LATVIJAS BANKA
EIROSISTĒMA

ISBN 978-9934-578-50-2

PATRICK
GRÜNING

FISCAL, ENVIRONMENTAL, AND BANK REGULATION POLICIES IN A SMALL OPEN ECONOMY FOR THE GREEN TRANSITION

WORKING PAPER
6 / 2022

Latvijas Banka
K. Valdemāra iela 2A, Riga, LV-1050
Tel.: +371 67022300 info@bank.lv
http://www.bank.lv https://www.macroeconomics.lv

Fiscal, Environmental, and Bank Regulation Policies in a Small Open Economy for the Green Transition

Patrick Grüning*

29 November 2022

Abstract

This study develops a small open economy dynamic stochastic general equilibrium model with green and brown intermediate goods, banks subject to capital requirements, and public investment. The domestic economy might face domestic or foreign carbon taxes and an emissions cap. The model is used to analyze which environmental, fiscal, and bank regulation policies are effective facilitators of the domestic economy's green transition and the costs involved. Among the policies that can generate an exogenously imposed and fixed emissions reduction, most costly is the exogenous world brown energy price increase, followed by the emissions cap reduction, while the introduction of domestic carbon taxes does not change GDP in the long run. The reason for this stark difference is that domestic carbon taxes and emissions cap violation penalties are used to stimulate public green investment. However, only domestic carbon tax revenues are substantial as brown entrepreneurs do not violate the emissions cap in equilibrium. Bank regulation policies and other fiscal policies are not capable of generating large emissions reductions. During the green transition induced by domestic carbon taxes, the first years of the transition are characterized by a run on brown energy in anticipation of higher prices in the future.

Keywords: small open economy, climate transition risk, energy, environmental policy, bank regulation, public investment

JEL codes: E30, F41, G28, H23, H41, Q50

---

*Monetary Research and Forecasting Division, Monetary Policy Department, Latvijas Banka, K. Valdemāra iela 2A, LV-1050, Riga, Latvia. E-mail: patrick.gruening@bank.lv.

First and foremost, I would like to thank Anup Mulay (discussant), Uldis Rutkaste, Soroosh Soofi-Siavash, Kārlis Vilerts, and Sophie Zhou (discussant) for their highly useful comments and suggestions as well as Vija Mičūne for her invaluable assistance on bank-related data collection and preparation. Moreover, I would like to thank the participants of the Internal Latvijas Banka Seminar, the 10th UECE Conference on Economic and Financial Adjustments in Europe, the ESCB Research Cluster on Climate Change Seminar (August 2022), and the Baltic Central Banks Research Seminar 2022 for their excellent remarks. The views expressed herein are solely those of the author and do not necessarily reflect the views of Latvijas Banka or the Eurosystem.

1 Introduction

Climate change and global warming constitute a considerable threat to the economy and the environment, and the global temperature increase since pre-industrial times in 2017 amounted to roughly 1°C already (IPCC, 2018). Moreover, the financial system considers climate change as a significant challenge for financial stability (Carney, 2015; NGFS, 2019) and central banks diligently think about playing a more active role in facilitating the green transition (Lagarde, 2020; European Central Bank, 2021). To limit the adverse consequences of climate change, the Paris Agreement tries to limit global warming to significantly below 2°C, which requires to reach zero-net emissions of CO_2 within the next 50–60 years (IPCC, 2018). This will imply an immense effort for many economic agents and exposes the global economy to transition risks (for a detailed review on the different types of climate change risks see, for example, Batten, 2018).

Traditionally, climate policy has solely been the focus of governments by introducing carbon taxes or cap-and-trade systems and providing subsidies to encourage investment in climate change abatement technologies (see Delgado-Téllez et al., 2022, for an overview of current environmental fiscal policies in the euro area). Most of the economic modelling literature also focuses on such policies (see, for example, Nordhaus, 1991, 2006, 2008; Fischer and Springborn, 2011; Heutel, 2012; Dietz and Stern, 2015; Pindyck, 2017). However, as the opening paragraph demonstrates, the fight against climate change involves the whole society and many economic agents can play a key or at least supporting role in achieving environmental policy targets. Therefore, this paper concentrates on the interplay of fiscal, environmental, and bank regulation policies to achieve emissions reductions in a small open economy dynamic stochastic general equilibrium (DSGE) model, calibrated to Latvia (an EU member state), which displays a low level of implemented or discussed green financial regulation (D'Orazio and Thole, 2022). The modelling literature combining fiscal, environmental, monetary, and bank regulation policies is still relatively limited (noteworthy studies include Benmir and Roman, 2020; Comerford and Spiganti, 2020; Carrattini et al., 2021; Diluiso et al., 2021; Ferrari and Nispi Landi, 2021; Giovanardi et al., 2021; Abiry et al., 2022) and – to the best of my knowledge – no small open economy model has been developed to analyze the effects of a combination of the aforementioned policies so far. This paper attempts to fill this gap in the literature.

Specifically, the economy features two domestically produced intermediate goods – brown and green goods. Moreover, brown intermediate goods can also be imported from abroad. The key difference between these domestically produced goods is that the brown intermediate good is produced with imported brown energy which results into emissions as a by-product, while the green intermediate goods production function utilizes domestically produced renewable energy as the third input besides labour and capital. There are three types of consumers. Workers supply labour to the three producers (green good, brown good, renewable energy), own the banks and hold deposits. They act as financial regulators and collect bank capital requirement costs. Furthermore, they own the perfectly competitive final goods firm which assembles the final goods using the three intermediate good types, buy foreign bonds, and pay foreign carbon taxes on brown intermediate goods imports. Green entrepreneurs own the green intermediate goods firm, the renewable energy producer, as well as the green and renewable energy capital stocks. Finally, brown entrepreneurs own the brown intermediate goods firm and the brown capital stock. Moreover, they have to pay penalties for violating the emissions cap and domestic carbon taxes on brown energy imports to the government.

The banks originate loans to both types of entrepreneurs who need to finance a fraction of their investments with loans, as per loan-in-advance constraints. Banks finance themselves using equity and deposits, subject to an incentive compatibility constraint. Bank regulation comes in the form of an asymmetric bank capital requirement cost function that depends on the distance of equity to a regulated share of risk-weighted assets.

The government collects revenues from consumption taxes, labour taxes, emissions cap violation penalties, and domestic carbon taxes to fund public investment in green and brown public capital and wasteful government spending. The environmental tax revenues are exclusively used for green public investment (and wasteful government spending, though at a lower share than for standard tax sources).

Regarding the small open economy elements, all consumers combine domestic and foreign final goods in their consumption bundles and entrepreneurs need to use both domestic and foreign goods for their investments in capital. Moreover, all imports are subject to iceberg and unit transport costs. The domestic final good is additionally exported. There are funds provided for by the foreign economy (these foreign funds are meant to represent EU structural investment and cohesion funds) that are used by the government to exclusively finance (green and brown) public investments in addition to the public investment share of domestic tax revenues.

Finally, I ignore externalities (in utility or production volumes) from emissions since the small open economy is so small that it cannot drive global warming. Instead, I exclusively focus on the transition risks of climate change and the efforts by the domestic economy to curb emissions due to international treaties such as the Paris Agreement.

Therefore, the model allows me to analyze a number of fiscal and environmental policies: (i) changing the domestic carbon tax rate; (ii) adjusting the emissions cap; (iii) changing the foreign carbon tax rate; (iv) adjusting the share of public resources directed to green public investment. Moreover, bank regulation can be made sector-specific by changing the relative absconding rates in the banks' incentive compatibility constraint and/or adjusting the risk weights for green and brown loans, respectively. For example, the risk weight for green loans could be lowered or the risk weight for brown loans could be increased to support the green transition. Additionally, the fractions of loans that need to be financed by bank loans can change, different for each sector. Naturally, a combination of different policies can also be analyzed.

The research question of this study is to quantify the effects of changes in fiscal, environmental, and bank regulation policies with respect to achieving a lower amount of emissions originating from the economic activity of the domestic economy. In particular, I provide model-based assessments with respect to the following questions: Can bank regulation policy help achieve climate policy targets and could it serve as a substitute to the traditional environmental policy instruments? How costly is it to significantly curb emissions in terms of output losses? What is the most effective policy, taking emissions reductions, welfare, and economic performance into account?

First, bank regulation policy alone does not generate enough reallocation pressure to the green sectors to considerably curb carbon emissions. They can nevertheless support fiscal and environmental policies in achieving climate change targets by alleviating the economic loss very slightly (in the order of 0.01–0.04 percentage points) that some of the other policies generate. The reason for this bank regulation policy failure is related to a relatively low asymmetry in the bank capital requirement cost function (needed to match several growth rate volatilities in the data) on the one hand and, probably, the absence of nominal frictions and New-Keynesian model elements on the other hand.

Second, by normalizing the induced reduction of emissions to 17% relative to the benchmark model in line with Latvia's climate change targets (see Treasury of the Republic of Latvia, 2021) for the following policies, I can meaningfully compare these policies with respect to their macroeconomic implications. The most costly policy is an exogenous increase of brown energy import prices due to developments on world fossil fuel markets. The emissions cost reduction of 17% comes at the cost of a GDP loss of −2.53%. This policy is followed by the reduction in the emissions cap which generates only an economic loss of −1.86%, which is, however, dependent on supplying a larger amount of public funds to green (vis-à-vis brown) investment. If instead carbon tax revenues and emissions cap penalties are used in the same way as standard tax revenues, then the economic loss slightly increases to −1.91%. Nevertheless, the effect of this green economy-supportive fiscal policy seems relatively small, at least in terms of GDP. This is very different when considering domestic carbon taxes. The GDP loss can then be −1.34%, if carbon tax revenues and emissions cap penalties are not used in a green economy-supportive way. However, GDP basically does not change (−0.07%) when these proceeds are distributed to the green sector.

Third, a number of fiscal policies can generate emissions reductions at various rates, while producing economic benefits or losses. Just introducing a foreign carbon tax rate (by foreign governments) is not an efficient way to reduce domestic carbon emissions since the emissions reduction only amounts to −0.04%, while domestic GDP declines by −3.99%. Interestingly though, if both the domestic carbon tax rate and the foreign carbon tax rate are set to the same level that is needed for the domestic carbon tax rate to reduce emissions by 17%, the emissions reduction even reaches −18.75%. This great environmental performance, however, still comes at a high price: GDP declines by −4.17%. Increasing either the domestic or the EU public green investment share (for standard tax revenues, i.e. consumption and labour taxes) to 100% (from 31.5% or 45%, respectively) leads to emissions reductions in the order of around 0.10% while producing aggregate economic losses of roughly −0.6%. Finally, increasing the domestic carbon tax rate to half the value needed in the aforementioned scenario to reach an emissions reduction of 17% and at the same time reducing the emissions cap half-way as well, one records an emissions reduction of about 10% while generating an economic expansion in terms of GDP of 0.15%. Therefore, the emissions reduction size and the mix of policies matter considerably for the aggregate economic outcome.

Fourth, I also study the transition period for the two most traditional environmental policies to combat climate change, i.e. the domestic carbon tax rate and the emissions cap. I find that, initially, a domestic carbon tax rate leads to more imported brown energy, in line with the stranded assets literature that expected tighter environmental policies can lead to a run of utilizing or mining fossil fuel resources before such policy is actually implemented (see, for example, Barnett, 2020). The transition of emissions to lower values appears much smoother when considering the emissions cap policy. In both cases, I find evidence that policy uncertainty significantly matters for the final outcome, by including shocks to the domestic carbon tax rate or the emissions cap in the respective simulations. Therefore, policy makers should ensure that the green transition is orderly and smooth, as otherwise outcomes might prove to be less beneficial than projected.

Fifth, I also develop a number of alternative models to explore the sensitivity and robustness of the aforementioned results. Two alternative models consider different uses of the productive public funds: instead of building public capital, these funds are used for lump-sum transfers to entrepreneurs or to partly finance the private investment expenditures of entrepreneurs. In the first case, these productive public funds do not play a role for aggregate GDP outcomes; consequently, different environmental and fiscal policies lead to the same effects. However, there are larger differences with respect to the welfare and aggregate consumption outcomes. In the second case, the productive public funds are less effective than in the benchmark model, but still significantly shape the GDP outcomes resulting from the different transition policies. In the second set of two alternative models, a higher asymmetry in the bank capital requirement cost function is applied and debt-to-income borrowing constraints are utilized as the main financial friction of entrepreneurs instead of loan-in-advance (LIA) constraints. A higher bank capital requirement cost asymmetry makes bank regulation policies matter more for economic outcomes, while switching to debt-to-income (DTI) borrowing constraints do not change the implications of the benchmark model considerably.

The remainder of the paper is organized as follows. The following section reviews the related literature. Section 3 outlines the model, while the derivation of the model's equilibrium is in Appendix A. Section 4 specifies the model's calibration and Section 5 is devoted to the analysis of the calibrated model's results. Section 6 explores the sensitivity of these results employing alternative models. Finally, Section 7 concludes.

2 Literature Review

The study closest to this one is probably Diluiso et al. (2021). They study an estimated New Keynesian (NK) model for the euro area with green and brown energy sectors which features banks subject to capital requirements and a central bank that engages in asset purchases. Their model does not feature a climate change externality as does my model. An important difference to my model is the absence of any fiscal policies (e.g. carbon tax). They study the effects of an orderly vs. a disorderly transition and find that the transition costs in an orderly transition are quite limited but become substantial in a disorderly transition. Monetary policy should thus react aggressively to inflation to mitigate the costs of a disorderly transition. Implementing green asset purchase programmes by the central bank in a financial crisis, simulated using a capital quality shock, stimulates the economy, but the stimulus is not much different to the stimulus of a market neutral asset purchase programme. Increasing the brown energy sector loan risk weight reduces the financial crisis-induced recession but leads to a prolonged recovery period.

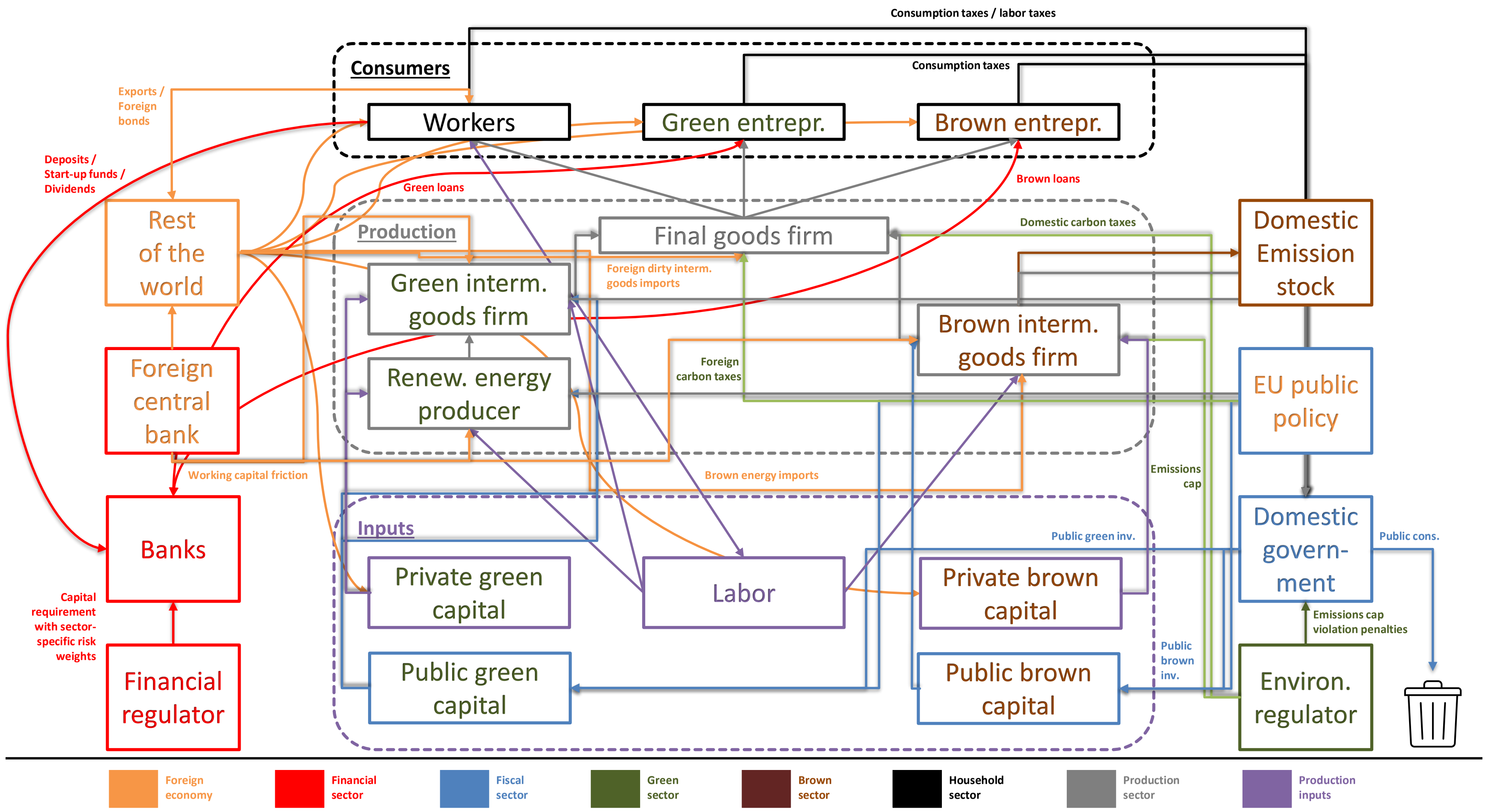
Another very related study is Benmir and Roman (2020) who develop an NK model with green and brown intermediate goods sectors, a banking sector subject to capital requirements, a government that can set a carbon tax, and a central bank engaging in quantitative easing (QE). The carbon tax is effective to achieve emissions reduction targets but comes with substantial welfare costs. Lower green loan risk weights lead to an increase in output at a minimal welfare cost, but this policy alone is not enough to achieve the ambitious Paris Agreement emissions reduction targets. Green QE policies are found to be more effective and become even more effective when applied in conjunction with carbon tax implementation. Similar findings with respect to the green bank regulation policy and the need for the implementation of a carbon tax are uncovered by Carrattini et al. (2021) who use a real business cycle model with green and brown final goods sectors. Ferrari and Nispi Landi (2021) exclusively study a temporary green QE policy in an NK model and find positive, yet small effects of implementing such a policy for emissions and welfare. Bartocci et al. (2022) uncover effective fiscal policies (green energy subsidies and labour tax cuts) for limiting the macroeconomic costs of higher carbon prices in their NK model and find that QE can offset the recessionary effects of these fiscal policies at the effective lower bound. Varga et al. (2021) using a dynamic general equilibrium model find similar results with respect to fiscal policy effects in the net-zero carbon transition period. Benkhodja et al. (2022) also investigate different fiscal policies to induce greener consumption and production in a model economy (calibrated to France) with private banks, green and brown firms, and green and brown goods-consuming households. The subsidy to green firms' labour costs is found to be the most efficient policy.

An integrated assessment model with green and brown sectors, a central bank, and a fiscal authority is developed by Abiry et al. (2022). In contrast to Ferrari and Nispi Landi (2021), they focus on the effects of a permanent (not temporary) green QE policy. However, their findings are similar and the benefits of such a QE policy relatively small. A carbon tax is once more found to be the more effective policy and, contrary to Benmir and Roman (2020), the carbon tax policy is not complementary with green QE.

Slightly different research questions are investigated by several other studies. First, Schuldt and Lessmann (2021) assess that the existence of financial frictions in an RBC model with clean and dirty entrepreneurs and sector-specific financial accelerator mechanisms lead to the 2030 climate mitigation target be missed by 11 percentage points (-44% emissions instead of -55%). Second, Comerford and Spiganti (2020) study the implications of the Carbon Bubble or stranded assets issue for the macro economy and economic policy. The Carbon Bubble pertains to the requirement of leaving unused a large proportion of the currently known fossil fuel reserves in order to keep global warming limited. They cast exogenous carbon budget targets into a model with zero-carbon and high-carbon investment goods and a financial accelerator mechanism. If the investors are leveraged, the Carbon Bubble may induce a fire-sale of assets. Economic policies protecting investors' balance sheets can mitigate such economic crises.

Having reviewed the literature studying various types of climate change policies in E-DSGE models with financial frictions, my study also relates to several other strands of literature. First, the initial economics of climate change literature concentrates on (optimal) carbon tax policies, cap-and-trade systems, and carbon abatement policies in macroeconomic models: Nordhaus (1991, 2006, 2008); Fischer and Springborn (2011); Heutel (2012); Dietz and Stern (2015); Pindyck (2017). Second, a growing literature concentrates on the analysis of monetary policy and its effects on climate change: Annicchiarico and Dio (2015, 2017); Economides and Xepapadeas (2018); Annicchiarico and Diluiso (2019); Economides and Xepapadeas (2019); Dietrich et al. (2021); Ferrari and Pagliari (2021); Annicchiarico et al. (2022). The third and final strand of literature to mention is theoretical and empirical studies that use asset pricing techniques to investigate the climate change, asset valuation, and economic policy nexus: Donadelli et al. (2020); Meinerding et al. (2020); Bolton and Kacperczyk (2021, 2022).

Figure 1: Helicopter View of the Model



Notes: This figure depicts a helicopter view of the benchmark model. It shows all the agents and the relationships between them via depicting all flows of goods or imposed policies, using distinct colours for the different sectors, agents, and goods.

3 Model

In this section, the model is described in detail. It belongs to the class of real business cycle models and, therefore, all quantities in the model are given in real terms. The domestic economy is a small open economy that trades with the rest of the world.

I do not model a climate change externality via a damage function in production or via a utility term because the small open economy, represented by Latvia in the real world, cannot influence global climate due to its tiny share in world GDP. Therefore, the focus is on climate change-induced transition risks; since Latvia needs to reduce its emissions to meet contractual obligations due to it being a member of the European Union and the Paris Agreement. In line with the empirical evidence presented in Ciccarelli and Marotta (2021) most shocks in the model are supply-side shocks to capture climate change transition risks. Figure 1 provides a summary of the model.

3.1 Workers and final goods firm

The workers in the model own the final goods firm and the banks in the model. They derive utility from consumption, subject to an additive internal habit, and leisure. Their total mass is equal to $\lambda_w \in (0,1)$ and their lifetime utility function is given by:

$$U_t = \sum_{s=0}^{\infty} \left\{ \frac{\beta_w^s (C_{w,t+s} - h_w C_{w,t+s-1})^{1-\gamma}}{1-\gamma_w} + \frac{\beta_w^s a(\overline{L} - L_{t+s})^{1+1/f}}{1+1/f} \right\}, \tag{1}$$

where $\beta_w \in (0,1)$ is the time discount factor, $h_w > 0$ is the habit parameter, $\gamma_w > 0$ denotes the relative risk aversion parameter, $\overline{L} > 0$ is the total time endowment, $a > 0$ is a scaling parameter, and $f > 0$ determines the labour supply elasticity. Moreover, $C_{w,t}$ is workers' consumption and L_t is labour supplied to the production sectors.

For final consumption goods production, a representative perfectly competitive firm uses an amount $C^{\ell}_{w,t}$ of the domestically produced (local) final good and an amount $C^{*}_{w,t}$ of the imported foreign good according to the following production technology:

$$C_{w,t} = \left((1-\omega_{w,c})^{\frac{1}{\eta_{w,c}}} (C^{l}_{w,t})^{\frac{\eta_{w,c}-1}{\eta_{w,c}}} + (\omega_{w,c})^{\frac{1}{\eta_{w,c}}} (C^{*}_{w,t})^{\frac{\eta_{w,c}-1}{\eta_{w,c}}} \right)^{\frac{\eta_{w,c}}{\eta_{w,c}-1}}, \tag{2}$$

where $\omega_{w,c} > 0$ is the weight of the foreign good in the production function and $\eta_{w,c} > 0$ denotes the elasticity of substitution between domestic and foreign consumption goods.

The workers' income consists of labour income, the output of the final goods firm, the revenue of exporting goods, the capital income from holding deposits and foreign bonds, the net worth of non-surviving banks as well as the bank capital requirement violation costs, and the revenues of working capital friction loans. This income is used to finance consumption expenditure, to invest in deposits and foreign bonds, to provide for the start-up fund for new banks, to purchase the green, domestic brown, and foreign brown intermediate goods for final goods production, to pay deposit adjustment costs, and to provide domestic final goods for export. Thus, the budget constraint is given by:

$$(1+\tau_c)(C^{\ell}_{w,t}+[(1+\iota^c_w)S_t+t^c_w]C^*_{w,t})+\frac{S_tA^*_{t+1}}{\lambda_w}+\frac{D_{t+1}}{\lambda_w}+\frac{p_{g,t}Y_{g,t}}{\lambda_w}+\frac{p_{b,t}Y^{\ell}_{b,t}}{\lambda_w}+\frac{\Phi_t}{\lambda_w}+ \quad (3)$$
$$\frac{[(1+\iota^*_{b,t}+\tau^*_{b,t})p_{b,t}S_t+t^*_b]Y^*_{b,t}}{\lambda_w}+\Gamma_{d,t}+\frac{(1+t^x_w)X_t}{\lambda_w}=\frac{Y_t}{\lambda_w}+(1-\tau_l^w)W_tL_t+\frac{X_t}{(1+\iota^x_w)S_t\lambda_w}$$
$$+\frac{R^*_{t-1}e^{\mathrm{RP}_{t-1}}S_tA^*_t}{\lambda_w}+\frac{R_{d,t-1}D_t}{\lambda_w}+\frac{(1-\theta_t)\mathrm{NW}_{t-1}+\theta_t\Gamma^{\mathtt{capreq}}_t}{\lambda_w}+\nu_f(R^*_te^{\mathrm{RP}_t}-1)W_tL_t,$$

where τ_c is the consumption tax rate, ι^c_w (t^c_w) denotes iceberg (unit) transport costs for workers importing foreign consumption goods, τ_l^w is the employee labour tax rate, W_t is the wage, A^*_t (D_t) is foreign bond holdings (bank deposits) between time $t-1$ and time t, $\Gamma_{d,t}=\phi_d/2[(D_{t+1}-\overline{D})/\lambda_w]^2$ denotes deposit adjustment costs, Y_t denotes final goods output, $p_{g,t}$ and $Y_{g,t}$ ($p_{b,t}$ and $Y^{\ell}_{b,t}$) are the price and quantity of green (domestic brown) intermediate goods, $(1+\iota^*_{b,t}+\tau^*_{b,t})S_tp_{b,t}+t^*_b$ and $Y^*_{b,t}$ are the price and quantity of foreign brown intermediate goods where $\iota^*_{b,t}$ (t^*_b) are iceberg (unit) transport costs and $\tau^*_{b,t}$ is the foreign carbon tax rate. The following function introduces time-varying iceberg transport costs which increase in the share of imported foreign brown intermediate goods:

$$\iota^*_{b,t}=\iota^*_{b,1}+\iota^*_{b,2}\cdot\frac{Y^*_{b,t}}{Y^{\ell}_{b,t}+Y^*_{b,t}}. \quad (4)$$

Moreover, X_t is the amount of exports of the domestic final good where exporting is subject to iceberg (unit) transport costs at rate ι^x_w (t^x_w) that are paid by the workers, and S_t is the exchange rate. Moreover, R^*_{t-1} is the gross foreign risk-free rate and $e^{\mathrm{RP}_{t-1}}$ a domestic risk premium earned on holdings of foreign bonds between time $t-1$ and time t. Similarly, $R_{d,t-1}$ is the gross deposit interest rate. Additionally, Φ_t denotes the start-up fund for new banks, θ_t is the survival probability of banks, NW_t is the aggregate net worth of banks, and $\Gamma^{\mathtt{capreq}}_t$ are the bank capital requirement costs (penalties) collected from surviving banks by the financial regulators, which are assumed to be part of the workers' population. Finally, the term $\nu_f(R^*_te^{\mathrm{RP}_t}-1)W_tL_t$ is the aggregate revenue of working capital loans collected from the entrepreneurs (which is by assumption not taken into account by workers in their optimization problem).

Domestic final goods are produced according to the following constant-elasticity-of-substitution (CES) production function:

$$Y_t=\left((\omega_{y,g})^{\frac{1}{\epsilon}}(Y_{g,t})^{1-\frac{1}{\epsilon}}+(\omega^{\ell}_{y,b})^{\frac{1}{\epsilon}}(Y^{\ell}_{b,t})^{1-\frac{1}{\epsilon}}+(\omega^*_{y,b})^{\frac{1}{\epsilon}}(Y^*_{b,t})^{1-\frac{1}{\epsilon}}\right)^{\frac{1}{1-\frac{1}{\epsilon}}}, \quad (5)$$

where $\epsilon>0$ denotes the elasticity of substitution between intermediate goods and

$\omega_{y,g}, \omega_{y,b}^{\ell}, \omega_{y,b}^{*} > 0$ are the input shares of green, domestic and imported brown intermediate goods ($1 = \omega_{y,g} + \omega_{y,b}^{\ell} + \omega_{y,b}^{*}$). Note that the prices of the domestic final good and of the final consumption good are normalized to 1.

The key difference between green and domestic brown intermediate goods concerns the amount of emissions generated by the production of these goods. Green intermediate goods production does not yield any emissions, whereas domestic brown intermediate goods production leads to emissions. The foreign brown intermediate goods generate emissions abroad, but this is not taken into account by the domestic economy.

3.2 Green entrepreneurs and green production sector

The lifetime utility function of green entrepreneurs is given by:

$$U_{g,t} = \sum_{s=0}^{\infty} \left\{ \frac{\beta_g^s (C_{g,t+s} - h_g C_{g,t+s-1})^{1-\gamma_g}}{1-\gamma_g} \right\}, \tag{6}$$

where $\beta_g \in (0,1)$ is the time discount factor, $h_g > 0$ is the habit parameter, and $\gamma_g > 0$ denotes relative risk aversion. The total mass of green entrepreneurs is $\lambda_g \in (0,1)$. Moreover, $C_{g,t}$ is green entrepreneurs' consumption.

For final consumption goods production, a representative perfectly competitive firm uses an amount $C_{g,t}^{\ell}$ of the domestically produced (local) final good and an amount $C_{g,t}^{*}$ of the imported foreign good according to the following production technology:

$$C_{g,t} = \left((1-\omega_{g,c})^{\frac{1}{\eta_{g,c}}} \left(C_{g,t}^{\ell}\right)^{\frac{\eta_{g,c}-1}{\eta_{g,c}}} + (\omega_{g,c})^{\frac{1}{\eta_{g,c}}} \left(C_{g,t}^{*}\right)^{\frac{\eta_{g,c}-1}{\eta_{g,c}}} \right)^{\frac{\eta_{g,c}}{\eta_{g,c}-1}}, \tag{7}$$

where $\omega_{g,c} > 0$ is the weight on the foreign good in the production function and $\eta_{g,c} > 0$ denotes the elasticity of substitution between domestic and foreign consumption goods.

The income of green entrepreneurs consists of the revenue from selling green intermediate goods, selling renewable energy output for green intermediate goods production, and taking out loans from the banks. This income is used to finance consumption expenditure, to pay wages, to buy renewable energy for green intermediate goods production, to invest in private green and renewable energy capital, and to pay back the loans from last period. Thus, the budget constraint of green entrepreneurs is given by:

$$\begin{aligned}
&(1+\tau_c)(C_{g,t}^{\ell} + [(1+\iota_g^c)S_t + t_g^c]C_{g,t}^{*}) + \frac{W_t(\nu_f R_t^* e^{\mathrm{RP}_t} + 1 - \nu_f + \tau_l^e)(\lambda_w L_{g,t} + \lambda_w L_{e,t})}{\lambda_g} \qquad (8)\\
&+ \frac{p_{e,t}E_t^d}{\lambda_g} + \frac{I_{g,t}^{\ell} + [(1+\iota_g^i)S_t + t_g^i]I_{g,t}^{*}}{\lambda_g} + \frac{I_{e,t}^{\ell} + [(1+\iota_e^i)S_t + t_e^i]I_{e,t}^{*}}{\lambda_g} + \frac{R_{g,t}B_{g,t}}{\lambda_g}\\
&= \frac{p_{g,t}Y_{g,t}}{\lambda_g} + \frac{p_{e,t}E_t^s}{\lambda_g} + \frac{B_{g,t+1}}{\lambda_g},
\end{aligned}$$

where $\lambda_w L_{g,t}$ ($\lambda_w L_{e,t}$) is the demand for labour in green intermediate goods (renewable energy) production, τ_l^e is the employer labour tax rate, ι_g^c (ι_g^i, ι_e^i) denotes the iceberg transport costs rate for green entrepreneurs importing foreign consumption (green investment, renewable energy investment) goods and, similarly, unit transport costs are denoted by t_g^c, t_g^i, and t_e^i, E_t^d (E_t^s) denotes the renewable energy demand (supply), $p_{e,t}$ is the price of renewable energy, $I_{g,t}^\ell$ ($I_{g,t}^*$) is the amount of domestic (foreign) goods directed to private green investment and, similarly, $I_{e,t}^\ell$ ($I_{e,t}^*$) for renewable energy investment. $R_{g,t}$ ($B_{g,t}$) is the gross interest rate on (amount of) green loans between time $t-1$ and time t. The term $\nu_f R_t^* e^{\mathrm{RP}_t} + 1 - \nu_f$ in the wage bill accounts for the assumption that a fraction ν_f of the pre-tax work bill has to be financed by taking out loans at the domestic risk-free rate.[1] This is introduced to give shocks to the domestic risk premium a larger role in the model. Taking out green bank loans is subject to the following LIA constraint or the following DTI constraint (only one is active and binds in equilibrium at a time):

$$B_{g,t+1} \geq \mathrm{LIA}_{g,t}(I_{g,t}^\ell + [(1+\iota_g^i)S_t + t_g^i]I_{g,t}^* + I_{e,t}^\ell + [(1+\iota_e^i)S_t + t_e^i]I_{e,t}^*), \tag{9}$$

$$m_b B_{g,t+1} \leq \mathrm{DTI}_{g,t}(p_{g,t}Y_{g,t} + p_{e,t}E_t^s), \tag{10}$$

where $\mathrm{LIA}_{g,t}$ denotes the fraction of loans relative to total investment expenditure that are required to be taken out by green entrepreneurs and $\mathrm{DTI}_{g,t}$ the maximum ratio of debt to income the green entrepreneurs are allowed to have,[2] which are governed by the following stochastic processes:

$$\mathrm{LIA}_{g,t} = (1-\rho_g^{\mathrm{LIA}})\overline{\mathrm{LIA}}_g + \rho_g^{\mathrm{LIA}} \cdot \mathrm{LIA}_{g,t-1} + \varepsilon_{g,t}^{\mathrm{LIA}}, \tag{11}$$

$$\mathrm{DTI}_{g,t} = (1-\rho_g^{\mathrm{DTI}})\overline{\mathrm{DTI}}_g + \rho_g^{\mathrm{DTI}} \cdot \mathrm{DTI}_{g,t-1} + \varepsilon_{g,t}^{\mathrm{DTI}}, \tag{12}$$

where the persistence parameters are given by $\rho_g^{\mathrm{LIA}}, \rho_g^{\mathrm{DTI}} \in (0,1)$ and $\varepsilon_{g,t}^{\mathrm{LIA}} \sim \mathcal{N}(0, \sigma_g^{\mathrm{LIA}})$, $\varepsilon_{g,t}^{\mathrm{DTI}} \sim \mathcal{N}(0, \sigma_g^{\mathrm{DTI}})$. Green intermediate goods are produced according to the following Cobb-Douglas production function:

$$Y_{g,t} = (E_t^d)^{\pi_1}(K_{g,t} + K_{g,t}^p)^{\pi_2}(A_{g,t}\lambda_w L_{g,t})^{\pi_3}, \tag{13}$$

where the parameters $\pi_1, \pi_2, \pi_3 \in (0,1)$ denote the input shares of renewable energy, green capital, and labour, respectively.[3] The quantity $K_{g,t}$ ($K_{g,t}^p$) is the amount of private (pub-

[1] These loans are provided for by the workers. Thus, these loans do not enter the balance sheets of banks but instead the budget constraint of workers, as shown in Equation (3).

[2] The constant $m_b = 3.3616$ is introduced to account for the fact that loans in reality typically have maturities of multiple years, while in the model they are one-period (one-year) loans.

[3] Several E-DSGE models do not rely on energy as an additional input but instead just on capital and labour: Benmir and Roman (2020); Carrattini et al. (2021); Schuldt and Lessmann (2021); Benkhodja et al. (2022). On the contrary, Diluiso et al. (2021); Ferrari and Nispi Landi (2021); Varga et al. (2021); Abiry et al. (2022) rely on renewable vs. non-renewable energy sources as in this paper. Typically,

lic) green capital. The variable $A_{g,t}$ introduces green labour productivity shocks, according to the following stochastic process ($\rho_g \in (0,1)$ – persistence level, $\varepsilon_{g,t} \sim \mathcal{N}(0,\sigma_g)$):

$$\ln(A_{g,t}) = \rho_g \ln(A_{g,t-1}) + \varepsilon_{g,t}, \tag{14}$$

Renewable energy is produced according to the following production function:

$$E_t^s = (K_{e,t} + K_{g,t}^p)^{\nu_1} (A_{e,t}\lambda_w L_{e,t})^{\nu_2}, \tag{15}$$

where the parameters $\nu_1, \nu_2 \in (0,1)$ denote the input shares of renewable energy capital and labour, respectively.[4] The quantity $K_{e,t}$ is the amount of renewable energy capital, and the variable $A_{e,t}$ introduces renewable energy labour productivity shocks ($\rho_e \in (0,1)$ – persistence level, $\varepsilon_{e,t} \sim \mathcal{N}(0,\sigma_e)$):

$$\ln(A_{e,t}) = \rho_e \ln(A_{e,t-1}) + \varepsilon_{e,t}. \tag{16}$$

Private green, renewable energy, and public green capital accumulate according to:

$$K_{g,t+1} = (1-\delta_g)K_{g,t} + \left[1 - \phi_{g,i}/2\left(I_{g,t-1}/I_{g,t-2} - 1\right)^2\right] I_{g,t-1}, \tag{17}$$
$$K_{e,t+1} = (1-\delta_e)K_{e,t} + \left[1 - \phi_{e,i}/2\left(I_{e,t-1}/I_{e,t-2} - 1\right)^2\right] I_{e,t-1}, \tag{18}$$
$$K_{g,t+1}^p = (1-\delta_g)K_{g,t}^p + \left[1 - \phi_{g,i}/2(I_{g,t-1}^p/I_{g,t-2}^p - 1)^2\right] I_{g,t-1}^p, \tag{19}$$

where $I_{g,t}^p$ is the amount of public green capital investment supplied by the government, $\delta_g, \delta_e \in (0,1)$ denote the green and renewable capital depreciation rates and $\phi_{g,i}, \phi_{e,i} > 0$ determine the amount of quadratic investment adjustment costs. Note that there is a time-to-build friction assumed so that it takes two periods after the investment is made until new capital becomes available.

For final green (renewable energy) investment goods production, representative perfectly competitive firms use an amount $I_{g,t}^\ell$ ($I_{e,t}^\ell$) of the domestically produced final good and an amount $I_{g,t}^*$ ($I_{e,t}^*$) of the imported foreign good according to the following production technologies:

$$I_{g,t} = \left((1-\omega_{g,i})^{\frac{1}{\eta_{g,i}}} \left(I_{g,t}^\ell\right)^{\frac{\eta_{g,i}-1}{\eta_{g,i}}} + (\omega_{g,i})^{\frac{1}{\eta_{g,i}}} \left(I_{g,t}^*\right)^{\frac{\eta_{g,i}-1}{\eta_{g,i}}} \right)^{\frac{\eta_{g,i}}{\eta_{g,i}-1}}, \tag{20}$$

different types of energy are bundled together and then used by other homogenous firms, but Abiry et al. (2022) also use renewable vs. fossil fuel energy in production to classify green and brown firms.

[4] The input share of capital will be chosen to be quite high relative to the other production functions (see Section 4 for details). In the related literature, one finds several assumptions on the capital shares of renewable energy production functions, ranging from a capital share of 0 (i.e. labour share of 1) in Abiry et al. (2022) to a capital share of 1 in Diluiso et al. (2021).

$$I_{e,t} = \left((1-\omega_{e,i})^{\frac{1}{\eta_{e,i}}} \left(I^{\ell}_{e,t}\right)^{\frac{\eta_{e,i}-1}{\eta_{e,i}}} + (\omega_{e,i})^{\frac{1}{\eta_{e,i}}} \left(I^{*}_{e,t}\right)^{\frac{\eta_{e,i}-1}{\eta_{e,i}}} \right)^{\frac{\eta_{e,i}}{\eta_{e,i}-1}}, \tag{21}$$

where $\omega_{g,i} > 0$ ($\omega_{e,i} > 0$) is the foreign good weight and $\eta_{g,i} > 0$ ($\eta_{e,i} > 0$) denotes the elasticity of substitution between domestic and foreign final goods.

3.3 Brown entrepreneurs and brown intermediate goods firm

The lifetime utility function of brown entrepreneurs is given by:

$$U_{b,t} = \sum_{s=0}^{\infty} \left\{ \frac{\beta_b^s (C_{b,t+s} - h_b C_{b,t+s-1})^{1-\gamma_b}}{1-\gamma_b} \right\}, \tag{22}$$

where $\beta_b \in (0,1)$ is the time discount factor, $h_b > 0$ is the habit parameter, and $\gamma_b > 0$ denotes relative risk aversion. The total mass of brown entrepreneurs is given by $\lambda_b \in (0,1)$ so that the shares of all consumers sum up to 1, i.e. $\lambda_w + \lambda_g + \lambda_b = 1$. Moreover, $C_{b,t}$ is brown entrepreneurs' consumption.

For final consumption goods production, a representative perfectly competitive firm uses an amount $C^{\ell}_{b,t}$ of the domestically produced final good and an amount $C^{*}_{b,t}$ of the imported foreign good according to the following CES production technology:

$$C_{b,t} = \left((1-\omega_{b,c})^{\frac{1}{\eta_{b,c}}} \left(C^{\ell}_{b,t}\right)^{\frac{\eta_{b,c}-1}{\eta_{b,c}}} + (\omega_{b,c})^{\frac{1}{\eta_{b,c}}} \left(C^{*}_{b,t}\right)^{\frac{\eta_{b,c}-1}{\eta_{b,c}}} \right)^{\frac{\eta_{b,c}}{\eta_{b,c}-1}}, \tag{23}$$

where $\omega_{b,c} > 0$ is the weight on the foreign good in the production function and $\eta_{b,c} > 0$ denotes the elasticity of substitution between domestic and foreign consumption goods.

