrace{\bar{r} + r_t^v}_{\text{Base interest}} + \underbrace{\kappa_1^n \left(\frac{NPL_t^n}{L_t^n} - \tilde{\Pi}_{t+q}^n \left(\frac{\tilde{\Pi}_t^n - \Pi_t^n}{\Pi_t^n} \right) \right)}_{\text{Credit score}} + \underbrace{\kappa_2^n (\chi^G - \chi^B)}_{\text{Green supporting factor}} \quad (30)$$

The middle part of Equation 30 approximates a credit score. The NPL share represents bank's considerations of firms' past economic performance, whereas expected profits $\tilde{\Pi}_{t+q}^n$ approximate bank's perceptions about firms' future economic performance.

Green Supporting Factor (GSF)

In this context, we consider the introduction of the GSF , (see Thomä & Hilke 2018; Campiglio et al. 2018a,b) that affects bank's credit conditions in two ways. First, it introduces a reduced risk weight for green assets $(\chi^G - \nu) < \chi^B$ that, in turn, affects bank's CAR and thus reduces bank's overall interest rate setting (Eq. 28). Second, by facing lower liquidity requirements for green loans, the bank has incentives for lending out money to the green sector and to provide lower interest rates. This is captured by the difference in risk weights for green and brown firms $(\chi^G - \nu) - \chi^B$ that affects the green capital good firm's (G) interest rate in Equation 30. The rationale is that credit conditions play an important role on firm's ability to expand investments and thus to grow in modern economies. Indeed, debt service represents a considerable share of firms' costs. Thus, higher interest rates could affect firms' investment spending, thus potentially slowing down economic growth (Juselius & Drehmann, 2015; Drehmann et al., 2015). In contrast, favorable credit conditions could affect prices via reduced firms' unit costs. This would affect the demand for green and brown capital goods and hinges on (relative) prices.

3.5. Modeling bank's climate sentiments

In this section, we describe the main innovations of our approach on the state of the art, that is, (i) modeling a functional non-linear function of bank's climate sentiments, and (ii), the introduction of bank's climate sentiments in an *SFC* macroeconomic framework to assess their macro-financial impacts.

To the best of our knowledge, this is the first time that banks' climate sentiments are defined in a functional form, and their transmission channels to GDP and financial stability are modelled via a revision of loans contracts' conditions (change in interest rate to green/brown firms).

We model bank's climate sentiments as a function of expectations of the climate-aligned policy, of former firms' performance and of future expected profitability. The condition for the bank's climate sentiments to play out and to cascade on the real economy are defined as; (i) a bank with *stronger* climate sentiments would anticipate the introduction of the climate policy by increasing the cost of credit to the brown firm, *ceteribus paribus* the historical credit risk performance (it would work like a brown penalizing factor) or, (ii), as a bank with *weaker* climate sentiments would not anticipate the introduction of a climate-aligned policy and thus doesn't revise the cost of credit to the brown or green firm, *ceteribus paribus* the historical credit risk performance.

The climate-aligned policy is modelled as a green fiscal policy (*CT*) (see the description of model's scenarios in Section 4). For analyzing the forecasted values of profits of green and brown firms, we build a non-linear adaptive forecasting function in the model. The forecasting process is described below.

General framework

The forecasting module fits a nonlinear function $f(\Omega, \Psi, \beta)$ for a given data series Ω . Ψ is the expected functional form of the green/brown firms' profits data defined by the parameter space β . The forecasting module assumes that observations are independent and normally distributed with mean μ_Ω and standard deviation σ_Ω . This model can be extended to a more generalizable time series analysis by introducing standard error weights, or to more advanced time series processes with correlated error terms (Azoff, 1994; Carol, 2001).

At time t , a dataset $\tilde{\Omega}_t = \{\Omega_{t-z}, \dots, \Omega_t\}$ comprising of z past values of green and brown firms' profits is built and is fitted to obtain a model $\hat{\Omega}_t = f(\tilde{\Omega}_t, \Psi, \beta)$. We use the model to estimate the values of the next q values to construct a predicted time series $\{\hat{\Omega}_{t+1}, \dots, \hat{\Omega}_{t+q}\}$. In total, $t - z$ models and their predicted values are generated. Values of z and q mimic bank's credit-risk evaluation approach. A large value of z implies that the bank takes into account long historical firm's profitability trends. Similarly, a large value of q implies that the bank expects extrapolations of existing time trends to continue into the future. These can be reasonable assumptions if sudden changes in macroeconomic conditions are not expected to occur.

Bank's climate sentiments

Stronger climate sentiments emerge when the bank starts to price the potential impacts of climate-aligned policies on green or brown firms' profitability, and thus on the risk associated to their respective loan contracts. Suppose at time $t = r$, the bank trusts the government's introduction of an announced climate-aligned policy, that is the *CT*. As a result of the *CT*, the bank expects the profitability of brown firms to decrease (due to the cost imposed by the policy) implying that their ability to repay loans might decline. In this context, the bank has at least two options. It could wait to revise its interest rate at $t \geq r$. This could result in conservative lending behaviour that could lead to price volatility and potential financial instability when the policy is introduced. Second, the bank could already start to increase the interest rate applied to the brown firm before the actual introduction of the policy in order to smooth the transition and the potential financial risk associated to its loan contracts.

We introduce two sets of assumptions. First, how much in advance banks anticipate the policy change. For simplicity, let's assume that the bank is aware of the forthcoming policy change, if it occurs in the forecasting interval such that $r \in [t + 1, t + q]$. Second, the bank needs to make an informed guess on the anticipated change in Ω as a result of this policy. Now, let us assume that firms' profitability is expected to change by a rate ζ at $t = r$. This implies that for all intervals where $r \in [t + 1, t + q]$, the predicted value of expected profits needs to be adjusted by the rate $1 + \zeta$ for all predicted profit values where $r \geq [t + 1, t + q]$. If $r \in [t - z, t]$, then the adjustment ζ is no longer necessary since the policy has already been implemented for the previous z periods. Unless no further policy changes are anticipated, the bank can go back to the usual risk prediction.

Thus, stronger climate sentiments work as a modification of the estimated series $\hat{\Omega}$ to generate a new series, $\hat{\Omega}_Z = \hat{\Omega} \cdot Z$. Z is a vector of length $i = [t + 1, \dots, t + q]$ where the i^{th} element equals $1 + \zeta$ if $i \geq q$, and 1 otherwise. The combined list of past values $\tilde{\Omega}_t$ and predicted values with climate sentiments $\hat{\Omega}_Z$ or $\tilde{\Omega}_Z = [\tilde{\Omega}, \hat{\Omega}_Z]$ goes through another fitting process to generate the second predicted series $\hat{\hat{\Omega}} = f(\tilde{\Omega}_Z, \Psi, \beta)$. From the series, the predicted value $z + s$, where $0 \leq s \leq q$ is used as the expected change in output. If $s = 0$, then banks use very conservative estimates for future changes, and if $s = q$, then the bank could take a higher risk in predicting the expected value of green/brown firm's profitability.

In summary, the bank's forecasting function of firms' profitability needs to be defined by the set $\{\Omega, \Psi, \beta, z, q, r, \zeta, s\}$. As in most financial forecasting models, there is no unique set of parameter values or functional forms (Clements et al., 2004; Dantas & Cyrino Oliveira, 2018). Effectively all prediction models make forecasts while dealing with issues like noisy data series, high level correlations, behavioral endogeneity, volatility, non-Gaussian distributions, as some examples (Timmermann, 2018).

We consider the two conditions of a more risk-averse or risk-taking bank. The choice of this parameter space has relevant implications. Even though banks might be well-informed about the time of the policy

introduction, they might misjudge the anticipated effects of the policy. This would result in another feedback adjustment round that might have unintended consequences on banks' *NPL* and financial stability via a change in relative green/brown firms' profitability. An illustrated example is provided in [Appendix B](#).

