# Cross-Border Financial Effects of Global Warming in a Two-Area Ecological SFC Model

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# Cross-Border Financial Effects of Global Warming
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Last revision: 18 Feb 2019

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**Abstract.** We develop an ecological open-economy SFC model that enables testing cross-area interactions among productive sectors, financial markets and the ecosystem. We show that the unequal technical progress across areas, coupled with rising ecological awareness, can force governments of less ecologically efficient areas to move further away from low-carbon assets. We argue that 'green' monetary and fiscal policies can be used to tackle climate change and financial instability. However, their effectiveness depends crucially on the impact of cross-border financial flows and growth rate differentials on exchange rates. Without a cross-area policy coordination plan, currency fluctuations can bring about unintended consequences, undermining green policies' effects.

**Keywords:** Stock-Flow Consistent Models, Climate Change, Financial Stability

**JEL codes:** D53, E44, F37, G17, Q54

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## 1. Introduction

Financial stability is paramount for promoting low-carbon transition. In order to achieve Paris Agreement's goals, low-carbon or 'green' investments are required worldwide (e.g. UNFCCC 2015). According to International Energy Agency (IEA), the current level of low-carbon investment is inadequate. In fact, additional 48 trillion USD are estimated to be necessary over the period 2020-2035 (IEA 2011). Besides, 3.5 trillion USD investment per year in the energy sector would be necessary up to 2050 (IEA, 2017). This means that the current level of green investment should be nearly doubled. In addition, appropriate policies to allocate private and public funds are required to boost green investment growth and trigger synergies among sectors and institutions. Several policies, mechanisms and incentives are to be implemented for promoting low-carbon assets and to share investment risks between private and public actors. For instance, some programmes have been undertaken to align the financial system with climate goals (UNEP, 2014). These strategies and other climate policies are expected to affect private investors' behaviour in the next decades (e.g. Ameli, et al. 2017; Boissinot et al. 2016). The importance of low-carbon-oriented finance to achieve long-term sustainable growth has been recognised by world-leading institution, including the High-Level Expert Group on Sustainable Finance (European Commission 2016). However, the volume of scientific studies on the effect of green finance and low-carbon investment on climate change is still limited – as reported by the Intergovernmental Panel on Climate Change report (IPCC 2018). Current understanding and opinions about how to channel more capitals towards green investment are also incomplete and quite contentious (e.g. Gupta et al. 2014).

In the attempt to contribute to this debate, we developed an ecological open-economy stock-flow consistent (SFC) model. The model enables us to test cross-area interactions among productive sectors, financial markets and the ecosystem. We aim at identifying possible transmission channels of climate risk, that is, the impact of global warming on the real economy, financial institutions and financial instruments. We also assess potential implications of policies aiming at alleviating the expected impact of climate change on economic variables, while mitigating climate-related financial risks. More precisely, we show that the unequal technical progress across areas, coupled with rising ecological awareness, can force governments of less ecologically-efficient areas to reduce cross-border transactions and move further away from green technologies. Monetary and fiscal policies can help counter these tendencies. Unlike most climate finance authors, we highlight the stabilising role of fiscal policies, as a complement of monetary policy. In line with Deleidi and Mazzucato (2018) and Deleidi et al. (2019), we posit that mission-oriented government spending is fundamental in defining the level of private green capital accumulation. We also consider the impact of selective credit rationing favouring green investment plans over conventional investment (e.g. Dafermos et al. 2018). However, possible side effects, linked with the impact of cross-border financial flows and output growth rate differentials on exchange rates, must be carefully considered and addressed. Looking at the theoretical foundations, our contribution builds upon the most recent literature on ecological macroeconomics and climate finance. While there are several methodological affinities, we depart from the existing literature in that we focus on cross-border (or cross-area) effects and interactions. We do so by using a model in which the world economy is likened to two interacting autonomous open systems. We use a brand-new method of determination of the exchange rate. This is a crucial variable, as it transmits the impulses from financial (and real) international transactions to the domestic economy and the broad ecosystem.

The rest of the paper is organised as follows. In section 2, we provide a short review of most recent literature on ecological macroeconomics modelling and climate finance. In section 3, we present the most relevant theoretical and methodological aspects of our contribution. We discuss the key features of our ecological open-economy model. We then use the model to analyse the impact of selected global warming-related shocks on key economic, financial and ecological variables. Our tentative findings are presented and discussed in section 4. We argue that, without a cross-area policy coordination plan, international financial flows, output growth rate differentials and the related exchange rate adjustments are likely to bring about unintended consequences, undermining green policies' effectiveness. Additional remarks are made in section 5.

## 2. Literature review

An increasing number of (either aggregative or microfounded) ecological and climate finance models have been developed in the last decade. These models aim at:

a) Detecting sustainable growth conditions and questioning the growth imperative (e.g. Jackson and Victor 2015 and Richters and Siemoneit 2017);
b) Studying the energy sector (e.g. Naqvi 2015, Berg et al. 2015);
c) Investigating the trajectories of key environmental, macroeconomic and financial variables (e.g. Dafermos et al. 2017, 2018);
d) Analysing the impact of green fiscal policies and 'green sovereign bonds' (e.g. Monasterolo and Raberto 2018; Bovari et al. 2018);
e) Examining the interaction between climate change and financial stability (e.g. Dafermos et al. 2018);
f) Assessing the impact of State-led innovation policies on climate change and other ecological variables (e.g. Mazzucato 2015; Mazzucato and Semieniuk 2018; Deleidi et al. 2019);
g) Addressing the questions of how to finance the transaction towards a 'greener' economy (e.g. Campiglio 2016; Ameli et al. 2017; Rademaekers et al. 2017) and how to tackle climate risks (e.g. Aglietta and Espagne 2016; Bardoscia et al. 2017; Battiston et al. 2017; Bovari et al. 2018; Dafermos et al. 2018).