The income of brown entrepreneurs consists of the revenue from selling brown intermediate goods and taking out brown loans from the banks. This income is used to finance consumption expenditure, to pay wages, to import brown energy, to invest in private brown capital, to pay back the loans from last period, and to potentially pay emissions cap violation costs and domestic carbon taxes. Thus, the budget constraint of the brown entrepreneurs is given by:

$$\begin{aligned} &(1+\tau_c)(C^{\ell}_{b,t} + [(1+\iota^c_b)S_t + t^c_b]C^{*}_{b,t}) + \frac{W_t(\nu_f R^*_t e^{\mathrm{RP}_t} + 1 - \nu_f + \tau^e_l)\lambda_w L_{b,t}}{\lambda_b} \\ &+ \frac{(S_t p_{z,t} + \tau_{z,t})Z_t}{\lambda_b} + \frac{I^{\ell}_{b,t} + [(1+\iota^i_b)S_t + t^i_b]I^{*}_{b,t}}{\lambda_b} + \frac{R_{b,t}B_{b,t}}{\lambda_b} + \frac{\Gamma_{z,t}}{\lambda_b} = \frac{p_{b,t}Y^{\ell}_{b,t}}{\lambda_b} + \frac{B_{b,t+1}}{\lambda_b}, \end{aligned} \tag{24}$$

where $\lambda_w L_{b,t}$ is the demand for labour in brown intermediate goods production, ι^c_b (ι^i_b) denotes the iceberg transport costs rate for brown entrepreneurs importing foreign consumption (investment) goods and, similarly, unit transport costs are denoted by t^c_b and t^i_b, Z_t denotes the brown energy demand, $S_t p_{z,t}$ is the price of brown energy in domestic units where $\tau_{z,t}$ is the domestic carbon tax rate levied on total emissions Z_t,[5] $I^{\ell}_{b,t}$ ($I^*_{b,t}$) is the amount of domestic (foreign) goods directed to private brown investment, and $R_{b,t}$ ($B_{b,t}$) is the interest rate on (amount of) brown loans between time $t-1$ and time t. Moreover, $\Gamma_{z,t}$ denotes the costs for violating the emissions cap, as imposed by the environmental regulator. See Section 3.4 for details on this function. Loans have to be taken out for financing a fraction of brown investment expenditure, subject to the following LIA (or DTI) constraint (where only one is active and binding in equilibrium at a time):

$$B_{b,t+1} \geq \text{LIA}_{b,t}(I^{\ell}_{b,t} + [(1+\iota^i_b)S_t + t^i_b]I^*_{b,t}), \tag{25}$$

$$m_b B_{b,t+1} \leq \text{DTI}_{b,t}(p_{b,t}Y^{\ell}_{b,t}), \tag{26}$$

where $\text{LIA}_{b,t}$ denotes the fraction of brown investment expenditure that has to be financed by brown loans and $\text{DTI}_{b,t}$ is the brown DTI ratio ($\rho^{\text{LIA}}_b \in (0,1), \rho^{\text{DTI}}_b \in (0,1)$ – persistence levels, $\varepsilon^{\text{LIA}}_{b,t} \sim \mathcal{N}(0, \sigma^{\text{LIA}}_b)$, $\varepsilon^{\text{DTI}}_{b,t} \sim \mathcal{N}(0, \sigma^{\text{DTI}}_b)$):

$$\text{LIA}_{b,t} = (1-\rho^{\text{LIA}}_b)\overline{\text{LIA}}_b + \rho^{\text{LIA}}_b \cdot \text{LIA}_{b,t-1} + \varepsilon^{\text{LIA}}_{b,t}, \tag{27}$$

$$\text{DTI}_{b,t} = (1-\rho^{\text{DTI}}_b)\overline{\text{DTI}}_b + \rho^{\text{DTI}}_b \cdot \text{DTI}_{b,t-1} + \varepsilon^{\text{DTI}}_{b,t}. \tag{28}$$

Brown intermediate goods are produced according to the following production function:

$$Y^{\ell}_{b,t} = (Z_t)^{\alpha_1}\left(A_{k,t}(K_{b,t} + K^p_{b,t})\right)^{\alpha_2}(A_{b,t}\lambda_w L_{b,t})^{\alpha_3}, \tag{29}$$

where the parameters $\alpha_1, \alpha_2, \alpha_3 \in (0,1)$ denote the input shares of brown energy, brown capital, and labour, respectively. The quantity $K_{b,t}$ ($K^p_{b,t}$) is the amount of private (public) brown capital. Both brown capital stocks are subject to capital quality shocks $A_{k,t}$ and the variable $A_{b,t}$ introduces brown labour productivity shocks ($\rho_k, \rho_b \in (0,1)$ – persistence levels, $\varepsilon_{k,t} \sim \mathcal{N}(0, \sigma_k)$, $\varepsilon_{b,t} \sim \mathcal{N}(0, \sigma_b)$):

$$\ln(A_{k,t}) = \rho_k \ln(A_{k,t-1}) + \varepsilon_{k,t}, \tag{30}$$

$$\ln(A_{b,t}) = \rho_b \ln(A_{b,t-1}) + \varepsilon_{b,t}, \tag{31}$$

Private and public brown capital accumulate according to the following laws of motion:

$$K_{b,t+1} = (1-\delta_b)A_{k,t}K_{b,t} + \left[1 - \phi_{b,i}/2\,(I_{b,t-1}/I_{b,t-2} - 1)^2\right] I_{b,t-1}, \tag{32}$$

$$K^p_{b,t+1} = (1-\delta_b)A_{k,t}K^p_{b,t} + \left[1 - \phi_{b,i}/2(I^p_{b,t-1}/I^p_{b,t-2} - 1)^2\right] I^p_{b,t-1}, \tag{33}$$

where $I^p_{b,t}$ is public brown capital investment supplied by the government, $\delta_b \in (0,1)$ denotes the brown capital depreciation rate and $\phi_{b,i} > 0$ determines the amount of quadratic

[5] As in Diluiso et al. (2021), the emissions flow is equal to the brown energy amount utilized in the economy, i.e. emissions are equal to Z_t.

investment adjustment costs. Note that there is again a time-to-build friction assumed so that it takes two periods after the investment is made until new capital becomes available.

For the production of the final private brown investment goods, a representative perfectly competitive firm uses an amount $I_{b,t}^{\ell}$ of the local final good and an amount $I_{b,t}^{*}$ of the imported foreign good according to the following production technology ($\omega_{b,i} > 0$ – foreign final good weight, $\eta_{b,i} > 0$ – elasticity of substitution between domestic and foreign final goods):

$$I_{b,t} = \left((1-\omega_{b,i})^{\frac{1}{\eta_{b,i}}} \left(I_{b,t}^{\ell}\right)^{\frac{\eta_{b,i}-1}{\eta_{b,i}}} + (\omega_{b,i})^{\frac{1}{\eta_{b,i}}} \left(I_{b,t}^{*}\right)^{\frac{\eta_{b,i}-1}{\eta_{b,i}}} \right)^{\frac{\eta_{b,i}}{\eta_{b,i}-1}}. \tag{34}$$

3.4 Environmental policies

On the one hand, environmental regulation comes in the form of domestic and foreign carbon taxes. The domestic and foreign carbon tax rates $\tau_{z,t}$ and $\tau_{b,t}^{*}$ are set according to the following exogenous stochastic processes:

$$\tau_{z,t} = (1-\rho_{\tau_z})\overline{\tau}_z + \rho_{\tau_z}\tau_{z,t-1} + \varepsilon_{\tau_z,t}, \tag{35}$$

$$\tau_{b,t}^{*} = (1-\rho_{\tau_b^*})\overline{\tau}_b^{*} + \rho_{\tau_b^*}\tau_{b,t-1}^{*} + \varepsilon_{\tau_b^*,t}, \tag{36}$$

where $\overline{\tau}_z \geq 0$ ($\overline{\tau}_b^{*} \geq 0$) is the steady-state domestic (foreign) carbon tax rate, the parameter $\rho_{\tau_z} \in (0,1)$ ($\rho_{\tau_b^*} \in (0,1)$) denotes the persistence of domestic (foreign) carbon tax rate shocks, and $\varepsilon_{\tau_z,t} \sim \mathcal{N}(0,\sigma_{\tau_z})$, $\varepsilon_{\tau_b^*,t} \sim \mathcal{N}(0,\sigma_{\tau_b^*})$.

On the other hand, environmental regulation also comes in the form of an emissions cap so that the following quantity is the amount of emissions each period that can be emitted without brown entrepreneurs paying significant penalties: $\phi_t Z^{nocap}$.

The constant Z^{nocap} is the amount of brown energy demanded if there were no emissions cap violation costs.[6] The penalty function for violating this emissions cap is:

$$\Gamma_{z,t} = \frac{\phi_1}{\phi_0} e^{-\phi_0(\phi_t Z^{nocap} - Z_{t-1})} - \phi_2(\phi_t Z^{nocap} - Z_{t-1}), \tag{37}$$

where the penalty to be paid by brown entrepreneurs at time t becomes very high if emissions at time $t-1$ (Z_{t-1}) exceed the limit ($\phi_t Z^{nocap}$). On the contrary, the amount to be paid becomes slightly negative when emissions lie considerably below the limit to proxy for revenue from selling unused, freely allocated certificates on the open market. This is due to using the asymmetric cost function above, whose functional form is similar to the capital requirement cost function in Valencia et al. (2017). Although free emissions are gradually phased out (European Commission, 2021), there are still free emissions and

[6] That is, the steady-state amount of brown energy in the equivalent model where the parameters ϕ_1 and ϕ_2 in Equation (37) are set to zero while all other parameters are set as in the benchmark calibration.

especially for sectors at high risk to reallocate their production out of the EU. Hence, assuming a part of the function being negative to proxy for selling unneeded, freely allocated certificates still seems to be a reasonable assumption. The process ϕ_t determines the current level of the emissions cap ($\rho_\phi \in (0,1)$ – persistence level, $\varepsilon_{\phi,t} \sim \mathcal{N}(0, \sigma_\phi)$):

$$\phi_t = (1-\rho_\phi)\overline{\phi} + \rho_\phi \phi_{t-1} - \varepsilon_{\phi,t}. \tag{38}$$

3.5 Banks

Banks grant loans to both types of entrepreneurs and finance them using a combination of net worth and deposits. The balance sheet and net worth accumulation of bank j are:

$$B_{g,j,t+1} + B_{b,j,t+1} = \mathrm{NW}_{j,t} + D_{j,t+1}, \tag{39}$$

$$\mathrm{NW}_{j,t+1} = R_{g,t+1}B_{g,j,t+1} + R_{b,t+1}B_{b,j,t+1} - R_{d,t}D_{j,t+1} - \Gamma^{\texttt{capreq}}_{j,t+1} - T_{ls,j,t+1}, \tag{40}$$

where $T_{ls,j,t+1}$ is a lump-sum type corporate tax that each bank j (also the non-surviving banks) needs to pay (to the government). I denote the value of bank j at time t by $V_{j,t}$, which is a function of bank j's net worth, i.e. $V_{j,t}(\mathrm{NW}_{j,t})$. Furthermore, a bank survives with probability θ_t ($\overline{\theta}$ – steady state of the bank survival probability, $\rho_\theta \in (0,1)$ – persistence of bank survival probability shocks, and $\varepsilon_{\theta,t} \sim \mathcal{N}(0, \sigma_\theta)$):

$$\theta_t = (1-\rho_\theta)\overline{\theta} + \rho_\theta \theta_{t-1} - \varepsilon_{\theta,t}. \tag{41}$$

If a bank does not survive, the remaining net worth is transferred to the workers, yielding the following law of motion ($\mathbb{M}_{t,t+1}$ – workers' stochastic discount factor):

$$V_{j,t}(\mathrm{NW}_{j,t}) = \mathbb{E}_t[(1-\theta_{t+1})\mathbb{M}_{t,t+1}\mathrm{NW}_{j,t+1} + \theta_{t+1}\mathbb{M}_{t,t+1}V_{j,t+1}(\mathrm{NW}_{j,t+1})]. \tag{42}$$

The banks are subject to a friction so that banks can divert a fraction of the funds unless the following incentive compatibility constraint holds:

$$V_{j,t}(\mathrm{NW}_{j,t}) \geq \Psi(\kappa_{g,t}B_{g,j,t+1} + \kappa_{b,t}B_{b,j,t+1}), \tag{43}$$

where $\Psi > 0$ determines the severity of this constraint and the variables $\kappa_{g,t}$ and $\kappa_{b,t}$ determine the relative absconding rates for green and brown loans, respectively. Since some banks are exiting each period, some new banks are born each period as well to keep the size of the banking sector constant. These new banks get a start-up fund from workers equal to a fraction $\tau \in (0,1)$ of aggregate worth of banks:

$$\Phi_t \equiv \tau \cdot \mathrm{NW}_t. \tag{44}$$

Therefore, aggregate net worth of banks evolves as follows:

$$\mathrm{NW}_{t+1} = \theta_{t+1}\Bigg(\Bigg[(R_{g,t+1}-R_{d,t})\frac{B_{g,t+1}}{\mathrm{NW}_t} + (R_{b,t+1}-R_{d,t})\frac{B_{b,t+1}}{\mathrm{NW}_t} + R_{d,t}\Bigg]\mathrm{NW}_t - \Gamma^{\texttt{capreq}}_{t+1} - T_{ls,t+1}\Bigg) + \Phi_t. \tag{45}$$

Finally, the banks are subject to a regulatory capital requirement. They have to pay costs equal to the following function which increase significantly when net worth falls below a fraction $\texttt{capreq} > 0$ of risk-weighted assets:

$$\Gamma^{\texttt{capreq}}_{t+1} = \frac{\gamma_1}{\gamma_0} e^{-\gamma_0(\mathrm{NW}_t - \mathrm{capreq}\cdot \mathrm{RWA}_{t+1})} + \gamma_2(\mathrm{NW}_t - \mathrm{capreq}\cdot \mathrm{RWA}_{t+1}), \tag{46}$$

where aggregate risk-weighted assets between times t and $t+1$ are:

$$\mathrm{RWA}_{t+1} = \upsilon_{g,t} B_{g,t+1} + \upsilon_{b,t} B_{b,t+1}. \tag{47}$$

This cost function is taken from Valencia et al. (2017). The relative absconding rates and risk weights are given by:

$$\kappa_{g,t} = (1-\rho_{\kappa_g})\overline{\kappa}_g + \rho_{\kappa_g}\kappa_{g,t-1} - \varepsilon_{\kappa_g,t}, \tag{48}$$

$$\kappa_{b,t} = (1-\rho_{\kappa_b})\overline{\kappa}_b + \rho_{\kappa_b}\kappa_{b,t-1} + \varepsilon_{\kappa_b,t}, \tag{49}$$

$$\upsilon_{g,t} = (1-\rho_{\upsilon_g})\overline{\upsilon}_g + \rho_{\upsilon_g}\upsilon_{g,t-1} - \varepsilon_{\upsilon_g,t}, \tag{50}$$

$$\upsilon_{b,t} = (1-\rho_{\upsilon_b})\overline{\upsilon}_b + \rho_{\upsilon_b}\upsilon_{b,t-1} + \varepsilon_{\upsilon_b,t}, \tag{51}$$

where $\overline{\kappa}_g \geq 0$ ($\overline{\kappa}_b \geq 0$) is the steady-state relative green (brown) loan absconding rate and $\overline{\upsilon}_g \geq 0$ ($\overline{\upsilon}_b \geq 0$) is the steady-state green (brown) loan risk weight. Furthermore, the parameters $\rho_{\kappa_g}, \rho_{\kappa_b}, \rho_{\upsilon_g}, \rho_{\upsilon_b} \in (0,1)$ denote the persistence levels as well as $\varepsilon_{\kappa_g,t} \sim \mathcal{N}(0,\sigma_{\kappa_g})$, $\varepsilon_{\kappa_b,t} \sim \mathcal{N}(0,\sigma_{\kappa_b})$, $\varepsilon_{\upsilon_g,t} \sim \mathcal{N}(0,\sigma_{\upsilon_g})$, $\varepsilon_{\upsilon_b,t} \sim \mathcal{N}(0,\sigma_{\upsilon_b})$.

Here, one can assume that the risk weight for green loans is lower than the risk weight for brown loans so that banks face tighter regulatory constraints if they lend a lot to brown entrepreneurs and looser regulatory constraints if they lend more to green entrepreneurs. This can be done to encourage banks to grant more funds to the green sector in order to facilitate the economy's green transition.[7]

[7] Sector-specific absconding rates can also serve as bank regulation policies as in Benmir and Roman (2020). Sector-specific risk weights as here are also used by Diluiso et al. (2021). Other sector-specific bank regulation or macro-prudential policies that have been investigated include taxes and/or subsidies to banks for green and/or brown loan issuance (Carrattini et al., 2021) as well as portfolio adjustment costs for deviating from a regulated brown loan share (Ferrari and Nispi Landi, 2021).

3.6 Government

Government income consists of consumption and labour taxes revenue. The government also receives revenues from domestic carbon taxes and penalties for the violation of the emissions cap, an exogenous amount of funds EU_t from abroad (i.e. EU funds from several infrastructure-related and cohesion funds), and the lump-sum corporate tax from banks $T_{ls,t}$. A share $1-s_i$ of the consumption and labour tax revenues is used for wasteful public consumption and the remaining revenues are channelled to public investment, whereas all the funds from abroad are used for public investment. In particular, a share $s_i s_{g,t}$ of consumption and labour tax revenues and a share $s_{g,t}^{EU}$ of EU funds are earmarked for public green capital investment and the remainder of these revenues with shares $s_i(1-s_{g,t})$ and $1-s_{g,t}^{EU}$ are earmarked for public brown capital investment. The carbon tax revenue as well as the penalties for the violation of the emissions cap are partly used for wasteful public consumption at a share s_b, while the remaining funds are completely earmarked for public green capital investment (in case $\mathbb{1}_{b,env}^{tax}=0$ as in the benchmark calibration) or used proportionally with share $s_{g,t}$ for both public green and brown investment as for standard tax revenues (in case $\mathbb{1}_{b,env}^{tax}=1$ as will be explored in the scenario analysis). Finally, the lump-sum corporate tax on banks is fully earmarked for wasteful public consumption. Thus, green and brown public investment expenditures are:

$$\begin{aligned}
I_{g,t}^p = {} & s_i\{s_{g,t}\tau_c(\lambda_w C_{w,t}^\ell + [(1+\iota_w^c)S_t + t_w^c]\lambda_w C_{w,t}^* + \lambda_g C_{g,t}^\ell + [(1+\iota_g^c)S_t + t_g^c]\lambda_g C_{g,t}^* \\
& + \lambda_b C_{b,t}^\ell + [(1+\iota_b^c)S_t + t_b^c]\lambda_b C_{b,t}^*) + s_{g,t}(\tau_l^w + \tau_l^e)\lambda_w W_t L_t\} + s_{g,t}^{EU}\mathrm{EU}_t \\
& + (1-s_b)(1-\mathbb{1}_{b,env}^{tax} + s_{g,t}\mathbb{1}_{b,env}^{tax})(\tau_{z,t}Z_t + \Gamma_{z,t}), \qquad (52)
\end{aligned}$$

$$\begin{aligned}
I_{b,t}^p = {} & s_i\{(1-s_{g,t})\tau_c(\lambda_w C_{w,t}^\ell + [(1+\iota_w^c)S_t + t_w^c]\lambda_w C_{w,t}^* + \lambda_g C_{g,t}^\ell + [(1+\iota_g^c)S_t + t_g^c]\lambda_g C_{g,t}^* \\
& + \lambda_b C_{b,t}^\ell + [(1+\iota_b^c)S_t + t_b^c]\lambda_b C_{b,t}^*) + (1-s_{g,t})(\tau_l^w + \tau_l^e)\lambda_w W_t L_t\} + (1-s_{g,t}^{EU})\mathrm{EU}_t \\
& + \mathbb{1}_{b,env}^{tax}(1-s_b)(1-s_{g,t})(\tau_{z,t}Z_t + \Gamma_{z,t}). \qquad (53)
\end{aligned}$$

The steady-state value of the domestic green public investment share $s_{g,t} = (1-\rho_g^p)\cdot\overline{s}_g + \rho_g^p\cdot s_{g,t-1} + \varepsilon_{g,t}^p$ is equal to the steady-state output share of the green sector in the economy, i.e. $\overline{s}_g = \overline{Y}_g/(\overline{Y}_g + \overline{Y}_b^\ell + \overline{Y}_b^*)$, and the steady state value of the EU green public investment share $s_{g,t}^{EU} = (1-\rho_g^{EU})\cdot\overline{s}_g^{EU} + \rho_g^{EU}\cdot s_{g,t-1}^{EU} + \varepsilon_{g,t}^{EU}$ is calibrated according to European Structural and Investment Funds data in Section 4. Wasteful public consumption $G_{c,t}$ is given by the following expression (which is the government budget constraint):

$$G_{c,t} = T_{aggr,t} + T_{ls,t} + \mathrm{EU}_t - I_{g,t}^p - I_{b,t}^p, \qquad (54)$$

where $T_{aggr,t}$ denotes aggregate domestic distortionary tax revenue (from standard tax sources, i.e. consumption and labour taxes, as well as the domestic carbon tax and emissions cap violations costs revenues, but excluding the bank lump-sum corporate tax).

3.7 Rest of the world

Brown energy is supplied inelastically at the following exogenous world market price:

$$\ln(p_{z,t}) = (1-\rho_z)\overline{p}_z + \rho_z \ln(p_{z,t-1}) + \varepsilon_{z,t}, \tag{55}$$

where the parameter $\rho_z \in (0,1)$ denotes the persistence level and $\varepsilon_{z,t} \sim \mathcal{N}(0,\sigma_z)$. The natural logarithm of the steady state of the brown energy price is $\overline{p}_z$.

The exchange rate is governed by the following law of motion ($\overline{s}$ – steady-state log exchange rate, ρ_s – persistence level, $\varepsilon_{s,t} \sim \mathcal{N}(0,\sigma_s)$):

$$\ln(S_t) = (1-\rho_s)\overline{s} + \rho_s \ln(S_{t-1}) + \varepsilon_{s,t}. \tag{56}$$

The foreign risk-free interest rate is for simplicity assumed to be a constant, while the foreign bond and domestic risk-free interest rates are subject to a risk premium:

$$R_t^* \equiv \ln(1/\beta), \tag{57}$$

$$\text{RP}_t = -\tilde{\phi}_a(A_{t+1}^*/Y_t - \overline{A}^*/\overline{Y}) + \varepsilon_{r,t}, \tag{58}$$

where the parameter $\tilde{\phi}_a > 0$ measures the sensitivity of the risk premium to the net foreign assets position and $\varepsilon_{r,t} \sim \mathcal{N}(0,\sigma_r)$.

The EU funds in the steady state are equal to a share of steady-state domestic output and obey the following law of motion ($s_{EU} \geq 0$ – steady-state size of EU funds as a share of steady-state domestic output $\overline{Y}$, ρ_{EU} – persistence level, $\varepsilon_{EU,t} \sim \mathcal{N}(0,\sigma_{EU})$):

$$\text{EU}_t = (1-\rho_{EU})s_{EU} \cdot \overline{Y} + \rho_{EU} \cdot \text{EU}_{t-1} + \varepsilon_{EU,t}. \tag{59}$$

Finally, the rest of the world demands domestic final goods. Foreign demand is given exogenously ($\overline{x}$ – natural logarithm of steady-state foreign demand, $\rho_x \in (0,1)$ – persistence level, $\varepsilon_{x,t} \sim \mathcal{N}(0,\sigma_x)$):

$$\ln(X_t) = (1-\rho_x)\overline{x} + \rho_x \ln(X_{t-1}) + \varepsilon_{x,t}. \tag{60}$$

3.8 Market clearing conditions and current account

The labour market clears when the following condition is satisfied:

$$L_t = L_{g,t} + L_{b,t} + L_{e,t}. \tag{61}$$

The renewable energy market clears when demand meets supply:

$$E_t^d = E_t^s. \tag{62}$$

The current account is given by:[8]

$$S_tA^*_{t+1} + S_tp_{z,t}Z_t + \lambda_w[(1+\iota^c_w)S_t + t^c_w]C^*_{w,t} + \lambda_g[(1+\iota^c_g)S_t + t^c_g]C^*_{g,t} \\ + \lambda_b[(1+\iota^c_b)S_t + t^c_b]C^*_{b,t} + (1+\Gamma^*_{b,t} + \tau^*_{b,t})S_tp_{b,t}Y^*_{b,t} + [(1+\iota^i_g)S_t + t^i_g]I^*_{g,t} \\ + [(1+\iota^i_e)S_t + t^i_e]I^*_{e,t} + [(1+\iota^i_b)S_t + t^i_b]I^*_{b,t} = X_t/[(1+\iota^x_w)S_t] + R^*_{t-1}e^{\mathrm{RP}_{t-1}}S_tA^*_t + \mathrm{EU}_t. \tag{63}$$

Aggregate private consumption, private investment, and public investment are given by:

$$C_{aggr,t} = \lambda_wC_{w,t} + \lambda_gC_{g,t} + \lambda_bC_{b,t}, \quad I_{aggr,t} = I_{g,t} + I_{e,t} + I_{b,t}, \quad I^p_{aggr,t} = I^p_{g,t} + I^p_{b,t}. \tag{64}$$

Finally, the aggregate resource constraint can be derived using the budget constraints of all three consumers and the government as well as the current account equation (Equations 3, 8, 24, 54, and 63):[9]

$$Y_t = \lambda_wC^\ell_{w,t} + \lambda_gC^\ell_{g,t} + \lambda_bC^\ell_{b,t} + I_{aggr,t} + I^p_{aggr,t} + G_{c,t} + \lambda_w\Gamma_{d,t} + (1+t^x_w)X_t. \tag{65}$$

4 Calibration and Data Fit

The model is calibrated to the Latvian economy. Latvia is a small open economy in an economic and monetary union, the euro area. Therefore, it is realistic to assume that world resource prices and other foreign quantities are taken as given by the domestic economy, as assumed throughout the model development. However, the main reason for considering Latvia as the domestic economy in our model is that Latvia probably mostly faces transition risks originating from climate change but only limited physical risks.[10]

Nevertheless, as a country that has signed the Paris Agreement and which is a member of the EU, substantial pressure exists to reduce domestic carbon emissions to keep global climate change limited. Therefore, transition risks of climate change certainly have to be taken into account and Latvia will need to increase the share of renewable energy production and consumption and achieve a green transition of the economy to fulfill its international obligations. These circumstances have been reflected in the model by

[8] Total imports expenditure is defined by $\mathrm{IMP}_t = p_{z,t}S_tZ_t + (1+\Gamma^*_{b,t}+\tau^*_{b,t})p_{b,t}S_tY^*_{b,t} + \lambda_w[(1+\iota^c_w)S_t + t^c_w]C^*_{w,t} + \lambda_g[(1+\iota^c_g)S_t + t^c_g]C^*_{g,t} + \lambda_b[(1+\iota^c_b)S_t + t^c_b]C^*_{b,t} + [(1+\iota^i_g)S_t + t^i_g]I^*_{g,t} + [(1+\iota^i_e)S_t + t^i_e]I^*_{e,t} + [(1+\iota^i_b)S_t + t^i_b]I^*_{b,t}$, and total exports revenue is given by: $\mathrm{EXP}_t = X_t/[(1+\iota^x_w)S_t]$.

[9] Additionally, I assume that the lump-sum corporate tax on banks is given by $T_{ls,t} = (\theta_t - 1)\mathrm{NW}_{t-1} + D_{t+1} - R_{d,t-1}D_t + R_{g,t}B_{g,t} - B_{g,t+1} + R_{b,t}B_{b,t} - B_{b,t+1} - \theta_t\Gamma^{\mathtt{capreq}}_t + \Phi_t$. In this way, one obtains a fairly standard aggregate resource constraint, as in the national accounts.

[10] Latvia's location in north-eastern Europe yields a humid continental or oceanic/maritime climate. Thus, winters can be cold and long, while summers are shorter and less hot than in Western and Southern Europe. Thus, temperature increases probably rather lead to positive effects for agriculture, tourism, and the population's sentiment than negative effects. Latvia has an extensive coast line and so negative effects from floods and storms can also be expected. However, the total direct (physical) effects of climate change might not be negative for Latvia.

assuming that there are no negative externalities from climate change or emissions, but including policies such as carbon taxes, emissions caps, and public green investment.

The annual data used for calibration of the model mostly spans the period 1995–2020 and mostly comes from Eurostat. For several time series the data is not available for the whole time period which implies using shorter series in these cases. All the details on the utilized data and all the parameter summary tables are supplied in Appendix B.

First, I discuss which parameters are borrowed from other papers. Table B.2 provides a summary of all borrowed parameters. The main source is Bušs and Grüning (2020) who develop and estimate a rich fiscal DSGE model for Latvia.

As in that paper, I set the consumption tax rate to $\tau_c = 0.21$ (corresponding to the effective rate of value-added and excise taxes), the labour tax rate for workers to $\tau_l^w = 0.225$ (corresponding to the effective rate of payroll taxes and social security contributions paid by employees), and the labour tax rate for firms to $\tau_l^e = 0.155$ (effective rate of social security contributions paid by employers). Bušs and Grüning (2020) set the import shares in consumption (investment) goods to 0.45 (0.65) and, thus, I set $\omega_{w,c} = \omega_{g,c} = \omega_{b,c} = 0.45$ ($\omega_{g,i} = \omega_{e,i} = \omega_{b,i} = 0.65$). They estimate the elasticities of substitution between domestic and foreign goods in consumption (investment) bundles to be 1.854 (1.059) and, therefore, I set $\eta_{w,c} = \eta_{g,c} = \eta_{b,c} = 1.854$ ($\eta_{g,i} = \eta_{e,i} = \eta_{b,i} = 1.059$).

Further following Bušs and Grüning (2020), I use their estimated habit parameter to set the workers' habit parameter to $h_w = 0.607$, set the working capital fraction to $\nu_f = 0.5$, and set the sensitivity of the risk premium to the foreign bonds to GDP ratio to $\tilde{\phi}_a = -0.01$. Moreover, the share of public investment expenditure in total public expenditure of standard tax revenue sources (i.e. consumption and labour taxes) is assumed to be $s_i = 0.117$, consistent with Latvian data.

The elasticity of substitution between green, domestic brown, and foreign brown goods is set as in Acemoglu et al. (2012) to $\epsilon = 3$.

Second, I compute a number of shares or ratios in the data to match as best as possible the corresponding steady-state ratios in the model by setting the appropriate parameters to certain values. Table B.3 provides a summary of these moments and parameters. For the actual fit with the data, see Table 1 further below which reports simulated moments.

In the data, the total private investment to GDP ratio is equal to just below 22%. In the model, this is closely matched by setting the capital depreciation rates to 10%, i.e. $\delta_g = \delta_e = \delta_b = 0.10$, as well as setting the capital shares to $\pi_2 = 0.21$, $\alpha_2 = 0.24$, and $\nu_1 = 0.70$ in green intermediate goods, brown intermediate goods, and renewable energy production, respectively. The labour share is assumed to be quite low in renewable energy production ($\nu_2 = 0.20$), but the most important input in the other sectors. Green intermediate goods production is assumed to be slightly less energy-intensive than brown intermediate goods production ($\pi_1 = 0.09$ vs. $\alpha_1 = 0.11$). The domestic green sector share[11] and the renewable energy share in the data are equal to roughly 34.5% and 35.5%, respectively. Setting the steady-state log brown energy price equal to the price of renewable energy in the steady state[12] and the weights of green (domestic brown, imported brown) intermediate goods in the final goods production function to $\omega_{y,g} = 0.35$ ($\omega^{\ell}_{y,b} = 0.55$, $\omega^{*}_{y,b} = 0.10$) allows the model to get close to these statistics. The shares in all intermediate goods production functions sum up to 0.9 to imply some non-zero steady-state profits for both types of entrepreneurs from firm ownership.

In the benchmark model, only the LIA constraints are active, while the DTI constraints are assumed to be not present. The different LIA ratios for green and brown loans ($\overline{\text{LIA}}_g = 0.75$ vs. $\overline{\text{LIA}}_b = 2.25$) are the key parameters to allow for a relatively low green loan share, as computed using data from Latvia's Credit Register.

Next, a number of parameters are set to match exactly key statistics in the data or set to conventional values in the literature, according to a standard procedure in the literature, or in ad-hoc way, if no good data guidance exists. Table B.4 provides a summary of these model parameters.

The steady-state real log exchange rate in the model is set to $\overline{s} = \ln(0.7382)$ in line with the purchasing power parity of Latvia for GDP relative to the EU-27 countries in 2020. The share of workers in the population is set to be $\lambda_w = 0.8844$ to account for the average manager share in Latvia's population of 11.56% over the period 2008–2020, while the shares of both green and brown entrepreneurs are 2.44% and 9.12%, respectively, to account for the relative size of employment in green sectors vs. brown sectors of 21.10%.

The time discount factor of workers is set to $\beta_w = 0.985$ and the time discount factors of entrepreneurs to $\beta_g = \beta_b = 0.98$. The spread between these discount factors contributes to a sizeable spread between the deposit interest rate and the loan interest rates. The habit parameters of entrepreneurs are set to lower values than for the workers, i.e. $h_g = h_b = 0.25$, since entrepreneurs are assumed to care less about smoothing consumption. The utility over consumption for all consumers is assumed to be logarithmic, i.e. $\gamma_w = \gamma_g = \gamma_b = 1$, a standard assumption in the macroeconomics literature. The labour elasticity is set to the standard value of $f = 0.7$. The total time endowment is assumed to be $\overline{L} = 3$ and the parameter a is pinned down by requiring that the workers work one third of their total time endowment in the steady state, which implies $a = 0.2920$.

Adjustment cost parameters for private and public investments are set to $\phi_{g,i} = \phi_{e,i} =$

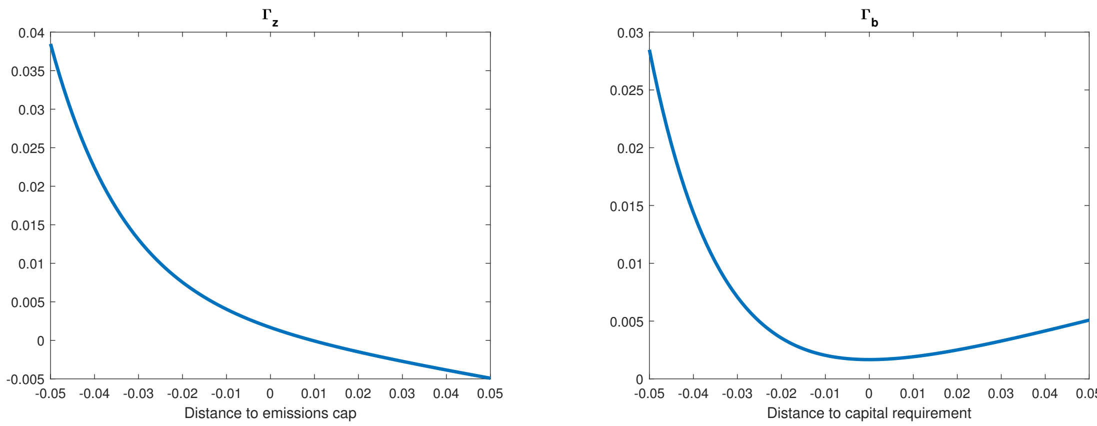
[11] The domestic green and brown sectors are constructed by first computing average emission intensities across the 44 sectors at the NACE 2 level of aggregation in Eurostat data and then taking the 11 sectors with the highest average emission intensities to aggregate them to the domestic brown sector and the 11 sectors with the lowest average emission intensities to aggregate them to the domestic green sector (in terms of real output produced). See Table B.1 for details on the NACE activities included in the green and brown sector, respectively.

[12] Evidence that renewable energy production is hardly more expensive than brown energy production is provided by Lazard (2019).

$\phi_{b,i} = 0.05$ to contribute to the high observed log private investment growth volatility and the adjustment costs parameter for deposits is set to $\phi_d = 1$ to imply sufficient hurdles for banks to quickly attract deposits. The steady-state unrestricted emissions quantity is found to be $Z^{nocap} = 0.8649$ by setting $\phi_1 = \phi_2 = 0$ and all other parameters to the same values as in the benchmark calibration. I assume that the current account is balanced in the model and let $\overline{x} = \ln(0.6271)$ be pinned down by requiring that the steady-state amount of net-foreign assets is $\overline{A} = 0$. To ensure that the banks' incentive compatibility constraint is binding, I set Ψ to a high value of 0.67 and the steady-state bank survival probability $\overline{\theta}$ to 0.9. The banks' start-up fund size is assumed to be 12.9% of steady-state bank net worth: $\tau = 0.129$.

Regarding fiscal, environmental, and bank regulation policies, the emissions cap is set at 100% of the unrestricted amount of brown energy imports, i.e. $\overline{\phi} = 1$; there are no carbon taxes domestically and abroad, i.e. $\overline{\tau}_z = \overline{\tau}_b^* = 0$; and the risk weights and absconding rates are equal for both green and brown loans, i.e. $\overline{\upsilon}_g = \overline{\kappa}_g = \overline{\upsilon}_b = \overline{\kappa}_b = 0.75$.

Figure 2: Emissions cap violation and capital requirement cost functions



Notes: The left panel depicts the emissions cap violation cost function $\Gamma_{z,t}$ as a function of the distance of the actual amount of emissions to the emissions cap $(\phi_t Z^{nocap} - Z_{t-1})$. The right panel depicts the capital requirement cost function $\Gamma_t^{\texttt{capreq}}$ as a function of the distance of the actual capital adequacy ratio to the regulatory capital adequacy ratio $(\text{NW}_t - \text{capreq} \cdot \text{RWA}_{t+1})$.

The regulatory capital adequacy ratio is set to $\texttt{capreq} = 0.135$ to act as a target capital adequacy ratio rather than just a simple regulatory minimum capital adequacy ratio. Thus, it is set much higher than the minimum ratio of bank regulation policy (for example, 8%). The bank capital requirement and the emissions cap violation cost functions are parametrized to feature substantial asymmetry, while at the same time being low enough to allow for a decent fit to macroeconomic volatilities.[13] Figure 2 depicts these costs functions. Latvia's share of EU ETS revenues as a share of Latvia's GDP was 0.09% in 2019 which is nicely matched by the model (see Table 1 below), lending

[13]The parameter choices are $\gamma_0 = 60$, $\gamma_1 = 0.1$, $\gamma_2 = 0.1$ and $\phi_0 = 60$, $\phi_1 = 0.1$, $\phi_2 = 0.1$, respectively.

further support for the parametrization of the emissions cap violation cost function.

The steady-state share of EU funds in domestic output that contribute to public investment in the domestic economy is set to $s_{EU} = 0.0342$ in line with data on European Structural and Investment Funds for the EU budgeting period 2014–2020. Classifying projects in the areas "Low-Carbon Economy", "Climate Change Adaptation & Risk Prevention", "Environment Protection & Resource Efficiency", and "Network Infrastructures in Transport and Energy" as green EU investment and computing the share of EU financing in these ares to total EU financing implies a share of $\overline{s}_g^{EU} = 0.4485$. A much larger fraction from environmental taxes and fees than from the general consumption and labour tax revenue is channelled to public investment, to be precise exactly three times more since $1 - s_b = 0.351$ which is three times s_i. This is reasonable to assume as environmental taxes and fees are more likely to be used to finance green transition projects than revenues from general taxation. The steady-state domestic green public investment share is set to the steady state green sector share in the model and, thus, it is given by $\overline{s}_g = 0.3156$. The minimum amount of iceberg transport costs for foreign brown goods is $\iota_{b,1}^* = 0.04$, while there is a significant sensitivity to the ratio of imported brown goods to total brown goods, i.e. $\iota_{b,2}^* = 0.06$, making it increasingly more costly to import foreign brown goods, relative to producing them domestically. These iceberg transport costs are assumed to be substantial to avoid that the economy switches to fully or largely importing brown goods, when confronted with an increase in the domestic carbon tax. For all other import goods, it is assumed that iceberg transport costs amount to 4%, in line with the evidence by Obstfeld and Rogoff (2001). For all imported goods, unit transport costs are assumed to be 6%, in line with the evidence portrayed in Irarrazabal et al. (2015) that the median additive trade costs are equal to 6%. The dummy parameter $\mathbb{1}_{b,env}^{tax}$ is set to 0 so that environmental tax revenues are exclusively used for green public investment.

Finally, Table B.5 reports the persistence levels and standard deviations of the model's exogenous shocks. Several shocks are muted since they are directly related to economic policies in the benchmark calibration.[14] Specifically, the emissions cap stringency shock, the risk weight shocks, the absconding rate shocks, the carbon tax rate shocks, the (domestic and EU) public green investment share shocks, and the LIA ratio shocks are muted. The largest active shocks are the labour productivity shocks in all three sectors, i.e. $\sigma_g = \sigma_b = \sigma_e = 0.02$, and the brown energy price shock ($\sigma_z = 0.02$). Next in line are the brown capital quality shock with an assumed volatility of $\sigma_k = 0.01$ and the bank survival probability shock with $\sigma_\theta = 0.005$. A number of small open economy shocks are also active with moderate volatilities, i.e. $\sigma_x = 0.004$ (foreign demand shock), $\sigma_{EU} = 0.0025$ (EU funds shock), $\sigma_s = 0.002$ (exchange rate shock), and $\sigma_r = 0.002$ (risk premium shock). The persistence levels of all shocks are set to the relatively standard

[14]They are, however, turned on when computing the benchmark model's impulse response functions.

value of 0.85.

Table 1: Simulated model moments and data counterparts

Moment	Description	Model	Data
$\mathbb{E}\left[\frac{E_t}{E_t+Z_t}\right]$	Renewable energy share	27.02	35.41
$\mathbb{E}\left[\frac{Y_{g,t}}{Y_{g,t}+Y^{\ell}_{b,t}+Y^{*}_{b,t}}\right]$	Green sector share	31.56	34.66
$\mathbb{E}\left[\omega_{g,t}=\frac{B_{g,t}}{B_{g,t}+B_{b,t}}\right]$	Green loan share	18.88	12.09
$\mathbb{E}\left[\frac{\Gamma_{z,t}}{Y_t}\right]$	Emissions cap violation costs to GDP ratio	0.10	0.09
$\mathbb{E}\left[\frac{\Gamma_{z,t}+\tau_z Z_t}{T_{aggr,t}}\right]$	Environmental tax revenue share	0.40	8.84
$\mathbb{E}\left[\frac{I_{aggr,t}}{Y_t}\right]$	Aggregate private investment to GDP ratio	19.97	21.84
$\mathbb{E}\left[\frac{\text{IMP}_t}{Y_t}\right]$	Imports to GDP ratio	52.30	56.10
$\mathbb{E}\left[\frac{\text{EXP}_t}{Y_t}\right]$	Exports to GDP ratio	49.97	48.56
$\mathbb{E}\left[\frac{B_{g,t}+B_{b,t}}{Y_t}\right]$	Total loans to GDP ratio	28.83	106.22
$\mathbb{E}\left[\frac{\text{NW}_t}{\text{RWA}_{t+1}}\right]$	Capital adequacy ratio (risk-weighted)	15.49	20.32
$\mathbb{E}\left[\frac{\text{NW}_t}{B_{g,t}+B_{b,t}}\right]$	Capital adequacy ratio (unweighted)	11.62	11.29
$\mathbb{E}[r_{d,t}]$	Deposit interest rate	1.45	1.51
$\mathbb{E}[\omega_{g,t}r_{g,t}+(1-\omega_{g,t})r_{b,t}]$	Average loan interest rate	2.47	2.68
$\mathbb{E}[r_{g,t}]$	Green loan interest rate	2.38	1.07
$\mathbb{E}[r_{b,t}]$	Brown loan interest rate	2.49	3.18
$\sigma(\Delta y_t)$	GDP growth rate volatility	5.31	5.72
$\sigma(\Delta i_{aggr,t})$	Aggregate private investment growth rate volatility	9.43	16.67
$\sigma(\Delta c_{aggr,t})$	Aggregate private consumption growth rate volatility	13.51	6.35
$\sigma(\Delta g_{c,t})$	Public consumption growth rate volatility	8.36	5.98
$\sigma(\Delta e_t)$	Renewable energy growth rate volatility	2.02	6.01
$\sigma(\Delta y_{g,t})$	Green output growth rate volatility	6.13	7.88
$\sigma(\Delta y_{b,t})$	Brown output growth rate volatility	5.19	8.07
$\sigma(\Delta i_{g,t})$	Private green investment growth rate volatility	18.37	21.44
$\sigma(\Delta i_{b,t})$	Private brown investment growth rate volatility	10.01	8.63
$\sigma(\text{NX}_t/Y_t)$	Net exports to GDP ratio volatility	2.86	5.33

Notes: This table reports the simulated model moments and the corresponding data counterparts (see Appendix B for the data details) for a variety of macroeconomic variables. The model moments have been obtained from a stochastic simulation of the model for 2500 periods (years) using a first-order perturbation approximation in `dynare` (version 4.5.4). All moments are reported in percentage points.