4. Model Scenarios

We simulate and compare the macroeconomic and financial stability implications of three scenarios characterized by the introduction of a *GSF*, a *CT* with stronger/weaker bank's climate sentiments, and a Business as usual (*BAU*) scenario characterized by no change in climate-aligned policy and regulation. Both the *CT* and *GSF* are aimed to foster green loans and investments to align the country economy to the EU2030 targets, proxied the share of green capital goods for consumption good production. The scenarios are defined as follows:

1. A Green Supporting Factor (*GSF*) **SC1** that decreases the risk weights of green loans that enter bank's *CAR* computation ($(\chi^G - \nu) < \chi^B$), allowing them to have a higher leverage (*SC1*). Hence, green lending becomes more attractive for banks, leading the bank to grant more favorable lending conditions for green capital goods companies. In this scenario, the banking sector has weaker climate sentiments, not anticipating the change in microprudential regulation.
2. A Carbon Tax (*CT*), in line with the Stiglitz-Stern recommendations (2017), aimed at increasing the production costs for brown capital goods and brown capital-based consumption goods ($\tau^X > 0$). This, in turn, contributes to decrease brown firms' profitability in the transition phase with implications on their ability to repay loans to banks. The bank could react with stronger or weaker climate sentiments in reaction to the *CT*, as follows.
 - (a) *A carbon tax and weaker climate sentiments SC2*: to increase the production costs for brown capital and with brown capital produced consumption goods. The bank does not anticipate the *CT* and keeps its current lending behaviour, that is granting more favourable credit conditions to the more profitable brown capital sector *before* the carbon tax is introduced.
 - (b) *A carbon tax and stronger climate sentiments SC3*: a carbon tax is introduced and contributes to increase the production costs for brown capital and with brown capital produced consumption goods. The bank anticipates the *CT* and adjusts downwards the credit conditions for the brown, the green and the consumption good producer *before* the carbon tax is implemented.
3. The policy scenarios are compared with a Business as Usual scenario **BAU**, where no *GSF* or *CT* is implemented. In addition, the bank doesn't change its current lending behavior nor conditions to green/brown firms (that is, no climate sentiments).

Thus, the scenarios differ with regard to the characteristics of the policy implemented, of the level of bank's climate sentiments and, importantly, of the channels and direction of risk transmission. Indeed, the

GSF affects first the banking sector, which transfers the policy shock to the real economy via adjusted lending conditions. In contrast, the *CT* hits the real economy via lower firms' profitability first, then cascading risk of default to the banking sector via higher *NPLs* and reduced profitability, with several rounds of feedbacks.

Each policy scenario is characterized by a different level of bank's climate sentiments that play out at different extent and direction through bank's lending behavior, that is the conditions of loans contracts, via interest rates, based on bank's expectations with regard to the policy (see Section 3.5 for technical details).

In case the bank anticipates the climate-aligned policy introduction (that is, it shows stronger climate sentiments), it would revise credit conditions (more favourable to green firms, less favourable to brown firms) beforehand. This anticipation contributes to smooth the risk transmission channel from the banking sector to the real economy, and to avoid cascading macro-financial losses and *NPLs*. In contrast, a bank with weaker climate sentiments would not anticipate the policy by revising its lending conditions.

The patterns of climate shocks transmission channels and the shocks' impacts on the credit market and to the agents and sectors of the real economy are explained in Section 4.1.

4.1. Shocks' transmission channels

Our modelling approach allows to assess the direction and magnitude of the climate-aligned policy shock and bank's climate sentiments' transmission channels. This is crucial to identify the drivers of cascading losses via indirect effects (see Stolbova et al. 2018).

In the scenarios characterized by *GSF* and stronger bank's climate sentiments, the climate shock first hits the bank and then cascades to the firms via a revision of the loans contracts and lending conditions (it becomes more favourable for green firms). In contrast, in the scenarios characterized by the *CT*, the shock generates in the real economy via lower profitability of the brown firms (and thus lower ability to repay loans) and transfers to the bank's lending conditions (less favorable for brown firms), eventually leading to *NPL* and financial instability.

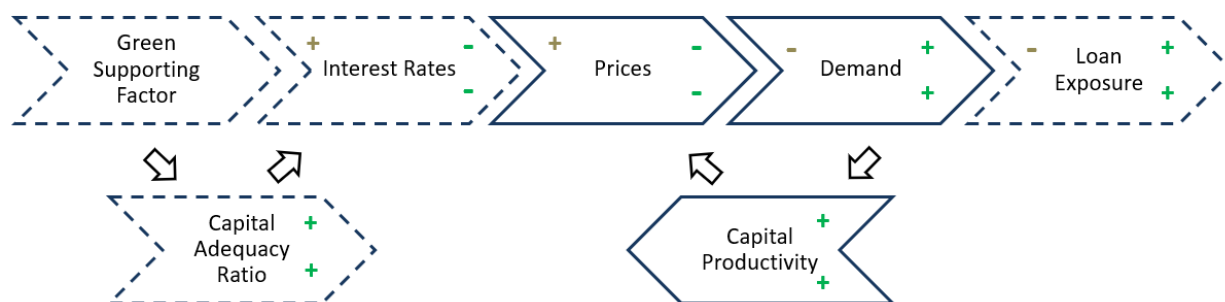
Figures 4.1-4.3 show the transmission channels. Dotted line arrows represent the effects to the banking sector, while straight line arrows represent implications for the real economy. *Green* + or - signs indicate positive or negative changes for the green capital good sector, while *brown* indicates changes for the brown capital good sector.

4.1.1. Shock transmission channel 1: Green Supporting Factor (*GSF*)

The effect transmission channel of the *GSF*, as simulated in *SC1*, is portrayed with Figure 4.1. The *GSF* relaxes the risk weights for loans to green firms that enter the denominator of the *CAR* (Eq. 28). The resulting higher *CAR* leads the bank to set overall lower interest rates thus stimulating green output via lower prices and higher demand. At the same time, the banking sector uses the additional credit leeway for

attracting more green loans by reducing green interest rates (see Eq. 30). Changes in green credit conditions affect prices and thus demand and green capital productivity, ultimately also adjusting bank's loan exposure towards higher green lending. At the same time, the higher productivity and lower prices of green capital goods make brown capital goods less attractive thus reducing B 's profits. Relying on profits as a proxy for sector's ability to pay back its debt, the bank adjusts interest rates accordingly, that is by decreasing interest rates for green firms (Eq. 30). This induces further feedback effects to brown and green capital goods demand, enhancing the aforementioned transmission channels.

Figure 4.1: Green supporting factor transmission channel

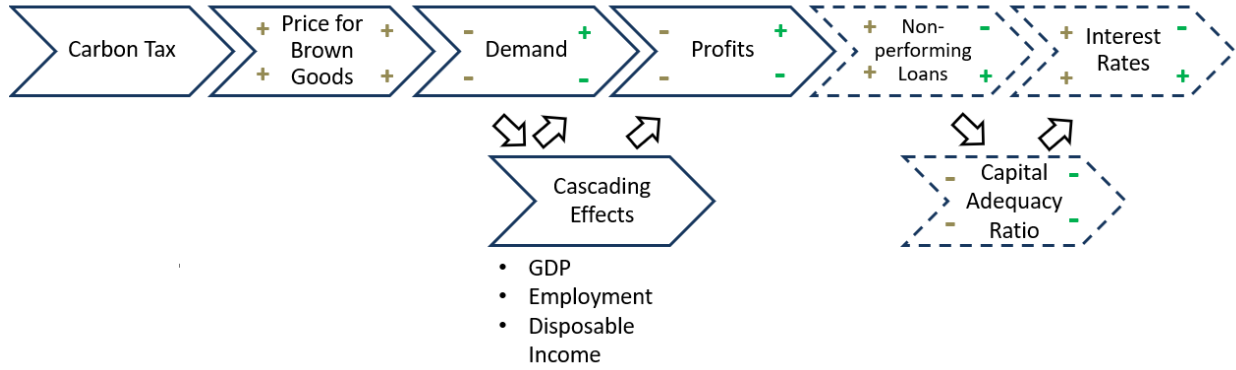


4.1.2. Shock transmission channel 2: Carbon Tax (CT)

Figure 4.2 shows the transmission channel of the implementation of a Carbon Tax ($SC2$ & $SC3$). Since we assume mark-up on costs, the CT is transferred through the consumption good sector (F) to households in the form of higher consumption prices (Eq. 16). F being sensitive to relative prices, captured by the portfolio choice specification (Eq. 5), will reduce its demand for brown capital goods. However, for households facing budget constraints, the higher consumption good prices will require them to cut down consumption. This, in turn, contributes to decrease the demand for consumption goods, with cascading effects via lower capital and consumption good production in the real economy. Indeed, they result in lower GDP growth and thus in lower employment, leading to lower households' disposable income. This, in turn, reinforces the negative feedback on GDP growth. These cascading effects strengthen the negative reinforcing feedback on consumption by decreasing firms' profits and thus households' dividends. Reduced household consumption affects all firms. In particular, the brown capital good firm (B) is hit harder due to the portfolio choice effect. Indeed, the consumption good firm (F) purchases now a higher share of the green capital good. While the CT is beneficial for the green capital good firm (G), being more price competitive and hence more attractive for F , the reduced demand and a lower capital productivity of green capital goods prevent the growth of the G to fully compensate the losses of the B . This leads GDP growth to decline in the transition phase. In addition, lower firms' profits might lead to an increase in $NPLs$ (Eq. 11), which in turn result into sector specific higher interest rates (the brown capital good sector being affected the most)

(Eq. 30). Higher $NPLs$ also affect bank's profits and savings, which lead to a lower CAR . In order to achieve its mandatory target level again, the bank also increases interest rates for all sectors, feeding back into the rest of the economy.