More precisely, Jackson and Victor (2015) raise the question whether growth is necessary for capitalist economies to survive. In other words, they check whether a 'growth imperative' exists, which is determined by the need for the borrowers to pay back the interests due on the stock of outstanding debt. For this purpose, they use a SFC dynamic macro-economic model accounting for the credit creation process led by banks and private equity in a closed economy. They find no evidence of a 'growth imperative'. In addition, they show how an economy can move from a growth to a stationary (or nongrowing) path. They argue that the countercyclical spending carried out by governments can promote such a transition by smoothing and dampening the oscillations associated with it.

Similarly, Richters and Siemoneit (2017) analyse several SFC post-Keynesian models and question the idea of positive interest rates as the main responsible for the 'growth imperative'. Particularly, a stationary state economy – characterised by zero net saving and investment – is compatible with positive interest rates. The paper confirms the idea of a debt-based monetary system that does not cause any growth imperative. A stationary state is generated by positive net saving and net investment decisions, which are permanently above zero, and not by a systemic and inevitable necessity.

Naqvic (2015) proposes a multi-sectoral SFC model for a closed economy. Production is demand-led and the economy is made up of several institutional sectors (firms, energy, households, government, and financial institutions), which interplay with the environment. The model is calibrated on the European economy and aims at evaluating the effect of five alternative environmental economic policies (i.e. a de-growth scenario, a capital stock damage function, a carbon tax, a higher share of low-emissions renewable energy, and an investment in technical innovation) on three main challenges (trilemma): (i) boosting output growth; (ii) fostering employment growth with a more equal distribution; or (iii) improving environmental sustainability. The study is motivated by a trilemma that European policy makers are currently facing. Naqvic's findings show that four out of five policies cannot solve the three challenges simultaneously. Only the investment in innovative technologies can increase output, foster employment (and wage growth), while reduce CO2 emissions.

A multi-sectoral ecological SFC model is also employed by Berg et al. (2015), who integrate the stock-flow analysis with the input-output methodology. This allows to model to detect the interaction among three types of flow variables: (i) monetary flows in the financial system; (ii) flows of goods and services produced by the real economy; and (iii) the flow of physical materials related to the natural environment. These models are more flexible than standard aggregate SFC models, for they allow modelling a variety of sectors. The model developed by Berg et al. (2015) considers an economy made up of five sectors: the government sector, the banking system, the household sectors, and two industrial sectors that produce energy and goods. The main findings of the paper can be summarised as follows: (i) a nongrowing economy can be associated with positive interest rates; (ii) an increase in energy prices can negatively affect the economic system by lowering real wages and aggregate demand, thus triggering a recession. Overall, the model shows hot to integrate heat emissions due to economic activities and climate change modelling.

Dafermos et al. (2017) develop a stock-flow-fund ecological macroeconomic model calibrated on global data, which combines a standard SFC framework with the flow-fund approach developed by Georgescu-Roegen. The authors assume that output is demand-led and finance is non-neutral. This allows considering the channels through which the monetary system, the real economy and the ecosystem interact. Supply constraints are determined by the exhaustion of natural resources and by environmental damages. Climate change is included in the analysis and affects aggregate demand through the influence of catastrophes, global warming, and health issues on the desired level of investment, savings, consumption and potential output. The analysis focuses on two types of green finance policy: (i) a reduction in interest rates and the relaxing of credit rationing criteria on green loans; (ii) a reduction in interest rates and the relaxing of credit rationing criteria on green loans, combined with tighter conditions on conventional types of loans. The second policy generates better environmental results than the first one, because of the lower economic growth rate. More precisely, it is associated with a lower output level combined with a larger share of green investment, lower CO2 emissions and lower atmospheric temperature. Finally, the leverage ratio of firms is lower under the second scenario, despite the lower economic growth rate. This is because damages due to global warming reduce as the share of green loans increases.

In a more recent paper, Dafermos et al. (2018) assess and investigate the existing links between climate change and financial (in)stability. By using a stock-flow-fund macro model, the authors argue that an increase in the average temperature can be detrimental for firms' profitability and financial stability, possibly leading to a higher default rate and increasing the risk of systemic bank losses. The authors focus on the physical risks implied by climate change. They maintain that 'climate-induced financial instability reinforces the adverse effects of climate change on economic activity' (Dafermos et al., 2018, p. 220). In addition, they consider the impact of global worming on households' portfolio choices. The latter tend to be diverted towards 'safer' and more liquid assets (because of the impact on economic agents' confidence), such as deposits and government bonds, causing in this way a decrease in corporate bonds' prices. To tackle the financial instability triggered by climate change, a green quantitative easing program, regarded as a long-term industrial policy, is proposed and discussed. The authors analyse a hypothetical scenario where central banks decide to buy a quarter of total green bonds worldwide. The policy's effectiveness is shown to vary according to the parameters of the model. More precisely, a crucial role is played by the sensitivity of investment in green capital assets to the differential between green bonds' and conventional bonds' yields. However, green QE policies usually help counter financial instability. Investment financing turns out to be less dependent on bank credit, and hence less subject to credit crunch risks. Moreover, slower climate change implies a reduced degree of economic damages. As a consequence, firms' profitability is restored, liquidity problems are dampened, and the default ratio decreases.

The model developed by Deleidi et al. (2018) is based on four different theoretical approaches: (i) the Sraffian supermultiplier model; (ii) the Neo-Schumpeterian framework which emphasises the entrepreneurial role of the State; (iii) the SFC approach to macro-economic modelling; (iv) and recent developments in ecological economics literature aiming at cross-breeding post-Keynesian theories with more traditional ecological framework. The paper aims at developing a simple analytical tool that can help examine: (i) the impact of innovation on economic growth and the ecosystem; and (ii) the impact of ecological feedbacks on economic growth and government spending effectiveness. The authors find that, in principle, government can be successful in supporting innovation and growth while slowing down natural reserves' depletion rates and tackling climate change. This requires targeting green innovations policies characterised by the highest ecological efficiency gains. More precisely, the State can actively promote green innovation, thus driving a change in the overall economic structure. However, ecological feedbacks affect government policy effectiveness. In addition, it is argued that the policy-makers are likely to be facing a conundrum in the next decade: green innovation allows for lower matter-, energy- and CO2-intensity coefficients, but the higher investment and production levels may well frustrate these efficiency gains.