To check how well the model reproduces the targeted data moments and some other moments, I simulate the model for 2500 years. Table 1 reports the simulated moments of this exercise and the corresponding empirical counterparts.

The targeted ratios (renewable energy share, green sector share, green loan share, emissions cap violation costs to GDP ratio, aggregate private investment share, imports and exports to GDP ratios) are all relatively well reproduced by the model. Notably, the share of environmental tax revenue in total tax revenue falls considerably short of the counterpart in the data. This can be mostly reconciled by noticing that certain consumption excise duties such as gasoline taxes are counted as environmental tax revenues in the data.[15] However, in the model only the domestic carbon tax and the emissions cap violation costs are counted as environmental taxes.

The risk-weighted capital adequacy ratio is at 15.49% above the target ratio of 13.5%, but roughly consistent with the long-run average in the data. The unweighted capital adequacy ratio is very slightly higher in the model than in the long-run data counterpart (11.62% vs. 11.29%). The deposit interest rate is in line with the data between 2004 and 2020. The average interest rate on loans in the model matches nicely the data from Latvia's Credit Register for total loans between 2018 and 2021. The green loan interest rate in this data is quite low at 1.07% and the brown loan interest rate is significantly higher than the average loan interest rate at a value of 3.18%, whereas in the model there is no significant variation across the rates due to sector-unspecific bank regulation policy.[16]

Aggregate log output volatility in the model is at about the same size as in the data. The log aggregate private consumption growth rate volatility is substantially too high in the model, whereas log public consumption growth rate volatility is about the same size in the model as in the data. Log aggregate private investment growth volatility is a lot higher than log output volatility but still does not reach the empirically observed excessively high volatility. Sector-specific output growth and investment growth volatilities are well in line with the data; however, renewable energy growth rates do not exhibit as much volatility as in the data. There is also substantial variation in the net exports to GDP ratio in the model, but it reaches only about half the variation in the real world.

5 Results and Analysis

This section presents and analyzes the calibrated model results. First, Section 5.1 contains a short-run analysis using impulse response functions from all economic shocks. Next, Section 5.2 discusses a long-run analysis by investigating the effects of permanent changes to economic policies in the model. Finally, Section 5.3 investigates the transition period dynamics for two environmental policies.

5.1 Short-run analysis (impulse response functions)

Impulse response functions are used to evaluate the dynamic short-run effects of all 21 economic shocks in the model. The description of the shocks and shock sizes as well as the full set of impulse response functions are relegated to Appendix C. In order

[15] The total amount of excise duty in Latvia's tax revenues was an impressive 11.8% in 2020, according to Tax Policy Strategy Division, Tax Analysis Department (2022), which probably already accounts for a large part of the gap between the model and the data.

[16] These rates are constructed by using value weights across the different NACE activities that form the green and brown sectors.

to conserve space, only a high-level summary of the results from the impulse response function analysis is provided in this section. Table 2 provides this summary.

Table 2: Impulse response function analysis summary

Shock	**Aggregate economy**	**Green economy**	**Brown economy**	**Domestic emissions**
Green labour productivity ($\varepsilon_{g,t}$)	+−	+	−	−
Brown labour productivity ($\varepsilon_{b,t}$)	+−	−	+	+
Renewable energy labour productivity ($\varepsilon_{e,t}$)	+−	+	−	−
Brown capital quality ($\varepsilon_{k,t}$)	+−	+−	+	+
Bank survival probability ($\varepsilon_{\theta,t}$)	+−	+−	+−	+−
Foreign demand ($\varepsilon_{x,t}$)	−+	−+	−+	−+
Exchange rate ($\varepsilon_{s,t}$)	+−	+−	+−	+−
Domestic risk premium ($\varepsilon_{r,t}$)	−+	−+	−+	−+
Brown energy price ($\varepsilon_{z,t}$)	+−	+−	+−	−
Domestic carbon tax rate ($\varepsilon_{\tau_z,t}$)	+	+	+−	−
Foreign carbon tax rate ($\varepsilon_{\tau_b^*,t}$)	−+	−+	−+	−+
Emissions cap ($\varepsilon_{\phi,t}$)	−+	+	−	−
EU funds ($\varepsilon_{EU,t}$)	+	+	+	+
Domestic green public investment share ($\varepsilon_{g,t}^{p}$)	+	+	−	−
EU green public investment share ($\varepsilon_{g,t}^{EU}$)	+	+	−	−
Green loan risk weight ($\varepsilon_{\upsilon_g,t}$)	+−	+−	−	−
Brown loan risk weight ($\varepsilon_{\upsilon_b,t}$)	−+	−+	−+	−+
Green loan absconding rate ($\varepsilon_{\kappa_g,t}$)	+−	+−	+−	+−
Brown loan absconding rate ($\varepsilon_{\kappa_b,t}$)	−+	−+	−+	−+
Green LIA ratio ($\varepsilon_{g,t}^{\mathrm{LIA}}$)	−+	−+	−+	−+
Brown LIA ratio ($\varepsilon_{b,t}^{\mathrm{LIA}}$)	−+	−+	−+	−+

Notes: This table summarizes the short-run effects of all 21 economic shocks in the model over a period of 30 years using impulse response functions on the aggregate economy (evaluated by looking at aggregate output Y_t), on the green economy (evaluated by looking at green intermediate goods output $Y_{g,t}$), on the brown economy (evaluated by looking at domestic brown intermediate goods output $Y_{b,t}^{\ell}$), and on domestic emissions (evaluated by looking at brown energy imports Z_t). The positive (negative) sign indicates that the response is positive (negative). If there are two signs, the first sign indicates the initial or extremely short-run reaction, while the second sign indicates the reaction over the longer run.

Shocks to labour productivity As the main technology shocks, the model features shocks to labour productivity in all three domestic production sectors. The positive shock to green labour productivity (see Figure C.1 for details) naturally leads to an expansion in green intermediate goods production which somewhat spills over to increased production volumes of renewable energy. Brown intermediate goods production decreases over the whole horizon, while there is an initial positive reaction of brown energy imports that turns negative after year 2. On the aggregate level, final goods output increases first significantly, then decreases, and eventually quickly converges to around 0. Aggregate private consumption follows the same pattern as final goods output. The technology shock leads to a short-lived investment boom in all sectors, but it only increases persistently in the brown sector, as the brown sector tries to catch up with the increased productivity of the green sector. The positive shock to brown labour productivity (Figure C.2) leads to more or less to similar reactions on the aggregate level, but at the sectoral level to opposite reactions, as compared to the previous shock. Thus, brown intermediate goods production increases throughout the horizon, whereas the green intermediate goods and renewable energy producers cut production volumes. As the final labour productivity shock, Figure C.3 depicts the impulse response functions of a positive shock to renewable energy labour productivity. The shock delivers similar consequences for the four dimensions mentioned in Table 2 as the green labour productivity shock, albeit at lower magnitudes, while also naturally providing for a persistent increase in renewable energy production.

Other macroeconomic and financial shocks A positive shock to brown capital quality (Figure C.4) leads to short-lived production booms in all three sectors, while investment in the two green sectors (in the brown sector) decreases (increases) strongly. Hence, the brown intermediate goods sector also experiences a longer-term expansion after a short period of decline in the years 2–5. The renewable energy production declines significantly over the long run. Final goods output experiences dynamics similar to the brown sector due to the dominant size of this sector. Aggregate consumption increases a lot in the first period, but decreases strongly in the next period, before converging relatively quickly to zero. Emissions exhibit an inconclusive behaviour. A negative shock to the bank survival probability (Figure C.5) leads to a fall in the capital adequacy ratio and small negative effects in the medium run (while one observes expansions in the first period in all production sectors) due to the depression of investment incentives in the green sectors. An increase in foreign demand (Figure C.6) makes the whole economy benefit, after an initial decline to finance additional investment in the green sectors. Brown investment sees a persistent decline, which is compensated for by increased brown public investment. Aggregate consumption, output, and investment experience expansions from year 2 to 10. However, also brown energy imports rise considerably during these years which is bad news for the environmental balance. The exchange rate shock (Figure C.7) that leads to higher costs for imports leads to the more or less exact opposite effects. As the next macroeconomic foreign shock, a domestic risk premium shock is considered (Figure C.8). Most directly, it makes the wage bills more expensive due to the working capital friction. This implies production volumes declines in all sectors initially, which are, however, reversed quickly due to increasing investment levels in the green sectors (at the expense of brown investment levels). The effects on the environment or brown energy imports remain negligible. As the final macroeconomic shock, an increase in fossil fuel prices, akin to the current energy price dynamics observed in most of Europe, is proxied by an increase in the price of brown energy in Figure C.9. As expected, negative effects materialize, especially in the brown intermediate goods sector, which cannot be compensated for by increased brown private investment. The small good news is that brown energy imports fall due to the higher price, which is good news for the environment.

Environmental policy shocks Due to the redistribution of carbon tax revenues to green public investment, a shock to the domestic carbon tax rate (Figure C.10) is expansionary, which is especially visible in large positive effects on green intermediate goods output and renewable energy production. These positive effects spill over to the brown sector, which experiences an expansion until around year 6 as well before turning negative. Thus, final goods output increases over the whole impulse response function horizon. However, aggregate private consumption declines considerably initially due to the increased size of public consumption. There is an investment boom in the green sectors, but not on aggregate due to the decline in brown private investment. Brown energy imports fall due to the higher price. A shock to the foreign carbon tax rate (Figure C.11) implies a redistribution from importing brown intermediate goods to producing them domestically. Also, production levels in the green sector increase. This only happens from year 2 onward due to the lag in building capital and, thus, the first year is characterized by a recession caused by higher prices for final goods production. Overall, the positive effects are much smaller and the (negative) effect on brown energy much more short-lived (turning positive after year 2 actually), due to this environmental policy mainly increasing costs to the domestic economy, while not providing for any benefits, such as increased public investment with the domestic carbon tax rate shock. The emissions cap shock (Figure C.12) is very effective in reducing emissions, while at the same time stimulating the green sectors due to public redistribution in the form of increased green public investment. Therefore, the long-run growth prospects are as good here as in the case of a domestic carbon tax rate increase. However, there is some very short-term pain in the initial period where GDP declines.

Fiscal policy shocks An increase in public funds available for public investment expenditure is simulated via a positive shock to EU funds in Figure C.13. Both green and brown public investments increase in response to the shock. The green intermediate goods and renewable energy sectors can manage to sustain a pronounced increase in their production volumes, while the brown intermediate goods sector experiences an initial decline in production volumes and brown energy imports as well as a less persistent production expansion afterward. Therefore, an increase in public funds is good news for the environment. Final goods output and aggregate consumption increase in the long run and decrease only initially. Both shocks that simulate an increase in the share of public resources directed to green public investment (domestic funds in Figure C.14 and EU funds in Figure C.15) lead to a short-term aggregate gain in final goods output and aggregate consumption due to the expansion in the green sectors. However, increased public investment in the green sector crowds out private green and renewable energy investment which is redirected to brown price investment and there is a decline in aggregate economic activity in the years 2–5. Thus, brown intermediate goods production does not decline as much and green production output does not increase as much as they could have without the crowding-out effect. Nevertheless, the environment benefits by experiencing a decrease in domestic emissions in the longer run.

Bank regulation and financial friction shocks Both the decrease in the green loan risk weight (Figure C.16) and the increase in the brown loan risk weight (Figure C.17) lead to benefits in all production sectors and a small expansion in final goods output, while the increase in the brown loan risk weight is more successful to lead to a persistent increase in green and aggregate economic activity. The effect on emissions is in both cases rather inconclusive. Similar dynamics are observed for shocks to the absconding rates (Figures C.18 and C.19). Positive shocks to both LIA ratios also lead to similar dynamics (see Figures C.20 and C.21). These shocks lead to more loans taken out by green and brown entrepreneurs, respectively. This, in turn, leads to larger investments in private green and renewable energy capital, which generates a boom in the green sectors from year 2 onward. Brown intermediate goods output also increases, which is due to increased brown public investment, financed by larger consumption tax revenues due to increased private aggregate consumption. The effects on brown energy imports remain again rather inconclusive.

5.2 Long-run analysis (scenarios)

The idea behind the long-run analysis is to investigate the effects of permanent changes in economic policies on several macroeconomic quantities. Technically, these permanent changes are assessed by comparing the steady states of the benchmark model to an alternative calibration (that incorporates 1–3 parameters changes relative to the benchmark calibration). The results of this scenario analysis are reported in Tables 3 and 4 as well as Figures 3 and 4 (Tornado charts). For many scenarios the parameter changes are normalized to induce a 17% reduction in emissions, in line with the indication mentioned on page 6 in Treasury of the Republic of Latvia (2021) that Latvia might have to achieve an emissions reduction (in the non-ETS sectors), relative to 2005 levels, of 17% by 2030 to reach its EU climate change target.[17] For the scenarios where such a reduction is technically not feasible, I impose a reasonable policy change to assess how large the emissions reduction can be from such a policy change.

5.2.1 Environmental policies

In this section, the following 6 scenarios are discussed: an increase in the domestic carbon tax rate from 0 to 11.68% (Scenario [1]); an increase in the price of imported brown energy by about 106% from 0.1507 to 0.3101 (Scenario [2]); an increase in the foreign carbon tax rate from 0 to 11.68% (Scenario [3]); a decrease in the emissions cap from 100% to 82.66% (Scenario [4]); a joint increase of domestic and foreign carbon tax rates from 0 to 11.68% (Scenario [7]); finally, Scenario [8] combines half of the increase in the domestic carbon tax rate of Scenario [1] and half of the decrease in the emissions cap of Scenario [4], i.e. setting $\overline{\tau}_z = 0.0584$, $\overline{\phi} = 0.9133$.

Firstly, the increase in the domestic carbon tax rate (Scenario [1]) is quite efficient in reaching the 17% emissions reduction target, while keeping economic costs at a minimum. This is due to the revenues of the domestic carbon tax being used for public green investment and wasteful public spending exclusively, while none of these revenues are diverted to public brown investment. Therefore, final goods output only decreases by a negligible -0.07%, which is due to a large increase in excess of $+10\%$ in green intermediate goods production that essentially compensates for the reduction in brown intermediate goods production (-5.06%) and foreign brown intermediate goods imports (-4.74%). Quite large is the increase in public green investment of 60.44% and in the renewable energy share from around 27% to about 36%. Thus, if public funds from environmental tax resources are used wisely, the green transition need not be recessionary. However, the decrease in aggregate consumption is substantial at -6.34%, which shows up in aggregate welfare figures as well.[18] One should keep in mind though that this result in the model is due to a quite efficient government that can identify very well efficient public green projects and finance them in a frictionless way.

Secondly, an increase in the price of fossil fuels or brown energy (Scenario [2]) also has the potential to reduce emissions by the targeted -17%. However, the transition will

[17] In several studies, such exogenous emissions reduction targets are used to study the effects on macroeconomic and financial variables. Diluiso et al. (2021) use a 24% reduction target for the period 2020–2030 in line with the current targets by the European Commission for the EU, Schuldt and Lessmann (2021) use the 55% reduction target of the EU by 2030 (relative to 1990 levels), and Varga et al. (2021) a 94% reduction target by 2050 in line with the EU-wide net zero emissions target. On the contrary, Benkhodja et al. (2022) simulate a 1 percentage point increase in the carbon tax rate and fiscal policy shocks worth around 1% of quarterly French GDP, while Carrattini et al. (2021) and Bartocci et al. (2022) simulate a carbon tax increase of \$30.5 and \$75, respectively, per ton of carbon.

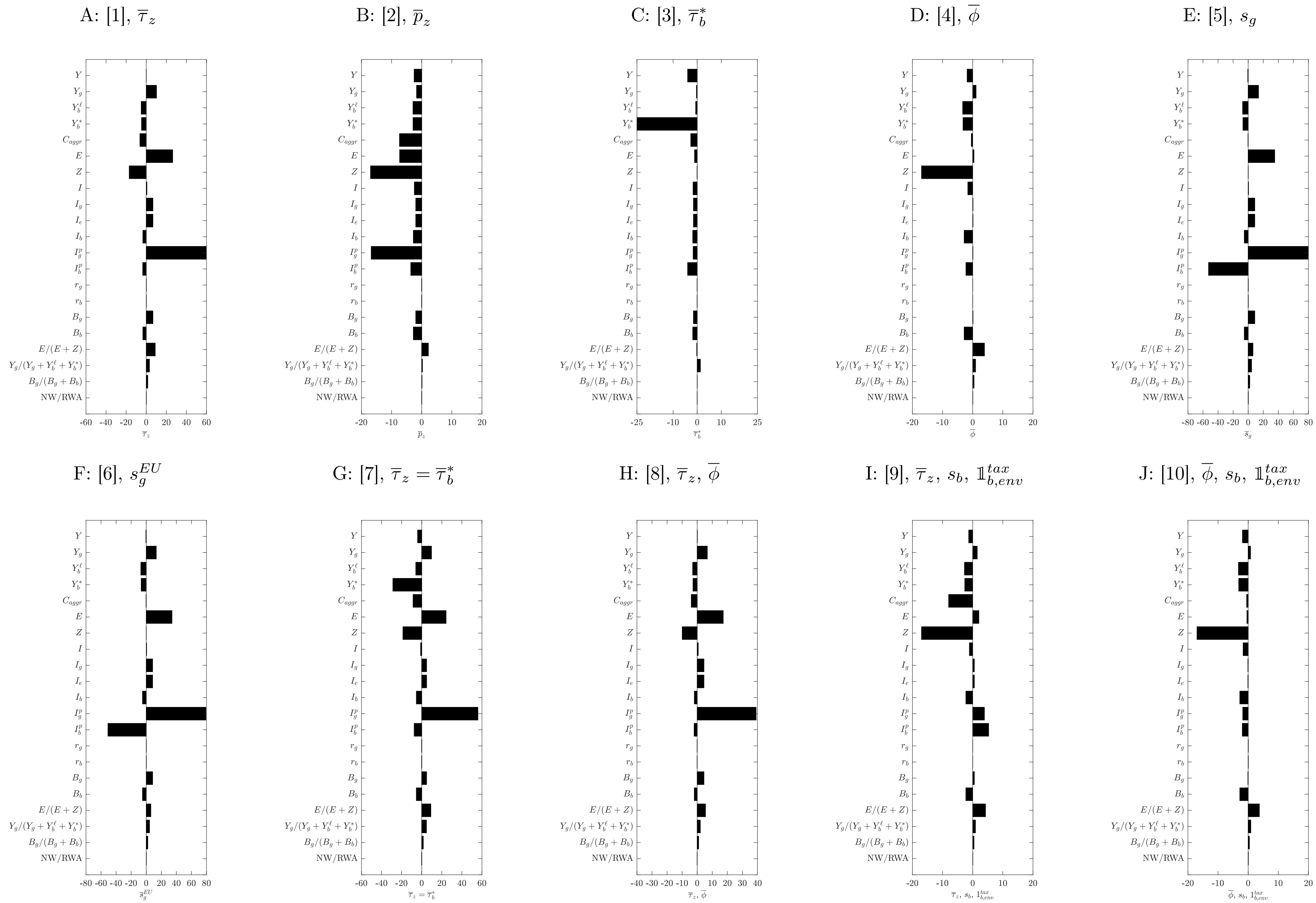
[18] A decrease in aggregate welfare from -35.68 to -38.59 is observed, which mostly originates from a decrease in welfare of the brown entrepreneurs (from -6.55 to -40.77), while the green entrepreneurs experience an increase in welfare from 42.23 to 45.48.

Table 3: Scenario analysis results, part I

	Bench	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Parameter 1	—	$\overline{\tau}_z = 0.117$	$e^{\overline{p}_z} = 0.310$	$\overline{\tau}_b^* = 0.117$	$\overline{\phi} = 0.827$	$\overline{s}_g = 1$	$\overline{s}_g^{EU} = 1$	$\overline{\tau}_z = 0.117$	$\overline{\tau}_z = 0.058$	$\overline{\tau}_z = 0.118$	$\overline{\phi} = 0.827$
Parameter 2	—	—	—	—	—	—	—	$\overline{\tau}_b^* = 0.117$	$\overline{\phi} = 0.913$	$s_b = 0.883$	$s_b = 0.883$
Parameter 3	—	—	—	—	—	—	—	—	—	$\mathbb{1}_{b,env}^{tax} = 1$	$\mathbb{1}_{b,env}^{tax} = 1$
Y	1.6350	−0.07%	−2.53%	−3.99%	−1.86%	−0.58%	−0.55%	−4.17%	0.15%	−1.34%	−1.91%
Y_g	0.5187	10.27%	−1.73%	−0.34%	1.13%	13.83%	13.41%	9.78%	6.74%	1.53%	0.81%
Y_b^ℓ	0.8657	−5.06%	−2.92%	−0.65%	−3.33%	−7.46%	−7.21%	−5.97%	−3.06%	−2.75%	−3.24%
Y_b^*	0.2592	−4.74%	−2.90%	−24.98%	−3.23%	−7.03%	−6.79%	−28.76%	−2.84%	−2.65%	−3.15%
C_{aggr}	0.8208	−6.34%	−7.40%	−2.69%	−0.47%	−0.34%	−0.31%	−8.66%	−3.96%	−7.99%	−0.53%
E	0.3202	26.38%	−7.34%	−1.12%	0.43%	35.30%	34.20%	24.31%	17.33%	2.07%	−0.44%
Z	0.8650	−17.00%	−17.00%	−0.04%	−17.00%	−0.12%	−0.11%	−18.75%	−9.97%	−17.00%	−17.00%
I_{aggr}	0.3263	0.74%	−2.47%	−1.74%	−1.62%	0.54%	0.55%	−1.14%	0.70%	−1.11%	−1.69%
I_g	0.1032	6.70%	−2.00%	−1.57%	0.13%	8.81%	8.55%	4.94%	4.51%	0.56%	−0.11%
I_e	0.0310	6.70%	−2.00%	−1.57%	0.13%	8.81%	8.55%	4.95%	4.51%	0.56%	−0.11%
I_b	0.1921	−3.43%	−2.80%	−1.87%	−2.85%	−5.23%	−5.05%	−5.38%	−1.95%	−2.28%	−2.80%
I_g^p	0.0413	60.44%	−16.78%	−1.70%	0.10%	81.84%	79.17%	55.99%	39.16%	3.90%	−1.81%
I_b^p	0.0648	−3.52%	−3.65%	−4.00%	−2.25%	−52.68%	−50.92%	−7.56%	−2.08%	5.32%	−1.96%
r_g	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
r_b	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
B_g	0.0890	6.70%	−2.00%	−1.57%	0.13%	8.81%	8.55%	4.93%	4.51%	0.56%	−0.11%
B_b	0.3821	−3.43%	−2.80%	−1.87%	−2.85%	−5.23%	−5.04%	−5.40%	−1.96%	−2.28%	−2.80%
$E/(E+Z)$	27.01	36.04	29.24	26.80	30.93	33.40	33.21	36.16	32.54	31.28	30.75
$Y_g/(Y_g+Y_b^\ell+Y_b^*)$	18.89	20.47	19.02	18.94	19.36	21.10	21.03	20.53	19.89	19.33	19.31
$B_g/(B_g+B_b)$	50.67	54.97	50.94	51.31	51.08	55.29	51.38	51.23	54.75	55.45	51.78
NW/RWA	15.27	15.30	15.32	15.31	15.31	15.32	15.32	15.34	15.29	15.30	15.29

Notes: This table reports the results of the effects of certain climate change policies (including combinations of different policies) on several variables of interest by comparing the steady states across different model calibrations. The loan interest rates r_g, r_b and the ratios $E/(E+Z), Y_g/(Y_g+Y_b^\ell+Y_b^*), B_g/(B_g+B_b)$, NW/RWA are reported in percentage points across all columns, all other quantities are reported in percentage deviations relative to the benchmark model. The second column reports the levels for all quantities of the benchmark model. From the third column onward, the results from the first set of scenarios are reported (Scenarios 1–10). Unless otherwise reported below, the parameter changes in all scenarios are calibrated to induce a reduction in emissions of 17% relative to the benchmark calibration. Scenario [1] ($\overline{\tau}_z$) entails an increase in the domestic carbon tax rate; Scenario [2] ($\overline{p}_z$) simulates an increase in the price of the brown energy good; Scenario [3] ($\overline{\tau}_b^*$) investigates the effects of an increase in the foreign carbon tax rate to the same rate as found in Scenario [1] for the domestic carbon tax rate; Scenario [4] ($\overline{\phi}$) entails reducing the emissions cap parameter; Scenario [5] ($\overline{s}_g$) simulates an increase in the domestic green public investment expenditure share to 1; similarly, Scenario [6] ($\overline{s}_g^{EU}$) simulates an increase in the EU green public investment expenditure share to 1; Scenario [7] ($\overline{\tau}_z = \overline{\tau}_b^*$) entails setting both the domestic and the foreign carbon tax rate to the same rate as found in Scenario [1]; Scenario [8] ($\overline{\tau}_z, \overline{\phi}$) simulates increasing the domestic carbon tax rate and decreasing the emissions cap target to half the values founds in Scenarios [1] and [4], respectively; Scenario [9] ($\overline{\tau}_z$, s_b, $\mathbb{1}_{b,env}^{tax}$) entails increasing the domestic carbon tax rate while distributing environmental tax revenues in the same way as revenues from standard tax sources; finally, Scenario [10] ($\overline{\phi}$, s_b, $\mathbb{1}_{b,env}^{tax}$) simulates lowering the emissions cap while distributing environmental tax revenues in the same way as revenues from standard tax sources.

Figure 3: Scenario analysis results, part I



Notes: This figure depicts Tornado charts for the first set of scenarios (Scenarios 1–10). The percentage differences between the alternative calibration and the benchmark model are depicted for all quantities with the exception of the loan interest rates $\overline{r}_g$, $\overline{r}_b$ and the ratios $\overline{E}/(\overline{E}+\overline{Z})$, $\overline{Y}_g/(\overline{Y}_g+\overline{Y}^\ell_b+\overline{Y}^*_b)$, $\overline{B}_g/(\overline{B}_g+\overline{B}_b)$, $\overline{\text{NW}}/\overline{\text{RWA}}$ for which absolute deviations in percentage points are depicted.

be quite painful as this is an exogenous shock that the domestic economy can only partly adapt to. It increases, first and foremost, the costs of important raw materials in the production processes, and results in a GDP loss of roughly −2.5% and thus a substantial welfare loss. It could be argued that such a shock in the model represents well the current dynamics on world fossil fuel markets after the start of Russia's war against Ukraine. This analysis also shows that countries with smaller dependence on fossil fuels would suffer less from such a shock. The good news of this analysis is that, even though there is a lot of economic pain involved, higher fossil fuel prices incentivize the domestic model economy to become 'greener', noticeable in the increase of the renewable energy share by more than 2 percentage points (pp) and the smaller output loss in green intermediate goods production (−1.73%), vis-à-vis brown intermediate goods production (−2.92%) and imports of foreign brown intermediate goods (−2.90%).

Thirdly, an increase in the foreign carbon tax rate at the same rate as the domestic carbon tax rate in Scenario [3] does not lead to a significant emissions reduction (the effect on the steady state of Z_t is only −0.04%), but leads to one of the largest output loss across all scenarios considered of −3.99%. The large reduction in imports of brown intermediate goods of around −25% does not spill over enough to a reduction in domestic brown intermediate goods production (−0.65%), as green intermediate goods and renewable energy production cannot hold their original production levels as well (−0.34% and −1.12%, respectively) to achieve significant reductions in emissions. There is even a reduction of −0.2pp in the renewable energy share observed. Interestingly, combining the domestic carbon tax increase with the foreign carbon tax rate increase (choosing the same rates of 11.68%) in Scenario [7] implies an interesting interaction effect as carbon emissions are now reduced at −18.75%. The large output loss of −4.17% is only 0.18pp higher than in Scenario [3] but a quite sizeable additional emissions reduction of 1.75pp is generated by the harmonized introduction of carbon taxes in the domestic economy and abroad. This can be explained by the effect of raising prices for brown products both domestically and abroad to strengthen the relocation from domestic brown intermediate goods production to green intermediate goods production. Green production increases a lot more than in Scenario [1] (+13.41% instead of +10.27%) and brown production decreases considerably more (−7.21% instead of −5.06%). Therefore, harmonized policy introduction seems to be very important to achieve significant emissions reductions as the key take-away of this analysis.

Fourthly, the emissions cap can be reduced to 82.66% to achieve the desired emissions reduction of 17% in Scenario [4]. This proves to be more painful than domestic carbon taxation but less painful than an exogenous increase of world brown energy prices in terms of output loss (−1.86%). Interestingly, aggregate consumption does not fall much in this scenario (−0.47%). Therefore, aggregate welfare is not harmed as much as in

Scenarios [1] or [2].[19] The reason for the lower reduction in consumption is the lower aggregate investment need (which decreases in this scenario by −1.62% but increases in Scenario [1] by +0.74%). The adjustment to produce greener in the domestic economy is thus mostly achieved by adjusting labour shares across the different sectors instead of adjusting capital shares. If one combines half the domestic carbon tax increase of Scenario [1] and half the just discussed emissions cap decrease in Scenario [8], the economy only manages to reduce emissions by roughly 10%, but at a net economic gain (GDP is up by +0.15%). Aggregate private consumption, however, still decreases significantly by almost −4%.

5.2.2 Fiscal policies

Next, I turn to analyze scenarios that pertain to changing fiscal policies to achieve emissions reductions. I discuss the following 3 scenarios in this section: an increase in the domestic green public investment share from 0.3156 to 1 (Scenario [5]); an increase in the EU green public investment share from 0.4485 to 1 (Scenario [6]); and an increase in both the domestic and EU green public investment shares to 0.9 (Scenario [20]).

Firstly, Scenario [5] implies a full diversion of domestic public funds from consumption and labour taxes allocated to public investment to green public investment, which experiences an increase of +8.81%. Thus, no more resources from these funds are spent on brown public investment anymore, which in total decreases by −5.23%. This fund reallocation implies an enormous increase of green intermediate goods production of close to but below +14% and a substantial decrease in brown intermediate goods production and imports (−7.46% and −7.03%, respectively). On aggregate, a relatively small decline in GDP is recorded (−0.58%), alongside a similar decrease in aggregate private consumption (−0.34%), which happens due to an increase in aggregate private investment (+0.54%). The emissions reduction is rather small at only −0.12% though and, thus, such policy cannot be the cornerstone of a general policy package to support the green transition. Very similar effects and sizes are observed when EU funds are exclusively used for green public investment in Scenario [6], which does not warrant another discussion, as the mechanism is very similar. Combining these two scenarios by setting both public green investment shares to 0.9 in Scenario [20],[20] implies an amplification of the effects, i.e. the magnitudes of the effects are larger than the sum of the effects in Scenarios [5] and [6]. The reason or this observance and the mechanism is similar to the amplification effect observed in Scenario [7], when combining domestic and foreign carbon taxation, i.e. the reallocation effect is amplified by diverting even more funds for green public investment

[19] Aggregate welfare only declines from −35.68 to −36.37 in Scenario [4], relative to −39.95 in Scenario [2] or −38.59 in Scenario [1].

[20] Setting both shares to 1 does not work due to model stability issues.

than in the individual scenarios. Therefore, the output loss is greater (-1.48%), the decline in aggregate consumption is larger (-1.16%), but the additional amount of private investment needed is smaller than in any of the scenarios [5] and [6] due to investment adjustments being smaller than the sum of the scenarios in all categories.

5.2.3 Bank regulation policies and changes in financial frictions

The final category of single-category policies I consider are discussed in this section. Specifically, the following 6 scenarios are analyzed: a decrease in both the green loan risk weight and the green loan absconding rate from 0.75 to 0.5 (Scenario [11]); an increase in both the brown loan risk weight and the brown loan absconding rate from 0.75 to 1 (Scenario [12]); an increase in the green LIA ratio from 0.75 to 1 (Scenario [13]); an increase in the brown LIA ratio from 2.25 to 3 (Scenario [14]); a decrease in the green loan risk weight from 0.75 to 0.5 (Scenario [18]); an increase in the brown loan risk weight from 0.75 to 1 (Scenario [19]).

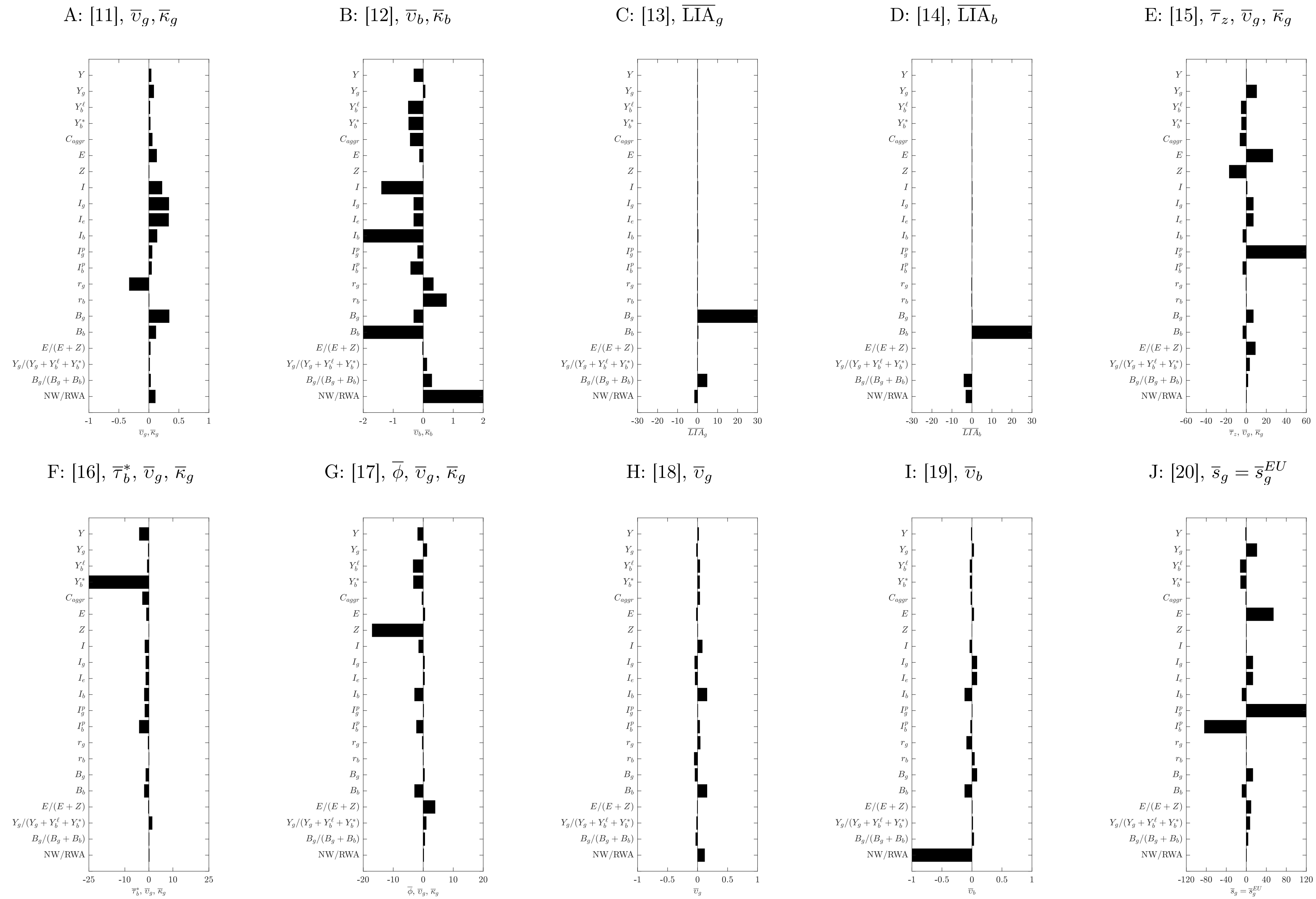
Firstly, just decreasing the green loan risk weight in Scenario [18] does not lead to the desired effect of a lower loan interest rate for green loans and, therefore, the green loans demanded by the green entrepreneur slightly decrease by -0.04%, alongside a decrease in green intermediate goods production of -0.02%. Therefore, the real scenario to assess the effect of reducing bank regulation frictions for green loans is Scenario [11], which combines the decrease in the green loan risk weight with a corresponding decrease in the green loan absconding rate. This works as desired as the green loan interest rate drops to 2.18 percentage points (pp), which provides benefits to the green intermediate goods sector, albeit at a low level of $+0.08\%$. This spills over to the brown sector, which can also increase production by $+0.02\%$. Therefore, emissions do not fall. Financial stability, as proxied by the capital adequacy ratio, is also not affected and just increases by 9 basis points to 15.38. Increasing solely the brown loan risk weight in Scenario [19] entails the desired effect of increasing the loan costs to brown entrepreneurs (the loan interest rate increases to 2.55pp) and, at the same time, leads to a small decrease in the green loan interest rate. Small benefits to the green sector's production ($+0.03\%$) and small declines in the brown sector's production (-0.03%) are recorded, while there is no effect on emissions. Combining the brown loan risk weight increase with an increase in the brown loan absconding rate in Scenario [12] is the bank regulation policy which has the largest effects on economic outcomes, similar to the findings of Diluiso et al. (2021) who demonstrate that the policy to relatively penalize brown loan issuance is more effective than to relatively reward green loan issuance. There is a considerable increase in both green loan financing costs ($r_g = 2.84$pp) and brown loan financing costs ($r_b = 3.28$pp). So, relatively speaking, taking out green loans becomes cheaper than taking out brown loans. This is reflected by green (brown) intermediate goods production increasing (decreasing) by

Table 4: Scenario analysis results, part II

	Bench	**[11]**	**[12]**	**[13]**	**[14]**	**[15]**	**[16]**	**[17]**	**[18]**	**[19]**	**[20]**
Parameter 1	—	$\overline{\upsilon}_g = 0.5$	$\overline{\upsilon}_b = 1$	$\overline{\text{LIA}}_g = 1$	$\overline{\text{LIA}}_b = 3$	$\overline{\tau}_z = 0.117$	$\overline{\tau}^*_b = 0.117$	$\overline{\phi} = 0.827$	$\overline{\upsilon}_g = 0.5$	$\overline{\upsilon}_b = 1$	$s_g = 0.9$
Parameter 2	—	$\overline{\kappa}_g = 0.5$	$\overline{\kappa}_b = 1$	—	—	$\overline{\upsilon}_g = 0.5$	$\overline{\upsilon}_g = 0.5$	$\overline{\upsilon}_g = 0.5$	—	—	$s_g^{EU} = 0.9$
Parameter 3	—	—	—	—	—	$\overline{\kappa}_g = 0.5$	$\overline{\kappa}_g = 0.5$	$\overline{\kappa}_g = 0.5$	—	—	—
Y	1.6350	0.04%	−0.31%	0.04%	0.02%	−0.06%	−3.97%	−1.84%	0.02%	−0.01%	−1.48%
Y_g	0.5187	0.08%	0.06%	−0.03%	0.03%	10.34%	−0.25%	1.22%	−0.02%	0.03%	21.06%
Y_b^ℓ	0.8657	0.02%	−0.50%	0.07%	0.01%	−5.07%	−0.67%	−3.35%	0.04%	−0.03%	−12.03%
Y_b^*	0.2592	0.02%	−0.48%	0.07%	0.01%	−4.75%	−25.00%	−3.25%	0.03%	−0.03%	−11.38%
C_{aggr}	0.8208	0.06%	−0.43%	0.03%	−0.06%	−6.31%	−2.66%	−0.43%	0.04%	−0.02%	−1.16%
E	0.3202	0.13%	−0.12%	−0.01%	0.05%	26.48%	−1.00%	0.55%	−0.02%	0.03%	54.13%
Z	0.8650	0.00%	−0.01%	0.00%	0.00%	−17.00%	−0.04%	−17.00%	0.00%	0.00%	−0.20%
I_{aggr}	0.3263	0.22%	−1.39%	0.17%	0.10%	0.85%	−1.64%	−1.51%	0.08%	−0.04%	0.32%
I_g	0.1032	0.33%	−0.31%	−0.02%	0.13%	7.02%	−1.27%	0.43%	−0.05%	0.08%	13.05%
I_e	0.0310	0.33%	−0.31%	−0.02%	0.13%	7.01%	−1.27%	0.43%	−0.04%	0.08%	13.05%
I_b	0.1921	0.14%	−2.14%	0.30%	0.08%	−3.45%	−1.89%	−2.87%	0.16%	−0.12%	−8.57%
I_g^p	0.0413	0.05%	−0.19%	0.01%	0.01%	60.47%	−1.65%	0.14%	0.00%	0.00%	128.81%
I_b^p	0.0648	0.05%	−0.42%	0.05%	0.00%	−3.52%	−3.99%	−2.25%	0.04%	−0.02%	−83.78%
r_g	2.51	2.18	2.84	2.40	2.36	2.18	2.18	2.18	2.55	2.42	2.51
r_b	2.51	2.51	3.28	2.40	2.36	2.52	2.52	2.52	2.45	2.55	2.51
B_g	0.0890	0.34%	−0.31%	33.31%	0.13%	7.01%	−1.26%	0.43%	−0.04%	0.08%	13.04%
B_b	0.3821	0.12%	−2.14%	0.30%	33.44%	−3.45%	−1.90%	−2.87%	0.16%	−0.12%	−8.59%
$E/(E+Z)$	27.01	27.04	26.99	27.01	27.02	36.06	26.82	30.96	27.01	27.02	36.37
$Y_g/(Y_g+Y_b^\ell+Y_b^*)$	31.56	31.57	31.68	31.54	31.56	34.88	32.92	32.56	31.54	31.57	38.78
$B_g/(B_g+B_b)$	18.89	18.92	19.18	23.64	14.88	20.52	18.99	19.41	18.86	18.92	22.36
NW/RWA	15.27	15.38	18.38	13.77	12.25	15.43	15.43	15.43	15.39	12.26	15.36

Notes: This table reports the results of the effects of certain climate change policies (including combinations of different policies) on several variables of interest by comparing the steady states across different model calibrations. The loan interest rates r_g, r_b and the ratios $E/(E+Z), Y_g/(Y_g+Y_b^\ell+Y_b^*), B_g/(B_g+B_b)$, NW/RWA are reported in percentage points across all columns, all other quantities are reported in percentage deviations relative to the benchmark model. The second column reports the levels for all quantities of the benchmark model. From the third column onward, the results from the second set of scenarios are reported (Scenarios 11–20). Scenario [11] ($\overline{\upsilon}_g, \overline{\kappa}_g$) entails lowering financial frictions for green loans by lowering both the green loan risk weight and absconding rate to 0.5; similarly, Scenario [12] ($\overline{\upsilon}_b, \overline{\kappa}_b$) simulates an increase in financial frictions for brown loans by increasing both the brown loan risk weight and absconding rate to 1; Scenario [13] ($\overline{\text{LIA}}_g$) investigates the effects of increasing the green loan LIA ratio to 1; similarly, Scenario [14] ($\overline{\text{LIA}}_b$) investigates the effects of increasing the green brown LIA ratio to 3; Scenario [15] ($\overline{\tau}_z$, $\overline{\upsilon}_g$, $\overline{\kappa}_g$) simulates a domestic carbon tax rate increase in conjunction with lowering financial frictions for green loans as in Scenario [11] to reduce emissions by 17%; similarly, Scenario [16] ($\overline{\tau}^*_b$, $\overline{\upsilon}_g$, $\overline{\kappa}_g$) simulates setting the foreign carbon tax rate to 11.7% as in Scenario [3] in addition to lowering financial frictions for green loans as in Scenario [11]; also similarly, Scenario [17] ($\overline{\phi}$, $\overline{\upsilon}_g$, $\overline{\kappa}_g$) simulates a decrease in the emissions cap alongside lowering financial frictions for green loans as in Scenario [11] to reduce emissions by 17%; Scenario [18] ($\overline{\upsilon}_g$) simulates lowering the green loan risk weight to 0.5; similarly, Scenario [19] ($\overline{\upsilon}_b$) entails increasing the brown loan risk weight to 1; finally, Scenario [20] ($\overline{s}_g = \overline{s}_g^{EU}$) simulates increasing both the domestic and the EU green investment shares to 0.9.