Figure 4.2: Carbon tax transmission channel



4.1.3. Shock transmission channel 3: Stronger climate sentiments

The risk transmission channel in case of bank's stronger climate sentiments (that is, the bank anticipates the change in climate-aligned policy impact on its profits), as simulated in $SC3$, is represented in Figure 4.3. As a main difference with the GSF transmission channel, here stronger climate sentiments lead the bank to increase interest rates for B . Thus, the stronger climate sentiments work similarly to an indirect brown penalizing factor by inducing the bank to anticipate the negative effects of a CT on brown firms' profits. Despite the bank doesn't know the exact timing and the magnitude of the CT , the bank forms expectations about the future (as described in Section 3.5). In particular, it expects higher (lower) future profits for the green (brown) capital good sector, and thus adjusts interest rates accordingly (Eq. 30). Lower (higher) interest rates transfer into lower (higher) prices, which affects intermediate and final goods' demands. F purchases a higher (lower) share of green (brown) capital goods, thus increasing (decreasing) output and actual profits in that sector. G uses additional capital stock to meet demand, which in turn supports increases in green capital productivity (Eq. 7). This contributes to reduce prices for green capital goods even further, since less green capital is required for producing one unit of green capital, eventually reducing its financing costs. Likewise, higher green capital productivity also directly stimulates F 's demand (Eq. 5). As a response to changes in demand that translate into higher (lower) investment, the green (brown) capital good producer requires more (less) credit, leading to an adjusted bank's loan exposure towards the respective sectors (Eq. 10).

Figure 4.3: Climate sentiments transmission channel

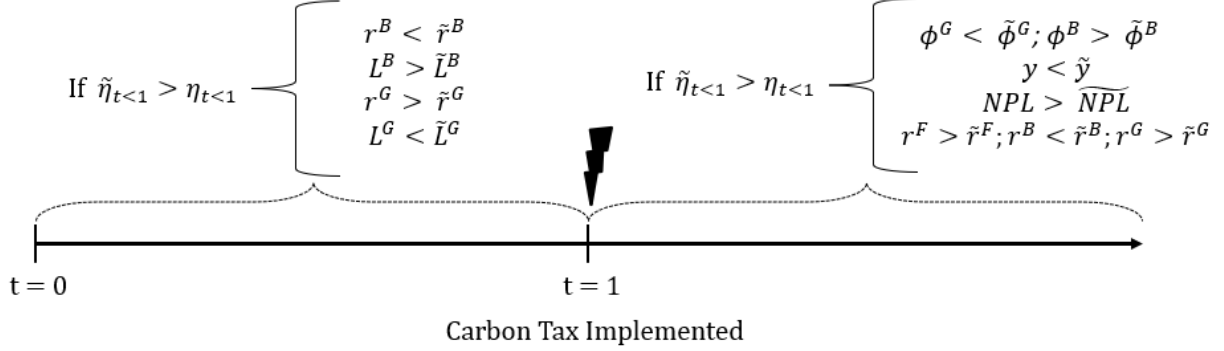


4.1.4. Shocks' comparison: Carbon Tax with stronger/weaker climate sentiments

The difference between the two *CT* scenarios (*SC2* & *SC3*) stands in the playing out of bank's climate sentiments *before* the introduction of the *CT*. A bank with stronger sentiments revises its lending behavior by changing the conditions of loans contracts for firms *G*, *B*, and *F* as shown in Figure 4.4.

In $t < 1$, bank's stronger climate sentiments $\tilde{\eta}_{t < 1}$ (*SC3*) lead to lower interest rates for the green sector and higher interest rates for the brown sector, thus also adjusting the loan exposure $L^B > \tilde{L}^B$ and $L^G < \tilde{L}^G$ via the transmission channel described above and displayed in Figure 4.3. This, in turn, has different macroeconomic and financial stability effects once the *CT* is implemented in $t > 1$. Having the *F* already adjusted its capital stock share due to the higher prices of brown capital goods relative to green capital goods, green capital productivity shows a convergence and the overall share of green capital goods at the time the *CT* is implemented is higher. The higher share of green capital in *F*'s capital stock leads to a lower *CT*'s cost for *F*. Consequently, households face lower prices, which grants them higher disposable income (and allow them to consume more), leading to higher GDP growth. Higher demand, in turn, leads to higher firms' profits, thus lowering the probability of *NPLs*, with positive effects for banks' financial stability. Similarly, the adjusted loan exposure in expectation of a *CT* contributes to decrease the probability of bank's *NPLs*, which materializes positively for Bank's *CAR* being less volatile since interest rates have already been adjusted beforehand. Green capital productivity improvements before the carbon tax result in a higher green capital share of *F*. This reduces profits of *B* to a larger extent after the carbon tax implementation in the stronger climate sentiments scenario (*SC3*). This in turn has effects on *B*'s *NPL* ratio and granted loan interest rates being higher in the case of stronger climate sentiments. Thus, stronger bank's climate sentiments would allow a higher share of green capital goods, higher GDP growth, and lower *NPL* ratios for the green capital and consumption good firms after the implementation of the carbon tax. The firm sector *B* would face deteriorated financial and economic conditions, however, its scale would have been decreased due to the stronger climate sentiments before the implementation of the carbon tax.

Figure 4.4: Time line of events and effect channels for climate sentiments



NOTE: $\eta_{t<1}$ = Bank's expectations before carbon tax; r = interest rates; L = loan exposure; y = GDP; NPL = non-performing loans; ϕ = capital goods share whereas superscript B and G stand for *brown* and *green* respectively and \sim represents higher climate sentiments of the bank.

5. Discussion of scenarios' results

Having theoretically discussed the shock transmission channels of the *GSF*, the *CT* and bank's climate sentiments, we now present the main results of the model's scenario simulations in Figures 5.1 to 5.4.

5.1. Macroeconomic effects

Figure 5.1a–c displays the policy effects on macroeconomic indicators such as real GDP (Fig. 5.1a) and prices in the green and brown sectors (Fig. 5.1b–c).

The *GSF* (*SC1*) scenario has slightly negative effects on GDP in the short-term because with improved green lending conditions, green capital goods' price decrease, thus contributing to increase the green capital share of consumption good firm, and thus the productivity of green capital goods. In contrast, the profits of brown firms decrease and thus the share of its *NPLs* increase. This, in turn, leads to higher endogenous interest rates for brown firms.

In addition, the *GFS* doesn't sufficiently affect the increase in green capital good's share (see Figure 5.2). This means that the interest rate effect is not strong enough to foster new green investments able to compensate the production losses in the brown sector.