Bovari et al. (2018) combine a SFC approach with a dynamic predator-prey of (Lotka-Volterra) model. They analyze the challenges posed by climate change in conjunction with private indebtedness. The starting point of the analysis is as follows: climate-change mitigation is an expensive process and, given the multiple constraints imposed on public finances, the private sector is expected to carry out most of the burden. However, this can lead to a further explosion of private debt and trigger financial instability. The latter is co-caused by global warming and private indebtedness. The proposed policy approach consists in pricing carbon emissions through a carbon tax, which should incentivize firms to devote part of their production to the abatement of emissions. The authors conclude that, in spite of the +2° C target being plausibly already out of reach, an adequate carbon tax can be conducive to a reduction in carbon emissions and to the achievement of the +2.5°C objective. This result can be obtained without affecting economic growth, as long as adequate policies aiming at increasing the wage share and fostering the employment rate are also set in motion.

Monasterolo and Raberto (2018) propose a mix of fiscal and monetary policies (green sovereign bonds) that aim at tackling climate change. The analytical tool used to conduct the analysis is the so-called EIRIN model. The latter is a SFC model with neo-Schumpeterian insights, where the supply side is defined through a Leontief production function. In addition, the economy is made up of 'heterogeneous economic sectors and subsectors characterized by adaptive behaviours and expectations (households, firms), heterogeneous capital goods characterized by different resource intensity, a credit sector characterized by endogenous money creation, and a foreign sector' (Monasterolo and Raberto, 2018, p. 229). The simulations show that green sovereign bonds significantly contribute to green investment and help reducing the import of raw materials. However, the implementation of this monetary policy can imply a short-run trade-off between positive effects in terms of green transition and the risk of wealth concentration. Focusing on green fiscal policies, incentives and taxes, climate change mitigation can come at the cost of negative feedbacks on the economy (for instance, in terms of an increase in the unemployment rate).

Finally, Campiglio (2016) analyses how the banking system and macroprudential policies can support low-carbon investments through selective funding. Other authors (e.g. Ameli et al. 2017, and Rademaekers et al. 2017) focus on the role played by different classes of investors, notably, institutional investors, pension funds and insurance companies. The effects of 'transition' and 'physical' risks (due to climate change) on the stability of the financial system are considered, among others, by Aglietta and Espagne (2016), Bardoscia et al. (2017), Battiston et al. (2017), Bovari et al. (2018) and Dafermos et al. (2018). Overall, it is argued that climate change is likely to have severe implications for the stability of the financial system in the next decades, by increasing bankruptcy rates, leading to 'flight to safety' behaviours, and worsening credit conditions. The impact of a variety of monetary policies (e.g. green QE programmes and selective credit) is analysed. There is a general agreement that green monetary policies can smooth climate-induced financial instability, although they can only slow down global warming.

## 3. Theory and method

### *3.1 Model features and key assumptions*

Our work innovates relative to the existing literature in that it focuses on (side) effects of international or cross-border financial flows. The formal tool we developed and used belongs to the class of stock-flow consistent (SFC) dynamic macroeconomic models. Unlike financial instability, ecological aspects were not initially covered by Godley and Lavoie (2007a) and early SFC works (e.g. Caverzasi and Godin 2015; Nikiforos and Zezza 2017). Arguably, ecological SFC models represent one of the most significant internal developments in that literature (e.g. Carnevali et al. 2019). While some ecological and climate finance SFC models have been developed in the last decade, they usually focus on a single-country or single-area economy. However, local impacts of climate change and natural resources' depletion are likely to be unequal across countries. Besides, when climate risk-related financial shocks hit an area, this can bring about indirect effects for other countries or areas – because of the interconnections of the balances of payments and the stock markets. To shed light on this yet-unexplored aspect, we developed an ecological open-economy or two-area SFC model. The model is an advanced version of the simple prototype presented by Carnevali et al. (2019). Its basic structure is made up of 225 equations and two redundant equilibrium conditions. Exogenous variables and parameters are 132. The full set of identities, equilibrium conditions and behavioural equations is displayed in the Appendix, while coefficient values are displayed by Table 5.

The key features of our model can be summarised as follows:

*a)* We divide the world economy in two main areas, named Greenland and Brownland, respectively.

*b)* Each domestic household sector is made up of two social groups or classes: the recipients of labour incomes (the workers) and the recipients of entrepreneurial and financial incomes (the capitalists).

*c)* While the workers can only hold their savings in form of cash (domestic currency) and bank deposits, capitalists can diversify their portfolios by purchasing domestic and foreign government bills and/or firms' shares (see Fig. 1, charts *g* and *h*).

*d)* Initial values of economic and financial stocks, and the related parameter values, are identical across areas (e.g. GDPs, wealth stocks, propensities to consume, return rates, etc.).

*e)* Both economies are demand-led in the short- and long-run. There is no constrain on the supply side, except for the availability of natural reserves and the impact of global warming. All variables are expressed at constant prices.

*f)* Productive firms can undertake both conventional investment and low-carbon or green investment. The latter can be supported (or not) by the government sector.

*g)* Current accounts are balanced in the baseline scenario, while government budgets are not (both government sectors record a small deficit indeed).

*h)* There is a floating exchange rate regime. As a result, it is the ebb and flow of the market that determine the relative price of the currencies. We will argue that financial flows play an essential role (along with cross-area output growth rate differentials).