Figure 4: Scenario analysis results, part II



Notes: This figure depicts Tornado charts for the second set of scenarios (Scenarios 11–20). The percentage differences between the alternative calibration and the benchmark model are depicted for all quantities with the exception of the loan interest rates $\overline{r}_g$, $\overline{r}_b$ and the ratios $\overline{E}/(\overline{E}+\overline{Z})$, $\overline{Y}_g/(\overline{Y}_g+\overline{Y}^\ell_b+\overline{Y}^*_b)$, $\overline{B}_g/(\overline{B}_g+\overline{B}_b)$, $\overline{\text{NW}}/\overline{\text{RWA}}$ for which absolute deviations in percentage points are depicted.

+0.06% (−0.50%), though this is achieved by adjusting labour shares across the sectors, as loan demands and investment needs fall in all sectors. Additionally, both renewable energy production (−0.12%) and brown energy imports and emissions (−0.01%) slightly decrease. On aggregate, final goods output (−0.31%), aggregate private consumption (−0.43%), and – most substantially – aggregate private investment (−1.39%) decrease. Notably, there is no loss of financial stability, but rather a gain, as the capital adequacy ratio increases to 18.38%, due to the higher loan interest rates the banks charge on brown loans in particular.

Secondly, simulating increasing LIA ratios for the green entrepreneurs (Scenario [13]) and for the brown entrepreneurs (Scenario [14]) can be both interpreted as increasing financial frictions or providing more loans in the respective sector. Due to the decreasing interest rates for both types of loans in both scenarios, the latter interpretation seems to prevail. Since these changes in the strength of financial frictions fail to imply different interest rates for the two types of loans, these policies cannot be considered successful sector-specific financial policies. Scenario [13] implies a small decline in production volumes of green intermediate goods (−0.03%) and renewable energy (−0.01%), while providing small stimuli to the brown sector, final goods output, and aggregate private consumption. Scenario [14] leads to increases in all production volumes and investments, while leading to a small decline in aggregate private consumption (−0.06%).

To sum up, bank regulation policies and changes in financial frictions in my model seem to imply very small aggregate effects and completely fail to reduce emissions.[21] Nevertheless, they can be used to stimulate certain sectors of the economy more than others. This finding does not come as a big surprise as several studies find rather small effects of using sector-specific bank loan risk weights or sector-specific loan issuance subsidies/taxes (Carrattini et al., 2021; Diluiso et al., 2021) or unconventional monetary policy (Ferrari and Nispi Landi, 2021; Abiry et al., 2022) for the purpose of reducing emissions in the long run (Diluiso et al., 2021, do find sizeable output effects of a policy penalizing brown loan issuance for the short to medium run up to 40 quarters, however). An interesting exception is Benmir and Roman (2020) who find that reducing the green loan absconding rate increases steady-state output by 1.03% and reduces the welfare loss due to carbon taxation from −1.18% to −0.53%.

5.2.4 Combinations of policies from different categories

I also analyze several scenarios that combine policies from the three categories above which are discussed in this section. In particular, these 5 scenarios are analyzed here:

[21] This failure is partly related to using a relatively small degree of asymmetry in the bank capital requirement cost function (Equation 46), relative to Valencia et al. (2017). However, this is needed to match the data statistics of the Latvian economy well (especially with respect to macroeconomic volatilities). See Section 6.2 for a sensitivity analysis using a higher asymmetry in the cost function.

an increase in the domestic carbon tax rate to 11.84%, alongside assuming that environmental tax revenues are utilized in the same way as standard tax revenues by increasing the share of wasteful spending from environmental tax revenues to 88.3%, i.e. setting $s_b = 0.883$, and reducing the share of the public investment spending from environmental tax revenues directed to green public investment from 1 to $\overline{s}_g$, i.e. setting $\mathbb{1}^{tax}_{b,env} = 1$ (Scenario [9]); similarly, Scenario [10] combines reducing the emissions cap to 82.66% with environmental tax revenues being utilized in the same way as standard tax revenues from consumption and labour taxation (Scenario [10]); Scenarios [15], [16], and [17] combine the joint reduction of the green loan risk weight and absconding rate with an increase in the domestic carbon tax rate to 11.7%, with an increase in the foreign carbon tax rate to 11.7%, and with a decrease in the emissions cap to 82.66%, respectively.

Firstly, I analyze the effects of assuming that environmental tax revenues in the green transition induced by one of two environmental policies (domestic carbon tax rate and emissions cap) are used just like the standard tax revenues in Scenarios [9] and [10]. These two scenarios combine a change in environmental policy with a change in fiscal policy. Relative to scenarios [1] and [4], these two scenarios entail larger aggregate losses, with respect to both final goods output and aggregate private consumption, due to the less favourable fiscal support of the green sector in these cases. This is especially pronounced when looking at the introduction of the domestic carbon tax rate, which now leads to a decline of −1.34% in GDP, while the change was virtually zero in Scenario [1].[22] For the emissions cap policy, the additional GDP loss is only equal to 5 basis points. These results can be easily explained by looking at the changes in public investments. Green public investment only increases by +3.90% in Scenario [9] which is even less than the increase in brown public investment of +5.32% (while in Scenario [1] these numbers were +60.44% and −3.52%, respectively). Both public investments now decrease in Scenario [10] at rates of change of close to −2%, while Scenario [4] entails an increase in public green investment of +0.10%. Generous green subsidy conditions are, therefore, instrumental to alleviate the negative aggregate economic effects of the green transition.

Secondly, bank regulation policy in the form of reducing the green loan risk weight and absconding rate is combined with one of three environmental policies (domestic carbon tax rate, foreign carbon tax rate, and emissions cap) in Scenarios [15], [16], and [17]. Thus, here I analyze scenarios that combine bank regulation and environmental policies. As expected from the previous analysis of the bank regulation policy to reduce both the green loan risk weight and absconding rate, the results are essentially almost indistinguishable to the Scenarios [1], [3], and [4], which just study environmental policy

[22] These numbers are in line with the current literature. For example, Diluiso et al. (2021) find a GDP loss of −0.8% in their euro area model for a larger emission reduction target (24% instead of 17% by 2030) without any carbon tax recycling, while Varga et al. (2021) find a value of −1.83% in the regulation policy case and values between −0.86% and −0.61% in the scenarios that feature a carbon tax and several revenue recycling methods for a 94% emissions reduction scenario by 2050.

changes. There is a little support to alleviate the negative aggregate GDP effect caused by environmental policy changes, but it does not prove to be a significant change. Hence, there is little interaction found between these policies, similar to Abiry et al. (2022) who also do not find significant feedback effects between green QE and carbon tax policies.

5.3 Transition period analysis

After discussing the short-run transitory dynamics of economic shocks in Section 5.1 and the effects of changes in parameters on the steady state of the model in 5.2, in this section I combine these two approaches and provide a transition period analysis of permanent shocks to the economy.

Specifically, only the two most successful and traditional environmental policies to achieve the desired carbon emissions reduction of 17% are analyzed in this section: domestic carbon tax and reduction in emissions cap. I use the benchmark calibration as the initial value for both transition period simulations and set 2005 as the starting date, in line with Latvia's likely target to reduce carbon emissions by 17% in 2030 with a baseline reference year of 2005. The scenario calibrations [1] and [4] discussed in the previous section are used as the main model. Therefore, the model converges to the long-run scenario values, as implied by the initial value for the exogenous variable (e.g. domestic carbon tax rate of 0%) and the final value (e.g. domestic carbon tax rate of 11.68%) and subject to the chosen persistence parameter (always 0.85) which implies convergence to the final value of the exogenous variable around 2030. However, the path is uncertain as shocks to the exogenous variable can happen in any year (see, for example, Barnett, 2020; Donadelli et al., 2020; Bretschger and Soretz, 2022, for reasons why uncertainty in environmental policies to combat climate change can be important to consider). The graphs containing the transition periods for these two scenarios are depicted for 55 years from 2005 to 2060 and provided in Appendix D.

Domestic carbon tax rate This transition scenario is depicted in Figure D.1. Shocks to the domestic carbon tax rate induce a large amount of uncertainty in the path of the domestic carbon tax rate (panel L) and, consequently, in the path of macroeconomic variables like final goods output (Panel A), green intermediate goods production (Panel D), brown intermediate goods production (Panel E), and – to a lesser extent – renewable energy production (Panel F). However, the general directions, as derived in Section 5.2, are clearly visible. Final goods output does not substantially change in the long run, while the mean path for green (brown) intermediate goods output converges to a considerably higher (lower) level. Renewable energy production behaves similarly to green intermediate goods production. And so do the capital stocks (Panels G–I). This results in a significantly lower level of emissions in the long run (Panel K), but there is substantial variability across the paths. Very noticeable is also the initial increase in carbon emissions due to the initial increase of brown intermediate goods production, in line with evidence from Barnett (2020) who demonstrates in his model that policy uncertainty can lead to a run on oil by oil firms before the uncertain point in time when oil mining will become restricted. This, in turn, also leads to an initial dip in green intermediate goods and renewable energy production (Panels D and F).

Emissions cap Finally, the transition dynamics induced by a convergence to a lower emissions cap are depicted in Figure D.2. In contrast to the previous transition dynamics, the transition here seems to be smoother, when looking at the emissions dynamics which smoothly converge to a lower value from the first year of the transition onward (Panel K). There are still some non-smooth dynamics in the first 2–3 years of the transition period in aggregate macroeconomic quantities and sector production volumes (Panels A–C and D–F) though, which originate from labour supply dynamics and adjustments in the current account (i.e. foreign bond holdings). However, an effect like a run on brown energy imports, as observed in the previous transition scenario, is absent here. Despite again displaying a considerable amount of uncertainty stemming from unexpected emissions cap shocks, one can still clearly see the loss in final goods output over the long run that was previously documented in the scenario analysis (Panel A). The green sector benefits again in the long run and the brown intermediate goods sector loses ground (Panels D and E), which is also reflected by capital stock dynamics (Panels G–I).

6 Robustness and Sensitivity Analysis

This section investigates three alternative setups of the model, two setups pertain to a different use of public funds and one setup to implementing a different financial friction (regulation). Moreover, one alternative calibration is explored in which the asymmetry in the capital requirement cost function is considerably increased. The technical details on the three alternative model setups as well as the tables with the results from all four robustness checks that are discussed below are provided in Appendix E.

6.1 Alternative uses of public funds

In the benchmark model, productive public funds (i.e. government revenue net of wasteful public consumption) are used to build public capital that increases firm productivity in the domestic economy. Here, I analyze two alternative uses: (i) these funds are distributed in a lump-sum fashion to both types of entrepreneurs and (ii) these funds are used as an investment subsidy that finances a fraction of private investment expenditures of both types of entrepreneurs. I will concentrate both on the effect of these assumptions on simulated moments of the model as well as on a subset of the 20 scenarios analyzed in the previous section.

Lump-sum transfers to entrepreneurs Switching to using productive public funds for lump-sum transfers requires me to slightly change some other parameters to ensure model convergence. The start-up funds of workers to banks have to be slightly increased as a share of bank net worth ($\tau = 0.133$). In addition, the emissions cap is taken out of the toolkit of the environmental regulator by setting $\phi_1 = \phi_2 = 0$. Table E.1 (fifth column) reports the simulated moments of this model variant. There are no significant deviations in the simulated means except for the expected change in moments involving the emissions cap violation costs, as both ratios become zero. One can, however, observe more economic fluctuations in this model. All volatilities of log growth rates increase, with the exception of log aggregate private consumption growth rate volatility that experiences a mild decline from 13.5pp to 11.3pp. The reason is the higher volatility in the income of entrepreneurs due to the novel public lump-sum transfer component which transcends to larger fluctuations in production quantities in general equilibrium.[23]

Turning to the scenario analysis, the left-hand side of Table E.2 reports the results of five scenarios in this alternative model. The first scenario simulates an increase in the domestic carbon tax rate to reduce emissions by 17%, which now leads to a large loss in final goods output of −1.88%, in contrast to the benchmark model, where the loss was a mere −0.07%. This stark difference, due to lump-sum transfers to green entrepreneurs, is much less effective in stimulating 'green' growth than public investments that lead to public capital. Realizing that the Scenarios [2] and [4] (brown energy price increase from 0.2583 in the alternative benchmark model to 0.3022 and domestic carbon tax increase plus environmental revenues being treated just like standard tax revenues, respectively) lead to exactly the same GDP and sector-specific production output and investment outcomes makes clear that lump-sum transfers have no effect on the production side of the economy whatsoever. One positive difference to the benchmark model is the considerably reduced loss in aggregate private consumption levels (−1.48% in Scenario [1], −1.73% in Scenario [2], and −1.83% in Scenario [4]), translating to a lower welfare loss.[24] Therefore, Scenario [3], which simulates an increase in the share of lump-sum transfers going to green entrepreneur, yields no real effects on the economy. In Scenario [5], the domestic

[23]The just discussed changes relative to the benchmark model should have been actually compared to an alternative benchmark model, in which the same parameter adjustments have been applied. Thus, it is not exactly a fair comparison and more like comparing apples with oranges what I have done here. Thus, I have also computed the moments of this alternative benchmark model (results are available from the author upon request), and the observations regarding volatilities stay the same. There are higher bank capital adequacy ratios in the lump-sum transfer model relative to the alternative benchmark model as an additional observation that can be made from this analysis.

[24]This might be partly due to the involuntary recalibration as well, however.

carbon tax rate increase is coupled with a reduction in the green loan risk weight and absconding rate leads to similar aggregate outcomes, while the green sector gains more and the brown sector loses more due to cheaper loans to the green entrepreneurs. One interesting difference to the benchmark scenario analysis that remains to be mentioned is the much smaller carbon tax rate (3.2% instead of 11.7%) needed to induce an emissions reduction of 17%.

Investment subsidies to partly finance private investments by entrepreneurs Table E.1 (sixth column) reports the simulated moments of this model variant. I had to adjust the model parameters slightly here as well for model stability and deactivated the emissions cap policy ($\phi_1 = \phi_2 = 0$). The relatively stable contribution of the government to private investment expenditure (the government finances around 25.7% of green entrepreneurs' investment expenditure and 27.7% of brown entrepreneurs' investment expenditure in the steady state) leads to a higher aggregate investment to GDP ratio (an increase by more than 7pp is observed relative to the benchmark model), which due to the import content in investment goods bundles also implies increases in trade to GDP ratios and lower investment growth volatility, which implies a small – yet substantial – stabilizing effect for other macroeconomic volatilities, in particular with respect to sector-specific investment growth rate volatilities. Notably, no change in public consumption growth volatility is observed. Similar remarks as in Footnote 23 also hold for these observations, and there is now no additional observation that can be made regarding capital adequacy ratios.

The right-hand side of Table E.2 reports the scenario analysis results. The same scenarios as for the previous model variant are analyzed to facilitate comparability. The public investment subsidies have an effect on growth, as in the benchmark model, but they seem to be smaller. Thus, building (efficiently) public capital is found to be the best policy regarding the use of public funds. There is still a sizeable GDP loss of −1.58% in the domestic carbon tax rate scenario and of −1.57% when coupled with a reduction in the green loan risk weight and absconding rate. But these scenarios fare better than the increase in the brown energy price (−1.90%) and Scenario [2.4] which couples the domestic carbon tax rate increase with environmental tax revenues used like standard tax revenues (−1.76%). The aggregate private consumption losses are slightly larger than in the previous model variant, however, pointing to lower welfare.

6.2 Different specifications and calibrations of financial frictions

Two robustness checks are analyzed in this section. Firstly, a higher asymmetry is chosen in the bank capital requirement cost function to explore whether this could help to make the capital requirement regulation more effective in assisting the green transition. Secondly, instead of loan-in-advance constraints as the main financial friction on the consumer side, I implement debt-to-income borrowing constraints.

High asymmetry in bank capital requirement cost function The left-hand side of Table E.3 reports the scenario analysis results (five scenarios), while the third column of Table E.1 reports the simulated moments of this alternative calibration. Also, this calibration required me to deactivate the emissions cap and to considerably increase the ratio of start-up funds to bank net worth to $\tau = 0.39$ in order to obtain a stable model. The increased asymmetry (and level) of the capital requirement cost function implies larger costs of the banks (the fraction of bank capital requirement costs to bank net worth increases from around 3% in the benchmark model to around 32%). The high asymmetry also means that changes in the capital adequacy ratio produce greater economic effects, as apparent from an enormous increase in macroeconomic volatility, especially for aggregate investment growth.

The scenarios considered in Table E.3 are an increase in the LIA ratio for green loans (Scenario [3.1]) or brown loans (Scenario [3.2]) on the left-hand side of the table. On both sides of the table, a domestic carbon tax rate increase is coupled with a reduction in green loan risk weight and absconding rate in Scenarios [3.3]/[4.3], a reduction in the green loan risk weight in Scenarios [3.4]/[4.4], and an increase in the brown loan risk weight in Scenarios [3.5]/[4.5]. As expected, there are indeed larger macroeconomic effects from changing these bank regulation policies. GDP increases or decreases more in the respective scenarios. However, emissions reductions still remain unfeasible to achieve with bank regulation policies alone in these scenarios. Notably, the domestic carbon tax rate increase coupled with the reduction in green loan regulation is slightly more harmful to the economy in Scenario [3.3], as compared to Scenario [15] in Table 4 (-0.29% vs. -0.06%), implying that the effectiveness of other green transition policies seem to be significantly affected as well.

Debt-to-income borrowing constraints Table E.1 (fourth column) reports the simulated moments of this model variant. Due to an enormous observed decrease in macroeconomic volatility, I not only adapted the bank start-up fund size which was needed again for model stability, but also increased volatility parameters to find a good match with the data. In line with macro-prudential regulation, currently implemented in Latvia by the financial regulator (see European Systemic Risk Board, 2022), I set the steady-state debt-to-income ratio for brown (green) entrepreneurs to $\overline{\text{DTI}}_b = 6$ ($\overline{\text{DTI}}_g = 2$). Therefore, brown entrepreneurs are regulated according to the nation-wide standard, while green entrepreneurs are more credit-constrained as in the benchmark model to match the low green loan ratio in the data and to capture potential resilience of banks to fund green projects. This model does a very good job in matching aggregate investment growth volatility, but fails to produce the high volatility observed in the other macroeconomic aggregates. Sector-specific intermediate goods production growth rates are, however, very similar to the benchmark model moments, while there is now more volatility in brown investment growth than in green investment growth, contrary to the data.

The right-hand side of Table E.3 reports the scenario analysis results. Unlike the left-hand side of the table, Scenario [4.1] simulates an increase in the green DTI ratio to 3 (from 2) and Scenario [4.2] a decrease in the brown DTI ratio to 4 (from 6). The key take-away from this side of the table is that switching to DTI instead of LIA constraints does not change the general big picture: Relieving financial constraints for the green sector or making it harder for the brown sector to take out loans is good for the green sector and harmful for the brown sector, but this leads neither to large aggregate effects nor sizeable emissions reductions.

7 Conclusion

In this study, I develop a small open economy model with green and brown sectors, banks subject to capital requirements, and public investment. In terms of fiscal, environmental, and bank regulation policies, domestic or foreign carbon taxes can be implemented, the shares of public revenues directed to green (vis-à-vis brown) public investment can be changed, a more stringent emissions cap can be set, as well as the relative severity of financial frictions in green and brown loan origination can be altered. I quantify the effects of changes in these policies with respect to achieving lower domestic emissions while taking into account the effects of these policy changes on macroeconomic outcomes.

Among the policies that can achieve an emissions reduction of 17%, in line with Latvia's goal for 2030 (relative to the year 2005 carbon emissions), I find that the most costly policy is the world price increase in brown energy (GDP loss equal to -2.53%). Second comes the emissions cap reduction policy (-1.86% or -1.91%[25]). Finally, the domestic carbon tax rate implies the emissions reduction at basically no GDP loss (-0.07%). However, it is important that these tax revenues are used for green (and not brown) public investment, since otherwise the GDP loss increases to -1.34%.

Furthermore, bank regulation policies and changes in sectoral financial frictions prove to be mostly useless to induce emissions reductions. They can, however, slightly stimulate aggregate economic activity (especially in the green sectors). Increasing the asymmetry in the bank capital requirement cost function makes the effects of such policy changes greater, but even then these policy changes do not generate large emissions reductions. Other fiscal policies might be quite costly (e.g. foreign carbon taxes producing domestic

[25] The outcome is -1.91% if environmental tax revenues are not exclusively distributed to green public investment and wasteful public spending but also to brown public investment in the same way as standard tax revenues.

GDP losses of -3.99%, changing green public investment shares producing GDP losses of roughly -0.6%) while failing to reduce domestic emissions considerably.

The transition period dynamics for the domestic carbon tax-induced green transition prove that the risk of stranded assets induce firms to utilize brown energy as long as it is not too costly in anticipation of considerably higher costs in the future. The green transition induced by lowering the emissions cap seems to be much smoother, in terms of emissions dynamics.

When productive public funds are used to provide lump-sum transfers to entrepreneurs instead of being used to build public capital, the differential results with respect to GDP losses disappear, but welfare and aggregate consumption outcomes appear to become better. When these productive public funds are used instead as subsidies to partly finance private investment expenditure of entrepreneurs, the GDP outcome becomes less optimistic for the domestic carbon tax introduction and there is a smaller amount of heterogeneity with respect to GDP outcomes, pointing to a lower efficiency of subsidizing private investment expenditure relative to building public capital.

Going forward, the transition period analysis could be extended to compare orderly vs. disorderly transitions directly. Moreover, the model allows for further extensions in future work, e.g. by including price setting frictions and inflation dynamics, by adding externalities caused by domestic emissions, or by extending the bank regulation policy tool set with reserve requirements or other tools. Furthermore, a two- or three-country model could be worthwhile to develop to better account for monetary policy implementation in the euro area and economic developments in foreign economies. This would allow to address some shortcomings of my one-country model. Specifically, channels like the international harmonization (in both level and timing) of carbon taxes or other environmental policies, the reallocation or attraction of green or brown industries, firms, or production via changes in foreign direct investment or trade flows, as well as differences in national or supranational bank regulation policies could be explored in such a multi-country setting.

References

Abiry, R., Ferdinandusse, M., Ludwig, A. and Nerlich, C. (2022). Climate change mitigation: how effective is green quantitative easing? ECB Working Paper No. 2701.

Acemoglu, D., Aghion, P., Bursztyn, L. and Hemous, D. (2012). The Environment and Directed Technical Change. American Economic Review, **102** (1), 131–166.

Annicchiarico, B. and Diluiso, F. (2019). International transmission of the business cycle and environmental policy. Resource and Energy Economics, **58**, 101112.

— and Dio, F. D. (2015). Environmental policy and macroeconomic dynamics in a New Keynesian model. Journal of Environmental Economics and Management, **69**, 1–21.

— and — (2017). GHG emissions control and monetary policy. Environmental and Resource Economics, **67** (4), 823–851.

—, — and Diluiso, F. (2022). Climate Actions, Market Beliefs, and Monetary Policy. Working Paper, available at SSRN, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3895754.

Barnett, M. (2020). A Run on Oil? The Implications of Climate Policy Action and Stranded Assets Risk. Working Paper.

Bartocci, A., Notarpietro, A. and Pisani, M. (2022). "Green" fiscal policy measures and non-standard monetary policy in the Euro Area. Banca D'Italia Working Paper No. 1377.

Batten, S. (2018). Climate change and the macro-economy: a critical review. Bank of England Staff Working Paper No. 706.

Benkhodja, M. T., Fromentin, V. and Ma, X. (2022). Macroeconomic Effects of Green Subsidies. Working Paper, available at SSRN, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4045551.

Benmir, G. and Roman, J. (2020). Policy interactions and the transition to clean technology. Center for Climate Change Economics and Policy Working Paper No. 368 / Grantham Research Institute on Climate Change and the Environment Working Paper No. 337.

Bolton, P. and Kacperczyk, M. (2021). Do investors care about carbon risk? Journal of Financial Economics, **142** (2), 517–549.

— and — (2022). Global Pricing of Carbon-Transition Risk. Working Paper, available at SSRN, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3550233.

Bretschger, L. and Soretz, S. (2022). Stranded Assets: How Policy Uncertainty affects Capital, Growth, and the Environment. Environmental and Resource Economics, **83**, 261–288.

Bušs, G. and Grüning, P. (2020). Fiscal DSGE model for Latvia. Latvijas Banka Working Paper No. 5/2020.

Carney, M. (2015). Breaking the Tragedy of the Horizon–Climate Change and Financial Stability. Speech given at Lloyd's of London, 29 September 2015.

Carrattini, S., Heutel, G. and Melkadze, G. (2021). Climate Policy, Financial Frictions, and Transition Risk. NBER Working Paper No. 28525.

Ciccarelli, M. and Marotta, F. (2021). Demand or supply? An empirical exploration of the effects of climate change on the macroeconomy. ECB Working Paper No. 2608.

Comerford, D. and Spiganti, A. (2020). The Carbon Bubble: Climate Policy in a Fire-Sale Model of Deleveraging. EUI Working Paper MWP 2020/04.

Delgado-Téllez, M., Ferdinandusse, M. and Nerlich, C. (2022). Fiscal policies to mitigate climate change in the euro area. In Economic Bulletin, vol. 6, European Central Bank, Frankfurt am Main, Germany, https://www.ecb.europa.eu/pub/economic-bulletin/articles/2022/html/ecb.ebart202206_01~8324008da7.en.html (accessed 21 September 2022).

Dietrich, A. M., Müller, G. J. and Schoenle, R. S. (2021). The Expectations Channel of Climate Change: Implications for Monetary Policy. CEPR Discussion Paper No. DP15866.

Dietz, S. and Stern, N. (2015). Endogenous growth, convexity of damage and climate risk: How Nordhaus' framework supports deep cuts in carbon emissions. The Economic Journal, **125** (583), 574–620.

Diluiso, F., Annicchiarico, B., Kalkuhl, M. and Minx, J. C. (2021). Climate actions and macro-financial stability: The role of central banks. Journal of Environmental Economics and Management, **110**, 102548.

Donadelli, M., Grüning, P. and Hitzemann, S. (2020). Understanding Macro and Asset Price Dynamics During the Climate Transition. Bank of Lithuania Discussion Paper No. 18/2019, newer version available at SSRN, https://ssrn.com/abstract=3801562.

D'Orazio, P. and Thole, S. (2022). Climate-related financial policy index: A composite index to compare the engagement in green financial policymaking at the global level. Ecological Indicators, **141**, 109065.

Economides, G. and Xepapadeas, A. (2018). Monetary policy under climate change. Bank of Greece Working Paper No. 247.

— and — (2019). The effects of climate change on a small open economy. Bank of Greece Working Paper No. 267.

European Central Bank (2021). ECB presents action plan to include climate change considerations in its monetary policy strategy. Press Release 8 July 2021, ECB.

European Commission (2021). EU Emissions Trading System (EU ETS) – Revision for phase 4 (2021-2030). https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/revision-phase-4-2021-2030_en#strengthening-the-eu-ets-for-the-next-decade (accessed 11 August 2022).

European Systemic Risk Board (2022). Overview of national macroprudential measures (last updated July 18, 2022). https://www.esrb.europa.eu/national_policy/html/index.en.html (accessed 21 October 2022).

Ferrari, A. and Nispi Landi, V. (2021). Whatever it takes to save the planet? Central banks and unconventional green policy. Bank of Italy Working Paper No. 1320.

Ferrari, M. and Pagliari, M. S. (2021). No country is an island: international cooperation and climate change. ECB Working Paper No. 2568.

Fischer, C. and Springborn, M. (2011). Emissions targets and the real business cycle: Intensity targets versus caps or taxes. Journal of Environmental Economics and Management, **62** (3), 352–366.

Giovanardi, F., Kaldorf, M., Radke, L. and Wicknig, F. (2021). The preferential treatment of green bonds. ECONtribute Discussion Paper No. 098.

Heutel, G. (2012). How should environmental policy respond to business cycles? Optimal policy under persistent productivity shocks. Review of Economic Dynamics, **15** (2), 244–264.

IPCC (2018). Global warming of $1.5°C$. An IPCC Special Report on the impacts of global warming of $1.5°C$ above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Technical Report, Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland.

Irarrazabal, A., Moxnes, A. and Opromolla, L. D. (2015). The Tip of the Iceberg: A Quantitative Framework for Estimating Trade Costs. The Review of Economics and Statistics, **97** (4), 777–792.

Lagarde, C. (2020). Closing remarks of the president, as provided by the European parliament plenary service.

Lazard (2019). Lazard's Levelized Cost of Energy Analysis – Version 13.0. Tech. rep., Lazard, `https://www.lazard.com/media/451086/lazards-levelized-cost-of-energy-version-130-vf.pdf` (accessed 3 October 2022).

Meinerding, C., Schüler, Y. S. and Zhang, P. (2020). Shocks to Transition Risk. Working Paper, available at SSRN, `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3654155`.

NGFS (2019). A call for action: Climate change as a source of financial risk. Technical Report April, NFGS First Comprehensive Report, Network for Greening the Financial System (NGFS).

Nordhaus, W. D. (1991). To Slow or Not to Slow: The Economics of The Greenhouse Effect. The Economic Journal, **101** (407), 920–937.

— (2006). Geography and macroeconomics: New data and new findings. Proceedings of the National Academy of Sciences of the United States of America, **103** (10), 3510–3517.

— (2008). A Question of Balance: Weighing the Options on Global Warming Policies. Yale University Press.

Obstfeld, M. and Rogoff, K. (2001). The Six Major Puzzles in International Macroeconomics: Is There a Common Cause? In B. S. Bernanke and K. Rogoff (eds.), NBER Macroeconomics Annual 2000, vol. 15, MIT Press, Cambridge, Massachusetts, pp. 339–412.

Pindyck, R. S. (2017). Coase Lecture—Taxes, Targets and the Social Cost of Carbon. Economica, **84** (335), 345–364.

Schuldt, H. and Lessmann, K. (2021). Financing the low-carbon transition: The impact of financial frictions on clean investment. Working Paper, available at SSRN, https://ssrn.com/abstract=4029841.

Tax Policy Strategy Division, Tax Analysis Department (2022). Taxes and Tax Structure in Latvia. Tech. rep., Ministry of Finance, Republic of Latvia, https://www.fm.gov.lv/en/media/9952/download (accessed 3 October 2022).

Treasury of the Republic of Latvia (2021). Sustainability Bond Framework. Tech. rep., Republic of Latvia, https://www.kase.gov.lv/sites/default/files/public/FRD/%C4%80r%C4%93jie%20aiz%C5%86%C4%93mumi/Latvia%20-%20Sustainability%20Bond%20Framework_FINAL.pdf (accessed 19 September 2022).

Valencia, O., Osorio, D. and Garaz, P. (2017). The role of capital requirements and credit composition in the transmission of macroeconomic and financial shocks. Ensayos sobre Política Económica, **35**, 203–221.

Varga, J., Roeger, W. and in 't Veld, J. (2021). E-QUEST – A Multi-Region Sectoral Dynamic General Equilibrium Model with Energy: Model Description & Applications to Reach the EU Climate Targets. European Economy Discussion Paper No. 146.

A Equilibrium

I solve for the competitive equilibrium of this economy by letting all agents maximize utility or value subject to the specific constraints the agents face. I first formulate and solve for the agent-specific optimization problems. Subsequently, I define the competitive equilibrium of the economy.

A.1 Workers

The workers maximize their expected utility (1) subject to the budget constraint (3) with the definition of the consumption bundle (2) substituted into the objective function. This gives rise to the following Lagrangian:

$$\begin{aligned}\mathcal{L} = \mathbb{E}_t\Bigg[\sum_{s=0}^{\infty}\Bigg\{&\frac{\beta_w^s\left(\left((1-\omega_{w,c})^{\frac{1}{\eta_{w,c}}}(C^\ell_{w,t+s})^{\frac{\eta_{w,c}-1}{\eta_{w,c}}}+(\omega_{w,c})^{\frac{1}{\eta_{w,c}}}(C^*_{w,t+s})^{\frac{\eta_{w,c}-1}{\eta_{w,c}}}\right)^{\frac{\eta_{w,c}}{\eta_{w,c}-1}}}{1-\gamma_w} \\ &\frac{-h_w\left((1-\omega_{w,c})^{\frac{1}{\eta_{w,c}}}(C^\ell_{w,t+s-1})^{\frac{\eta_{w,c}-1}{\eta_{w,c}}}+(\omega_{w,c})^{\frac{1}{\eta_{w,c}}}(C^*_{w,t+s-1})^{\frac{\eta_{w,c}-1}{\eta_{w,c}}}\right)^{\frac{\eta_{w,c}}{\eta_{w,c}-1}}\Bigg)^{1-\gamma_w}}{1-\gamma_w}\Bigg\} \\ &+\frac{\beta_w^s a(\overline{L}-L_{t+s})^{1+\frac{1}{f}}}{1+\frac{1}{f}}\Bigg\}-\sum_{s=0}^{\infty}\beta_w^s\lambda_{w,t+s}\Bigg((1+\tau_c)(C^\ell_{w,t+s}+[(1+\iota^c_w)S_{t+s}+t^c_w]C^*_{w,t+s})+\frac{S_{t+s}A^*_{t+s+1}}{\lambda_w} \\ &+\frac{D_{t+s+1}}{\lambda_w}+\frac{\Phi_{t+s}}{\lambda_w}+\frac{p_{g,t+s}Y_{g,t+s}}{\lambda_w}+\frac{p_{b,t+s}Y^\ell_{b,t+s}}{\lambda_w}+\frac{[(1+\iota^*_{b,t+s}+\tau^*_{b,t+s})S_{t+s}p_{b,t+s}+t^*_b]Y^*_{b,t+s}}{\lambda_w}+\frac{(1+t^x_w)X_{t+s}}{\lambda_w} \\ &+\frac{\phi_b}{2}\left(\frac{D_{t+s+1}-\overline{D}}{\lambda_w}\right)^2-(1-\tau^w_l)W_{t+s}L_{t+s}-\frac{X_{t+s}}{(1+\iota^x_w)S_{t+s}\lambda_w}-\frac{R^*_{t+s-1}e^{\mathrm{RP}_{t+s-1}}S_{t+s}A^*_{t+s}}{\lambda_w}-\frac{R_{b,t+s-1}D_{t+s}}{\lambda_w} \\ &-\frac{\left((\omega_{y,g})^{\frac{1}{\epsilon}}(Y_{g,t+s})^{1-\frac{1}{\epsilon}}+(\omega^\ell_{y,b})^{\frac{1}{\epsilon}}(Y^\ell_{b,t+s})^{1-\frac{1}{\epsilon}}+(\omega^*_{y,b})^{\frac{1}{\epsilon}}(Y^*_{b,t+s})^{1-\frac{1}{\epsilon}}\right)^{\frac{1}{1-\frac{1}{\epsilon}}}}{\lambda_w}-\frac{(1-\theta_{t+s})\mathrm{NW}_{t+s}}{\lambda_w} \\ &-\nu_f(R^*_{t+s}e^{\mathrm{RP}_{t+s}}-1)W_{t+s}L_{t+s}\Bigg)\Bigg],\end{aligned} \tag{A.1}$$

where $\lambda_{w,t}$ denotes the Lagrange multiplier attached to the budget constraint. First, the first order conditions with respect to domestic consumption $C^\ell_{w,t}$, foreign consumption $C^*_{w,t}$, and total labour supply L_t are derived (please note again that the last term above, i.e. the aggregate revenue from working capital loans which are transferred to the workers from the entrepreneurs, is not taken into account by the workers in their optimization problem w.r.t. the optimal labour supply decision):

$$C^\ell_{w,t}:(1+\tau_c)\lambda_{w,t}=\left((C_{w,t}-h_wC_{w,t-1})^{-\gamma_w}-\beta_wh_w\mathbb{E}_t\Big[(C_{w,t+1}-h_wC_{w,t})^{-\gamma_w}\Big]\right)\left(\frac{(1-\omega_{w,c})C_{w,t}}{C^\ell_{w,t}}\right)^{\frac{1}{\eta_{w,c}}}, \tag{A.2}$$

$$C^*_{w,t}:(1+\tau_c)[(1+\iota^c_w)S_t+t^c_w]\lambda_{w,t}=\left((C_{w,t}-h_wC_{w,t-1})^{-\gamma_w}-\beta_wh_w\mathbb{E}_t\Big[(C_{w,t+1}-h_wC_{w,t})^{-\gamma_w}\Big]\right)\left(\frac{\omega_{w,c}C_{w,t}}{C^*_{w,t}}\right)^{\frac{1}{\eta_{w,c}}}, \tag{A.3}$$

$$L_t:a(\overline{L}-L_t)^{\frac{1}{f}}=\lambda_{w,t}(1-\tau^w_l)W_t, \tag{A.4}$$

which can be combined to yield the following expression for the household's stochastic discount factor:

$$\mathbb{M}_{t,t+1}=\frac{\beta_w\lambda_{w,t+1}}{\lambda_{w,t}}=\beta\frac{(C_{w,t+1}-h_wC_{w,t})^{-\gamma_w}-\beta_wh_w\mathbb{E}_t\Big[(C_{w,t+2}-h_wC_{w,t+1})^{-\gamma}\Big]}{(C_{w,t}-h_wC_{w,t-1})^{-\gamma_w}-\beta_wh_w\mathbb{E}_t\Big[(C_{w,t+1}-h_wC_{w,t})^{-\gamma}\Big]}\left(\frac{C_{w,t+1}}{C_{w,t}}\right)^{\frac{1}{\eta_{w,c}}}\left(\frac{C^\ell_{w,t+1}}{C^\ell_{w,t}}\right)^{-\frac{1}{\eta_{w,c}}}, \tag{A.5}$$

and the following consumption-labour trade-off condition:

$$\frac{a(\overline{L}-L_t)^{\frac{1}{f}}(1+\tau_c)}{1-\tau^w_l}=W_t\left((C_{w,t}-h_wC_{w,t-1})^{-\gamma_w}-\beta_wh_w\mathbb{E}_t\Big[(C_{w,t+1}-h_wC_{w,t})^{-\gamma_w}\Big]\right)\left(\frac{(1-\omega_{w,c})C_{w,t}}{C^\ell_{w,t}}\right)^{\frac{1}{\eta_{w,c}}}. \tag{A.6}$$

Second, the first order condition with respect to deposits D_{t+1} is:

$$D_{t+1} : 0 = \lambda_{w,t} + \lambda_{w,t}\phi_d \left(\frac{D_{t+1} - \overline{D}}{\lambda_w}\right) - \beta_w R_{d,t}\mathbb{E}_t[\lambda_{w,t+1}], \tag{A.7}$$

which yields the following basic Euler equation:

$$1 + \phi_d \left(\frac{D_{t+1} - \overline{D}}{\lambda_w}\right) = \mathbb{E}_t[\mathbb{M}_{t,t+1}R_{d,t}]. \tag{A.8}$$

Third, the three first order conditions with respect to green intermediate goods demand $Y_{g,t}$, domestic brown intermediate goods demand $Y_{b,t}^{\ell}$, and foreign brown intermediate goods demand $Y_{b,t}^{*}$ are given by:

$$Y_{g,t} : p_{g,t} = (\omega_{y,g})^{\frac{1}{\epsilon}} Y_t^{\frac{1}{\epsilon}} (Y_{g,t})^{-\frac{1}{\epsilon}}, \tag{A.9}$$

$$Y_{b,t}^{\ell} : \left[1 - \iota_{b,2}^{*}\left(\frac{Y_{b,t}^{*}}{Y_{b,t}^{\ell} + Y_{b,t}^{*}}\right)^2 S_t\right] p_{b,t} = (\omega_{y,b}^{\ell})^{\frac{1}{\epsilon}} Y_t^{\frac{1}{\epsilon}} (Y_{g,t})^{-\frac{1}{\epsilon}}, \tag{A.10}$$

$$Y_{b,t}^{*} : \left[1 + \iota_{b,t}^{*} + \iota_{b,2}^{*}\frac{Y_{b,t}^{\ell}Y_{b,t}^{*}}{(Y_{b,t}^{\ell} + Y_{b,t}^{*})^2} + \tau_{b,t}^{*}\right] S_t p_{b,t} + t_b^{*} = (\omega_{y,b}^{*})^{\frac{1}{\epsilon}} Y_t^{\frac{1}{\epsilon}} (Y_{b,t}^{\ell})^{-\frac{1}{\epsilon}}. \tag{A.11}$$