The introduction of a *CT* with weaker climate sentiments has negative effects on real GDP in comparison to the *BAU* scenario. Indeed, in this scenario, the short-term real economy effects are not compensated by a revision in the interest rates conditions applied by the bank to green companies (see transmission channel in Section 4.2). In the short-term, the *CT* increases the costs of carbon-intensive products, which cannot be fully compensated by a shift to the initially less productive low-carbon products (due to initial higher costs

of credit and thus of production for green firms). This contributes to explain the better GDP performance of the *BAU* scenario. In addition, we should also consider that the model does not incorporate long-term physical damages stemming from unmitigated climate change (Burke et al., 2018; IPCC, 2014) and it doesn't consider the medium to long term economic adjustments.⁵

Consumption goods prices increase with the introduction of a *CT* (b), while the *GSF* (*SC1*) has smoothed effects on consumption goods prices because it only rewards green lending (by lowering green loan interest rates) but it does not directly penalize brown lending. This effect emerges when we consider the relative prices of green capital goods to brown capital goods (c). In case of the *GSF*, relative prices show a lower decline compared to both carbon tax scenarios (*SC2* & *SC3*). This can be explained with its strong effect on green capital good prices via improved green lending conditions, thus leading to the transmission channels described above (see 4.1.1). In contrast to both *CT* scenarios (*SC2* & *SC3*), the *GSF* has only a residual effect on brown capital good prices, resulting in lower relative prices for green capital goods under *SC2* and *SC3*.

5.2. Bank's climate sentiments

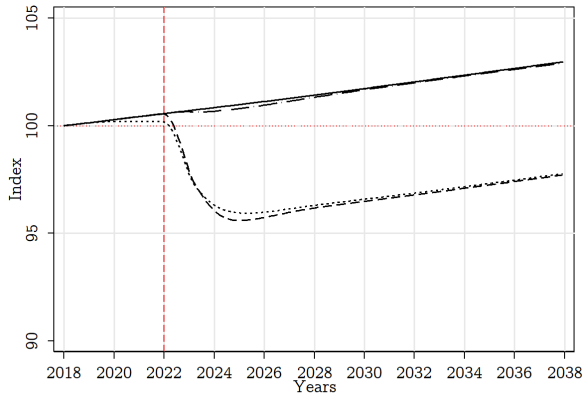
Comparing the two *CT* scenarios (*SC2* & *SC3*), we notice a positive GDP effect in the case of stronger bank's climate sentiments as a result of *F*'s increase of its green capital stock share before the *CT* is implemented, due to the relative productivity and price effects induced by the change in bank's interest rate conditions for the green firms. This contributes to lower the tax's cost for *F* and to stimulate green capital productivity enhancements. Both effects contribute positively to GDP growth after the *CT* implementation.

When stronger bank's climate sentiments play out, prices change already before the introduction of a *CT* (b & c), because the bank increases interest rates by expecting lower profits of *F* and *B*. We notice that with stronger climate sentiments consumption good prices stabilize at a lower level after the introduction of the *CT* (b) compared to *SC2*, as a consequence of lower interest rates for the *F* in *SC3* (see Figure 5.4b).

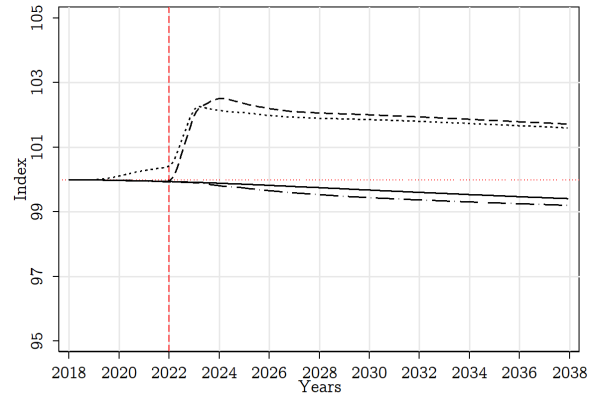
With regard to the share of green and brown capital on total capital goods production, Figure 5.2a shows that the *CT* (*SC2* & *SC3*) is more successful in boosting green capital goods production (and in lowering brown capital good production) than the *GSF* (*SC1*). In addition, bank's stronger climate sentiments contribute to reinforce the effect of *CT* (*SC3*) by greening firms' investments and thus stimulating green productivity gains, which make it more competitive with respect to brown capital. Figure 5.2b shows the relative productivity gains of green capital with respect to brown capital. Stronger climate sentiments (*SC3*) improve green capital productivity the most, as a result of the timing of the reaction (compared to *SC2*) and of the lower relative prices of green capital goods (see Figure 5.4c) compared to the *GSF* (*SC1*).

⁵The model simulations run for 10-15 years in order to represent a monetary policy cycle.

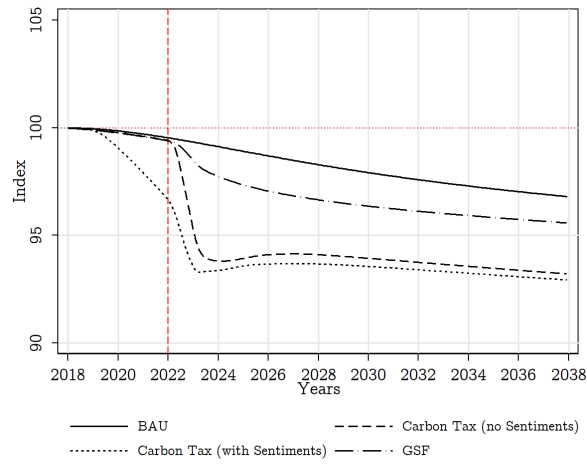
Figure 5.1: Macroeconomic Indicators



(a) Real GDP (y)

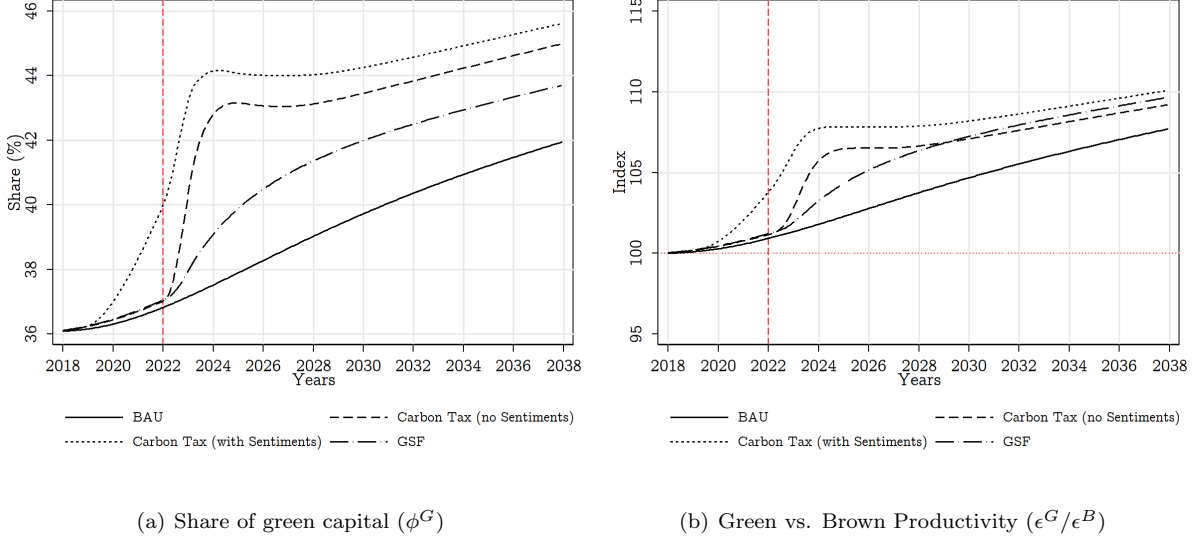


(b) Consumption Goods Prices (p^N)



(c) Green/Brown Capital Goods Prices (p^G/p^B)