*i)* Natural resources endowments (matter and energy) are identical across areas. Each area can only access its own reserves. However, ecological policies of each area can affect the other area both via the balance of payment channel and through changes in the average temperature (due to industrial $CO_2$ emissions).

*j)* Unlike economic and financial coefficients, techniques of production are different: compared to Brownland, Greenland is marked by lower $CO_2$-, energy- and matter-intensity coefficients, and a higher share of renewable energy to total energy (see Table 5).

In formal terms, assumptions (*a*) to (*j*) result in eighteen blocks of equations (see Appendix). The first block – equations (1) to (16) – defines disposable income and net wealth of households in each area. This is quite standard in SFC literature, except for equations (3)-(5) and (10)-(12), which account for the revaluation of foreign currency-denominated financial assets generated by changes in the exchange rate.[1] The second block – equations (17) to (38) – defines domestic consumption levels and income shares. Notice that equations (30) and (37) determine the cross-border net flows of profits (dividends) between the two areas. The third block – equations (39) to (60) – defines investment plans of firms and capital accumulation. Equations (45) to (48) are the most important in defining private investment dynamics of the first area considered. Taken together, equations (45) and (46) hold that productive firms invest as long as their current stock of capital is below a target level, defined as a percentage of output. The speed of adjustment is inversely related to credit rationing factors, meaning inversely related to the interest rate on loans and firms' leverage ratios, and positively related to banks' liquidity ratios and the share of green investment to total investment – see equations (221) and (223). Equation (47) defines private green investment as a share of output *plus* two additional components depending on government green spending and the

[1] Capital gains due to changes in the market values of shares are implicitly considered, as portfolio equations determine nominal demanded (and supplied) stocks of shares, inclusive of price revaluation effects.

interest rate on (green) loans, respectively. In line with Deleidi and Mazzucato (2018) and Deleidi et al. (2019), we posit that mission-oriented government spending is crucial in defining the level of private green capital accumulation.[2] The latter improves the ecological efficiency of the productive system (lower matter-, energy and $CO_2$-intensity ratios and higher recycling rate). It is implicitly assumed that, first, the firms choose the amount of optimal investment; second, they set the share of it to be devoted to green investment; third, they calculate the amount of conventional investment as a residual level. This is the meaning of equation (48). Identical considerations go for equations (56) to (59), which are referred to the other area. The fourth block define imports and exports for the two areas. The fifth block – equations (65) to (82) – defines households' portfolio equations. Six types of financial instruments are considered: cash, bank deposits, domestic government bills, foreign bills, shares issued by domestic firms and foreign shares. Workers can only hold cash and deposits, while capitalists are also allowed to hold domestic and foreign bills and/or shares. Capitalists' portfolio choices are made based on standard Tobinesque principles. Bank deposits are the residual asset. The sixth block – equations (83) to (98) – shows that government bills' supplies adjust smoothly to nominal demand, while, in the stock market, prices are determined in such a way to match nominal demands with supplies (based on investment plans). The seventh block – equations (99) to (114) – defines the banking sector in a quite conventional way: in each area, commercial banks grant loans to domestic firms and 'collect' deposits from households. They can also purchase government bills and borrow from central banks (advances). Bank profit is simply the amount of interests perceived on their asset holdings (loans and government bills), as the interest rate accruing on the liabilities (deposits and central bank's advances) is null. The eight block – equations (115) to (124) – shows that central banks act as lenders of last resorts for both commercial banks and governments. In fact, this is the way cash is created and inputted into the system.[3] Each government sector can undertake two different types of spending: green spending and conventional spending. Like the latter, the former does not influence ecological efficiency directly. However, unlike the latter, it triggers a green innovation cascade, as it supports private green investment. The ninth block defines the exchange rate. More precisely, equations (125) and (126) show that a floating exchange rate is used, which can be simply thought as the relative price of the two currencies. In other words, the exchange rate is determined by demand and supply forces, considering both the real side (the trade balance) and the financial side (financial incomes in the current account and the financial account).[4] Blocks ten to fourteen – equations (127) to (190) – are devoted to the ecosystem and its interactions with the financial and productive sectors. The way we model these relationships resembles the method proposed by Dafermos et al. (2017, 2018; see also Carnevali et al. 2019, and Deleidi et al. 2019). The main points are as follows. The tenth and eleventh block track the evolution over time of matter and energy reserves, where recycling and renewable sources of energy are also considered. The twelfth block defines the change in global atmospheric temperature as a simple function of $CO_2$ emissions in the two areas.

[2] In fact, the second and third components of equation (47) can be regarded as defining the share of green investment that private firms would not be undertaking if they were not supported by the State or by privileged credit conditions, respectively.
[3] We assume that commercial banks hold no idle balances of high-power money (reserves) at the central bank.
[4] Notice that perfect capital mobility is assumed, but capital substitutability is not. In other words, economic agents make their portfolio choices based on relative return rates on assets. However, differences in return rates are persistent, because assets are not perfect substitutes. There is no return rate equalisation tendency.

The thirteenth block defines ecological efficiency in an endogenous way. More precisely, matter-, energy- and $CO_2$-intensity coefficients of each area are determined by the share of green capital to total capital stock. Similarly, national renewable energy shares grow as the shares of green capital stock grow. Besides, block fourteen holds that both working-class households' propensities to consume (out of income) and capital depreciation rates depend on climate change. The reason is that extreme weather conditions, catastrophes and uncertainty can undermine the pace of capital accumulation. In addition, uncertainty and rising ecological awareness can affect consumption and/or incentive hoarding behaviours. The last four blocks – equation (191) to (225) – contain auxiliary equations, which are used to define domestic and foreign balances, inequality indices within areas, additional financial indices, and credit rationing variables, respectively.