A.2 Green entrepreneurs

The green entrepreneurs maximize their lifetime utility (6), subject to their budget constraint (8), the private green and renewable energy capital accumulation equations (17) and (18), the loan-in-advance constraint (9), and the debt-to-income borrowing constraint (10), after substituting the green intermediate goods production function (13) and renewable energy production function (15) into the objective function:

$$\begin{aligned}
\mathcal{L}_g = \mathbb{E}_t\Bigg[\sum_{s=0}^{\infty}\Bigg\{ & \frac{\beta_g^s\left(\left((1-\omega_{g,c})^{\frac{1}{\eta_{g,c}}}(C_{g,t+s}^{\ell})^{\frac{\eta_{g,c}-1}{\eta_{g,c}}} + (\omega_{g,c})^{\frac{1}{\eta_{g,c}}}(C_{g,t+s}^{*})^{\frac{\eta_{g,c}-1}{\eta_{g,c}}}\right)^{\frac{\eta_{g,c}}{\eta_{g,c}-1}}\right.}{1-\gamma_g} \\
& \frac{\left.-h_g\left((1-\omega_{g,c})^{\frac{1}{\eta_{g,c}}}(C_{g,t+s-1}^{\ell})^{\frac{\eta_{g,c}-1}{\eta_{g,c}}} + (\omega_{g,c})^{\frac{1}{\eta_{g,c}}}(C_{g,t+s-1}^{*})^{\frac{\eta_{g,c}-1}{\eta_{g,c}}}\right)^{\frac{\eta_{g,c}}{\eta_{g,c}-1}}\right)^{1-\gamma_g}}{1-\gamma_g}\Bigg\} \\
& - \sum_{s=0}^{\infty}\beta_g^s\lambda_{g,t+s}\Bigg((1+\tau_c)(C_{g,t+s}^{\ell} + [(1+\iota_g^c)S_{t+s} + t_g^c]C_{g,t+s}^{*}) \\
& + \frac{W_{t+s}(\nu_f R_{t+s}^{*}e^{\mathrm{RP}_{t+s}} + 1 - \nu_f + \tau_l^e)(\lambda_w L_{g,t+s} + \lambda_w L_{e,t+s})}{\lambda_g} + \frac{p_{e,t+s}E_{t+s}^d}{\lambda_g} \\
& + \frac{I_{g,t+s}^{\ell} + [(1+\iota_g^i)S_{t+s} + t_g^i]I_{g,t+s}^{*}}{\lambda_g} + \frac{I_{e,t+s}^{\ell} + [(1+\iota_e^i)S_{t+s} + t_e^i]I_{e,t+s}^{*}}{\lambda_g} \\
& + \frac{R_{g,t+s}B_{g,t+s}}{\lambda_g} - \frac{p_{g,t+s}(E_{t+s}^d)^{\pi_1}(K_{g,t+s} + K_{g,t+s}^p)^{\pi_2}(A_{g,t+s}\lambda_w L_{g,t+s})^{\pi_3}}{\lambda_g} \\
& - \frac{p_{e,t+s}(K_{e,t+s} + K_{g,t+s}^p)^{\nu_1}(A_{e,t+s}\lambda_w L_{e,t+s})^{\nu_2}}{\lambda_g} - \frac{B_{g,t+s+1}}{\lambda_g}\Bigg) \\
& + \sum_{s=0}^{\infty}\frac{\beta_g^s q_{g,t+s}}{\lambda_g}\left(\left[1 - \frac{\phi_{g,i}}{2}\left(\frac{I_{g,t+s-1}}{I_{g,t+s-2}} - 1\right)^2\right]I_{g,t+s-1} + (1-\delta_g)K_{g,t+s} - K_{g,t+s+1}\right) \\
& + \sum_{s=0}^{\infty}\frac{\beta_g^s q_{e,t+s}}{\lambda_g}\left(\left[1 - \frac{\phi_{e,i}}{2}\left(\frac{I_{e,t+s-1}}{I_{e,t+s-2}} - 1\right)^2\right]I_{e,t+s-1} + (1-\delta_e)K_{e,t+s} - K_{e,t+s+1}\right) \\
& + \sum_{s=0}^{\infty}\frac{\beta_g^s\lambda_{g,t+s}\mu_{g,t+s}^{\mathrm{LIA}}}{\lambda_g}\Big(B_{g,t+s+1} - \mathrm{LIA}_{g,t+s}\big(I_{g,t}^{\ell} + [(1+\iota_g^i)S_{t+s} + t_g^i]I_{g,t+s}^{*} + I_{e,t}^{\ell} + [(1+\iota_e^i)S_{t+s} + t_e^i]I_{e,t+s}^{*}\big)\Big) \\
& + \sum_{s=0}^{\infty}\frac{\beta_g^s\lambda_{g,t+s}\mu_{g,t+s}^{\mathrm{DTI}}}{\lambda_g}\Big(\mathrm{DTI}_{g,t+s}\big(p_{g,t+s}Y_{g,t+s} + p_{e,t+s}E_{t+s}^s\big) - m_b B_{g,t+s+1}\Big)\Bigg].
\end{aligned} \tag{A.12}$$

Note that for readability purposes the functional form of the green investment goods production function has not been substituted into above Lagrangian. One also needs to substitute the following functions into the Lagrangian, i.e.

$$I_{g,t+s} = \left((1-\omega_{g,i})^{\frac{1}{\eta_{g,i}}} (I^{\ell}_{g,t+s})^{\frac{\eta_{g,i}-1}{\eta_{g,i}}} + (\omega_{g,i})^{\frac{1}{\eta_{g,i}}} (I^{*}_{g,t+s})^{\frac{\eta_{g,i}-1}{\eta_{g,i}}} \right)^{\frac{\eta_{g,i}}{\eta_{g,i}-1}},$$

$$I_{e,t+s} = \left((1-\omega_{e,i})^{\frac{1}{\eta_{e,i}}} (I^{\ell}_{e,t+s})^{\frac{\eta_{e,i}-1}{\eta_{e,i}}} + (\omega_{e,i})^{\frac{1}{\eta_{e,i}}} (I^{*}_{e,t+s})^{\frac{\eta_{e,i}-1}{\eta_{e,i}}} \right)^{\frac{\eta_{e,i}}{\eta_{e,i}-1}},$$

for deriving the first order conditions. First, the two first order conditions with respect to the domestic and foreign consumption goods demand of green entrepreneurs are given by:

$$C^{\ell}_{g,t} : (1+\tau_c)\lambda_{g,t} = \left((C_{g,t} - h_g C_{g,t-1})^{-\gamma_g} - \beta_g h_g \mathbb{E}_t\left[(C_{g,t+1} - h_g C_{g,t})^{-\gamma_g} \right] \right) \left(\frac{(1-\omega_{g,c}) C_{g,t}}{C^{\ell}_{g,t}} \right)^{\frac{1}{\eta_{g,c}}}, \tag{A.13}$$

$$C^{*}_{g,t} : (1+\tau_c)[(1+\iota^{c}_{g}) S_t + t^{c}_{g}]\lambda_{g,t} = \left((C_{g,t} - h_g C_{g,t-1})^{-\gamma_g} - \beta_g h_g \mathbb{E}_t\left[(C_{g,t+1} - h_g C_{g,t})^{-\gamma_g} \right] \right) \left(\frac{\omega_{g,c} C_{g,t}}{C^{*}_{g,t}} \right)^{\frac{1}{\eta_{g,c}}}. \tag{A.14}$$

Second, the next ten first order conditions with respect to green labour $L_{g,t}$, renewable energy demand E^d_t, private green (renewable energy) capital demand $K_{g,t+1}$ ($K_{e,t+1}$), domestic private green (renewable energy) investment goods $I^{\ell}_{g,t}$ ($I^{\ell}_{e,t}$), foreign private green (renewable energy) investment goods $I^{*}_{g,t}$ ($I^{*}_{e,t}$), green loans $B_{g,t+1}$, and renewable energy labour $L_{e,t}$ are given by:

$$L_{g,t} : W_t(\nu_f R^*_t e^{\mathrm{RP}_t} + 1 - \nu_f + \tau^e_l)\lambda_w = \frac{\pi_3(1+\mu^{\mathrm{DTI}}_{g,t}\mathrm{DTI}_{g,t}) p_{g,t} Y_{g,t}}{L_{g,t}}, \tag{A.15}$$

$$E^d_t : p_{e,t} = \frac{\pi_1(1+\mu^{\mathrm{DTI}}_{g,t}\mathrm{DTI}_{g,t}) p_{g,t} Y_{g,t}}{E^d_t}, \tag{A.16}$$

$$K_{g,t+1} : q_{g,t} = \mathbb{E}_t\left[\frac{\beta_g \lambda_{g,t+1} \pi_2 (1+\mu^{\mathrm{DTI}}_{g,t+1}\mathrm{DTI}_{g,t+1}) p_{g,t+1} Y_{g,t+1}}{K_{g,t+1}} \right] + \mathbb{E}_t[\beta_g q_{g,t+1}(1-\delta_g)], \tag{A.17}$$

$$K_{e,t+1} : q_{e,t} = \mathbb{E}_t\left[\frac{\beta_g \lambda_{g,t+1} \nu_1 (1+\mu^{\mathrm{DTI}}_{g,t+1}\mathrm{DTI}_{g,t+1}) p_{e,t+1} E^s_{t+1}}{K_{e,t+1}} \right] + \mathbb{E}_t[\beta_g q_{e,t+1}(1-\delta_e)], \tag{A.18}$$

$$\begin{aligned} I^{\ell}_{g,t} : \mathbb{E}_t\left[\beta_g q_{g,t+1}\left[1 - \frac{\phi_{g,i}}{2}\left(\frac{I_{g,t}}{I_{g,t-1}} - 1 \right)^2 - \phi_{g,i}\left(\frac{I_{g,t}}{I_{g,t-1}} - 1 \right) \frac{I_{g,t}}{I_{g,t-1}} \right] \right] ((1-\omega_{g,i}) I_{g,t})^{\frac{1}{\eta_{g,i}}} (I^{\ell}_{g,t})^{-\frac{1}{\eta_{g,i}}} \\ + \mathbb{E}_t\left[\beta_g^2 q_{g,t+2}\left[\phi_{g,i}\left(\frac{I_{g,t+1}}{I_{g,t}} - 1 \right)\left(\frac{I_{g,t+1}}{I_{g,t}} \right)^2 \right] \right] ((1-\omega_{g,i}) I_{g,t})^{\frac{1}{\eta_{g,i}}} (I^{\ell}_{g,t})^{-\frac{1}{\eta_{g,i}}} = (1+\mu^{\mathrm{LIA}}_{g,t}\mathrm{LIA}_{g,t})\lambda_{g,t}, \end{aligned} \tag{A.19}$$

$$\begin{aligned} I^{*}_{g,t} : \mathbb{E}_t\left[\beta_g q_{g,t+1}\left[1 - \frac{\phi_{g,i}}{2}\left(\frac{I_{g,t}}{I_{g,t-1}} - 1 \right)^2 - \phi_{g,i}\left(\frac{I_{g,t}}{I_{g,t-1}} - 1 \right) \frac{I_{g,t}}{I_{g,t-1}} \right] \right] (\omega_{g,i} I_{g,t})^{\frac{1}{\eta_{g,i}}} (I^{*}_{g,t})^{-\frac{1}{\eta_{g,i}}} \\ + \mathbb{E}_t\left[\beta_g^2 q_{g,t+2}\left[\phi_{g,i}\left(\frac{I_{g,t+1}}{I_{g,t}} - 1 \right)\left(\frac{I_{g,t+1}}{I_{g,t}} \right)^2 \right] \right] (\omega_{g,i} I_{g,t})^{\frac{1}{\eta_{g,i}}} (I^{*}_{g,t})^{-\frac{1}{\eta_{g,i}}} = (1+\mu^{\mathrm{LIA}}_{g,t}\mathrm{LIA}_{g,t})\lambda_{g,t}[(1+\iota^i_g) S_t + t^i_g], \end{aligned} \tag{A.20}$$

$$\begin{aligned} I^{\ell}_{e,t} : \mathbb{E}_t\left[\beta_g q_{e,t+1}\left[1 - \frac{\phi_{e,i}}{2}\left(\frac{I_{e,t}}{I_{e,t-1}} - 1 \right)^2 - \phi_{e,i}\left(\frac{I_{e,t}}{I_{e,t-1}} - 1 \right) \frac{I_{e,t}}{I_{e,t-1}} \right] \right] ((1-\omega_{e,i}) I_{e,t})^{\frac{1}{\eta_{e,i}}} (I^{\ell}_{e,t})^{-\frac{1}{\eta_{e,i}}} \\ + \mathbb{E}_t\left[\beta_g^2 q_{e,t+2}\left[\phi_{e,i}\left(\frac{I_{e,t+1}}{I_{e,t}} - 1 \right)\left(\frac{I_{e,t+1}}{I_{e,t}} \right)^2 \right] \right] ((1-\omega_{e,i}) I_{e,t})^{\frac{1}{\eta_{e,i}}} (I^{\ell}_{e,t})^{-\frac{1}{\eta_{e,i}}} = (1+\mu^{\mathrm{LIA}}_{g,t}\mathrm{LIA}_{g,t})\lambda_{g,t}, \end{aligned} \tag{A.21}$$

$$\begin{aligned} I^{*}_{e,t} : \mathbb{E}_t\left[\beta_g q_{e,t+1}\left[1 - \frac{\phi_{e,i}}{2}\left(\frac{I_{e,t}}{I_{e,t-1}} - 1 \right)^2 - \phi_{e,i}\left(\frac{I_{e,t}}{I_{e,t-1}} - 1 \right) \frac{I_{e,t}}{I_{e,t-1}} \right] \right] (\omega_{e,i} I_{e,t})^{\frac{1}{\eta_{e,i}}} (I^{*}_{e,t})^{-\frac{1}{\eta_{e,i}}} \\ + \mathbb{E}_t\left[\beta_g^2 q_{e,t+2}\left[\phi_{e,i}\left(\frac{I_{e,t+1}}{I_{e,t}} - 1 \right)\left(\frac{I_{e,t+1}}{I_{e,t}} \right)^2 \right] \right] (\omega_{e,i} I_{e,t})^{\frac{1}{\eta_{e,i}}} (I^{*}_{e,t})^{-\frac{1}{\eta_{e,i}}} = (1+\mu^{\mathrm{LIA}}_{g,t}\mathrm{LIA}_{g,t})\lambda_{g,t}[(1+\iota^i_e) S_t + t^i_e], \end{aligned} \tag{A.22}$$

$$B_{g,t+1} : 1 + \mu^{\mathrm{LIA}}_{g,t} + m_b \mu^{\mathrm{DTI}}_{g,t} = \mathbb{E}_t\left[\beta_g \frac{\lambda_{g,t+1}}{\lambda_{g,t}} R_{g,t+1} \right], \tag{A.23}$$

$$L_{e,t} : W_t(\nu_f R^*_t e^{\mathrm{RP}_t} + 1 - \nu_f + \tau^e_l)\lambda_w = \frac{\nu_2(1+\mu^{\mathrm{DTI}}_{g,t}\mathrm{DTI}_{g,t}) p_{e,t} E^s_t}{L_{e,t}}. \tag{A.24}$$

A.3 Brown entrepreneurs

The brown entrepreneurs maximize their lifetime utility (22), subject to their budget constraint (24), the brown capital accumulation equation (32), the loan-in-advance constraint (25), and the debt-to-income borrowing constraint (26), after substituting the brown intermediate goods production function (29) into the objective function:

$$\mathcal{L}_b = \mathbb{E}_t\Bigg[\sum_{s=0}^{\infty}\Bigg\{\frac{\beta_b^s\left(\left((1-\omega_{b,c})^{\frac{1}{\eta_{b,c}}}(C^{\ell}_{b,t+s})^{\frac{\eta_{b,c}-1}{\eta_{b,c}}}+(\omega_{b,c})^{\frac{1}{\eta_{b,c}}}(C^{*}_{b,t+s})^{\frac{\eta_{b,c}-1}{\eta_{b,c}}}\right)^{\frac{\eta_{b,c}}{\eta_{b,c}-1}}}{1-\gamma_b} \tag{A.25}$$
$$\frac{-h_b\left((1-\omega_{b,c})^{\frac{1}{\eta_{b,c}}}(C^{\ell}_{b,t+s-1})^{\frac{\eta_{b,c}-1}{\eta_{b,c}}}+(\omega_{b,c})^{\frac{1}{\eta_{b,c}}}(C^{*}_{b,t+s-1})^{\frac{\eta_{b,c}-1}{\eta_{b,c}}}\right)^{\frac{\eta_{b,c}}{\eta_{b,c}-1}}\Bigg)^{1-\gamma_b}}{1-\gamma_b}\Bigg\}$$
$$-\sum_{s=0}^{\infty}\beta_b^s\lambda_{b,t+s}\Bigg((1+\tau_c)(C^{\ell}_{b,t+s}+[(1+\tau_b^g)S_{t+s}+t_b^g]C^{*}_{b,t+s})+\frac{W_{t+s}(\nu_f R^*_{t+s}e^{\mathrm{RP}_{t+s}}+1-\nu_f+\tau_l^e)\lambda_w L_{b,t+s}}{\lambda_b}$$
$$+\frac{(S_{t+s}p_{z,t+s}+\tau_{z,t+s})Z_{t+s}}{\lambda_b}+\frac{I^{\ell}_{b,t+s}+[(1+\tau_b^i)S_{t+s}+t_b^i]I^{*}_{b,t+s}}{\lambda_b}$$
$$+\frac{\frac{\phi_1}{\phi_0}e^{-\phi_0(\phi_{t+s}Z^{nocap}-Z_{t+s-1})}-\phi_2(\phi_{t+s}Z^{nocap}-Z_{t+s-1})}{\lambda_b}$$
$$+\frac{R_{b,t+s}B_{b,t+s}}{\lambda_b}-\frac{p_{b,t+s}(Z_{t+s})^{\alpha_1}\left(A_{k,t+s}(K_{b,t+s}+K^p_{b,t+s})\right)^{\alpha_2}(A_{b,t+s}\lambda_w L_{b,t+s})^{\alpha_3}}{\lambda_b}-\frac{B_{b,t+s+1}}{\lambda_b}\Bigg)$$
$$+\sum_{s=0}^{\infty}\frac{\beta_b^s q_{b,t+s}}{\lambda_b}\left(\left[1-\frac{\phi_{b,i}}{2}\left(\frac{I_{b,t+s-1}}{I_{b,t+s-2}}-1\right)^2\right]I_{b,t+s-1}+(1-\delta_b)A_{k,t+s}K_{b,t+s}-K_{b,t+s+1}\right)$$
$$+\sum_{s=0}^{\infty}\frac{\beta_b^s\lambda_{b,t+s}\mu^{\mathrm{LIA}}_{b,t+s}}{\lambda_b}\left(B_{b,t+s+1}-\mathrm{LIA}_{b,t+s}(I^{\ell}_{b,t}+[(1+\iota_b^i)S_{t+s}+t_b^i]I^{*}_{b,t+s})\right)$$
$$+\sum_{s=0}^{\infty}\frac{\beta_b^s\lambda_{b,t+s}\mu^{\mathrm{DTI}}_{b,t+s}}{\lambda_b}\left(\mathrm{DTI}_{b,t+s}p_{b,t}Y^{\ell}_{b,t}-m_bB_{b,t+s+1}\right)\Bigg].$$

Note that for readability purposes the functional form of the brown investment goods production function has not been substituted into above Lagrangian. One needs to also substitute the following function into the Lagrangian, i.e. $I_{b,t+s}=\left((1-\omega_{b,i})^{\frac{1}{\eta_{b,i}}}(I^{\ell}_{b,t+s})^{\frac{\eta_{b,i}-1}{\eta_{b,i}}}+(\omega_{b,i})^{\frac{1}{\eta_{b,i}}}(I^{*}_{b,t+s})^{\frac{\eta_{b,i}-1}{\eta_{b,i}}}\right)^{\frac{\eta_{b,i}}{\eta_{b,i}-1}}$, for deriving the first order conditions. First, the two first order conditions with respect to the domestic and foreign consumption goods demand of brown entrepreneurs are:

$$C^{\ell}_{b,t}:(1+\tau_c)\lambda_{b,t}=\left((C_{b,t}-h_bC_{b,t-1})^{-\gamma_b}-\beta_bh_b\mathbb{E}_t\left[(C_{b,t+1}-h_bC_{b,t})^{-\gamma_b}\right]\right)\left(\frac{(1-\omega_{b,c})C_{b,t}}{C^{\ell}_{b,t}}\right)^{\frac{1}{\eta_{b,c}}}, \tag{A.26}$$

$$C^{*}_{b,t}:(1+\tau_c)[(1+\iota_b^c)S_t+t_b^c]\lambda_{b,t}=\left((C_{b,t}-h_bC_{b,t-1})^{-\gamma_b}-\beta_bh_b\mathbb{E}_t\left[(C_{b,t+1}-h_bC_{b,t})^{-\gamma_b}\right]\right)\left(\frac{\omega_{b,c}C_{b,t}}{C^{*}_{b,t}}\right)^{\frac{1}{\eta_{b,c}}}. \tag{A.27}$$

Second, the next six first order conditions with respect to brown labour $L_{b,t}$, brown energy Z_t, brown capital $K_{b,t+1}$, domestic brown investment goods $I^{\ell}_{b,t}$, foreign brown investment goods $I^{*}_{b,t}$, and brown loans $B_{b,t+1}$ are given by:

$$L_{b,t}:W_t(\nu_fR^*_te^{\mathrm{RP}_t}+1-\nu_f+\tau_l^e)\lambda_w=\frac{\alpha_3(1+\mu^{\mathrm{DTI}}_{b,t}\mathrm{DTI}_{b,t})p_{b,t}Y^{\ell}_{b,t}}{L_{b,t}}, \tag{A.28}$$

$$Z_t:\lambda_{b,t}(S_tp_{z,t}+\tau_{z,t})+\mathbb{E}_t\left[\beta_b\lambda_{b,t+1}\left(\phi_1e^{-\phi_0(\phi_{t+1}Z^{nocap}-Z_t)}-\phi_2\right)\right]=\frac{\lambda_{b,t}\alpha_1(1+\mu^{\mathrm{DTI}}_{b,t}\mathrm{DTI}_{b,t})p_{b,t}Y^{\ell}_{b,t}}{Z_t}, \tag{A.29}$$

$$K_{b,t+1}:q_{b,t}=\mathbb{E}_t\left[\frac{\beta_b\lambda_{b,t+1}\alpha_2(1+\mu^{\mathrm{DTI}}_{b,t+1}\mathrm{DTI}_{b,t+1})p_{b,t+1}Y_{b,t+1}}{K_{b,t+1}}\right]+\mathbb{E}_t[\beta_bq_{b,t+1}A_{k,t+1}(1-\delta_b)], \tag{A.30}$$

$$I^{\ell}_{b,t}:\mathbb{E}_t\left[\beta_bq_{b,t+1}\left[1-\frac{\phi_{b,i}}{2}\left(\frac{I_{b,t}}{I_{b,t-1}}-1\right)^2-\phi_{b,i}\left(\frac{I_{b,t}}{I_{b,t-1}}-1\right)\frac{I_{b,t}}{I_{b,t-1}}\right]\right]((1-\omega_{b,i})I_{b,t})^{\frac{1}{\eta_{b,i}}}(I^{\ell}_{b,t})^{-\frac{1}{\eta_{b,i}}} \tag{A.31}$$
$$+\mathbb{E}_t\left[\beta_b^2q_{b,t+2}\left[\phi_{b,i}\left(\frac{I_{b,t+1}}{I_{b,t}}-1\right)\left(\frac{I_{b,t+1}}{I_{b,t}}\right)^2\right]\right]((1-\omega_{b,i})I_{b,t})^{\frac{1}{\eta_{b,i}}}(I^{\ell}_{b,t})^{-\frac{1}{\eta_{b,i}}}=(1+\mu^{\mathrm{LIA}}_{b,t}\mathrm{LIA}_{b,t})\lambda_{b,t},$$

$$I^*_{b,t}: \mathbb{E}_t\left[\beta_b q_{b,t+1}\left[1-\frac{\phi_{b,i}}{2}\left(\frac{I_{b,t}}{I_{b,t-1}}-1\right)^2-\phi_{b,i}\left(\frac{I_{b,t}}{I_{b,t-1}}-1\right)\frac{I_{b,t}}{I_{b,t-1}}\right]\right](\omega_{b,i}I_{b,t})^{\frac{1}{\eta_{b,i}}}(I^*_{b,t})^{-\frac{1}{\eta_{b,i}}} \tag{A.32}$$
$$+\mathbb{E}_t\left[\beta_b^2 q_{b,t+2}\left[\phi_{b,i}\left(\frac{I_{b,t+1}}{I_{b,t}}-1\right)\left(\frac{I_{b,t+1}}{I_{b,t}}\right)^2\right]\right](\omega_{b,i}I_{b,t})^{\frac{1}{\eta_{b,i}}}(I^*_{b,t})^{-\frac{1}{\eta_{b,i}}}=(1+\mu^{\text{LIA}}_{b,t}\text{LIA}_{b,t})\lambda_{b,t}[(1+\iota^i_b)S_t+t^i_b],$$
$$B_{b,t+1}: 1+\mu^{\text{LIA}}_{b,t}+m_b\mu^{\text{DTI}}_{b,t}=\mathbb{E}_t\left[\beta_b\frac{\lambda_{b,t+1}}{\lambda_{b,t}}R_{b,t+1}\right]. \tag{A.33}$$

A.4 Banks

The banks maximize their value $V_{j,t}(\text{NW}_{j,t})$, defined by the Bellman Equation (42) which is assumed to satisfy $V_{j,t}(\text{NW}_{j,t}) = \upsilon_t\text{NW}_{j,t}$, subject to their incentive compatibility constraint (43). This implies bank j's optimization problem:

$$\mathcal{L}_j=\mathbb{E}_t\left[(1-\theta_{t+1})\mathbb{M}_{t,t+1}\frac{\text{NW}_{j,t+1}}{\lambda_w}+\theta_{t+1}\mathbb{M}_{t,t+1}\upsilon_{t+1}\frac{\text{NW}_{j,t+1}}{\lambda_w}\right]-\frac{\upsilon_t\text{NW}_{j,t}}{\lambda_w} \tag{A.34}$$
$$-\frac{\mu_{\texttt{icc},t}}{\lambda_w}\Big(\Psi(\kappa_{g,t}B_{g,j,t+1}+\kappa_{b,t}B_{b,j,t+1})-\upsilon_t\text{NW}_{j,t}\Big),$$

where the Lagrange multiplier $\mu_{\texttt{icc},t}$ is attached to the incentive compatibility constraint. For deriving the following first order conditions with respect to green loans $B_{g,j,t+1}$, brown loans $B_{b,j,t+1}$, and net worth $\text{NW}_{j,t}$, one also has to substitute into the objective function the law of motion for individual bank's net worth (40):

$$B_{g,j,t+1}: \mu_{\texttt{icc},t}\Psi\kappa_{g,t}=\mathbb{E}_t\left[\mathbb{M}_{t,t+1}\Omega_{t+1}\Big(R_{g,t+1}-R_{d,t}-\text{capreq}\cdot\upsilon_{g,t}\gamma_1 e^{-\gamma_0(\text{NW}_{j,t}-\text{capreq}\cdot\text{RWA}_{j,t})}+\text{capreq}\cdot\gamma_2\upsilon_{g,t}\Big)\right], \tag{A.35}$$

$$B_{b,j,t+1}: \mu_{\texttt{icc},t}\Psi\kappa_{b,t}=\mathbb{E}_t\left[\mathbb{M}_{t,t+1}\Omega_{t+1}\Big(R_{b,t+1}-R_{d,t}-\text{capreq}\cdot\upsilon_{b,t}\gamma_1 e^{-\gamma_0(\text{NW}_{j,t}-\text{capreq}\cdot\text{RWA}_{j,t})}+\text{capreq}\cdot\gamma_2\upsilon_{b,t}\Big)\right], \tag{A.36}$$

$$\text{NW}_{j,t}: (1-\mu_{\texttt{icc},t})\upsilon_t=\mathbb{E}_t\left[\mathbb{M}_{t,t+1}\Omega_{t+1}\Big(R_{d,t}+\gamma_1 e^{-\gamma_0(\text{NW}_{j,t}-\text{capreq}\cdot\text{RWA}_{j,t})}-\gamma_2\Big)\right], \tag{A.37}$$

where the bank's stochastic discount factor is different from the worker's stochastic discount factor by the term:

$$\Omega_{t+1}=1-\theta_{t+1}+\theta_{t+1}\upsilon_{t+1}. \tag{A.38}$$

A.5 Definition of the equilibrium (LIA constraint version)

The competitive equilibrium system with just LIA constraints (and no DTI constraints) consists of a set of 87 variables that solves a set of 87 equations. In particular, the following set of 87 variables, i.e.

$$\Big\{C_{w,t}; C^\ell_{w,t}; C^*_{w,t}; L_t; L_{g,t}; L_{b,t}; L_{e,t}; Y_t; Y_{g,t}; Y^\ell_{b,t}; Y^*_{b,t}; W_t; I_{g,t}; I^\ell_{g,t}; I^*_{g,t}; I_{b,t}; I^\ell_{b,t}; I^*_{b,t}; I_{e,t}; I^\ell_{e,t}; I^*_{e,t}; \tag{A.39}$$
$$I^p_{g,t}; I^p_{b,t}; C_{g,t}; C^\ell_{g,t}; C^*_{g,t}; C_{b,t}; C^\ell_{b,t}; C^*_{b,t}; K_{g,t}; K_{e,t}; K_{b,t}; S_t; X_t; A^*_t; K^p_{g,t}; K^{p,g}_{g,t}; I_t; A_{k,t}; E^s_t; E^d_t; Z_t; A_{g,t}; A_{b,t}; A_{e,t};$$
$$D_t; NW_t; \Omega_t; \upsilon_t; \text{RWA}_t; B_{g,t}; B_{b,t}; R_{g,t}; R_{b,t}; R_{d,t}; R^*_t; \theta_t; \Phi_t; \mu^{\text{LIA}}_{b,t}; \mu^{\text{LIA}}_{g,t}; \mu^{\text{DTI}}_{b,t}; \mu^{\text{DTI}}_{g,t}; \mu_{\texttt{icc},t}; \Gamma_{z,t}; \Gamma^{\texttt{capreq}}_t; \Gamma^*_{b,t}$$
$$p_{g,t}; p_{b,t}; p_{e,t}; p_{z,t}; \text{RP}_t; \mathbb{M}_{t,t+1}; \lambda_{w,t}; \lambda_{g,t}; \lambda_{b,t}; q_{g,t}; q_{e,t}; q_{b,t}; \phi_t; \tau_{z,t}; \tau^*_{b,t}; \kappa_{g,t}; \kappa_{b,t}; \upsilon_{g,t}; \upsilon_{b,t}; \text{EU}_t; \text{LIA}_{g,t}; \text{LIA}_{b,t}\Big\}$$

solves the following 85 equations – (2), (3), (4), (5), (7), (8), (9), (11), (13), (14), (15), (16), (17), (18), (19), (20), (21), (23), (24), (25), (27), (29), (30), (31), (32), (33), (34), (35), (36), (37), (38), (39), (41), (43), (44), (45), (46), (47), (48), (49), (50), (51), (52), (53), (55), (56), (57), (58), (59), (60), (61), (62), (63), (A.2), (A.3), (A.4), (A.5), (A.8), (A.9), (A.10), (A.11), (A.13), (A.14), (A.15), (A.16), (A.17), (A.18), (A.19), (A.20), (A.21), (A.22), (A.23), (A.24), (A.26), (A.27), (A.28), (A.29), (A.30), (A.31), (A.32), (A.33), (A.35), (A.36), (A.37), (A.38) – and the following two equations:

$$\mu^{\text{DTI}}_{g,t}\equiv 0, \tag{A.40}$$
$$\mu^{\text{DTI}}_{b,t}\equiv 0. \tag{A.41}$$

The necessary modifications of this equilibrium system to include DTI borrowing constraints and to remove the LIA constraints are discussed in the third paragraph of Appendix E.

B Data and Parameter Summary Tables

B.1 Details on the data

The Latvian data used to calibrate the model and to assess the data fit mostly comes from Eurostat. Whenever possible, the time period 1995–2020 is used; however, a number of time series are only available for a shorter period of time. Data from Latvia's Credit Register for the period 2018–2021 is also used to obtain information about (sectoral) loan amounts and loan interest rates. Information on the aggregate banking sector in Latvia comes from the ECB Statistical Data Warehouse for the period 2010–2020.

Macroeconomic aggregates For the macroeconomic aggregates, per-capita quarterly time series are constructed by using the annual data on "Total population national concept" as the denominator and linearly interpolating the annual population numbers to obtain a quarterly time series. Quarterly nominal GDP is "Gross domestic product at market prices" and made real by using the GDP deflator "Price index (implicit deflator), 2010=100, euro". Nominal consumption is "Final consumption expenditure" and deflated using the 2010 consumption deflator, and nominal investment is "Gross fixed capital formation" and deflated using the 2010 investment deflator. Nominal imports and exports are downloaded using the time series "Imports of goods and services" and "Exports of goods and services" and deflated using the respective deflator series. Net exports are defined as exports minus imports.

All series are seasonally and calendar adjusted data and all these series are available from 1995:Q1 to 2020:Q4. For the log growth rates, first, quarterly log growth rates are constructed and then summed up to form annual growth rate series.

Employment data To obtain the share of entrepreneurs in total population, I use quarterly Eurostat data for Latvia between 2005:Q1 and 2020:Q4 on "Employment by sex, age and professional status" and divide "Employed persons except employees" by "Employed persons". To obtain the ratio of green entrepreneurs to brown entrepreneurs, I use quarterly Eurostat data for Latvia between 2008:Q1 and 2020:Q4 on "Employment by sex, age and detailed economic activity (from 2008 onwards, NACE Rev. 2 two digit level)" (age class 15–64 years) and sum up all the employed people in green sectors and all the employed people in brown sectors (according to the sectoral classification in Table B.1 and as far as available) and divide the obtained green sector employment numbers by the brown sector employment numbers.

Government-related data In the same way as the aforementioned macroeconomic aggregates, nominal government consumption is given by "Final consumption expenditure

Table B.1: Green and brown sector: Composition and emissions intensities

NACE 2 activity	Green, brown, or neutral sector	Emissions intensity
Crop and animal production, hunting and related service activities	Brown	1928.65
Manufacture of other non-metallic mineral products	Brown	1754.80
Air transport	Brown	1024.70
Land transport and transport via pipelines	Brown	853.31
Fishing and aquaculture	Brown	811.64
Manufacture of basic metals	Brown	305.57
Water transport	Brown	267.98
Forestry and logging	Brown	207.92
Manufacture of chemicals and chemical products	Brown	138.75
Manufacture of basic pharmaceutical products and pharmaceutical preparations	Brown	118.07
Other personal service activities	Brown	110.10
Repair and installation of machinery and equipment	Neutral	93.91
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Neutral	89.92
Water collection, treatment and supply	Neutral	88.08
Wholesale trade, except of motor vehicles and motorcycles	Neutral	81.48
Rental and leasing activities	Neutral	81.10
Manufacture of coke and refined petroleum products	Neutral	75.00
Wholesale and retail trade and repair of motor vehicles and motorcycles	Neutral	67.03
Manufacture of other transport equipment	Neutral	61.54
Postal and courier activities	Neutral	59.01
Human health activities	Neutral	53.69
Manufacture of paper and paper products	Neutral	50.75
Manufacture of machinery and equipment n.e.c.	Neutral	46.98
Sports activities and amusement and recreation activities	Neutral	46.93
Warehousing and support activities for transportation	Neutral	45.46
Architectural and engineering activities; technical testing and analysis	Neutral	45.07
Retail trade, except of motor vehicles and motorcycles	Neutral	41.40
Manufacture of rubber and plastic products	Neutral	40.09
Manufacture of fabricated metal products, except machinery and equipment	Neutral	30.80
Repair of computers and personal and household goods	Neutral	29.02
Manufacture of electrical equipment	Neutral	26.29
Printing and reproduction of recorded media	Neutral	23.22
Manufacture of motor vehicles, trailers and semi-trailers	Neutral	22.88
Advertising and market research	Green	21.49
Publishing activities	Green	17.16
Scientific research and development	Green	13.77
Insurance, reinsurance and pension funding, except compulsory social security	Green	10.67
Activities auxiliary to financial services and insurance activities	Green	10.27
Telecommunications	Green	9.33
Travel agency, tour operator and other reservation service and related activities	Green	9.10
Manufacture of computer, electronic and optical products	Green	7.10
Financial service activities, except insurance and pension funding	Green	6.58
Employment activities	Green	5.42
Activities of membership organisations	Green	4.69

Notes: This table reports average emissions intensities of 44 different NACE 2 activities for the period 2008–2019, calculated using Eurostat data for Latvia. Specifically, the emissions intensity is calculated as CO2 equivalent emissions (in gram) per euro of output (2010 chain linked volumes) by using anual Eurostat data for Latvia on "air emissions intensities by NACE Rev. 2 activity". Moreover, the table indicates in the second column whether the activity belongs to the brown sector, to the green sector, or to neither of the two, according to being either in the top quartile of emissions intensities or the lowest quartile, or being in the two quartiles in the middle, respectively.

of general government", deflated using the respective government consumption deflator and made a per-capita series by using the total linearly interpolated population data.

Regarding the ratio of environmental tax revenues to total tax revenues, annual Eurostat data for Latvia for the period 1995–2020 is used on "Percentage of total revenues from taxes and social contributions (excluding imputed social contributions)".

Sectoral data Sectoral emissions intensities are calculated as CO2 equivalent emissions (in grams) per euro of output (2010 chain linked volumes) by using annual Eurostat data for Latvia on "air emissions intensities by NACE Rev. 2 activity" for the period 2008–2019.

To construct real sectoral output data, annual Eurostat data for Latvia between 1995 and 2019 on "National accounts aggregates by industry (up to NACE A*64)" is used. Specifically, output is the national accounts indicator and the units of measure "Current prices, million euro" and "Price index (implicit deflator), 2010=100, euro" are used to construct real sectoral output data. According to the classification in Table B.1, the 11 green sectors' output levels are summed up to form a green sector real output series and, similarly, for the brown sector. The green sector share is the green sector's output divided by the sum of the green sector's output and the brown sector's output.

In the same way, sectoral real investment data is constructed by using the dataset "Gross capital formation by industry (up to NACE A*64)".

Environmental data The renewable energy share is available at Eurostat for the period 2004–2020 and named "Share of energy from renewable sources". Renewable energy consumption is given by annual Eurostat data for Latvia for the period 1995–2020 on "Final energy consumption (Europe 2020–2030)" times the renewable energy share (thus renewable energy consumption is available only between 2004 and 2020 for Latvia. The resulting annual time series is used to construct an annual log growth rate series.

To construct the share of the EU ETS revenues distributed to Latvia as a percentage of Latvia's GDP, the total nominal EU ETS revenue from 2019 is used[26] and taken to be exactly 14 billion euros and the share of Latvia's GDP in total EU GDP (2019) is computed to be 0.19%. Latvia's share of EU ETS revenues are then 0.19% times 14 billion euros and this is divided by nominal Latvia's GDP in 2019 to obtain 0.09%, as reported in Table 1.

Bank, loan, and interest rate data Latvia's household deposit rates for new deposits come from the ECB Statistical Data Warehouse from 2004 onwards. The series name is

[26]Extracted from (accessed 12 August 2022) `https://climate.ec.europa.eu/news-your-voice/news/carbon-market-report-emissions-eu-ets-stationary-installations-fall-over-9-2020-11-18_en`.

"Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector – Deposits with agreed maturity, Up to 1 year original maturity, New business coverage, Households and non-profit institutions serving households (S.14 and S.15) sector, denominated in euro". This monthly annualized series is utilized for the period 2004:M1–2020:M12.

The total loans to GDP ratio is constructed by dividing Non-MFI corporate loans in Latvia by Latvia's GDP. The resulting series is quarterly and available between 2011:Q1 and 2020:Q4. The Non-MFI corporate loans data is available from the ECB Statistical Data Warehouse with the series name being "Loans vis-a-vis domestic NFC reported by MFI excluding ESCB in Latvia (stock)". Unweighted and risk-weighted capital adequacy ratios are based on Latvijas Banka's internal estimates for the period between 2011:Q1 and 2020:Q4.

Latvia's Credit Register is used to obtain the outstanding nominal loan amounts in December of each year and the nominal loan interest rates in December of each year for sectors at the NACE 2 level. The data is available on an annual basis for the years 2018–2021 only. The sectoral classification in Table B.1 is used to classify the loan amounts and loan interest rates as green vs. brown. The loan amounts are then summed up to form the green and brown sector's loan amounts. The green loan share is the green sector's loan amount divided by the sum of the green sector's loan amount and the brown sector's loan amount. The corresponding green and brown sector's interest rates are computed by using a value-weighted average (weighted by the share of the loans taken out by a particular NACE 2 activity sector to the whole green or brown sector).

B.2 Parameter summary tables

The following Tables B.2–B.5 summarize all the parameters in use for the benchmark model.

Table B.2: Parameters borrowed from other studies

Parameter	Description	Value	Source
$\{\omega_{w,c}, \omega_{g,c}, \omega_{b,c}\}$	Import share consumption bundles	0.45	1
$\{\eta_{w,c}, \eta_{g,c}, \eta_{b,c}\}$	Substitution elasticity consumption bundles	1.854	1
$\{\omega_{g,i}, \omega_{e,i}, \omega_{b,i}\}$	Import share investment bundles	0.65	1
$\{\eta_{g,i}, \eta_{e,i}, \eta_{b,i}\}$	Substitution elasticity investment bundles	1.059	1
h_w	Worker habit parameter	0.607	1
ν_f	Working capital fraction	0.5	1
$\tilde{\phi}_a$	Risk premium sensitivity to foreign bonds to GDP ratio	-0.01	1
s_i	Share of public investment expenditure	0.117	1
τ_c	Consumption tax rate	0.210	1
τ_l^w	Labour-related tax rate (employees)	0.225	1
τ_l^e	Labour-related tax rate (employers)	0.155	1
ϵ	Green and brown intermediate goods substitution elasticity	3	2

Notes: This table reports the model parameters that are borrowed from other papers. Source codes: 1=Bušs and Grüning (2020); 2=Acemoglu et al. (2012).

Table B.3: Data moments and parameters set to match these moments

Parameter	Description	Value
	Targeted steady states / data moments	
$\frac{\overline{I}_{aggr}}{\overline{Y}}$	Aggregate private investment to GDP ratio	0.2184
$\frac{\overline{Y}_g}{\overline{Y}_g+\overline{Y}_b^\ell+\overline{Y}_b^*}$	Green sector share	0.3466
$\frac{\overline{B}_g}{\overline{B}_g+\overline{B}_b}$	Green loan share	0.1209
$\frac{\overline{E}}{\overline{E}+\overline{Z}}$	Renewable energy share	0.3541
	Implied parameters	
$\{\delta_g, \delta_e, \delta_b\}$	Capital depreciation rates	0.10
$\overline{p}_z$	Steady-state log brown energy price	ln(0.1507)
$\omega_{y,g}$	Green intermediate goods share in final goods production	0.35
$\omega_{y,b}^\ell$	Domestic brown intermediate goods share in final goods production	0.55
$\omega_{y,b}^*$	Foreign brown intermediate goods share in final goods production	0.10
π_1	Renewable energy share in green intermediate goods production	0.09
π_2	Green capital share in green intermediate goods production	0.21
π_3	Labour share in green intermediate goods production	0.60
α_1	Brown energy share in brown intermediate goods production	0.11
α_2	Brown capital share in brown intermediate goods production	0.24
α_3	Labour share in brown intermediate goods production	0.55
ν_1	Green capital share in renewable energy production	0.70
ν_2	Labour share in renewable energy production	0.20
$\overline{\text{LIA}}_g$	Steady-state green LIA ratio	0.75
$\overline{\text{LIA}}_b$	Steady-state brown LIA ratio	2.25

Notes: This table reports some data moments in the upper panel and the model parameters that are set to match these data statistics in the lower panel.