Figure 5.2: Capital Goods Indicators

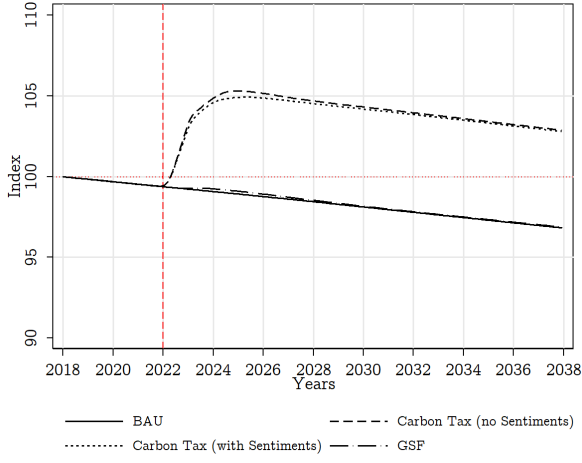


5.3. Financial stability

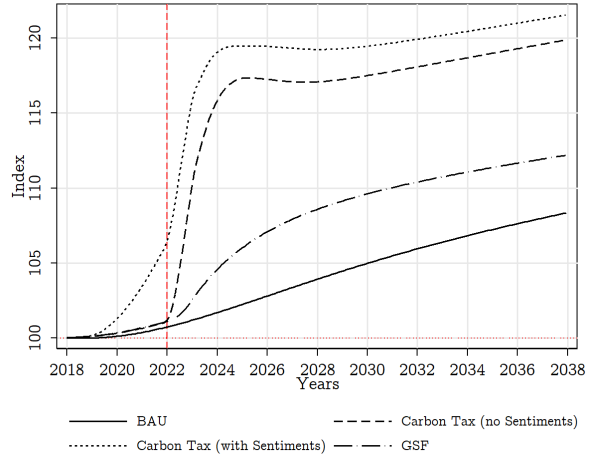
Figures 5.3a-f show the bank's indicators that we consider as proxies for financial stability. In particular, Figures 5.3a-c present the nonperforming loan (*NPLs*) ratios of the green and brown sectors across the policy scenarios. The *NPLs* ratio for the green capital producer (Fig. 5.3c) decreases in all scenarios, earlier and stronger in case of the stronger climate sentiments (*SC3*), thus responding to the higher share of green capital goods emerging in these scenarios. In contrast, the brown capital producer (Fig. 5.3b) faces higher *NPLs*. Here, climate sentiments play a crucial role when looking at the *NPL* ratio for *F* (Fig. 5.3a), since *F* increased its green capital goods share earlier and at a higher level thus reducing the brown capital share dependent carbon tax payments. This, in turn, has positive effects on *F*'s profits. The *GSF* has higher effects on *B* (Fig. 5.3b) and *G* (Fig. 5.3c), by worsening the *NPL* conditions for the former (Fig. 5.3b) and improving the conditions for the latter (Fig. 5.3c). With regard to the transmission channels 4.1), the introduction of *CT* contributes to decrease bank's lending to *F* and *B* (Fig. 5.3(d,f)) due to reduced credit demand as a result of higher prices and lower household's demand. Stronger climate sentiments strengthen the effect because they affect the decrease in the price for green capital goods more than in *SC2* (see 5.1c). Further, stronger climate sentiments generate stronger productivity gains for the green capital goods, which lead to lower investment demand for *F* (Fig. 5.3f) compared to weaker climate sentiments (*SC2*). The *GSF* (*SC1*) also contributing to decrease the loan demand for all sectors. While *B* requires lower loans in response to lower demand for its products, *G* and *F* require lower investment due to the productivity gains and lower prices of the green capital good sector and the slight induced shift of capital patterns.

Figure 5.4 shows the results of the policy scenarios and climate sentiments on bank's capital adequacy

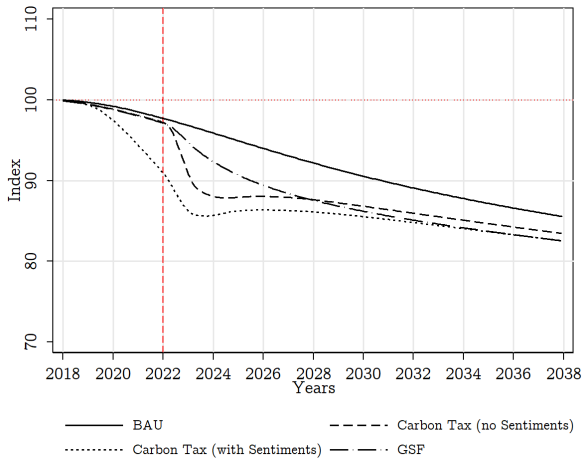
Figure 5.3: Bank Indicators



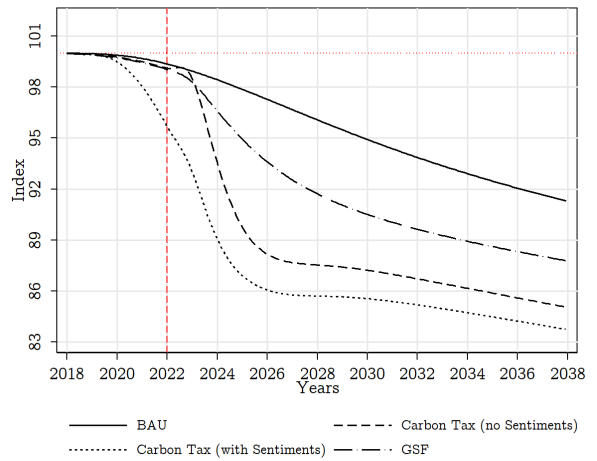
(a) Nonperforming Loans ratio (ξ^F) F



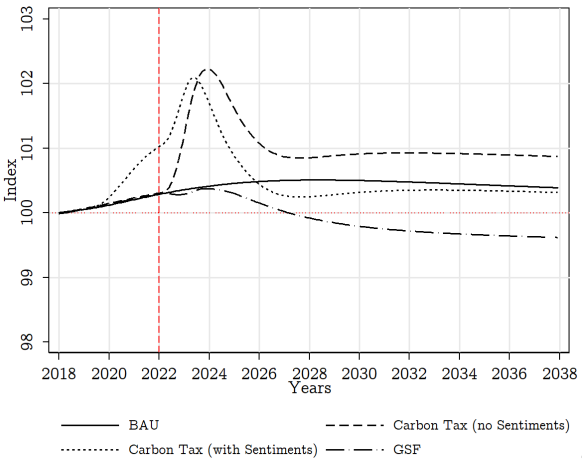
(b) Nonperforming Loans ratio (ξ^B) B



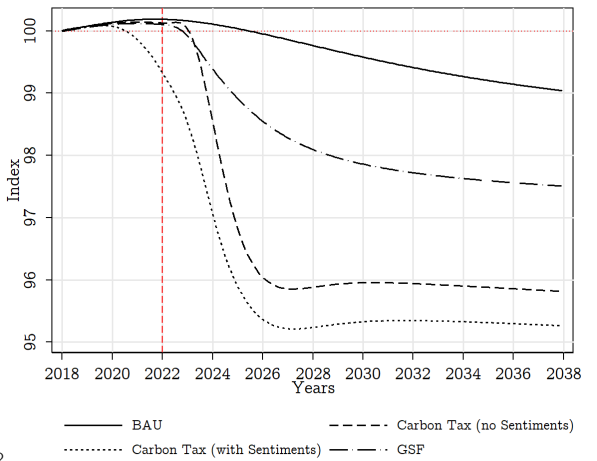
(c) Nonperforming Loans ratio (ξ^G) G



(d) Loan Exposure (L^B) B



(e) Loan Exposure (L^G) G



(f) Loan Exposure (L^F) F

ratio (CAR) and interest rates. Expected profits, real profits and the CAR affect bank's interest rate setting (Eq. 29). Bank's CAR shows lower volatility and lower decline in $SC3$ after the introduction of the carbon tax (a), and is negatively affected by the GSF ($SC1$) as a result of the improved interest rates conditions for green loans (Fig. 5.4d). We notice that interest rates for B (Fig. 5.4c) and F (Fig. 5.4b) increase consistently in case of stronger climate sentiments ($SC3$) due to the bank expecting lower profits in these sectors as a consequence of the tax. However, after the carbon tax implementation, no considerable change in interest rates occur. In contrast, in the scenario characterised by stronger climate sentiments, G 's interest rates fall. After the carbon tax implementation, brown capital interest rates are the highest, thus mirroring the lower revenue and profits of the brown capital good sector (Fig. 5.2b). For F , stronger climate sentiments ($SC3$) result in a lower interest rate level compared to $SC2$, since F has already adjusted (and greened) its capital stock composition beforehand, thus implying lower carbon tax payments. The GSF only slightly increases interest rates for B and F because it doesn't directly penalize the brown sector. In contrast, we notice a strong interest rate decrease for the green capital goods firm in response to the GSF . This result should be taken with caution. Indeed, it could have detrimental effects on financial stability and result in a green assets bubble if not supported by real asset values.