### *3.2 Calibration and experiments*

Economic parameters of each area are taken from standard SFC modelling literature or calibrated to obtain a 'real world' baseline. The ecological part of the model is based on Dafermos et al. (2017, 2018) and IPCC (2018), instead.[5] More precisely, model coefficients are set in such a way to obtain a gross world output equal to 80 trillion ca of currency units (say, USD) in the baseline scenario. World output grows steadily up until 2020 and then stabilises. Under the baseline, total financial assets (liabilities) are roughly 1.3 times the gross world output (i.e. more than 100 trillion of USD) in 2020.[6] As a result, the baseline output of a single block roughly amounts to the combined GDPs of the two biggest economic areas worldwide, namely, the United States and the European Union. Likewise, the other block can be likened to the rest of the world's economy.[7] In line with IPCC report, worldwide annual industrial $CO_2$ emissions are 46 billion Gt ca in 2020 baseline (from 15 billion GT ca in the late 1960s). They are expected to drop to 15 billion Gt per year in 2060. Cumulative emissions are 2,100 billion Gt ca in 2020 (from 700 billion Gt ca in the late 1960s), and are expected to stabilise at 3,100 Gt ca in 2060. As a result, the average atmospheric temperature in 2020 is +1.5C above its level in the 1950s, and is expected to be +2C in 2060 (or > 2.5C ca in the 'business as usual' scenario). Matter resources are calculated in such a way to match 390,000 Gt ca in 2015, while matter reserves are 6,000 Gt ca in the same year. Energy resources are 540,000 Ej ca, whereas energy reserves are 39,000 Ej ca. The socio-economic stock for the world economy is 1,140 Gt ca in the baseline. Fig. 1 displays baseline values and trends for selected variables.

[FIGURE 1]

[5] See Table 5 for the full set of coefficient values, initial values of stocks and lagged endogenous variables. The balance sheet and the transactions-flow matrix for the two areas are displayed by Table 1 and Table 2, respectively. The physical stock-flow and the flow matrices are displayed by Table 3 and Table 4. We are happy to provide our model's program file upon request.

[6] Arguably, this value is lower than the actual amount of financial assets, which is estimated to be around 160 trillion USD worldwide (i.e. twice size world output).

[7] Since the purpose of our paper is theoretical, no specific geographic meaning should be attributed to Greenland and Brownland. In fact, our labels only define different techniques of production.

Baseline values were obtained by running the model from 1952 to 2020, and then up to 2150, on an annual basis. We used the model to test the reaction of selected economic, financial and ecological variables to the following events or shocks linked with global warming:[8]

1. *Preference for 'safer' financial assets*. Higher risk aversion and hoarding behaviours can result from the increase in the frequency of natural catastrophes. We test the effect of investors' flight to safety.
2. *Preference for 'greener' financial assets*. This can be the effect of a higher ecological awareness of the population. We test the effect of investors reducing their holdings of Brownland's assets, while increasing Greenland's.
3. *Preference for 'greener' products*. A higher ecological awareness can lead consumers to turn to low-impact products, 'zero kilometre' food, etc. We test the effect of the decision of both Greenland's and Brownland's households to reduce their consumption of goods made in Brownland, while increasing Greenland's.
4. *Brownland's austerity (and autarchy) measures*. Green policies – e.g. green incentives – lead Brownland's private sector to import 'greener' products and intermediate goods from Greenland. This affects Brownland's trade balance and therefore the government budget balance. Hence the decision of Brownland policy-makers to address the twin deficit by cutting green incentives. We test the effect of this policy option.
5. *Selective credit rationing*. A way to boost green investment is to reduce interest rate on loans used for low-carbon production and investment purposes. We test the effect of it in Brownland.
6. *Increase of green government spending*. Another, more direct, way to boost low-carbon investment is to support it through active fiscal policies, aiming at generating a green innovation cascade. We test the effect of these policies on both Greenland and Brownland.

## 4. Results and discussion

We used our model to analyse the effects of the above 'possible worlds', treated as shocks to exogenous variables and/or parameter values (see Table 5). We focused on implications for economic activity, financial stability and the ecosystem. Overall, it is shown that, when cross-border effects are considered, many unexpected and unintended results show up. The main reason is that international financial flows and output growth rate differentials modify the relative price of currencies (i.e. the exchange rate), thereby affecting the real economy and the ecosystem, hence the financial sector.

*Preference for 'safer' assets* (Fig. 2). The decision of investors to move from risky to safer financial assets is one of the most frequently reported effects of uncertainty. It is usually associated with the higher frequency of adverse meteorological conditions. The resulting flight to safety may bring about unexpected or unintended implications though.

[FIGURE 2]

For instance, both Greenland's and Brownland's households (capitalists, in our model) may want to reduce the portion of shares held in their portfolios. They can replace firms' shares with liquidity and/or government bills. Whatever the specific mix chosen, output (GDP) benefits from that change if the portion of idle balances (including both cash and deposits) reduces,

[8] Shocks are all run in 2025.

despite the lower amount of equity. By contrast, output is negatively affected if the overall portion of liquidity increases. This is the case displayed by Fig. 2a. The point is that financial assets are not perfect substitutes. Consequently, nonlinear effects are possible when economic agents redefine their portfolios. Fig. 2j and 2k shows that, in the case considered, the percentage of cash increases, along with the portion of domestic bills. The portions of shares and foreign bills fall, and so does the portion of banks deposits (which are replaced with 'more' cash). Notice that the lower output does not necessarily harm government budget. In fact, it can bring about an improvement of it if central banks act as lenders of last resort – Fig. 2b. The reason is that a higher portion of bills are now held by the central banks, whose profits (i.e. *seigniorage* incomes, which are transferred to the government sector) can offset the fall in tax revenues. In addition, the lower absolute level of asset holdings (including bills) held by households help reducing the interest burden for the government. If households' behaviour is symmetrical across areas, balance of payments' entries are not affected, neither is the exchange rate – Fig. 2b, 2i and 2l. This is one of the few cases where international financial flows play no role. Looking at the ecosystem, a lower output entails lower $CO_2$ emissions and thus a lower average temperature relative to the baseline – Fig. 2c, 2d and 2e. However, the financial sector does not benefit from it. Fig. 2f and 2g show that firms' leverage ratios are now higher and their valuation ratios (as expressed by Tobin's q) lower compared to baseline values. Similarly, banks' liquidity ratios are worse off in the new scenario, because bank deposits fall more rapidly than loans – Fig. 2h. In short, a flight to safety can improve ecological indices, but affects private sector's financial condition. The net impact on the government sector depends on the role played by central banks, instead.