Table B.4: Data-implied, conventional, or ad-hoc parameters

Parameter	Description	Value
λ_w	Share of workers in population	0.8844
λ_g	Share of green entrepreneurs in population	0.0244
λ_b	Share of brown entrepreneurs in population	0.0912
β_w	Worker time discount factor	0.985
β_g	Green entrepreneur time discount factor	0.98
β_b	Brown entrepreneur time discount factor	0.98
$\{\gamma_w, \gamma_b, \gamma_g\}$	Relative risk aversions	1
h_g	Green entrepreneur habit parameter	0.25
h_b	Brown entrepreneur habit parameter	0.25
f	Labour supply elasticity	0.7
$\overline{L}$	Total time endowment	3
a	Worker leisure utility parameter	0.2920
$\{\phi_{g,i}, \phi_{e,i}, \phi_{b,i}\}$	Investment adjustment costs parameters	0.05
ϕ_d	Deposit adjustment costs	1
Z^{nocap}	Steady-state unrestricted emissions quantity	0.8649
$\overline{x}$	Steady-state log export quantity	ln(0.6271)
$\overline{s}$	Steady-state log real exchange rate	ln(0.7382)
Ψ	Incentive compatibility constraint stringency	0.67
$\overline{\theta}$	Steady-state bank survival probability	0.9
τ	Size of bank start-up fund	0.129
capreq	Regulatory capital adequacy ratio	0.135
$\{\overline{v}_g, \overline{v}_b\}$	Steady-state loan risk weights	0.75
$\{\overline{\kappa}_g, \overline{\kappa}_b\}$	Steady-state loan absconding rates	0.75
γ_0	Bank capital requirement cost function parameter 1	60
γ_1	Bank capital requirement cost function parameter 2	0.1
γ_2	Bank capital requirement cost function parameter 3	0.1
$\overline{\phi}$	Steady-state emissions cap stringency	1
$\overline{\tau}_z$	Steady-state domestic carbon tax rate	0
$\overline{\tau}_b^*$	Steady-state foreign carbon tax rate	0
ϕ_0	Emissions cap violation cost function parameter 1	60
ϕ_1	Emissions cap violation cost function parameter 2	0.1
ϕ_2	Emissions cap violation cost function parameter 3	0.1
s_{EU}	Steady-state share of EU funds as a fraction of GDP	0.0342
$\overline{s}_g^{EU}$	Steady-state EU green public investment share	0.4485
s_b	Share of wasteful spending of environmental taxes and fees	0.649
$\overline{s}_g$	Steady-state domestic green public investment share	0.3156
$\mathbb{1}_{b,env}^{tax}$	Distribution indicator for environmental tax revenues	0
$\{\iota_w^x, \iota_b^c, \iota_g^c, \iota_g^c,$ $\iota_g^i, \iota_e^i, \iota_b^i\}$	Iceberg transport costs (all goods except imported brown goods)	0.04
$\{t_w^x, t_b^c, t_g^c, t_g^c,$ $t_g^i, t_e^i, t_b^i, t_b^*\}$	Unit transport costs (all goods)	0.06
$\iota_{b,1}^*$	Minimum iceberg transport costs for brown goods	0.04
$\iota_{b,2}^*$	Iceberg transport costs sensitivity to brown goods import share	0.06

Notes: This table reports the model parameters that are set exactly equal to empirical counterparts, to conventional values in the literature, or in an ad-hoc way.

Table B.5: Parameters of exogenous processes

Parameter	Description	Value
$\{\rho_g, \rho_e, \rho_b, \rho_k, \rho_z, \rho_x, \rho_s,$ $\rho_\theta, \rho_{EU}, \rho_\phi, \rho_{\upsilon_g}, \rho_{\kappa_g}, \rho_{\upsilon_b}, \rho_{\kappa_b},$ $\rho_{\tau_z}, \rho_{\tau_b^*}, \rho_g^p, \rho_g^{EU}, \rho_g^{\text{LIA}}, \rho_b^{\text{LIA}}\}$	Persistence levels (all shocks)	0.85
σ_g	Volatility green labour productivity shocks	0.02
σ_e	Volatility renewable energy labour productivity shocks	0.02
σ_b	Volatility brown labour productivity shocks	0.02
σ_z	Volatility brown energy price shocks	0.02
σ_k	Volatility brown capital quality shocks	0.01
σ_θ	Volatility bank survival probability shocks	0.005
σ_x	Volatility export quantity shocks	0.004
σ_{EU}	Volatility EU funds shocks	0.0025
σ_s	Volatility exchange rate shocks	0.002
σ_r	Volatility risk premium shocks	0.002
$\{\sigma_g^p, \sigma_g^{EU}, \sigma_\phi, \sigma_{\upsilon_g}, \sigma_{\kappa_g}, \sigma_{\upsilon_b}$ $\sigma_{\kappa_b}, \sigma_{\tau_z}, \sigma_{\tau_b^*}, \sigma_g^{\text{LIA}}, \sigma_b^{\text{LIA}}\}$	Volatility parameters (inactive shocks)	0

Notes: This table reports the persistence levels and shock standard deviations of the exogenous processes in the model.

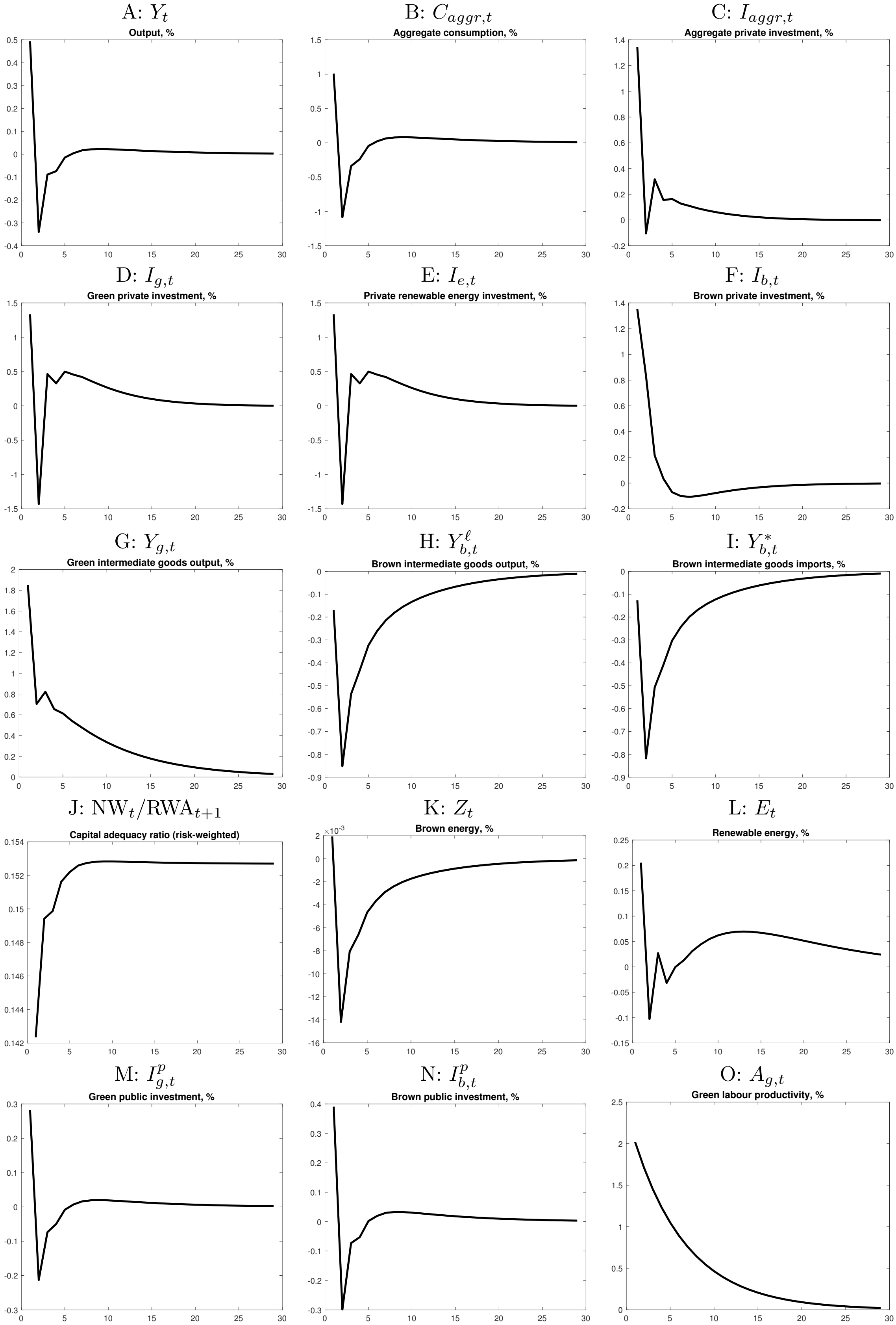
C Impulse Response Functions

The following figures contain the impulse response functions for all shocks in the model and for a selected number of variables.

The variables are: (A) final goods output (GDP) Y_t, (B) aggregate private consumption $C_{aggr,t}$, (C) aggregate private investment $I_{aggr,t}$, (D) green private investment $I_{g,t}$, (E) renewable energy private investment $I_{e,t}$, (F) brown private investment $I_{b,t}$, (G) green intermediate goods output $Y_{g,t}$, (H) domestic brown intermediate goods output $Y^{\ell}_{b,t}$, (I) imported brown intermediate goods $Y^{*}_{b,t}$, (J) risk-weighted capital adequacy ratio $\text{NW}_t/\text{RWA}_{t+1}$, (K) brown energy imports (emissions) Z_t, (L) renewable energy output/consumption E_t, (M) green public investment $I^{p}_{g,t}$, (N) brown public investment $I^{p}_{b,t}$, (O) exogenous variable that is experiencing an unexpected shock.

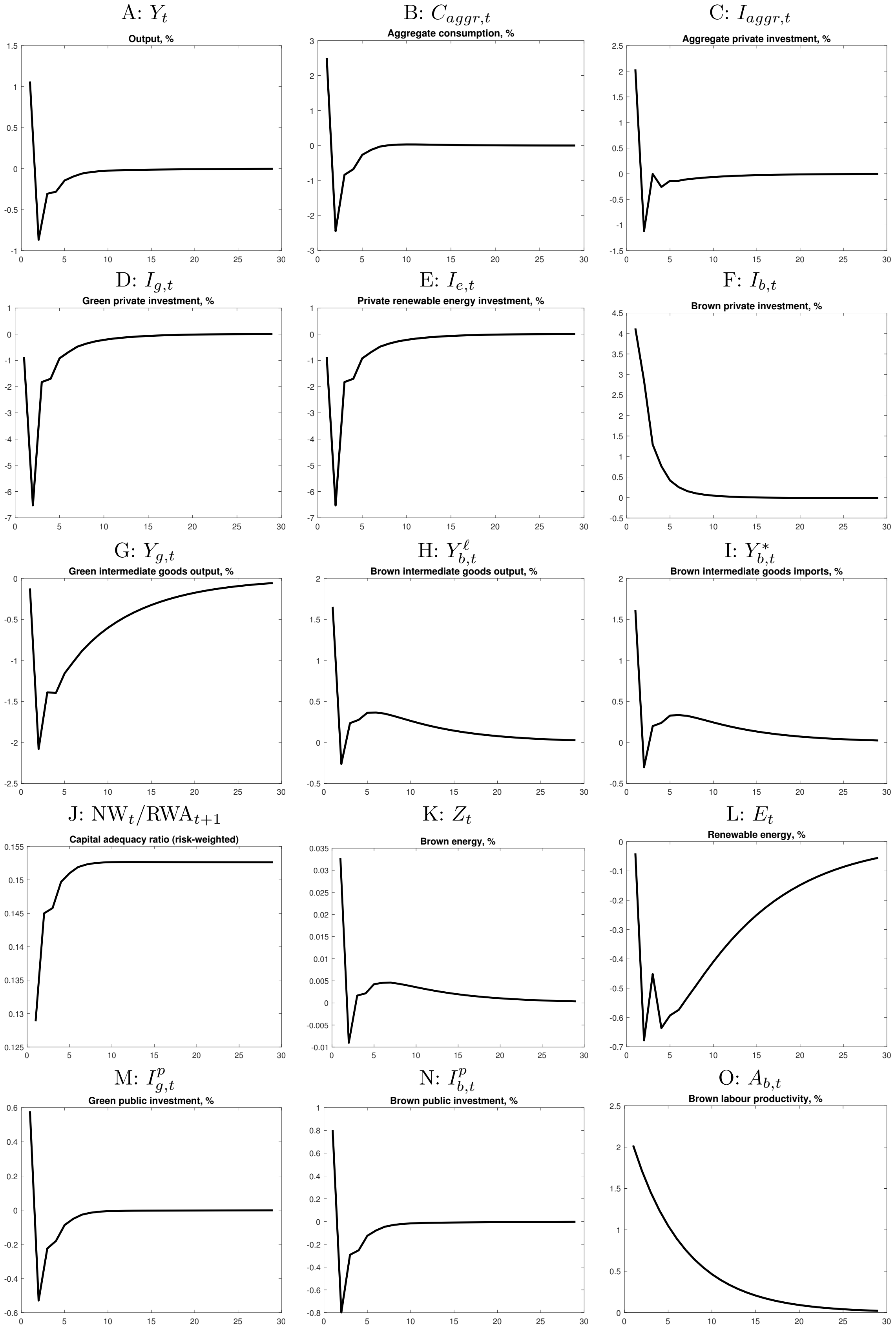
The considered shocks are (all simulated shocks happen in period 1 and are subject to a persistence level of 0.85): (Figure C.1) a positive shock to green labour productivity $A_{g,t}$ of size $\varepsilon_{g,1} = 0.02$, (Figure C.2) a positive shock to green labour productivity $A_{b,t}$ of size $\varepsilon_{b,1} = 0.02$, (Figure C.3) a positive shock to green labour productivity $A_{e,t}$ of size $\varepsilon_{e,1} = 0.02$, (Figure C.4) a positive shock to brown capital quality $A_{k,t}$ of size $\varepsilon_{k,1} = 0.01$, (Figure C.5) a negative shock to the bank survival probability θ_t of size $\varepsilon_{\theta,1} = 0.005$, (Figure C.6) a positive shock to foreign demand X_t of size $\varepsilon_{x,1} = 0.004$, (Figure C.7) a positive shock to the exchange rate S_t of size $\varepsilon_{s,1} = 0.002$, (Figure C.8) a positive shock to the domestic risk premium RP_t of size $\varepsilon_{r,1} = 0.002$, (Figure C.9) a positive shock to the price of brown energy $p_{z,t}$ of size $\varepsilon_{z,1} = 0.02$, (Figure C.10) a positive shock to the domestic carbon tax rate $\tau_{z,t}$ of size $\varepsilon_{\tau_z,1} = 0.01$, (Figure C.11) a positive shock to the foreign carbon tax rate $\tau^{*}_{b,t}$ of size $\varepsilon_{\tau^{*}_{b},1} = 0.01$, (Figure C.12) a negative shock to the emissions cap ϕ_t of size $\varepsilon_{\phi,1} = 0.025$, (Figure C.13) a positive shock to the amount of EU funds EU_t of size $\varepsilon_{EU,1} = 0.0025$, (Figure C.14) a positive shock to the domestic green public investment share $s_{g,t}$ of size $\varepsilon^{p}_{g,1} = 0.01$, (Figure C.15) a positive shock to the EU green public investment share $s^{EU}_{g,t}$ of size $\varepsilon^{EU}_{g,1} = 0.01$, (Figure C.16) a negative shock to the green loan risk weight $\upsilon_{g,t}$ of size $\varepsilon_{\upsilon_g,1} = 0.10$, (Figure C.17) a positive shock to the brown loan risk weight $\upsilon_{b,t}$ of size $\varepsilon_{\upsilon_b,1} = 0.10$, (Figure C.18) a negative shock to the green loan absconding rate $\kappa_{g,t}$ of size $\varepsilon_{\kappa_g,1} = 0.10$, (Figure C.19) a positive shock to the brown loan absconding rate $\kappa_{b,t}$ of size $\varepsilon_{\kappa_b,1} = 0.10$, (Figure C.20) a positive shock to the green LIA ratio $\text{LIA}_{g,t}$ of size $\varepsilon^{\text{LIA}}_{\upsilon_g,1} = 0.10$, (Figure C.21) a positive shock to the brown LIA ratio $\text{LIA}_{b,t}$ of size $\varepsilon^{\text{LIA}}_{\upsilon_b,1} = 0.10$.

Figure C.1: Impulse response functions – green labour productivity shock



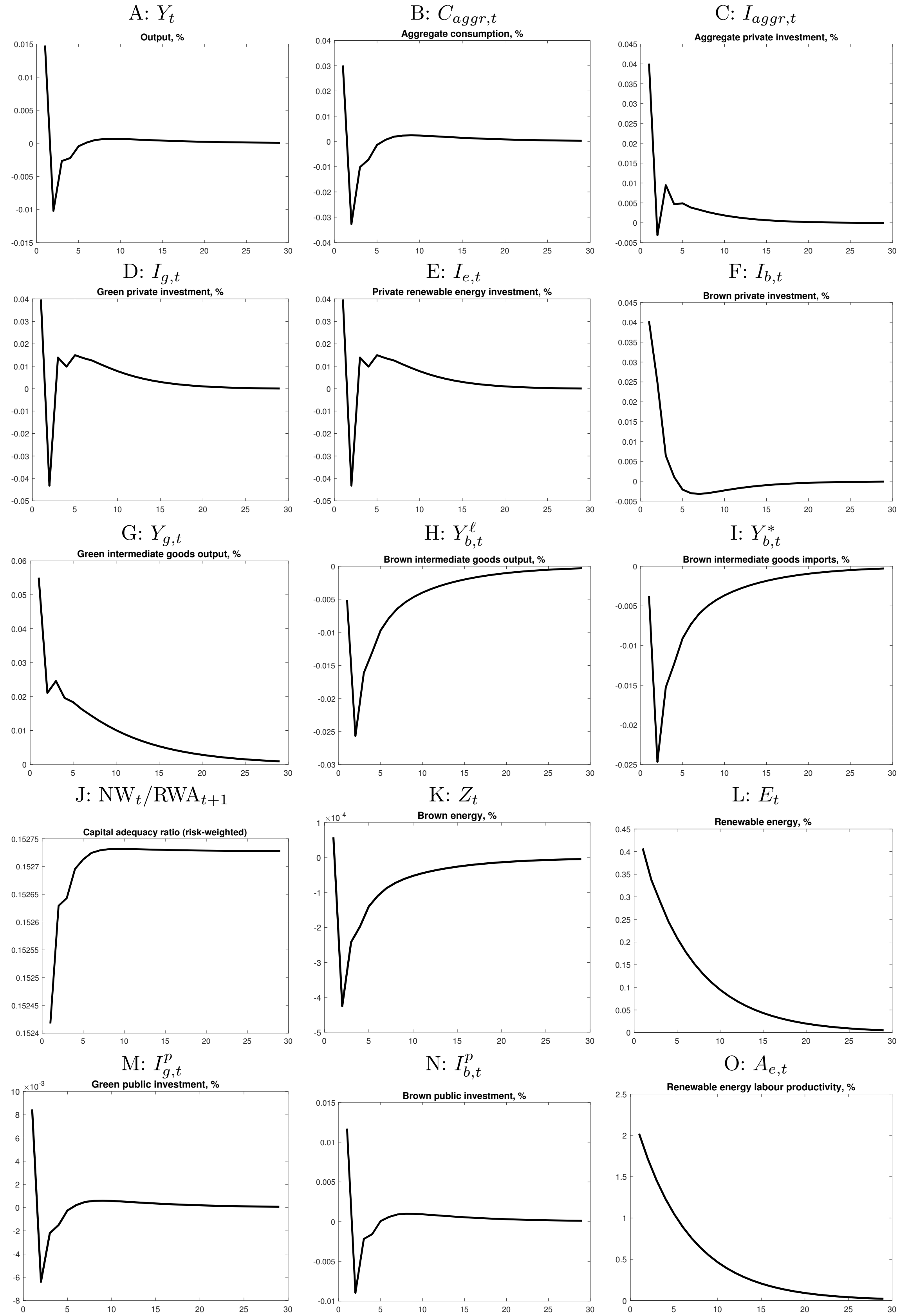
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to the labour productivity of green intermediate goods production $A_{g,t}$ ($\varepsilon_{g,1} = 0.02$).

Figure C.2: Impulse response functions – brown labour productivity shock



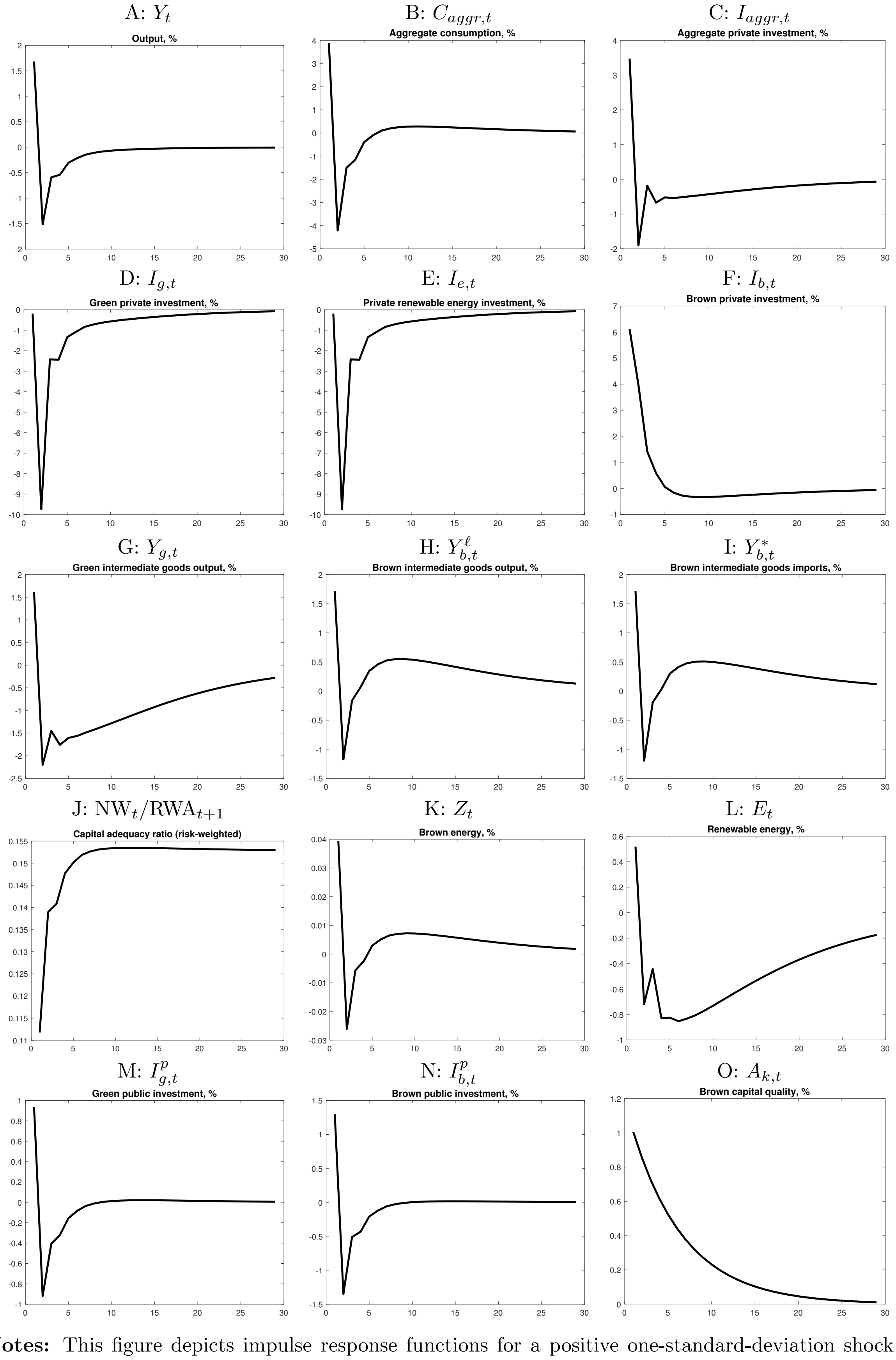
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to the labour productivity of brown intermediate goods production $A_{b,t}$ ($\varepsilon_{b,1} = 0.02$).

Figure C.3: Impulse response functions – renewable energy labour productivity shock



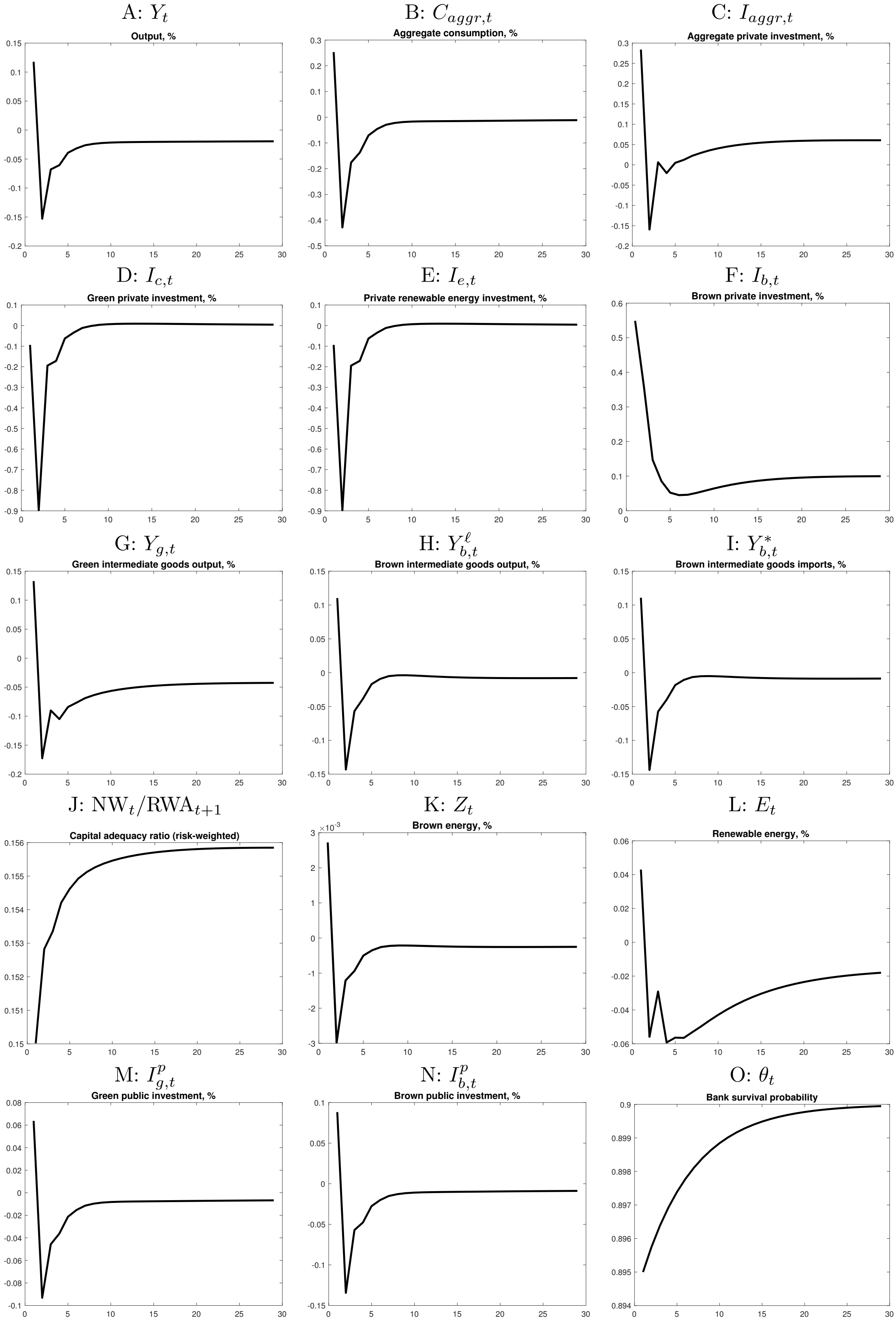
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to the labour productivity of renewable energy production $A_{e,t}$ ($\varepsilon_{e,1} = 0.02$).

Figure C.4: Impulse response functions – brown capital quality shock



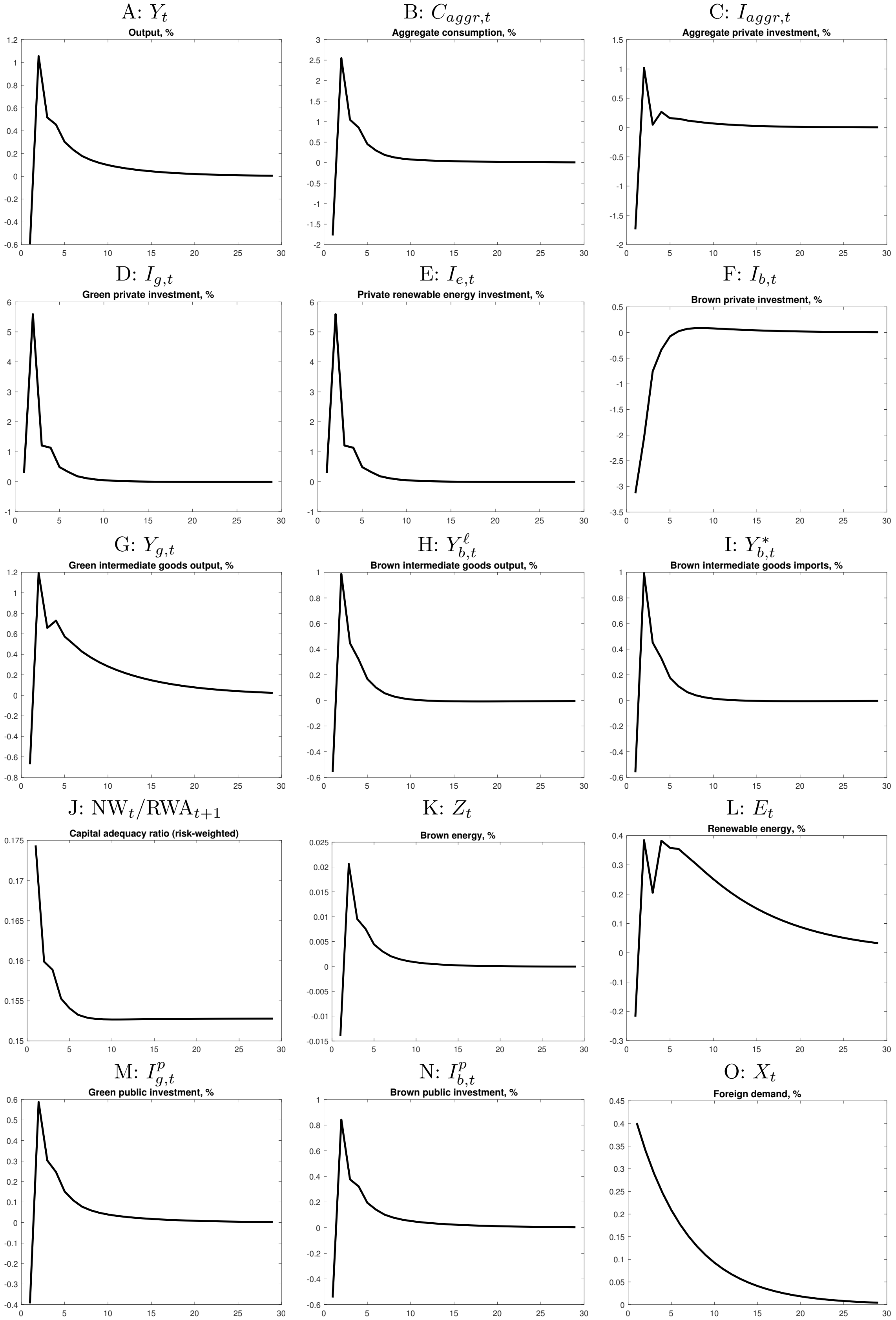
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to brown capital quality $A_{k,t}$ ($\varepsilon_{k,1} = 0.01$).

Figure C.5: Impulse response functions – bank survival probability shock



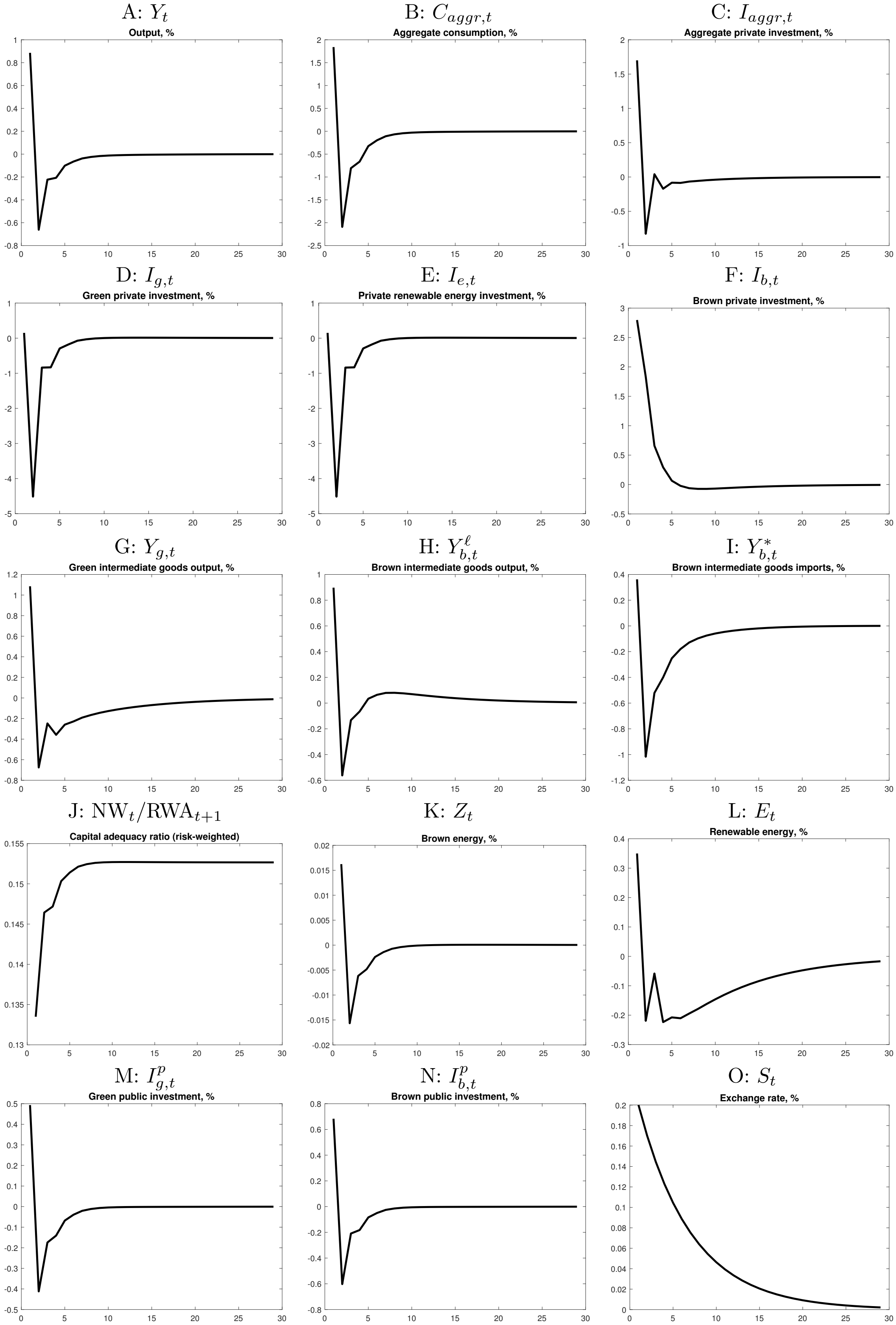
Notes: This figure depicts impulse response functions for a negative one-standard-deviation shock to the bank survival probability θ_t ($\varepsilon_{\theta,1} = 0.005$).

Figure C.6: Impulse response functions – foreign demand shock



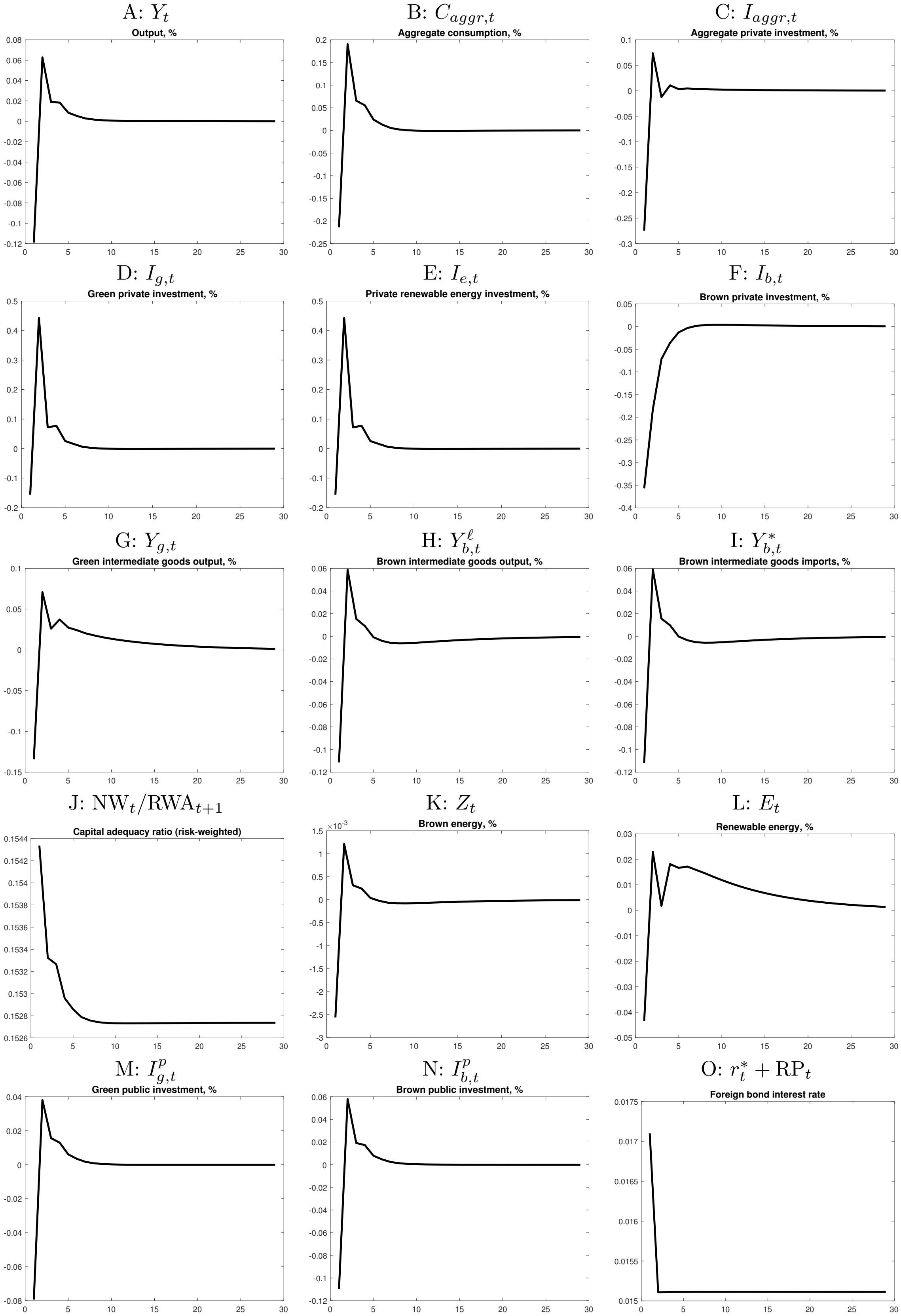
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to foreign demand X_t ($\varepsilon_{x,1} = 0.004$).

Figure C.7: Impulse response functions – exchange rate shock



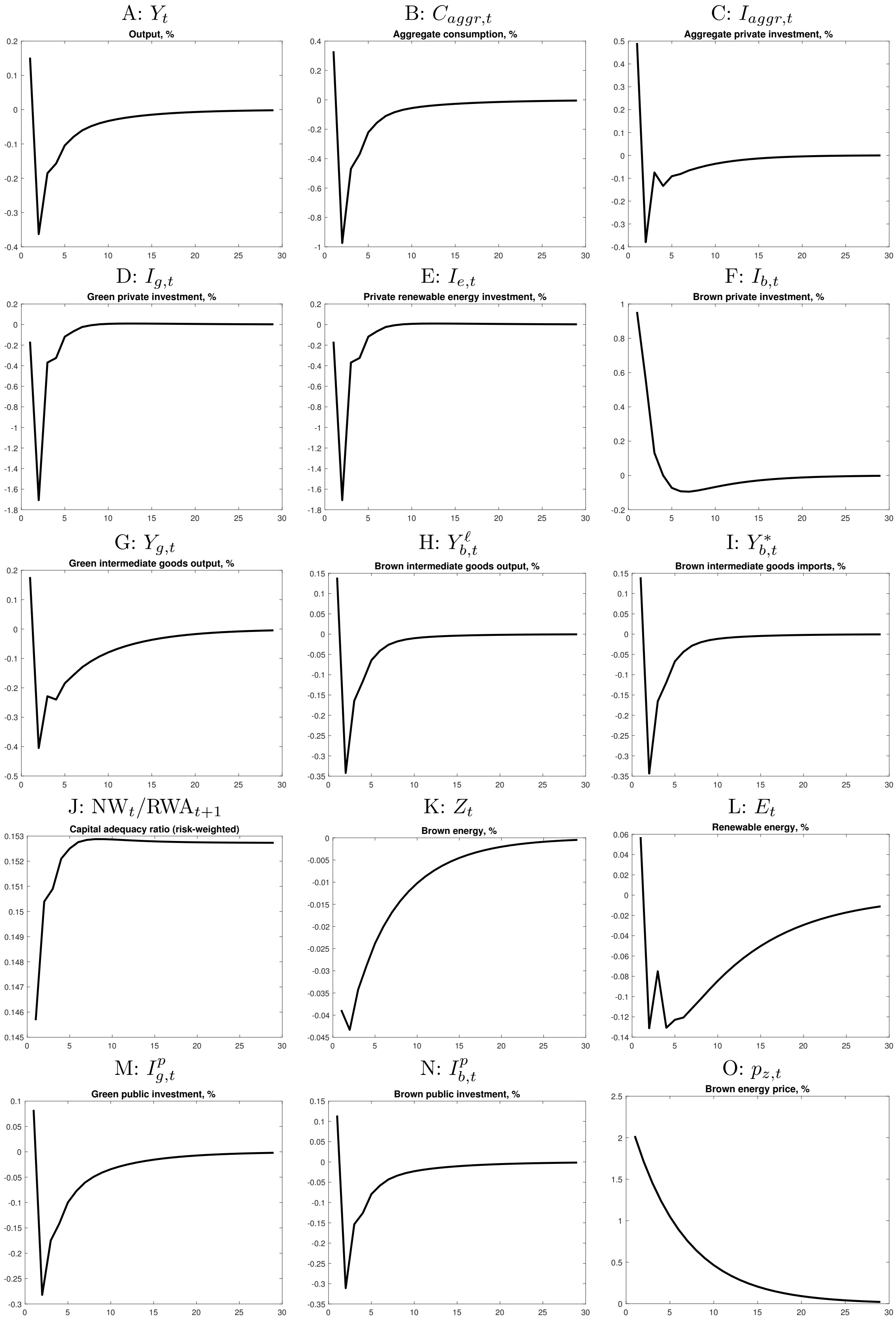
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to the exchange rate S_t ($\varepsilon_{s,1} = 0.002$).