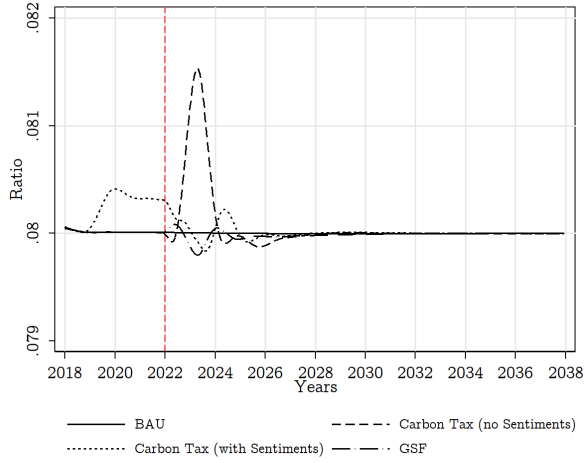
Table 1 summarizes the results of the comparison of the three climate-aligned policy scenarios in terms of their impacts on GDP, relative prices, green capital share, Capital Adequacy Ratio, and sector-specific Non-Performing Loans.

Table 1: Climate policy scenarios classified according to their impacts

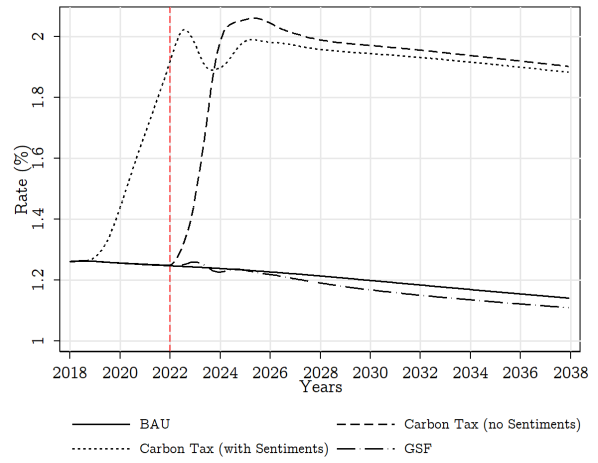
Impact on	GSF ($SC1$)	CT & weaker climate sentiments ($SC2$)	CT & stronger climate sentiments ($SC3$)
GDP (y)	~	↓↓	↓
Relative Prices (Green vs. Brown) (p^G/p^B)	↓	↓↓	↓↓↓
Green Capital Share (ϕ^G)	↑	↑↑	↑↑↑
Capital Adequacy Ratio Volatility (CAR)	↑	↑↑	↑
NPL F (NPL^F)	~	↑	↑
NPL B (NPL^B)	↑	↑↑	↑↑↑
NPL G (NPL^G)	↓↓	↓	↓↓

Note: The table provides a classification of climate-aligned policy scenarios analyzed in terms of their impact on GDP, relative prices, green capital share, Capital Adequacy Ratio, and sector-specific Non-Performing Loans. ~ indicates no significant impact, whereas ↑ and ↓ represent increases and decreases of variable values compared to the BAU, respectively. The number of arrows shows the relative impact strength of the particular scenario compared to the other scenarios.

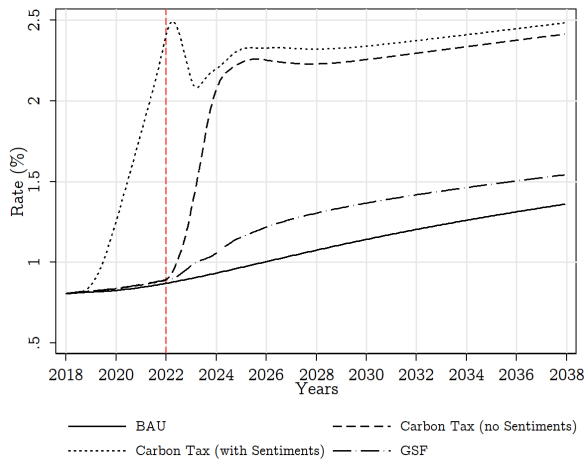
Figure 5.4: Interest Rates & CAR



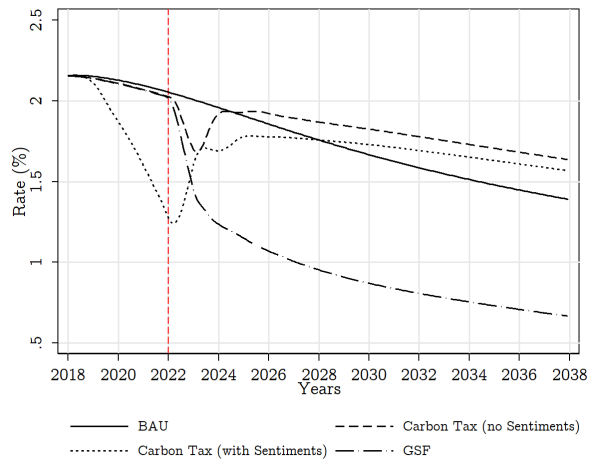
(a) Capital Adequacy Ratio (CAR)



(b) Interest Rate (r^F) F



(c) Interest Rate (r^B) B



(d) Interest Rate (r^G) G

6. Conclusion

In this paper we have developed a stylized one-country, Stock-Flow Consistent (SFC) macroeconomic behavioral model that embeds for the first time a functional form of banks' climate sentiments. We model climate sentiments as a non-linear adaptive function of bank's expectations of the climate-aligned policies, considering also past performance of firms, and their expected future profits. This, in turn, indicates their ability to repay loans. We have then integrated the climate sentiments in a SFC macroeconomic model, where representative national account sectors – Households, green/Brown Capital and Consumption Goods Firms, a Bank, and the Government – are represented as a network of interconnected balance sheets that interact through behavioral rules. The Firm sector is composed of a consumption good producer, a brown capital good producer, and a green capital good producer, which differ in terms of carbon intensity of their production.

This modeling approach has several advantages for the analysis of the impact of climate-aligned policies on sustainable growth and financial stability. First, it allows us to consider agents' expectations and emerging reactions with regard to the change in green fiscal and monetary policy, microprudential regulation and bank's lending conditions. Second, it allows us to analyze the impact of a *GSF* and a *CT* on green new loans and investments in the real economy, and on bank's financial stability, measured through the Capital Adequacy Ratio (*CAR*), under banks' stronger or weaker climate sentiments. In addition, we can identify and assess the macro-financial risk transmission channels and feedbacks leading to cascading shocks via loans contracts. Third, we can analyse the conditions for the onset of financial risk and instability stemming from macro-financial reactions to climate-aligned policies, and identify pathways for resilience.

Our results suggest that the *GSF* is not sufficient to effectively scale up green investments via a change in lending conditions to green firms. Indeed, under the modelling and current market conditions, the signaling effect via the interest rate channel alone is not strong enough to foster a relevant reallocation of investments towards the green sector. Nevertheless, it could create the conditions for weakening bank and firms' financial stability, by decreasing the bank's *CAR*, and by increasing the rate of *NPL* in the brown sector.

Under the model's conditions, the introduction of a stable climate-aligned policy, i.e. a *CT*, could shift the bank's loans and the green/brown firms' investments towards green sector. Nevertheless, it could imply short-term negative transition effects on GDP growth and financial stability, according to how the policy is implemented. To avoid these shortcomings, the government might contribute to smooth the negative short-term effect on GDP by allocating the *CT*' revenues in green subsidies or green public investment (for example, see [Monasterolo & Raberto 2019](#)).

Finally, our results show that bank's anticipation, through stronger climate sentiments, of a climate-aligned policy could smooth the risk for financial stability and foster green investments. This is achieved by signaling the banking sector that starts to revise the lending conditions to green or brown companies,

thus avoiding green/brown price volatility. Therefore, bank's climate sentiments could play a crucial role in supporting an effective policy's implementation.