*Preference for 'greener' assets* (Fig. 3). Climate change can induce investors of both areas to reduce their holdings of Brownland's financial assets (including both shares and bills), while increasing Greenland's – Fig. 3j and 3k. Our experiments show that Greenland's economy does not necessarily benefit from that.

[FIGURE 3]

The adjustment in the exchange rate is the key variable here. Under a floating regime, the higher flows of capitals from Brownland to Greenland result in an appreciation of Greenland's currency – see Fig. 3b and 3i. Greenland's current account (which is nothing but the opposite of Brownland's current account displayed by Fig. 3b) worsens, because of the fall in net export coupled with the fall in net incomes (dividends and interest payments) – Fig. 3b and 3l. This affects Greenland's GDP – Fig. 3a. The increase in Brownland's output almost offsets the reduction in Greenland's output. Unfortunately, this goes along with higher $CO_2$ emissions, due to the lower ecological efficiency of Brownland's firms, and thus higher temperature in the short to medium run – Fig. 3c, 3d and 3e. Looking at the domestic financial side, Brownland's firms increase their leverage ratio, while Greenland's firms are forced to deleverage – Fig. 3f and 3g. This is reflected in banks' liquidity ratios – Fig. 3h. In short, under a floating exchange rate regime, a higher preference for green financial assets can harm, rather than safeguard, the ecosystem, while boosting financial imbalances. Notice that Greenland GDP would be virtually unaffected by capital in-flows under a fixed exchange rate regime. The reason is that its financial account surplus would result in the accumulation of international reserves, not in the appreciation of Greenland currency.[9]

[9] See Fig. 3b displaying the same shock under a fixed exchange rate regime, where central banks stabilise exchange rates by accumulating or reducing gold reserves (or the 'anchor currency'). All in all,

*Preference for 'greener' products* (Fig. 4). Arguably, the impact of consumers reducing their demand for "made in Brownland" (and/or increasing their demand for "made in Greenland") is far more intuitive.

[FIGURE 4]

Both Greenland's economy and the ecosystem benefit from greener consumption habits worldwide – Fig. 4a, 4b, 4c, 4d and 4e. The aggregate liquidity ratio of Greenland's banks worsens, but this is due to their higher lending activity. The leverage ratio of Greenland's productive sector is also higher, but the increase in firms' valuation ratio outstrips the former – Fig. 4g and 4h. Looking at their portfolios, households now hold more liquid assets, because of the increase in money demand for transaction and precautionary motives – Fig. 4j and 4k. It is worth stressing that Brownland's economy is expected to recover in the medium to long run, despite the initial negative impact. For the strong depreciation of Brownland currency ends up boosting its net export and net incomes (dividends and interest payments) from Greenland – Fig. 4a, 4b, 4i and 4l. However, Brownland records a twin deficit in the short run when consumers turn to green products.[10]

*Brownland's austerity (and autarchy) measures* (Fig. 5). For Brownland's policy makers, a possible way to counter the twin deficit is to pursue a contractionary fiscal policy. This intervention is more effective when targets green incentives and other types of green spending, as most green consumer- and intermediate-goods are made in Greenland.[11]

[FIGURE 5]

It is no surprise that austerity measures in Brownland are associated with a fall in Brownland's output. Fig. 5a shows that Greenland's economy is also affected, because of the reduction its export to Brownland. Focusing on rebalancing effects, austerity is effective. Both government budget and current account balance of Brownland benefit from government cuts – Fig. 5b. However, as Fig. 5i and 5l shows, the appreciation of the currency ends up undermining Brownland products' competiveness, thereby depressing further the economy. The lower world output entails lower $CO_2$ emissions and thus a lower average temperature, relative to the baseline – Fig. 5c, 5d and 5e. Looking at the financial side, all indices show a worsening for both firms and banks based in Brownland. Households also reduce sharply their assets holdings. These trends can be interpreted as the beginning of a financial crisis triggered by the economic recession – Fig. 5f, 5g, 5h, 5j and 5k.[12] Austerity cures the disease, but kills the patient.

*Selective credit rationing* (Fig. 6). Instead of pursuing (green) austerity measures, Brownland's policy-makers can try to boost green investment. For instance, they can lower the interest rate on green loans (that is, loans funding low-carbon investment plans).

[FIGURE 6]

the importance of exchange rate adjustments can be appreciated by looking at Fig. 8, where the market value of Greenland currency (i.e. Brownland exchange rate) under all considered scenarios is plotted.

[10] See Fig. 4b displaying the same shock under a fixed exchange rate regime.

[11] The link between Brownland's green government spending and the propensity to import is captured by equation (225) in our model.

[12] See Fig. 5b displaying the same shock under a fixed exchange rate regime.

In our model, selective credit rationing is effective because of a four-fold relationship: first, firms adjust their investment to reach the optimal capital to output ratio; second, green investment grows as interest rate reduces; third, interest rate reduces, and the speed of capital adjustment increases, as the share of green investment to total investment grows; fourth, conventional investment is a residual variable.[13] As a result, there is a cumulative causation linking low interest rates and high green investments. If banks incentive green investment (either voluntarily or by law) there is a beneficial, though temporary, effect on Brownland's output – Fig. 6a. However, both the government budget and the current account balance deteriorate in the short run (thus possibly exacerbating, rather than smoothing, greener consumption side-effects). Significantly, Brownland' economy ends up paying an increasing amount of dividends and interests to Greenland's investors, which can be unsustainable in the medium run – Fig. 6b, 6i and 6l. The impact on industrial emissions and climate change is ambiguous, depending on the scale of ecological efficiency gains. Fig. 6c, 6d and 6e show that $CO_2$ emissions are initially higher relative to the baseline, because output increase is too rapid. The worsening of real economy conditions can affect firms' financial indices in the long run, while banks are more exposed in the short run, due to the reduction in their profit margin. No major side-effect for Greenland is recorded instead.