Figure C.8: Impulse response functions – domestic risk premium shock



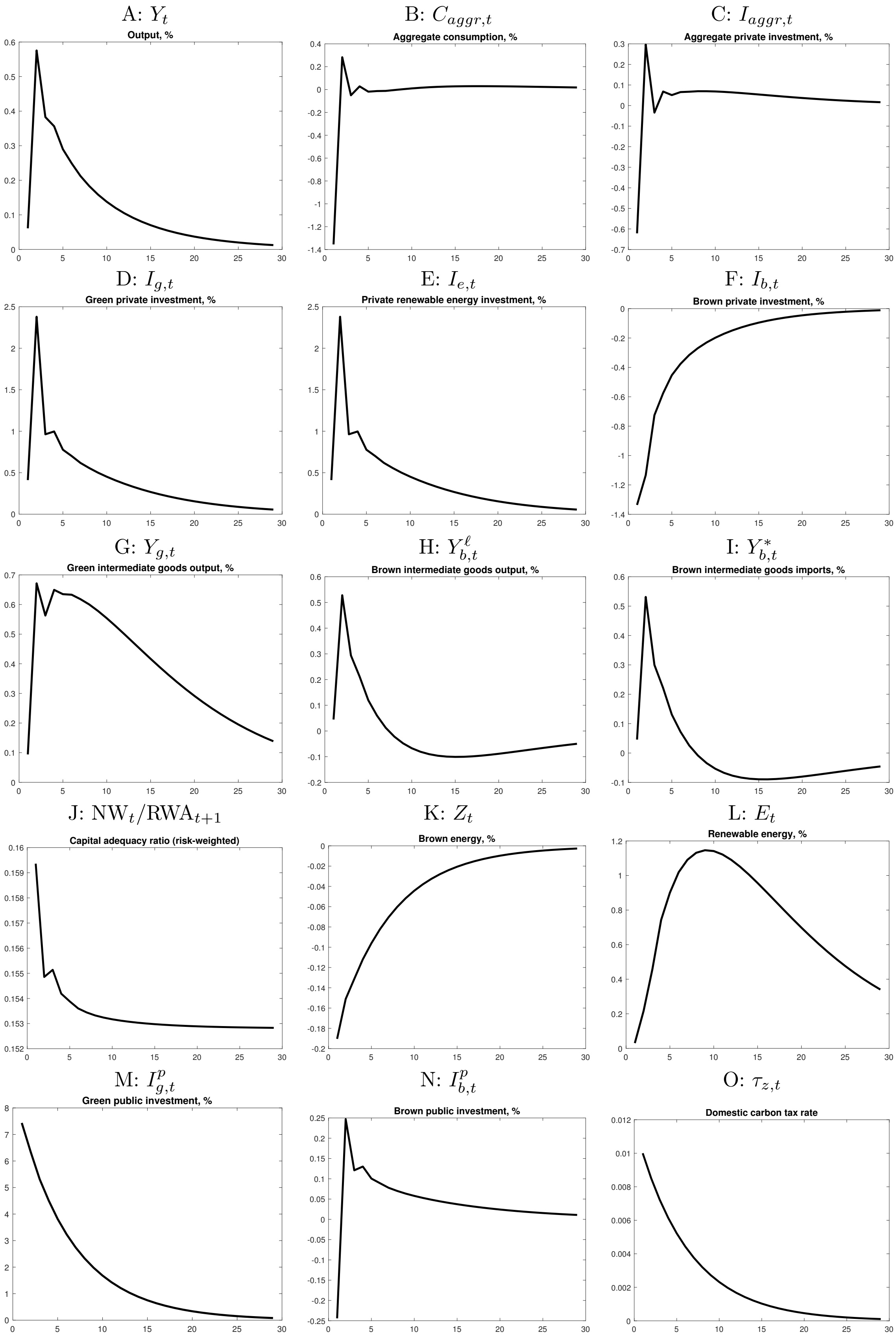
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to the domestic risk premium RP_t ($\varepsilon_{r,1} = 0.002$).

Figure C.9: Impulse response functions – brown energy price shock



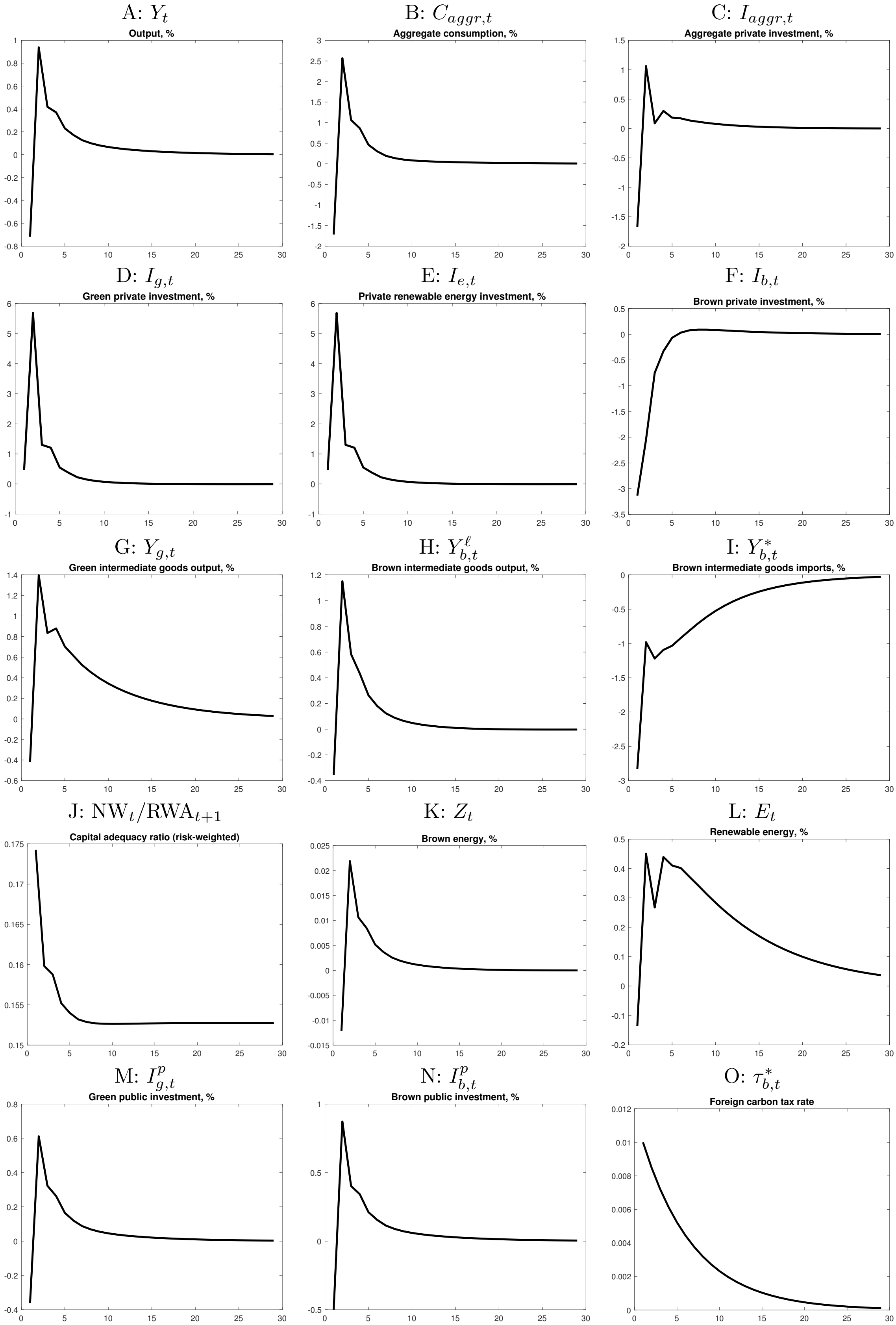
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to the brown energy price $p_{z,t}$ ($\varepsilon_{z,1} = 0.02$).

Figure C.10: Impulse response functions – domestic carbon tax rate shock



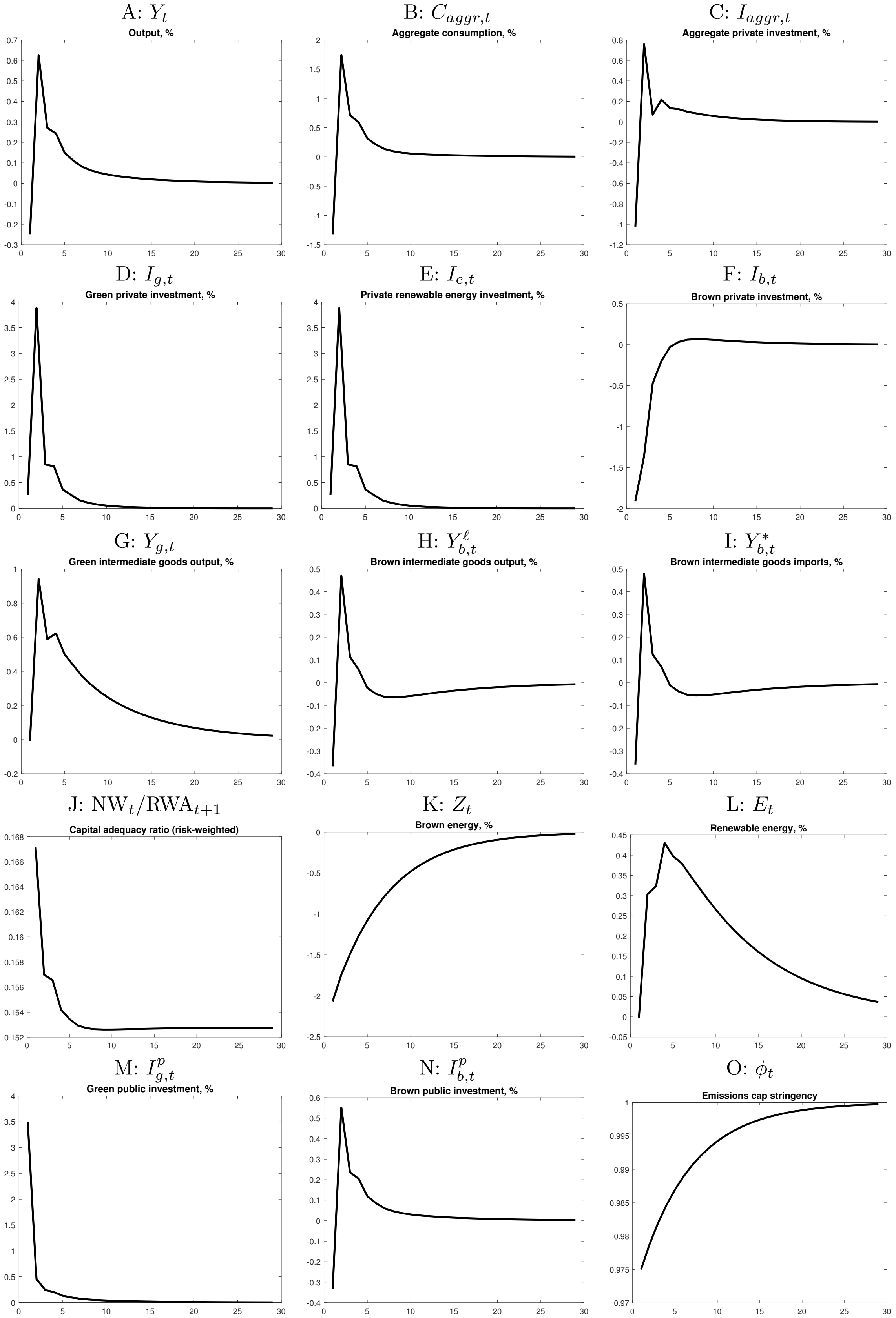
Notes: This figure depicts impulse response functions for a positive shock to the domestic carbon tax rate $\tau_{z,t}$ ($\varepsilon_{\tau_z,1} = 0.01$).

Figure C.11: Impulse response functions – foreign carbon tax rate shock



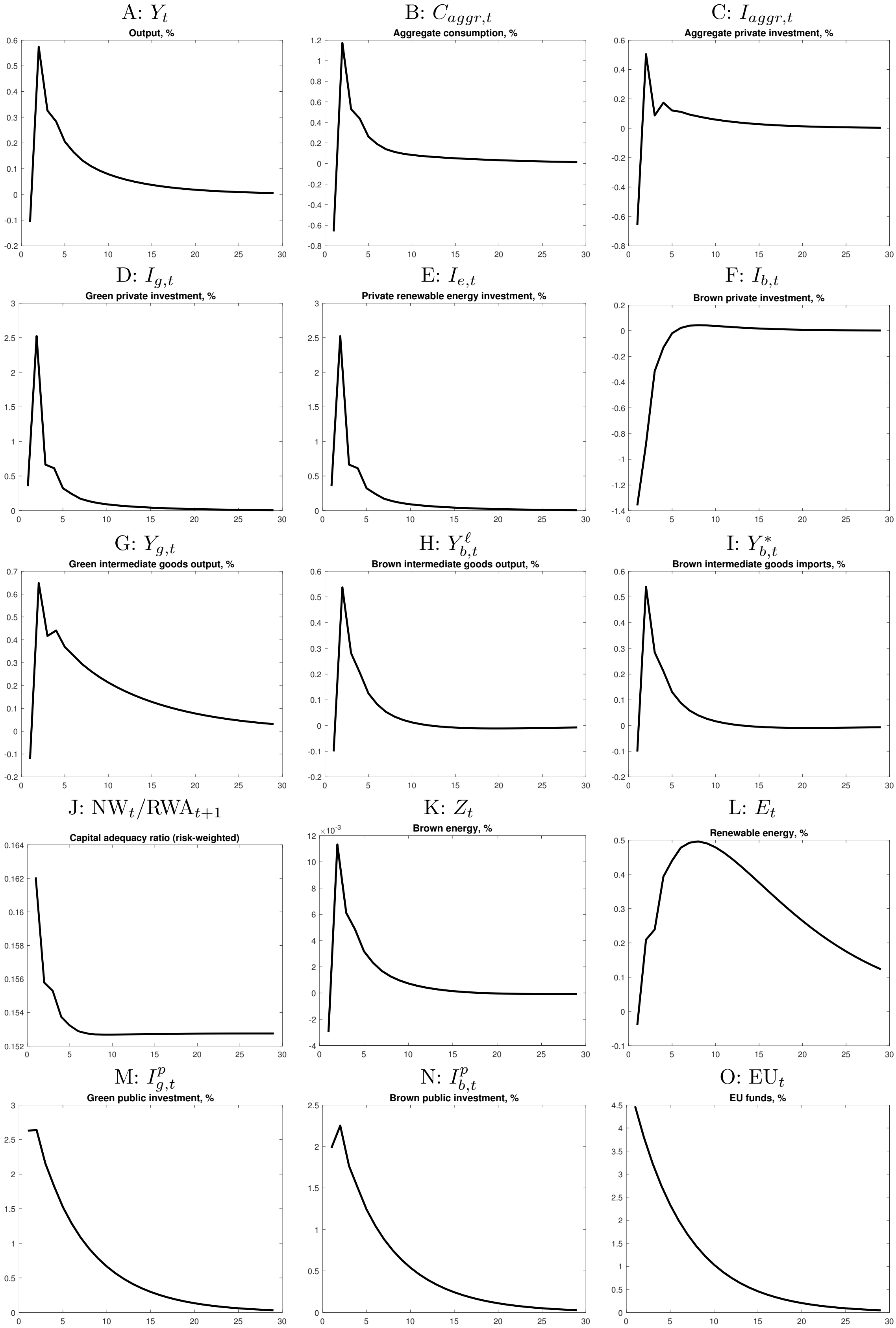
Notes: This figure depicts impulse response functions for a positive shock to the foreign carbon tax rate $\tau^*_{b,t}$ ($\varepsilon_{\tau^*_b,1} = 0.01$).

Figure C.12: Impulse response functions – emissions cap shock



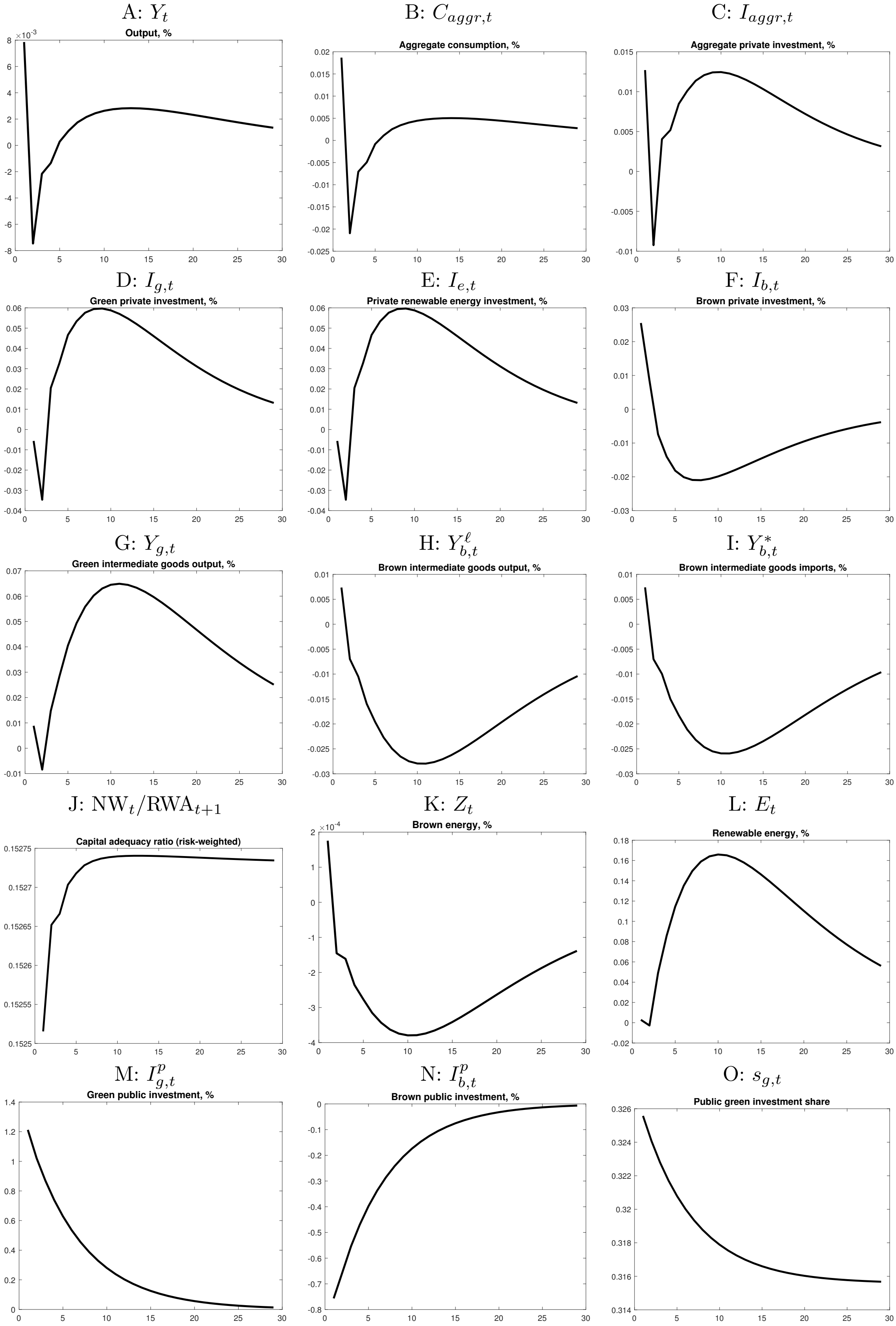
Notes: This figure depicts impulse response functions for a negative shock to the emissions cap ϕ_t ($\varepsilon_{\phi,1} = 0.025$).

Figure C.13: Impulse response functions – EU funds shock



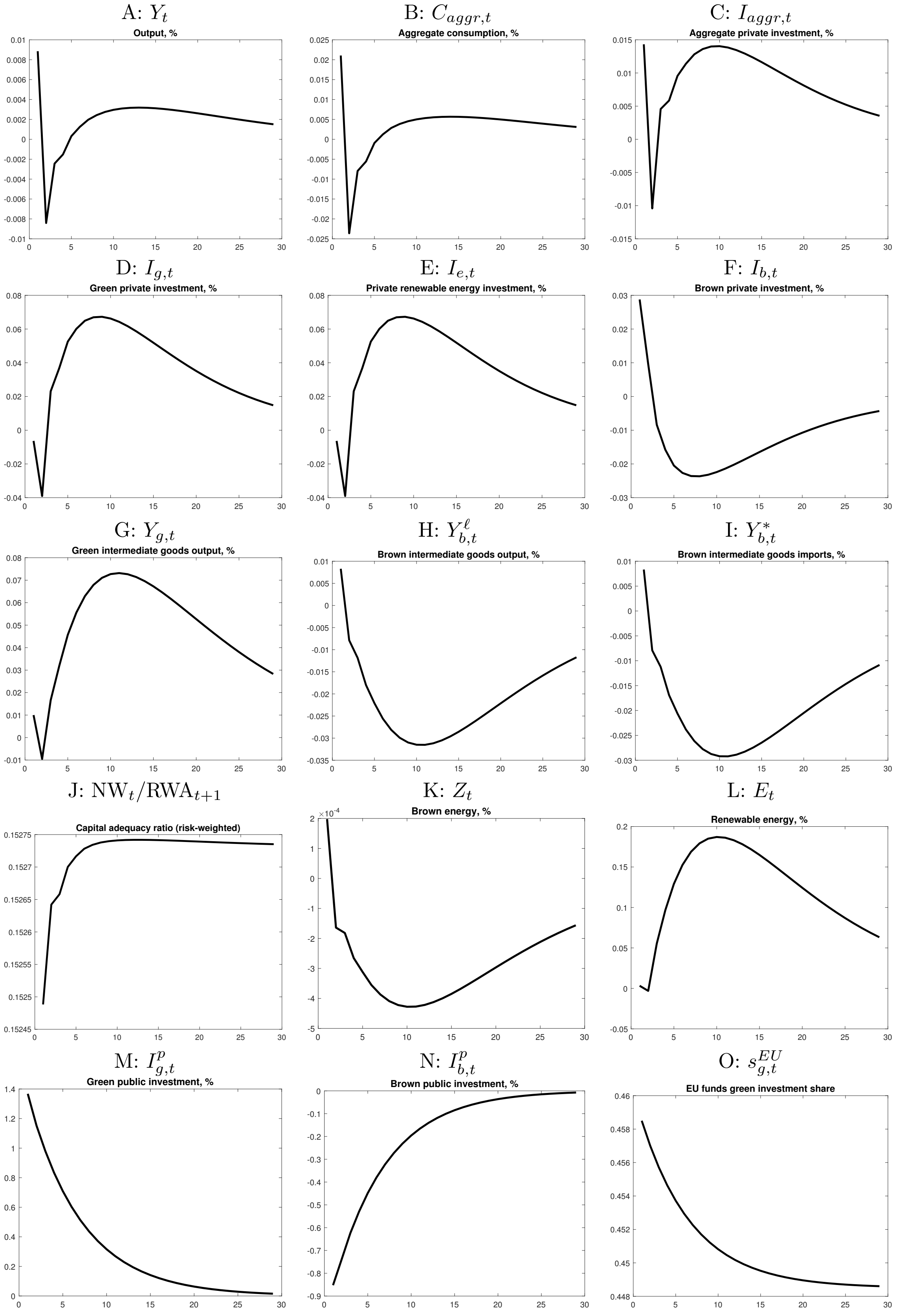
Notes: This figure depicts impulse response functions for a positive one-standard-deviation shock to EU funds EU_t ($\varepsilon_{EU,1} = 0.0025$).

Figure C.14: Impulse response functions – domestic green public investment share shock



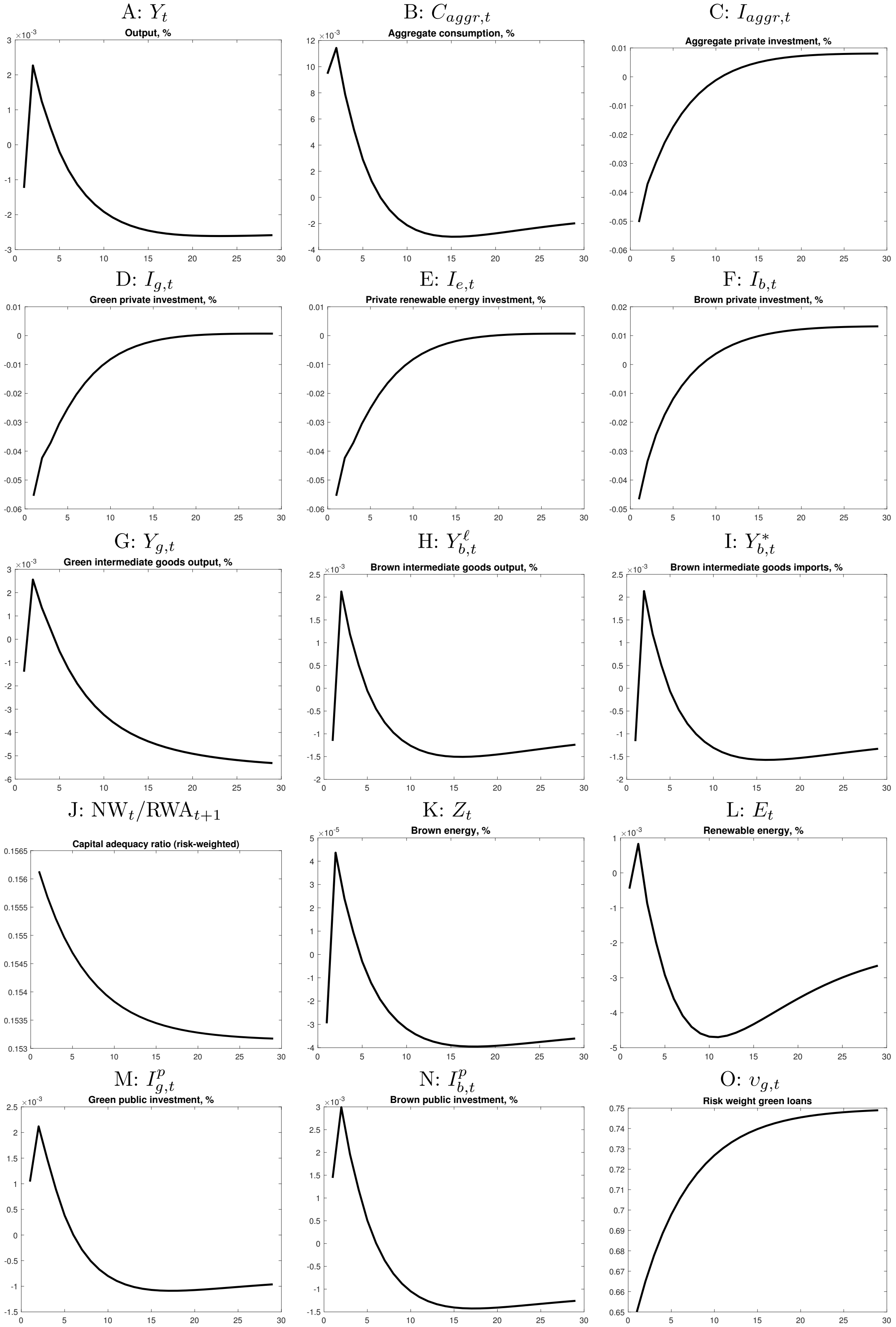
Notes: This figure depicts impulse response functions for a positive shock to the domestic green public investment share $s_{g,t}$ ($\varepsilon^{p}_{g,1} = 0.01$).

Figure C.15: Impulse response functions – EU green public investment share shock



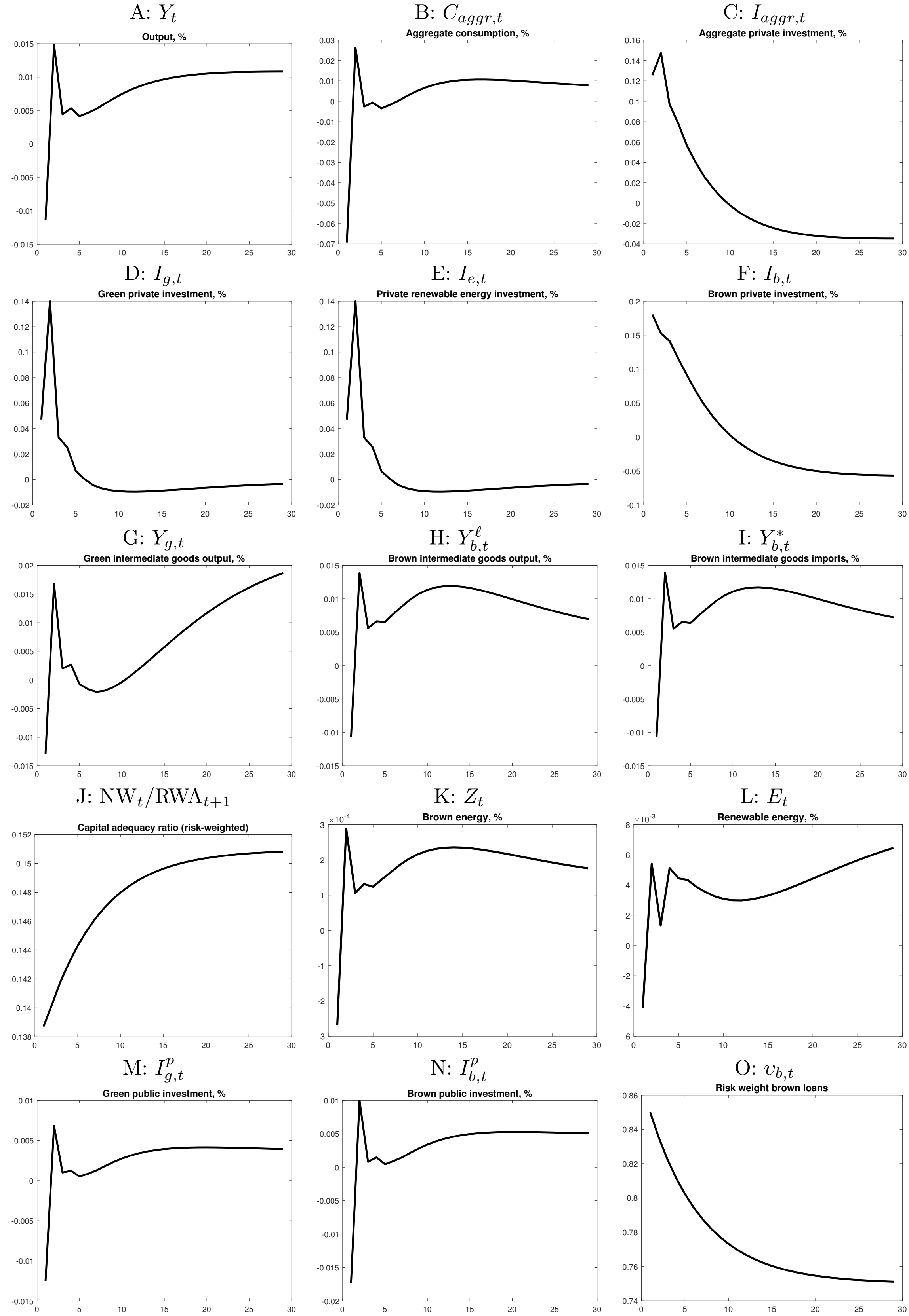
Notes: This figure depicts impulse response functions for a positive shock to the EU green public investment share $s^{EU}_{g,t}$ ($\varepsilon^{EU}_{g,1} = 0.01$).

Figure C.16: Impulse response functions – green loan risk weight shock



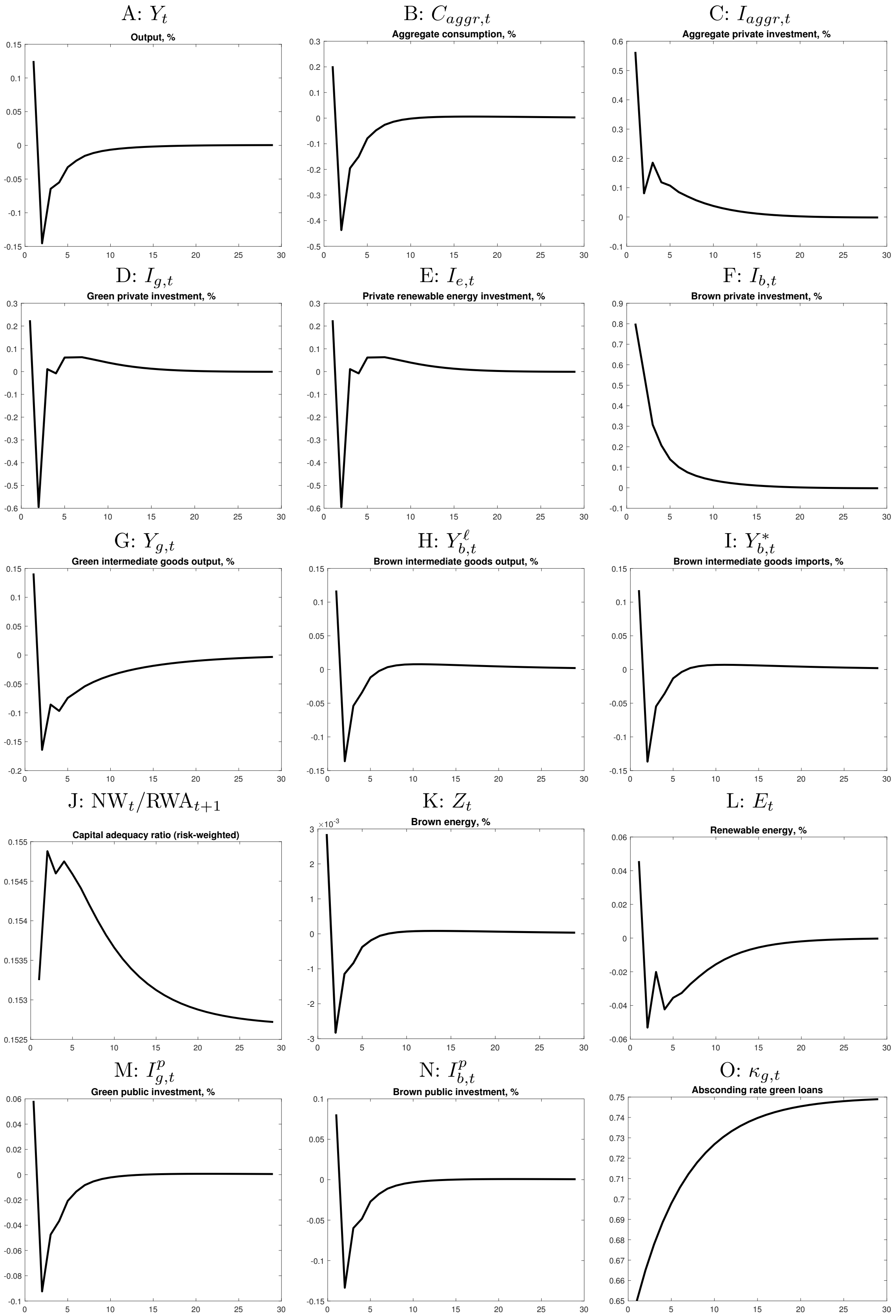
Notes: This figure depicts impulse response functions for a negative shock to the green loan risk weight $\upsilon_{g,t}$ ($\varepsilon_{\upsilon_g,1} = 0.10$).

Figure C.17: Impulse response functions – brown loan risk weight shock



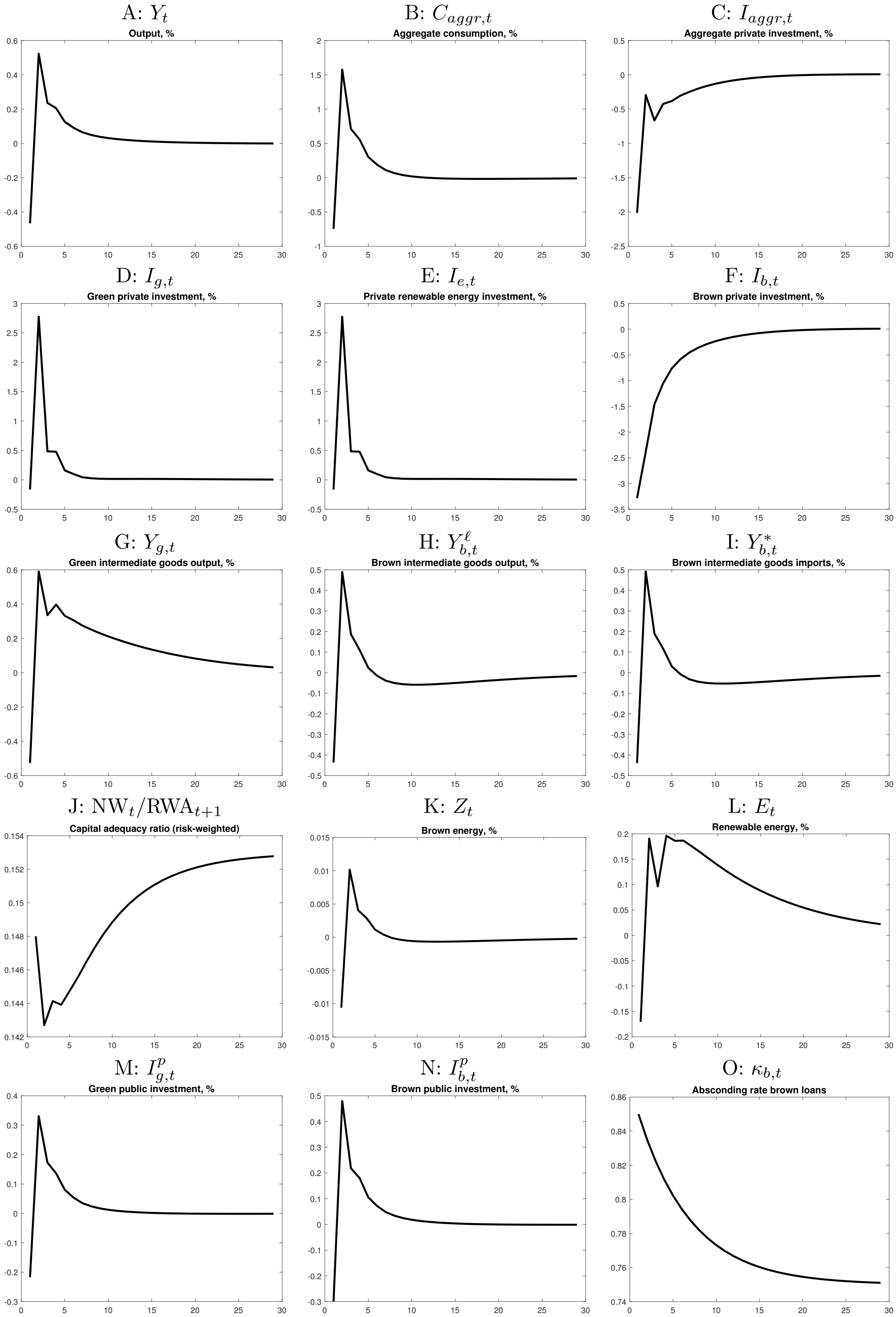
Notes: This figure depicts impulse response functions for a positive shock to the brown loan risk weight $\upsilon_{b,t}$ ($\varepsilon_{\upsilon_b,1} = 0.10$).

Figure C.18: Impulse response functions – green loan absconding rate shock



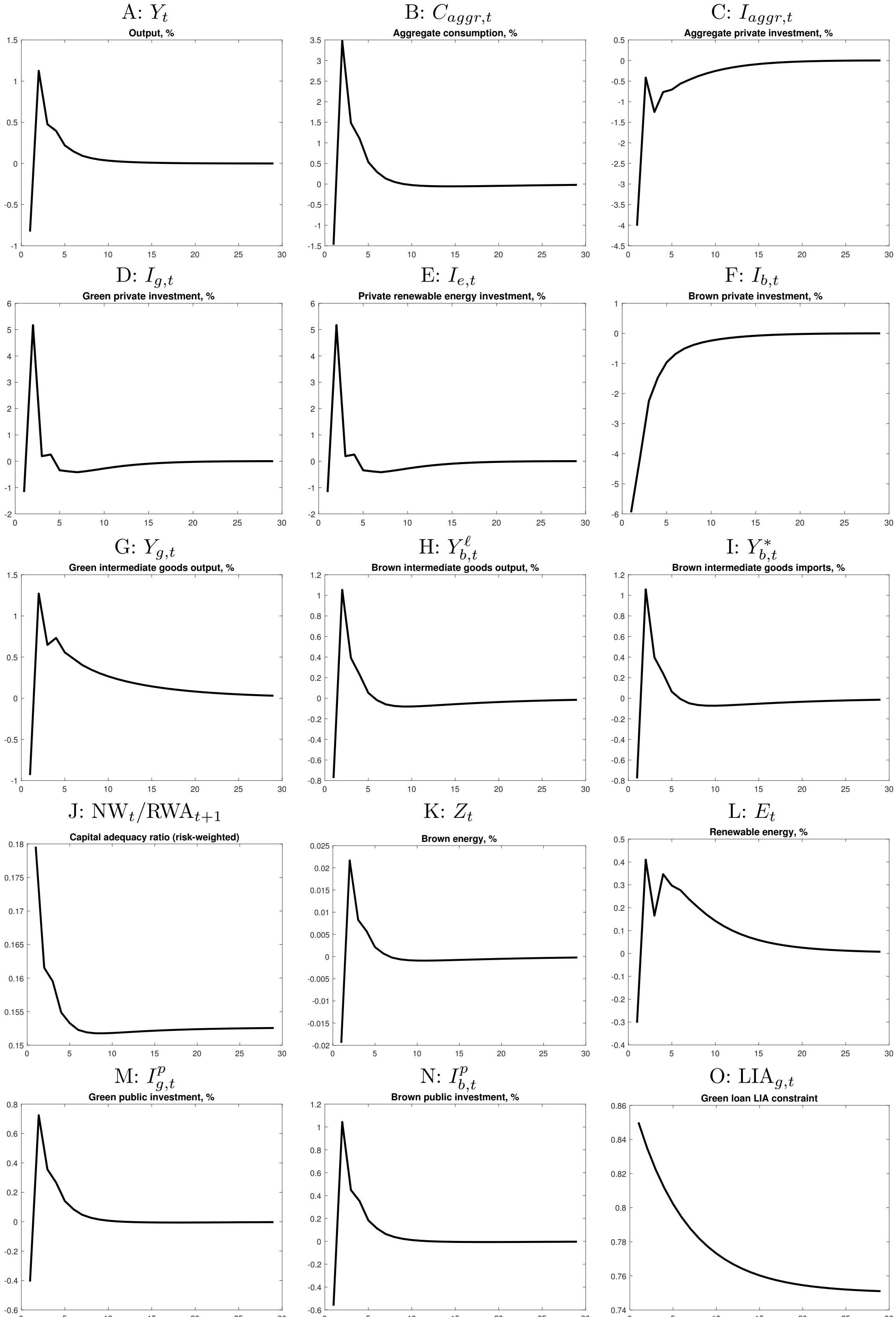
Notes: This figure depicts impulse response functions for a negative shock to the green loan absconding rate $\kappa_{g,t}$ ($\varepsilon_{\kappa_g,1} = 0.10$).