The model presented here is being further developed by including an equity market and dynamic equity prices; joint simulation of a *GSF* and a *CT* with weaker and stronger climate sentiments. Modeling the equity market would allow us to analyze the implications of climate-aligned policies on the profitability of green and brown firms, their feedback on the private and public sector's consumption decisions and subsequently GDP and growth. Therefore, we expect the effects of the climate-aligned policies to be stronger for both the green and brown sector, and thus on the low-carbon transition. In addition, the joint simulation of the climate-aligned policies would allow to identify potentially unintended trade-offs due to market adjustments.

Finally, our results highlight the importance of a stable policy framework on investors' expectations and investments decisions in the low-carbon transition. In this regard, policy credibility is crucial to build bank's trust and thus avoid a disordered low-carbon transition and its implications on financial stability.

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Appendix A. Balance sheet and the Transaction Flow Matrix

Table A.2: Balance Sheet of Economy

	Households (H)	Cons. Firms (F)	Brown cap. (B)	Green cap. (G)	Govt. (Gov)	Banks (Bk)	Σ
Capital Stock		$+K_t^F$	$+K_t^B$	$+K_t^G$	$+K_t^{Gov}$		$+K_t$
Deposits	$+V_t^H$	$+V_t^F$	$+V_t^B$	$+V_t^G$		$-V_t + V_t^{Bk}$	0
Government Bonds					$-GBond_t$	$+GBond_t$	0
Loans		$-L_t^F$	$-L_t^B$	$-L_t^G$		$+L_t$	0
Non-performing Loans		$+NPL_t^F$	$+NPL_t^B$	$+NPL_t^G$		$-NPL_t$	0
Balance Net Worth	$-NW_t^H$	$-NW_t^F$	$-NW_t^B$	$-NW_t^G$	$+NW_t^{Gov}$		$-NW_t$
Σ	0	0	0	0	0	0	0

Table A.3: Transaction Flow Matrix

	Firm Sector												Σ
	Households (H)		Consumption Good (F)		Brown Capital (B)		Green Capital (G)		Govt. (Gov)		Banks (Bk)		
	Cur	Cap	Cur	Cap	Cur	Cap	Cur	Cap	Cur	Cap	Cur	Cap	
Consumption	$-C_t^H$		$+C_t^H$										0
Govt. Exp.			$+C_t^{Gov}$						$-C_t^{Gov}$				0
Investment			$-I_t^F$		$+I_t^B$	$-I_t^B$	$+I_t^G$	$-I_t^G$	$-I_t^{Gov}$				0
Wages	$+WB_t$		$-WB_t^F$		$-WB_t^B$		$-WB_t^G$						0
Profits	$+Div_t$		$-PI_t^F$		$-PI_t^B$	$+RE_t^B$	$-PI_t^G$	$+RE_t^G$			$-PI_t^{Bk}$	$+RE_t^{Bk}$	0
Loan Repay			$-\rho L_{t-1}^F$		$-\rho L_{t-1}^B$	$+\rho L_{t-1}^B$	$-\rho L_{t-1}^G$	$+\rho L_{t-1}^G$					0
Taxes	$-T_t^H$		$-T_t^F$		$-T_t^B$		$-T_t^G$		$+T_t$				0
i Loans			$-r_t^F(L_{t-1}^F - NPL_{t-1}^F)$		$-r_t^B(L_{t-1}^B - NPL_{t-1}^B)$		$-r_t^G(L_{t-1}^G - NPL_{t-1}^G)$				$+r_t(L_{t-1} + NPL_{t-1})$		0
i Deposits	$+r^V V_{t-1}^H$		$+r^V V_{t-1}^F$		$+r^V V_{t-1}^B$		$+r^V V_{t-1}^G$				$-r^V V_{t-1}^i$		0
i Gov. Bonds									$-r^{Gov} GBond_{t-1}$		$+r^{Gov} GBond_{t-1}$		0
Δ Loans			$+\Delta L_t^F$		$+\Delta L_t^B$	$+\Delta L_t^B$		$+\Delta L_t^G$				$-\Delta L_t$	0
Δ NPL			$-\Delta NPL_t^F$		$-\Delta NPL_t^B$	$-\Delta NPL_t^B$		$-\Delta NPL_t^G$				$+\Delta NPL_t$	0
Δ Deposits	$-\Delta V_t^H$		$-\Delta V_t^F$		$-\Delta V_t^B$		$-\Delta V_t^G$				$-\Delta V_t^{Bk}$	$+\Delta V_t$	0
Δ Gov. Bonds									$+\Delta GBond_t$		$-\Delta GBond_t$		0
Σ	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix B. Forecasting module: An illustrated example

We generate a simple data series y as shown in Figure B.1. The x-axis value is 100 for the first 20 time periods. This value jumps to 200 at period 21 and stays here till the 50th time period.

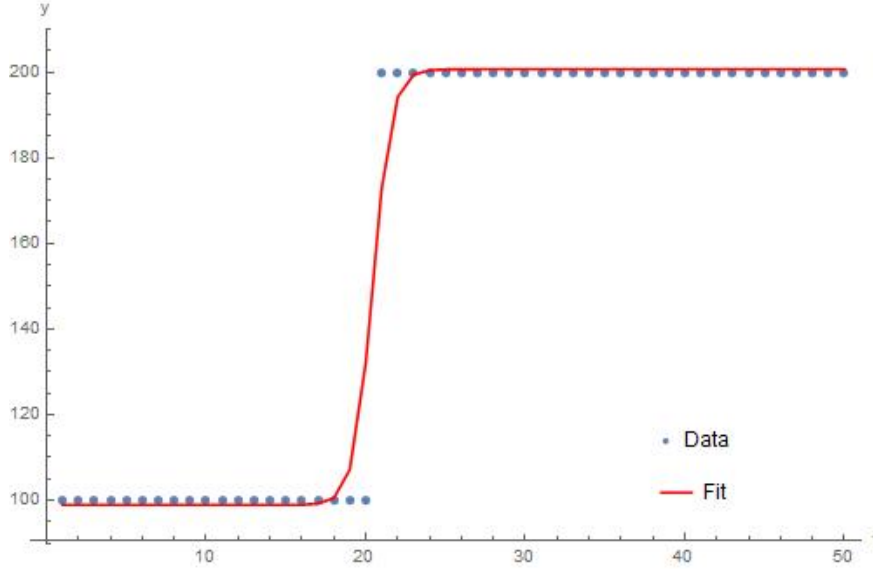


Figure B.1: Sample data and fitted curve

If we know this data series in advance, then we can clearly see that a logistic functional form fits this data very well. This is indeed the case as we see the fitted curve in Figure B.1. To obtain this data series we make use of the non-linear prediction function defined in section 3 above:

$$\hat{y} = f(y, \Psi, \beta) \tag{B.1}$$

$$\hat{y} = f\left(y, a + \frac{b-a}{1 + ce^{-dx}}, \{a, b, c, d\}\right) \tag{B.2}$$

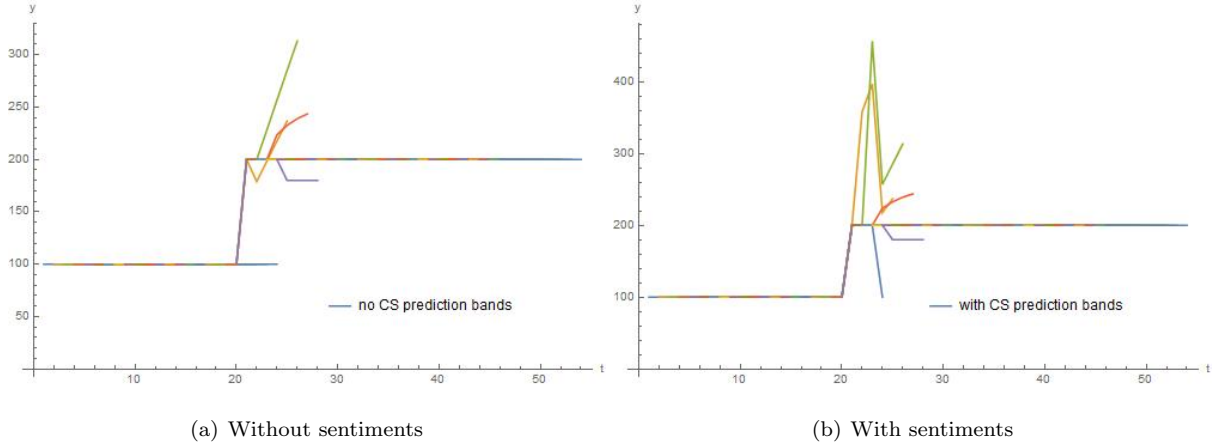
$$\hat{y} = 98.91 + \frac{101.74}{1 + 1.32 \times 10^{15} e^{-1.70x}} \tag{B.3}$$

Now we assume that instead of observing the complete data series, we are at time step 6, where we know the first 5 periods and need to make a prediction about the next 5 periods. Since the first 5 periods, basically is a straight line, a logistic function will be an overfit, and a lower order functional form will suffice. We can estimate it using a quadratic function of the form $a + bx + cx^2$. While this might also seem overspecified for a linear dataset, it accommodates small variations in data well.