*Increase of green government spending* (Fig. 7). Arguably, the most effective policy in our artificial economy is Greenland government policies aiming at supporting green investment. This policy can generate a green innovation cascade (see Deleidi and Mazzucato 2018, Deleidi et al. 2019) that boosts private activity, while offsetting (or smoothing) its impact on climate change.

[FIGURE 7]

Fig. 7a shows that Brownland's economy takes advantage from Greenland's policy too. The effect is only temporary though. For it is progressively counterbalanced by the appreciation of Brownland currency. This, in turn, is due to the higher deficit (or lower surplus) recorded by Greenland's current account balance (because of the fall in net export) – Fig. 7b, 7i and 7l. In addition, Fig. 7c and 7e remind us that the reduction in $CO_2$ emissions is anything but obvious. Despite the higher share of low-carbon investments and green innovation, economic growth may well outstrip any efficiency gain – Fig. 7d. Looking at the financial side, balance sheets of both banks and firms are quite sound in Greenland. Paradoxically, Brownland households' wealth is gradually eroded by the appreciation of their currency, which affects income and hence saving. Brownland's banks are also affected – see Fig. 7f, 7g, 7h, 7j and 7k.[14] The only way to take full advantage from government green-oriented spending, while limiting its possible side effects, is for the two areas to pursue green expansionary policies in a simultaneous way.

## 5. Conclusions

We have developed an ecological open-economy SFC model that enables testing cross-area and cross-sector effects on productive sectors, financial markets and the ecosystem. We have argued that an unequal technical progress across areas, coupled with rising ecological awareness of investors and consumers, can force governments of less ecologically-efficient areas to reduce international trade and move further away from low-carbon assets. This

[13] See equations (45)-(48), (56)-(59) and (221)-(224).

[14] See Fig. 7b displaying the same shock under a fixed exchange rate regime.

paradoxical effect goes along with possible financial instability and higher industrial emissions per unit of output. Our main findings can be summarised as follows:

a) The search for safe financial assets (brought about by climate-related uncertainty) can worsen, rather than improve, financial stability.
b) The search for green financial assets can boost, rather than smooth, climate change.
c) Green consumption can affect domestic and external financial balances of less ecologically-efficient areas.
d) If governments of less-ecologically efficient areas react by cutting (green) spending, this is likely to affect both output and financial stability.
e) Selective credit rationing, aiming at supporting low-carbon investment, may improve ecological efficiency and support economic growth. However, it can also affect current account and government balances in the short run
f) Selective (or green) innovation-oriented government policy is effective in supporting growth, while smoothing the impact of anthropic activities on climate. However, it is likely to entail side-effects for the other area.

To conclude, the most important lesson we can learn from our experiments is that the effectiveness of green policies depends crucially on the impact of cross-border financial flows (and output growth rate differentials) on the exchange rates. On the one hand, currency fluctuations bring about unintended consequences, which can undermine beneficial effects of low-carbon transition on the environment and on financial stability. On the other hand, a fixed exchange regime requires strong coordination to cope with possible external imbalances. Consequently, some form of monetary and/or macroeconomic cooperation and coordination between areas seems paramount to assure a financially- and ecologically-sustainable growth path.

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# Tables and charts

Table 1. Balance-sheet of the two-area economy

| | GREENLAND ($G$) | | | | | | BROWNLAND ($B$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Households (capitalists + workers) | Firms | Commercial banks | Government | Central bank | | Households (capitalists + workers) | Firms | Commercial banks | Government | Central bank | Σ |
| Money (cash) | $+H_h^G$ | | | | $-H_s^G$ | | $+H_h^B$ | | | | $-H_s^B$ | 0 |
| CB advances | | | $-A_d^G$ | | $+A_d^G$ | | | | $-A_d^B$ | | $+A_d^B$ | 0 |
| Deposits | $+M_h^G$ | | $-M_s^G$ | | | | $+M_h^B$ | | $-M_s^B$ | | | 0 |
| Loans | | $-L_f^G$ | $+L_s^G$ | | | | | $-L_f^B$ | $+L_s^B$ | | | 0 |
| G gov. bills | $+B_d^{GG}$ | | $+B_b^G$ | $-B_s^G$ | $+B_{cb}^{GG}$ | $\cdot xr_G$ | $+B_d^{BG} \cdot xr_G$ | | | | | 0 |
| B gov. bills | $+B_d^{GB} \cdot xr_B$ | | | | | | $+B_d^{BB}$ | | $+B_b^B$ | $-B_s^B$ | $+B_{cb}^{BB}$ | 0 |
| G firms' shares | $+p_e^G \cdot e_d^{GG}$ | $-p_e^G \cdot e_s^{GG}$ | | | | | $+p_e^G \cdot e_d^{BG} \cdot xr_G$ | | | | | 0 |
| B firms' shares | $+p_e^B \cdot e_d^{GB} \cdot xr_B$ | | | | | | $+p_e^B \cdot e_d^{BB}$ | $-p_e^B \cdot e_s^{BB}$ | | | | 0 |
| Conv. capital | | $+K_{con}^G$ | | | | | | $+K_{con}^B$ | | | | $+K_{con}^G \cdot xr_G + K_{con}^B$ |
| Green capital | | $+K_{gr}^G$ | | | | | | $+K_{gr}^B$ | | | | $+K_{gr}^G \cdot xr_G + K_{gr}^B$ |
| Balance (net worth) | $-V_h^G$ | $-NW_f^G$ | 0 | $-NW_g^G$ | 0 | | $-V_h^B$ | $-NW_f^B$ | 0 | $-NW_g^B$ | 0 | $-(K_{con} + K_{gr})$ |
| **Σ** | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |

Notes: A '+' before a magnitude denotes an asset, whereas '–' denotes a liability (except for Balance's entries, where signs are reversed). Floating exchange rates are assumed. Capitalists and workers are aggregated and consolidated in the household sector.