Figure C.19: Impulse response functions – brown loan absconding rate shock



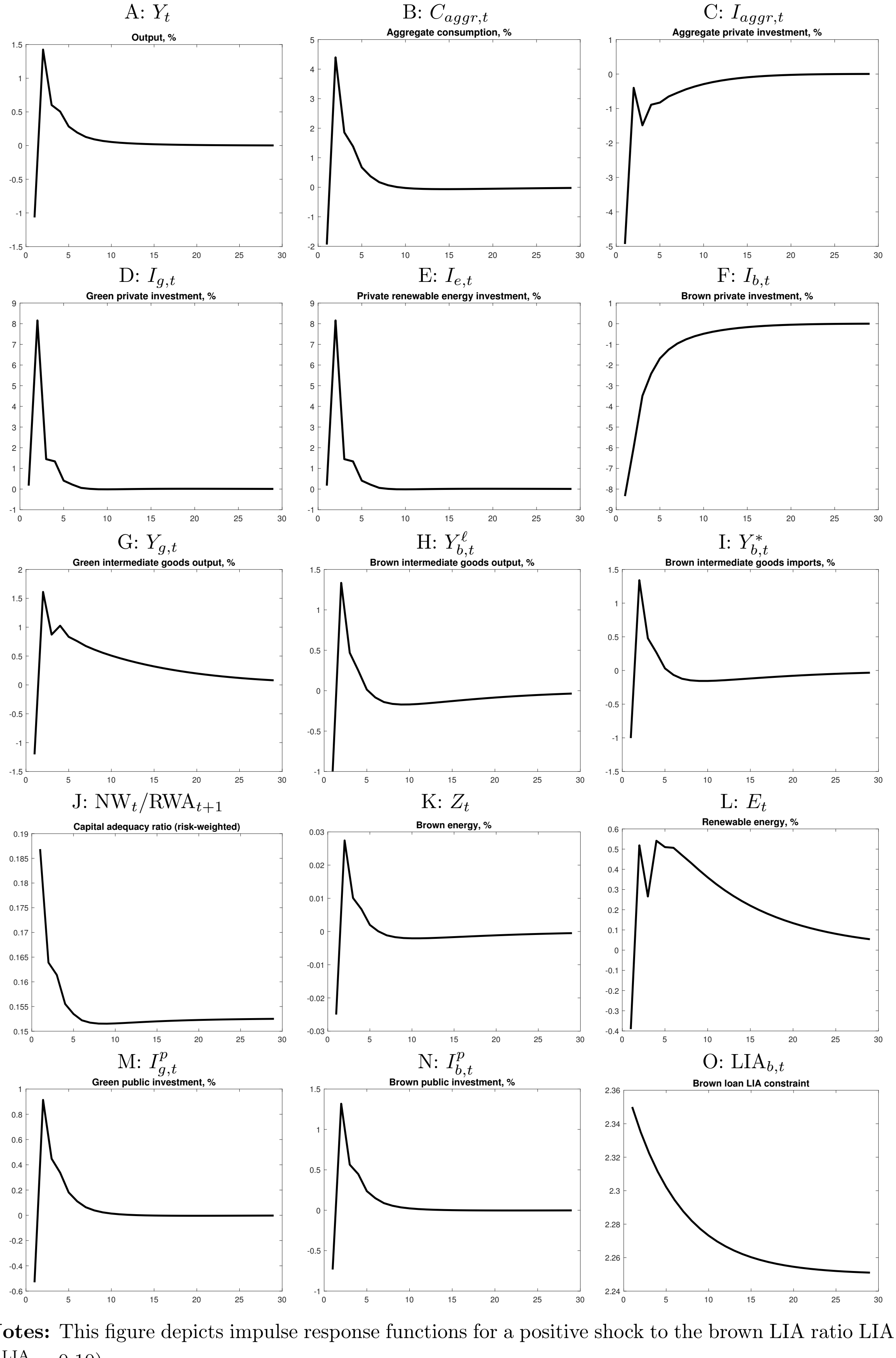
Notes: This figure depicts impulse response functions for a positive shock to the brown loan absconding rate $\kappa_{b,t}$ ($\varepsilon_{\kappa_b,1} = 0.10$).

Figure C.20: Impulse response functions – green LIA ratio shock



Notes: This figure depicts impulse response functions for a positive shock to the green LIA ratio $\mathrm{LIA}_{g,t}$ ($\varepsilon^{\mathrm{LIA}}_{g,1} = 0.10$).

Figure C.21: Impulse response functions – brown LIA ratio shock



Notes: This figure depicts impulse response functions for a positive shock to the brown LIA ratio $\mathrm{LIA}_{b,t}$ ($\varepsilon^{\mathrm{LIA}}_{b,1} = 0.10$).

D Transition Period Dynamics

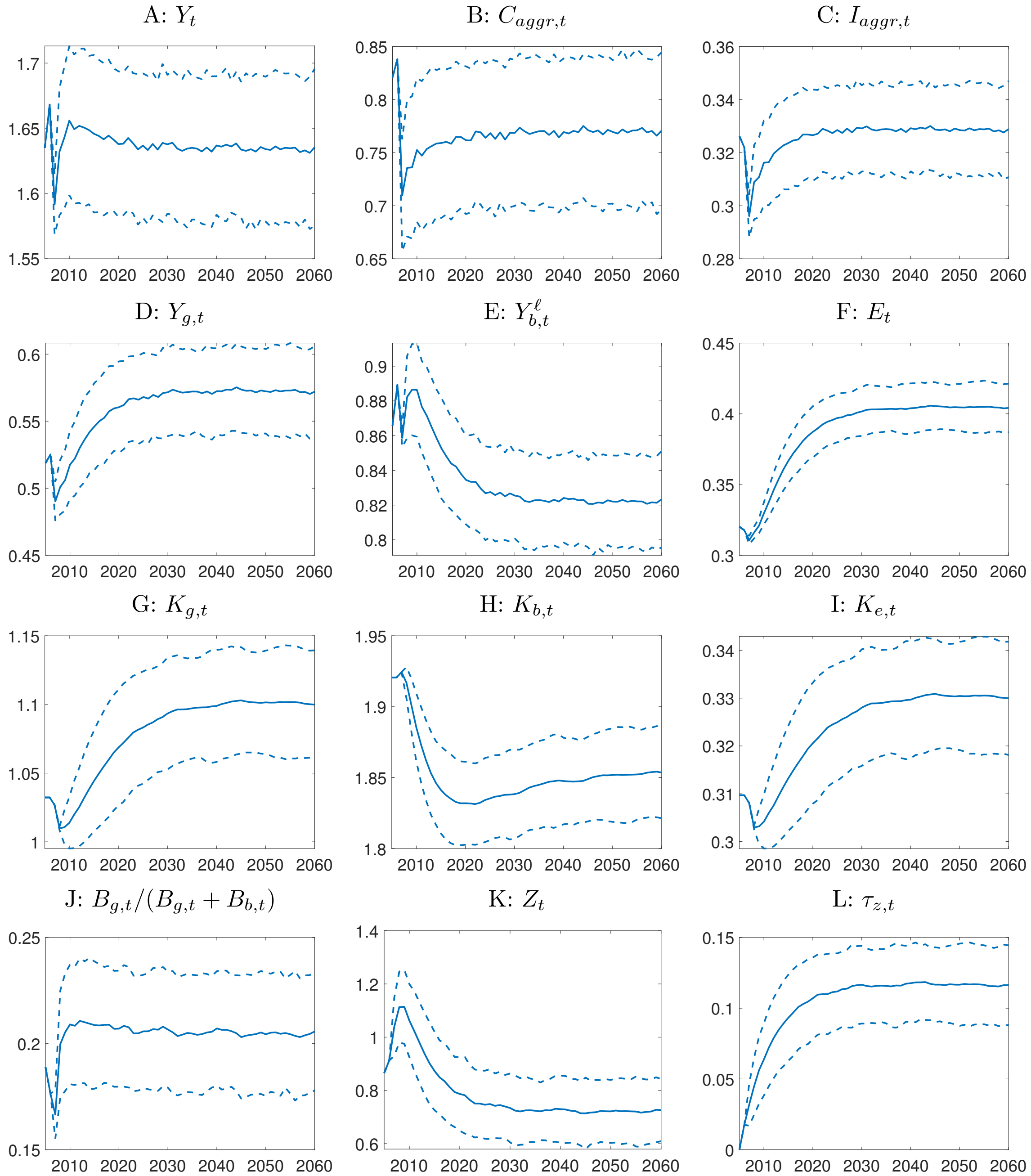
The following figures provide simulations of transition dynamics from the current benchmark model to the alternative model corresponding to specific scenarios, as discussed in Section 5.2, for the period 2005–2060. Therefore, the benchmark model is taken to be representative of the year 2005.[27] Its steady state is taken as initial starting values for the simulations. The model corresponding to the specific scenario is then utilized to let the model converge from the initial steady state (benchmark calibration) to the alternative calibration according to the specific scenario. All volatilities are, however, chosen to be zero, except for the specific shock that induces the transition.

Specifically, Figure D.1 depicts the dynamics for the introduction of the domestic carbon tax rate and a transition to the level needed to imply an emissions reduction of 17%. Shocks to the domestic carbon tax rate $\tau_{z,t}$ might happen along the way to account for policy uncertainty ($\sigma_{\tau_z} = 0.01$). Next, Figure D.2 depicts the dynamics for a decrease in the emissions cap that implies an emissions reduction of 17% in the long run. Shocks to the emissions cap ϕ_t might happen along the way to account for policy uncertainty ($\sigma_z = 0.01$).

In each figure, 12 variables are depicted: (A) final goods output (GDP) Y_t, (B) aggregate private consumption $C_{aggr,t}$, (C) aggregate private investment $I_{aggr,t}$, (D) green intermediate goods output $Y_{g,t}$, (E) brown intermediate goods output/consumption $Y^{\ell}_{b,t}$, (F) renewable energy output E_t, (G) private green capital stock $K_{g,t}$, (H) private brown capital stock $K_{b,t}$, (I) private renewable energy capital stock, (J) green loan ratio $B_{g,t}/(B_{g,t}+B_{b,t})$, (K) brown enery imports (emissions) Z_t, and (L) the exogenous variable that is inducing the transition, i.e. the domestic carbon tax rate $\tau_{z,t}$ or the emissions cap ϕ_t.

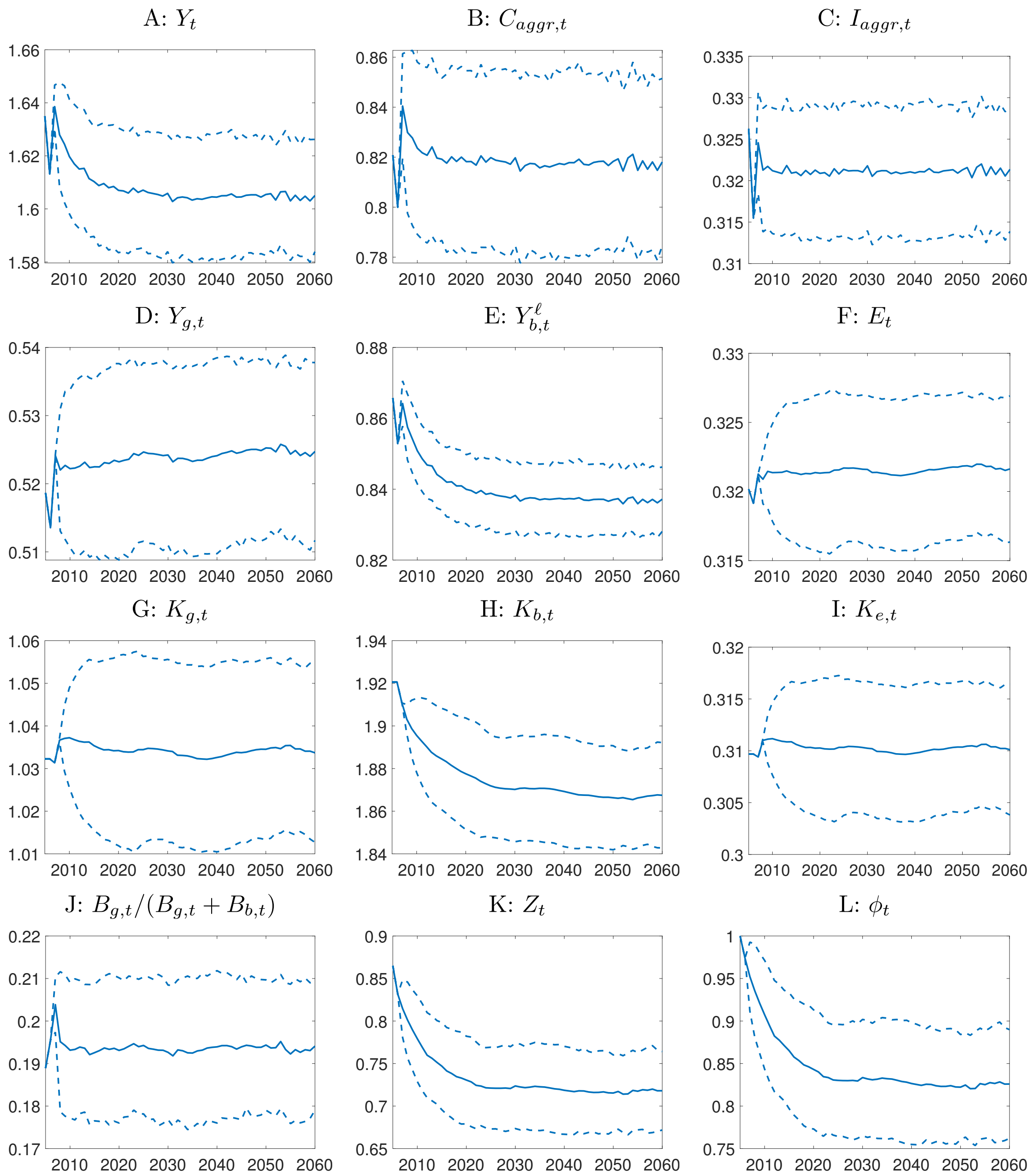
[27]Since the 17% emissions target for Latvia is chosen corresponding to 2005 base levels, as discussed in Section 4, 2005 is chosen as the start date.

Figure D.1: Transition dynamics – domestic carbon tax rate



Notes: This figure depicts transition dynamics induced by an increasing domestic carbon tax rate $\tau_{z,t}$. The only shock active is the shock to the carbon tax rate $\varepsilon_{\tau_z,t}$ with an assumed volatility of $\sigma_{\tau_z} = 0.01$ to capture policy uncertainty in the model. The solid blue line depicts the mean response across 250 simulations for 55 years, whereas the dashed blue lines represent confidence bands, computed as mean response $\pm$ 1.645 times the standard deviation across the 250 simulations at each point in time.

Figure D.2: Transition dynamics – emissions cap



Notes: This figure depicts transition dynamics induced by a decreasing emissions cap ϕ_t. The only shock active is the shock to the emissions cap $\varepsilon_{\phi,t}$ with an assumed volatility of $\sigma_\phi = 0.01$ to capture policy uncertainty in the model. The solid blue line depicts the mean response across 250 simulations for 55 years, whereas the dashed blue lines represent confidence bands, computed as mean response $\pm$ 1.645 times the standard deviation across the 250 simulations at each point in time.

E Robustness and Sensitivity Analysis: Details

The following three paragraphs describe model modifications that are analyzed in Section 6 to explore the sensitivity and robustness of the main results with respect to key assumptions about the nature of public funds usage (the first paragraph describes the model where productive public funds are distributed in a lump-sum fashion to entrepreneurs instead of being used to build public capital, and the second paragraph describes the model where productive public funds are used to partly finance the investment expenditures of entrepreneurs instead) and the nature of financial frictions (the third paragraph describes the necessary modifications to the equilibrium system to include the debt-to-income borrowing constraints instead of the loan-in-advance constraints).

Lump-sum transfer model The public funds used as (green and brown) public investment expenditure in the benchmark model are now redistributed to the (green and brown) entrepreneurs as lump-sum transfers.

Firstly, just to use more appropriate notation, let me denote these lump-sum transfers by $T^p_{g,t}$ and $T^p_{b,t}$, keeping the definitions unchanged relative to the benchmark model:

$$\begin{aligned} T^p_{g,t} &= s_i\{s_{g,t}\tau_c(\lambda_w C^\ell_{w,t} + [(1+\iota^c_w)S_t + t^c_w]\lambda_w C^*_{w,t} + \lambda_g C^\ell_{g,t} + [(1+\iota^c_g)S_t + t^c_g]\lambda_g C^*_{g,t} \\ &\quad + \lambda_b C^\ell_{b,t} + [(1+\iota^c_b)S_t + t^c_b]\lambda_b C^*_{b,t}) + s_{g,t}(\tau^w_l + \tau^e_l)\lambda_w W_t L_t\} + s^{EU}_{g,t}\mathrm{EU}_t \\ &\quad + (1-s_b)(1 - \mathbb{1}^{tax}_{b,env} + s_{g,t}\mathbb{1}^{tax}_{b,env})(\tau_{z,t}Z_t + \Gamma_{z,t}), \qquad \text{(E.1)} \\ T^p_{b,t} &= s_i\{(1-s_{g,t})\tau_c(\lambda_w C^\ell_{w,t} + [(1+\iota^c_w)S_t + t^c_w]\lambda_w C^*_{w,t} + \lambda_g C^\ell_{g,t} + [(1+\iota^c_g)S_t + t^c_g]\lambda_g C^*_{g,t} \\ &\quad + \lambda_b C^\ell_{b,t} + [(1+\iota^c_b)S_t + t^c_b]\lambda_b C^*_{b,t}) + (1-s_{g,t})(\tau^w_l + \tau^e_l)\lambda_w W_t L_t\} + (1 - s^{EU}_{g,t})\mathrm{EU}_t \\ &\quad + \mathbb{1}^{tax}_{b,env}(1-s_b)(1-s_{g,t})(\tau_{z,t}Z_t + \Gamma_{z,t}). \qquad \text{(E.2)} \end{aligned}$$

Secondly, one has to delete the public capital accumulation equations (19) and (33) from the set of equilibrium conditions and remove the public capital stocks from the productions functions for green intermediate goods, renewable energy, and brown intermediate goods, which yields the following production functions:

$$\begin{aligned} Y_{g,t} &= (E^d_t)^{\pi_1}(K_{g,t})^{\pi_2}(A_{g,t}\lambda_w L_{g,t})^{\pi_3}, \qquad \text{(E.3)} \\ E^s_t &= (K_{e,t})^{\nu_1}(A_{e,t}\lambda_w L_{e,t})^{\nu_2}, \qquad \text{(E.4)} \\ Y^\ell_{b,t} &= (Z_t)^{\alpha_1}\,(A_{k,t}(K_{b,t}))^{\alpha_2}\,(A_{b,t}\lambda_w L_{b,t})^{\alpha_3}. \qquad \text{(E.5)} \end{aligned}$$

Thirdly, the budget constraints of the entrepreneurs change to:

$$(1+\tau_c)(C^\ell_{g,t} + [(1+\iota^c_g)S_t + t^c_g]C^*_{g,t}) + \frac{W_t(\nu_f R^*_t e^{\mathrm{RP}_t} + 1 - \nu_f + \tau^e_l)(\lambda_w L_{g,t} + \lambda_w L_{e,t})}{\lambda_g}$$

$$+\frac{p_{e,t}E_t^d}{\lambda_g}+\frac{I^{\ell}_{g,t}+[(1+\iota_g^i)S_t+t_g^i]I^*_{g,t}}{\lambda_g}+\frac{I^{\ell}_{e,t}+[(1+\iota_e^i)S_t+t_e^i]I^*_{e,t}}{\lambda_g}+\frac{R_{g,t}B_{g,t}}{\lambda_g}$$
$$=\frac{p_{g,t}Y_{g,t}}{\lambda_g}+\frac{p_{e,t}E_t^s}{\lambda_g}+\frac{B_{g,t+1}}{\lambda_g}+\frac{T^p_{g,t}}{\lambda_g}, \tag{E.6}$$

and

$$(1+\tau_c)(C^{\ell}_{b,t}+[(1+\iota_b^c)S_t+t_b^c]C^*_{b,t})+\frac{W_t(\nu_f R_t^* e^{\mathrm{RP}_t}+1-\nu_f+\tau_l^e)\lambda_w L_{b,t}}{\lambda_b} \tag{E.7}$$
$$+\frac{(S_t p_{z,t}+\tau_{z,t})Z_t}{\lambda_b}+\frac{I^{\ell}_{b,t}+[(1+\iota_b^i)S_t+t_b^i]I^*_{b,t}}{\lambda_b}+\frac{R_{b,t}B_{b,t}}{\lambda_b}+\frac{\Gamma_{z,t}}{\lambda_b}=\frac{p_{b,t}Y^{\ell}_{b,t}}{\lambda_b}+\frac{B_{b,t+1}}{\lambda_b}+\frac{T^p_{b,t}}{\lambda_b}.$$

Investment subsidy model The modifications of the model in the previous paragraph are very simple to make. For this model, where the public productive funds are used to partly finance private investment expenditures of entrepreneurs, some more modifications are necessary.

Firstly, some modifications are as in the last paragraph. Thus, Equations (E.1), (E.2), (E.3), (E.4), and (E.5) are also valid for this model variant. Additionally, the public capital accumulation equations (19) and (33) are again removed from the set of equilibrium conditions.

Secondly, I introduce two additional variables, $s^{p,g}_{\mathtt{inv},t}$ and $s^{p,b}_{\mathtt{inv},t}$, which denote the shares of private investment expenditure by green and brown, respectively, entrepreneurs, financed by the government. These variables satisfy the following equilibrium conditions:

$$T^p_{g,t}=s^{p,g}_{\mathtt{inv},t}\left(I^{\ell}_{g,t}+[(1+\iota_g^i)S_t+t_g^i]I^*_{g,t}+I^{\ell}_{e,t}+[(1+\iota_e^i)S_t+t_e^i]I^*_{e,t}\right), \tag{E.8}$$
$$T^p_{b,t}=s^{p,g}_{\mathtt{inv},t}\left(I^{\ell}_{b,t}+[(1+\iota_b^i)S_t+t_b^i]I^*_{b,t}\right). \tag{E.9}$$

Thirdly, the budget constraint of green entrepreneurs changes to:

$$(1+\tau_c)(C^{\ell}_{g,t}+[(1+\iota_g^c)S_t+t_g^c]C^*_{g,t})+\frac{W_t(\nu_f R_t^* e^{\mathrm{RP}_t}+1-\nu_f+\tau_l^e)(\lambda_w L_{g,t}+\lambda_w L_{e,t})}{\lambda_g}$$
$$+\frac{p_{e,t}E_t^d}{\lambda_g}+\frac{(1-s^{p,g}_{\mathtt{inv},t})\{I^{\ell}_{g,t}+[(1+\iota_g^i)S_t+t_g^i]I^*_{g,t}+I^{\ell}_{e,t}+[(1+\iota_e^i)S_t+t_e^i]I^*_{e,t}\}}{\lambda_g}$$
$$+\frac{R_{g,t}B_{g,t}}{\lambda_g}=\frac{p_{g,t}Y_{g,t}}{\lambda_g}+\frac{p_{e,t}E_t^s}{\lambda_g}+\frac{B_{g,t+1}}{\lambda_g}, \tag{E.10}$$

Moreover, the brown entrepreneurs' budget constraint is here given by:

$$(1+\tau_c)(C^{\ell}_{b,t}+[(1+\iota_b^c)S_t+t_b^c]C^*_{b,t})+\frac{W_t(\nu_f R_t^* e^{\mathrm{RP}_t}+1-\nu_f+\tau_l^e)\lambda_w L_{b,t}}{\lambda_b}$$
$$+\frac{(S_t p_{z,t}+\tau_{z,t})Z_t}{\lambda_b}+\frac{(1-s^{p,b}_{\mathtt{inv},t})\{I^{\ell}_{b,t}+[(1+\iota_b^i)S_t+t_b^i]I^*_{b,t}\}}{\lambda_b}+\frac{R_{b,t}B_{b,t}}{\lambda_b}+\frac{\Gamma_{z,t}}{\lambda_b}$$

$$= \frac{p_{b,t} Y^{\ell}_{b,t}}{\lambda_b} + \frac{B_{b,t+1}}{\lambda_b}. \tag{E.11}$$

Fourthly, the LIA constraints for both types of entrepreneurs are adapted to look as follows (replacing Equations 9 and 25):

$$B_{g,t+1} \geq \text{LIA}_{g,t}(1 - s^{p,g}_{\texttt{inv},t})(I^{\ell}_{g,t} + [(1 + \iota^i_g)S_t + t^i_g]I^*_{g,t} + I^{\ell}_{e,t} + [(1 + \iota^i_e)S_t + t^i_e]I^*_{e,t}), \tag{E.12}$$

$$B_{b,t+1} \geq \text{LIA}_{b,t}(1 - s^{p,b}_{\texttt{inv},t})(I^{\ell}_{b,t} + [(1 + \iota^i_b)S_t + t^i_b]I^*_{b,t}). \tag{E.13}$$

Finally, a number of first order conditions in the optimization problems of the entrepreneurs change. Specifically, the right-hand sides of Equations (A.19), (A.20), (A.21), (A.22), (A.31), and (A.32) change to:

$$\ldots = (1 - s^{p,g}_{\texttt{inv},t})(1 + \mu^{\text{LIA}}_{g,t}\text{LIA}_{g,t})\lambda_{g,t}, \tag{E.14}$$

$$\ldots = (1 - s^{p,g}_{\texttt{inv},t})(1 + \mu^{\text{LIA}}_{g,t}\text{LIA}_{g,t})\lambda_{g,t}[(1 + \iota^i_g)S_t + t^i_g], \tag{E.15}$$

$$\ldots = (1 - s^{p,g}_{\texttt{inv},t})(1 + \mu^{\text{LIA}}_{g,t}\text{LIA}_{g,t})\lambda_{g,t}, \tag{E.16}$$

$$\ldots = (1 - s^{p,g}_{\texttt{inv},t})(1 + \mu^{\text{LIA}}_{g,t}\text{LIA}_{g,t})\lambda_{g,t}[(1 + \iota^i_e)S_t + t^i_e], \tag{E.17}$$

$$\ldots = (1 - s^{p,b}_{\texttt{inv},t})(1 + \mu^{\text{LIA}}_{b,t}\text{LIA}_{b,t})\lambda_{b,t}, \tag{E.18}$$

$$\ldots = (1 - s^{p,b}_{\texttt{inv},t})(1 + \mu^{\text{LIA}}_{b,t}\text{LIA}_{b,t})\lambda_{b,t}[(1 + \iota^i_b)S_t + t^i_b]. \tag{E.19}$$

Model modifications to replace LIA constraints by DTI borrowing constraints
It is very simple to change the model of Section 3 and its equilibrium (described in Appendix A) such that loan-in-advance constraints are replaced by debt-to-income borrowing constraints. Firstly, assume that Equations (9) and (25) are replaced by $\mu^{\text{LIA}}_{g,t} \equiv 0$ and $\mu^{\text{LIA}}_{b,t} \equiv 0$, respectively, in order to deactivate the loan-in-advance constraints. Secondly, one needs to replace equilibrium conditions (A.40) and (A.41) by the debt-to-income borrowing constraints in Equations (10) and (26).

Table E.1: Alternative models and calibrations: Simulated moments

Moment	Bench-mark	High cap. req. asymmetry	DTI model	Lump-sum transfer	Investment subsidy	Data
$\mathbb{E}\left[\frac{E_t}{E_t+Z_t}\right]$	27.02	27.02	26.75	27.54	26.70	35.41
$\mathbb{E}\left[\frac{Y_{g,t}}{Y_{g,t}+Y^{\ell}_{b,t}+Y^{*}_{b,t}}\right]$	31.56	31.58	31.26	32.58	31.19	34.66
$\mathbb{E}\left[\omega_{g,t}=\frac{B_{g,t}}{B_{g,t}+B_{b,t}}\right]$	18.88	18.92	18.01	19.39	18.71	12.09
$\mathbb{E}\left[\frac{\Gamma_{z,t}}{Y_t}\right]$	0.10	0.10	0.10	0.00	0.00	0.09
$\mathbb{E}\left[\frac{\Gamma_{z,t}+\tau_z Z_t}{T_{aggr,t}}\right]$	0.40	0.00	0.40	0.00	0.00	8.84
$\mathbb{E}\left[\frac{I_{aggr,t}}{Y_t}\right]$	19.97	19.93	20.22	20.00	27.26	21.84
$\mathbb{E}\left[\frac{\text{IMP}_t}{Y_t}\right]$	52.30	52.27	52.01	55.09	56.51	56.10
$\mathbb{E}\left[\frac{\text{EXP}_t}{Y_t}\right]$	49.97	49.94	49.67	52.78	54.64	48.56
$\mathbb{E}\left[\frac{B_{g,t}+B_{b,t}}{Y_t}\right]$	28.83	28.77	117.36	28.66	28.87	106.22
$\mathbb{E}\left[\frac{\text{NW}_t}{\text{RWA}_{t+1}}\right]$	15.49	16.52	12.79	16.18	15.56	20.32
$\mathbb{E}\left[\frac{\text{NW}_t}{B_{g,t}+B_{b,t}}\right]$	11.62	12.39	9.59	12.13	11.67	11.29
$\mathbb{E}[r_{d,t}]$	1.45	1.51	1.48	1.47	1.46	1.51
$\mathbb{E}[\omega_{g,t}r_{g,t}+(1-\omega_{g,t})r_{b,t}]$	2.47	2.57	2.37	2.54	2.48	2.68
$\mathbb{E}[r_{g,t}]$	2.38	2.46	2.37	2.42	2.40	1.07
$\mathbb{E}[r_{b,t}]$	2.49	2.60	2.37	2.56	2.50	3.18
$\sigma(\Delta y_t)$	5.31	7.01	2.25	7.22	5.18	5.72
$\sigma(\Delta i_{aggr,t})$	9.43	17.28	15.63	13.55	8.19	16.67
$\sigma(\Delta c_{aggr,t})$	13.51	15.98	1.34	11.34	13.58	6.35
$\sigma(\Delta g_{c,t})$	8.36	9.98	1.88	11.34	8.36	5.98
$\sigma(\Delta e_t)$	2.02	2.64	1.94	2.74	1.86	6.01
$\sigma(\Delta y_{g,t})$	6.13	7.96	6.09	7.25	5.36	7.88
$\sigma(\Delta y_{b,t})$	5.19	6.78	4.06	7.50	5.43	8.07
$\sigma(\Delta i_{g,t})$	18.37	25.68	8.57	24.88	13.84	21.44
$\sigma(\Delta i_{b,t})$	10.01	18.85	21.15	15.23	8.39	8.63
$\sigma(\text{NX}_t/Y_t)$	2.86	3.76	3.18	4.35	3.24	5.33

Notes: This table reports the simulated model moments for the benchmark model (reproduced from Table 1), for four alternative calibrations and models (described in Appendix E and analyzed in Section 6), and the corresponding data counterparts for a variety of macroeconomic variables. The four alternative calibrations and models are the following variations: (1) "High cap. req. asymmetry" assumes a calibration of the bank capital requirement costs function as in Valencia et al. (2017) ($\gamma_0 = 120$, $\gamma_1 = 3.5$, $\gamma_2 = 1$) with additionally setting $\tau = 0.39$, $\phi_1 = 0$, $\phi_2 = 0$ due to technical stability constraints in the model; (2) "DTI model" assumes that there are no loan-in-advance constraints but instead debt-to-income borrowing constraints in the model (assumed parameters, different from the benchmark model: $\overline{\text{DTI}}_g = 2$, $\overline{\text{DTI}}_b = 6$, $\tau = 0.11$, $\sigma_g = \sigma_b = \sigma_e = 0.06$, $\sigma_k = 0.005$, $\sigma_\theta = \sigma_s = \sigma_x = \sigma_r = \sigma_{EU} = 0.01$); (3) "Lump-sum transfer" assumes that the productive public funds are used to finance lump-sum transfers to entrepreneurs with additionally setting $\tau = 0.133$, $\phi_1 = \phi_2 = 0$ due to technical stability constraints; (4) "Investment subsidy" assumes that the productive public funds are used to finance a fraction of private investment expenditures of entrepreneurs with additionally setting $\phi_1 = \phi_2 = 0$ due to technical stability constraints. The model moments have been obtained from a stochastic simulation of the model for 2500 years using a first-order perturbation approximation in `dynare` (version 4.5.4). All moments are reported in percentage points.

Table E.2: Scenario analysis results – alternative models with respect to the use of public funds

	Lump-sum transfer model					Investment subsidy model				
	[1.1]	[1.2]	[1.3]	[1.4]	[1.5]	[2.1]	[2.2]	[2.3]	[2.4]	[2.5]
Parameter 1	$\overline{\tau}_z = 0.032$	$e^{\overline{p}_z} = 0.302$	$\overline{s}_g = 1$	$\overline{\tau}_z = 0.032$	$\overline{\tau}_z = 0.032$	$\overline{\tau}_z = 0.027$	$e^{\overline{p}_z} = 0.255$	$\overline{s}_g = 1$	$\overline{\tau}_z = 0.028$	$\overline{\tau}_z = 0.027$
Parameter 2	—	—	—	$s_b = 0.883$	$\overline{\upsilon}_g = 0.5$	—	—	—	$s_b = 0.883$	$\overline{\upsilon}_g = 0.5$
Parameter 3	—	—	—	$\mathbb{1}^{tax}_{b,env} = 1$	$\overline{\kappa}_g = 0.5$	—	—	—	$\mathbb{1}^{tax}_{b,env} = 1$	$\overline{\kappa}_g = 0.5$
Y	−1.88%	−1.88%	0.00%	−1.88%	−1.86%	−1.58%	−1.90%	−2.12%	−1.76%	−1.57%
Y_g	1.14%	1.14%	0.00%	1.14%	1.28%	2.61%	1.05%	11.83%	1.16%	2.71%
Y_b^ℓ	−3.40%	−3.40%	0.00%	−3.40%	−3.44%	−3.61%	−3.33%	−8.70%	−3.18%	−3.63%
Y_b^*	−3.31%	−3.31%	0.00%	−3.31%	−3.33%	−3.48%	−3.24%	−8.29%	−3.08%	−3.50%
C_{aggr}	−1.48%	−1.73%	0.00%	−1.83%	−1.44%	−1.61%	−1.75%	−1.45%	−1.89%	−1.56%
E	0.45%	0.45%	0.00%	0.45%	0.71%	3.25%	0.26%	19.51%	0.56%	3.44%
Z	−17.00%	−17.00%	−0.01%	−17.00%	−17.00%	−17.00%	−17.00%	−6.56%	−17.00%	−17.00%
I_{aggr}	−1.64%	−1.64%	0.00%	−1.64%	−1.51%	−0.10%	−1.70%	−1.21%	−1.17%	−0.01%
I_g	0.12%	0.12%	0.00%	0.12%	0.49%	3.94%	−0.13%	26.13%	0.31%	4.19%
I_e	0.12%	0.12%	0.00%	0.12%	0.48%	3.94%	−0.13%	26.13%	0.31%	4.19%
I_b	−2.91%	−2.91%	0.00%	−2.91%	−2.94%	−2.82%	−2.76%	−19.60%	−2.17%	−2.84%
TR_g^p	10.73%	−0.56%	83.53%	0.68%	10.80%	11.92%	−0.67%	81.64%	0.69%	11.96%
TR_b^p	−2.51%	−2.56%	−53.25%	−0.99%	−2.51%	−2.50%	−2.51%	−53.68%	−0.74%	−2.50%
r_g	2.57	2.57	2.56	2.57	2.22	2.51	2.51	2.52	2.51	2.19
r_b	2.57	2.57	2.56	2.57	2.58	2.51	2.51	2.52	2.51	2.52
B_g	0.12%	0.12%	0.00%	0.12%	0.48%	1.19%	0.05%	6.97%	0.17%	1.51%
B_b	−2.90%	−2.90%	0.00%	−2.90%	−2.94%	−2.94%	−2.86%	−6.57%	−2.72%	−2.97%
$E/(E+Z)$	31.51	31.51	27.54	31.51	31.56	31.18	30.55	31.77	30.61	31.22
$Y_g/(Y_g+Y_b^\ell+Y_b^*)$	33.59	33.59	32.58	33.59	33.63	32.54	32.14	35.68	32.13	32.57
$B_g/(B_g+B_b)$	19.88	19.88	19.39	19.88	19.94	19.36	19.17	20.86	19.17	19.41
NW/RWA	16.08	16.08	16.02	16.08	16.26	15.41	15.41	15.44	15.41	15.54

Notes: This table reports the results of the effects of a subset of climate change policies (analyzed in Tables 3 and 4) for the two model variants, described in Appendix E and analyzed in Section 6.1, with respect to the use of public funds. In the "Lump-sum transfer model", the public productive funds (i.e. excluding wasteful public consumption) are distributed as lump-sum transfers to the two types of entrepreneurs and, in the "Investment subsidy model", the public productive funds are used to partly finance private investment expenditures. The deterministic steady states relative to the respective alternative model's benchmark calibrations (see Table E.1 for the simulated moments of these calibrations) are compared for five scenarios each: Scenarios [x.1] entail an increase in the domestic carbon tax rate; Scenarios [x.2] investigate an increase in the price of the brown energy good; Scenarios [x.3] simulate an increase in the domestic share of transfers directed to green entrepreneurs to 1; Scenarios [x.4] entail increasing the domestic carbon tax rate while distributing environmental tax revenues in the same way as revenues from standard tax sources; and Scenarios [x.5] simulate a domestic carbon tax rate increase in conjunction with lowering financial frictions for green loans. The loan interest rates r_g, r_b and the ratios $E/(E+Z), Y_g/(Y_g+Y_b^\ell+Y_b^*), B_g/(B_g+B_b)$, NW/RWA are reported in percentage points across all columns, all other quantities are reported in percentage deviations. The parameter changes in all scenarios (with the exception of Scenarios [x.3]) are calibrated to induce a reduction of emissions of 17% relative to the respective alternative model's benchmark calibration.

Table E.3: Scenario analysis results – alternative specifications and calibrations with respect to financial frictions

	High cap. req. asymmetry calibration					DTI model				
	[3.1]	[3.2]	[3.3]	[3.4]	[3.5]	[4.1]	[4.2]	[4.3]	[4.4]	[4.5]
Parameter 1	$\overline{\mathrm{LIA}}_g = 1$	$\overline{\mathrm{LIA}}_b = 3$	$\overline{\tau}_z = 0.116$	$\overline{v}_g = 0.5$	$\overline{v}_b = 1$	$\overline{\mathrm{DTI}}_g = 3$	$\overline{\mathrm{DTI}}_b = 4$	$\overline{\tau}_z = 0.117$	$\overline{v}_g = 0.5$	$\overline{v}_b = 1$
Parameter 2	—	—	$\overline{v}_g = 0.5$	—	—	—	—	$\overline{v}_g = 0.5$	—	—
Parameter 3	—	—	$\overline{\kappa}_g = 0.5$	—	—	—	—	$\overline{\kappa}_g = 0.5$	—	—
Y	0.26%	0.43%	−0.29%	−0.21%	0.31%	0.00%	−0.05%	−0.06%	0.00%	0.12%
Y_g	0.04%	0.03%	10.34%	−0.21%	0.85%	0.13%	0.21%	10.20%	−0.16%	−0.61%
Y_b^ℓ	0.38%	0.63%	−5.40%	−0.20%	0.04%	−0.06%	−0.17%	−4.97%	0.07%	0.48%
Y_b^*	0.37%	0.62%	−5.07%	−0.20%	0.06%	−0.05%	−0.16%	−4.65%	0.07%	0.46%
C_{aggr}	0.31%	0.44%	−6.45%	−0.18%	0.41%	−0.29%	0.70%	−6.28%	0.17%	−0.67%
E	0.22%	0.31%	26.28%	−0.40%	1.30%	0.16%	0.14%	26.44%	−0.20%	−0.44%
Z	0.01%	0.01%	−17.00%	−0.01%	0.00%	0.00%	−0.01%	−17.00%	0.00%	0.02%
I_{aggr}	1.25%	2.02%	−0.16%	−1.07%	1.90%	0.09%	−0.16%	0.61%	−0.09%	0.33%
I_g	0.58%	0.83%	6.66%	−1.05%	3.42%	0.21%	0.12%	6.47%	−0.25%	−0.47%
I_e	0.58%	0.83%	6.66%	−1.05%	3.42%	0.33%	0.12%	6.28%	−0.39%	−0.58%
I_b	1.71%	2.85%	−4.93%	−1.07%	0.84%	−0.01%	−0.35%	−3.38%	0.03%	0.90%
I_g^p	0.19%	0.28%	60.09%	−0.20%	0.54%	0.03%	0.12%	61.32%	−0.06%	−0.19%
I_b^p	0.32%	0.52%	−3.78%	−0.20%	0.21%	−0.06%	0.00%	−3.46%	0.04%	0.22%
r_g	1.97	1.68	2.60	3.71	−1.04	2.41	2.40	2.09	2.16	2.22
r_b	1.97	1.68	3.14	2.96	2.26	2.41	2.40	2.39	2.39	2.70
B_g	34.11%	0.83%	6.66%	−1.05%	3.42%	50.14%	0.12%	6.65%	−0.12%	−0.38%
B_b	1.71%	37.14%	−4.93%	−1.07%	0.84%	−0.04%	−33.42%	−3.36%	0.05%	0.36%
$E/(E+Z)$	27.06	27.08	36.03	26.94	27.28	26.78	26.78	35.75	26.71	26.66
$Y_g/(Y_g+Y_b^\ell+Y_b^*)$	31.50	31.44	34.97	31.57	31.74	31.31	31.35	34.52	31.22	31.04
$B_g/(B_g+B_b)$	23.52	14.64	20.74	18.91	19.30	24.81	24.83	19.51	17.98	17.90
NW/RWA	15.62	14.49	17.38	17.35	14.55	12.73	13.69	12.88	12.86	12.69

Notes: This table reports the results of the effects of a subset of climate change policies (analyzed in Tables 3 and 4) for the two model variants, described in Appendix E and analyzed in Section 6.2, with respect to the specification and calibration of the financial frictions in the model. In the "High cap. req. asymmetry calibration" the bank capital requirement cost function $\Gamma_{t+1}^{\mathtt{capreq}}$ (see Equation 46) is assumed to be considerably more asymmetric and calibrated as in Valencia et al. (2017) ($\gamma_0 = 120$, $\gamma_1 = 3.5$, $\gamma_2 = 1$) and, in the "DTI model", the loan-in-advance constraints are replaced by debt-to-income borrowing constraints. The deterministic steady states relative to the respective alternative model's benchmark calibrations (see Table E.1 for the simulated moments of these calibrations) are compared for five scenarios each: Scenario [3.1] ([4.1]) entails an increase in the green LTI ratio (green DTI ratio); Scenario [3.2] ([4.2]) investigates an increase (decrease) in the brown LTI ratio (brown DTI ratio); Scenarios [x.3] simulate an increase in the domestic carbon tax rate while lowering the stringency of bank-related financial frictions with respect to green loans; Scenarios [x.4] entail lowering the green loan risk weight; and Scenarios [x.5] simulate the effects of increasing the brown loan risk weight. The loan interest rates r_g, r_b and the ratios $E/(E+Z), Y_g/(Y_g+Y_b^\ell+Y_b^*), B_g/(B_g+B_b)$, NW/RWA are reported in percentage points across all columns, all other quantities are reported in percentage deviations. The parameter change in Scenarios [x.3] is calibrated to induce a reduction of emissions of 17% relative to the respective alternative model's benchmark calibration.