In the next step, we build in climate sentiments, such that we know that at time period 21 the policy will come into effect and it will result in an estimated 100% increase in our variable of interest y . We estimate

the list of piece-wise predicted series for the next 5 periods which yields \tilde{y}^* shown in Figure B.2. The normal predicted series is multiplied with climate sentiments Z , which gives us our modified series \tilde{y}_Z^* .

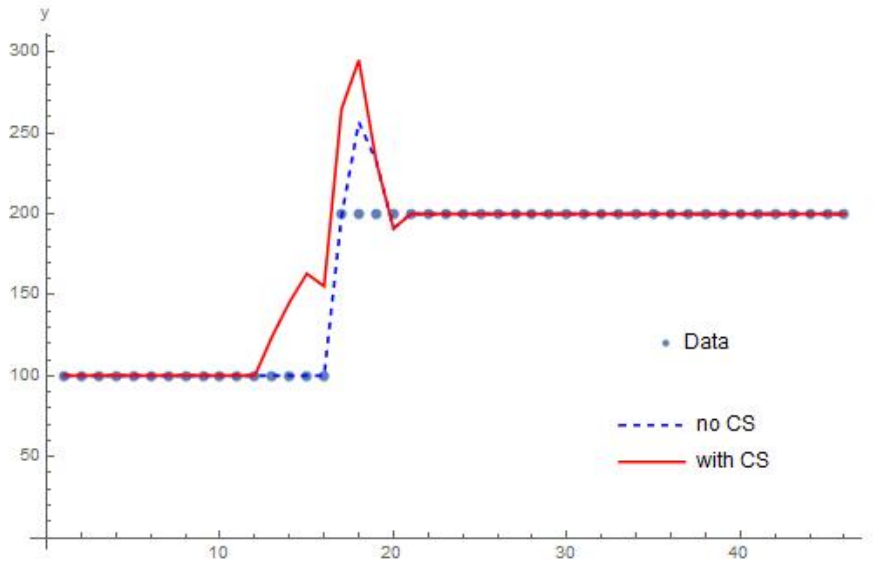
Figure B.2: Building in sentiments



We create a new series $\hat{y}_Z = \{\tilde{y}^*, \tilde{y}_Z^*\}$, which consists of five past and five predicted values. This series goes through another fitting $\hat{y} = f(\hat{y}_Z, \Psi, \beta)$ and from this fitting, the middle 5th value is taken as a predictor.

Figure B.3 shows the fitting of the series with and without climate sentiments. Here we see that the curve showing climate sentiments starts predicted an increase in the value of y much earlier slowly converging to the actual data. This also mimics a logistic function that is derived from piece-wise functions.

Figure B.3: Predicted values



Appendix C. Variables and Parameters

Table C.4: Parameter Values 1

Parameter	Description	Value
<i>The Firm Sector</i>		
λ_0^B	Autonomous brown capital good demand	0.5
λ_0^G	Autonomous green capital good demand	0.5
λ_{11}^B	Sensitivity of brown capital good demand to brown capital good prices	-0.5
λ_{12}^B	Sensitivity of brown capital good demand to green capital good prices	0.5
λ_{13}^B	Sensitivity of brown capital good demand to brown capital productivity	0.5
λ_{14}^B	Sensitivity of brown capital good demand to green capital good prices	-0.5
λ_{21}^G	Sensitivity of green capital good demand to brown capital good prices	0.5
λ_{22}^G	Sensitivity of green capital good demand to green capital good prices	-0.5
λ_{23}^G	Sensitivity of green capital good demand to brown capital productivity	-0.5
λ_{24}^G	Sensitivity of green capital good demand to green capital productivity	0.5
δ	Capital depreciation rate	0.1
γ_i	Investment rate	0.1
γ_ϵ^B	Brown productivity adjustment	0.05
γ_ϵ^G	Green productivity adjustment	0.1
\bar{u}	Target capacity utilization rate	0.8
ρ	Loan repayment rate	0.1
η	Investment share of retained earnings	0.25
π^X	Share of non-retained earnings	0.75
ω	Wage rate	1
ϵ^L	Labor productivity	1.25
θ	Markup costs	0.1
τ^n	Profit tax on firms	0.2
τ^{CT}	Potential carbon tax	0.02

Table C.5: Parameter Values 2

Parameter	Description	Value
<i>The Household Sector</i>		
α_1	Propensity to consume out of income	0.85
α_2	Propensity to consume out of savings	0.1
<i>The Government Sector</i>		
g_0	Exogenous government spending	5
g_1	Tax dependent government spending	0.5
g_2	Tax dependent government investment	0.001
r^{Gov}	Interest rate on government bonds	0.01
<i>The Banking Sector</i>		
χ^F	Risk weight consumption good sector	1
χ^B	Risk weight brown capital good sector	1
χ^G	Risk weight green capital good sector	1
ν	Reduction of green capital risk weight (<i>GSF</i> scenario)	0.1
CAR^T	Target capital adequacy ratio	0.08
\bar{r}	Central Bank interest rate	0.02
κ_0	Capital adequacy ratio adjustment rate	0.1
κ_1^F	Sectoral interest rate adjustment rate	0.01
κ_1^m	Sectoral interest rate adjustment rate	0.1
κ_2^G	GSF interest rate adjustment rate	0.05
$\kappa_2^{B,F}$	CGSF interest rate adjustment rate	0
<i>Forecasting module</i>		
Ω	Data series	
β	Parameter space	0.1
Ψ	Expected functional form	0.1
z	Amount of backward looking periodes	0.1
q	Length of predicted time series	0.1
Z	Vector length	
ζ	Expected change in profits	
r	Expected time when carbon tax is introduced	0.1

Table C.6: Variable Description

Variable	Description	Equation No.
<i>The Firm Sector</i>		
Y_t, y_t	Nominal, real output	1,3
C_t	Nominal household consumption	1,20,21
I_t, i_t	Nominal, real investment	1,2, 10, 9,8
J_t	Nominal government expenditures	1,23
K_t, k_t	Nominal, real capital stock	4,9,8
N_t	Labor demand	4
ϕ_t	Share of green or brown capital investment	5,24
ϵ_t	Capital productivity	7
u_t	Capacity utilization rate	9
RE_t	Retained earnings	10
Div_t	Dividends	19
L_t	Loan demand	10
NPL_t	Non-performing loans (level)	11,14,30
ξ_t	Non-performing loans ratio	12
WB_t	Wage Bill	13,15,17,19
KB_t	Investment costs	14,15,17
UC_t	Unit costs	15,16
p_t	Sectoral price level	16
Π_t	Sectoral profits	17,30
T_t	Profit Tax	22
<i>The Household Sector</i>		
YD_t	Disposable Income	19,20,21
T_t^H	Household Taxes	22
V_t	Deposits	20,21
<i>The Government Sector</i>		
$GBond_t$	Government Bonds	26
<i>The Banking Sector</i>		
CAR_t	Capital Adequacy Ratio	28,29
S_t	Bank Equity	28
r_t^V	Deposit interest rates	29,30,17
r_t^n	Sector specific interest rate	30,14
$\tilde{\Pi}_t$	Bank's expected sectoral profits	30



WIRTSCHAFTS
UNIVERSITÄT
WIEN VIENNA
UNIVERSITY OF
ECONOMICS
AND BUSINESS

WU Vienna
Institute for Ecological Economics

Welthandelsplatz 2/D5
A-1020 Vienna

+43 (0)1 313 36 4848
ecolecon@wu.ac.at