Table 2. Transactions-flow matrix of the two-area economy

| | **GREENLAND ($G$)** | | | | | | **BROWNLAND ($B$)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Households (capitalists + workers)** | **Firms** | **Commercial banks** | **Government** | **Central bank** | | **Households (capitalists + workers)** | **Firms** | **Commercial banks** | **Government** | **Central bank** | **Σ** |
| Consumption | $-C_G$ | $+C_G$ | | | | | $-C_B$ | $+C_B$ | | | | 0 |
| Conv. investment | | $+INV^G_{con}$ $[-INV^G_{con}]$ | | | | | | $+INV^B_{con}$ $[-INV^B_{con}]$ | | | | 0 |
| Green investment | | $+INV^G_{con}$ $[-INV^G_{con}]$ | | | | | | $+INV^B_{con}$ $[-INV^B_{con}]$ | | | | 0 |
| Conv. gov. spend. | | $+GOV^G_{con}$ | | $-GOV^G_{con}$ | | | | $+GOV^B_{con}$ | | $-GOV^B_{con}$ | | 0 |
| Green gov. spend. | | $+GOV^G_{gr}$ | | $-GOV^G_{gr}$ | | | | $+GOV^B_{gr}$ | | $-GOV^B_{gr}$ | | 0 |
| G exports to B | | $+X_G$ | | | | | | $+X_B$ | | | | 0 |
| B exports to G | | $-IM_G$ | | | | | | $-IM_B$ | | | | 0 |
| Wages | $+\omega_G \cdot Y^G$ | $-\omega_G \cdot Y^G$ | | | | | $+\omega_B \cdot Y^B$ | $-\omega_G \cdot Y^B$ | | | | 0 |
| Taxes | $-T_G$ | | | $+T_G$ | | | $-T_B$ | | | $+T_B$ | | 0 |
| Deprec. allowances | | $-DA_G$ $[+AF_G]$ | | | | $\cdot\, xr_G$ | | $-DA_B$ $[+AF_B]$ | | | | 0 |
| Interests on loans | | $-r^G_{l,-1} \cdot L^G_{f,-1}$ | $+r^G_{l,-1} \cdot L^G_{s,-1}$ | | | | | $-r^B_{l,-1} \cdot L^B_{f,-1}$ | $+r^B_{l,-1} \cdot L^B_{s,-1}$ | | | 0 |
| Interests on G bills | $+r_{G,-1} \cdot B^{GG}_{d,-1}$ | | $+r_{G,-1} \cdot B^G_{b,-1}$ | $-r_{G,-1} \cdot B^G_{s,-1}$ | $+r_{G,-1} \cdot B^{GG}_{cb,-1}$ | | $+r_{G,-1} \cdot B^{BG}_{d,-1} \cdot xr_G$ | | | | | 0 |
| Interests on B bills | $+r_{B,-1} \cdot B^{GB}_{d,-1} \cdot xr_B$ | | | | | | $+r_{B,-1} \cdot B^{BB}_{d,-1}$ | | $+r_{B,-1} \cdot B^B_{b,-1}$ | $-r_{B,-1} \cdot B^B_{s,-1}$ | $+r_{B,-1} \cdot B^{BB}_{cb,-1}$ | 0 |
| G firms' dividends | $+F^{GG}_d$ | $-F^G_f$ | | | | | $+F^{BG}_d \cdot xr_G$ | | | | | 0 |
| B firms' dividends | $+F^{GB}_d \cdot xr_B$ | | | | | | $+F^{BB}_d$ | $-F^B_d$ | | | | 0 |
| Retained profits | | $[+F^G_u]$ | | | | | | $[+F^B_u]$ | | | | 0 |
| Managers' compens. | $+F^G_m$ | $-F^G_m$ | | | | | $+F^B_m$ | $-F^B_m$ | | | | 0 |
| Banks' profit (distrib.) | $+F^G_b$ | | $-F^G_b$ | | | | $+F^B_b$ | | $-F^B_b$ | | | 0 |
| CB profits | | | | $+F^G_{cb}$ | $-F^G_{cb}$ | | | | | $+F^B_{cb}$ | $-F^B_{cb}$ | 0 |
| Δ in cash | $-\Delta H^G_h$ | | | | $+\Delta H^G_s$ | | $-\Delta H^B_h$ | | | | $+\Delta H^B_s$ | 0 |
| Δ in CB advances | | | $+\Delta A^G_d$ | | $-\Delta A^G_s$ | $\cdot\, xr_G$ | | | $+\Delta A^B_d$ | | $-\Delta A^B_s$ | 0 |
| Δ in deposits | $-\Delta M^G_h$ | | $+\Delta M^G_s$ | | | | $-\Delta M^B_h$ | | $+\Delta M^B_s$ | | | 0 |
| Δ in loans | | $+\Delta L^G_f$ | $-\Delta L^G_s$ | | | | | $+\Delta L^B_f$ | $-\Delta L^B_s$ | | | 0 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Δ in G bills | $-\Delta B_d^{GG}$ | | $-\Delta B_b^G$ | $+\Delta B_s^G$ | $-\Delta B_{cb}^{GG}$ | | $-\Delta B_d^{BG} \cdot xr_G$ | | | | | 0 |
| Δ in B bills | $-\Delta B_d^{GB} \cdot xr_B$ | | | | | | $-\Delta B_d^{BB}$ | | $-\Delta B_b^B$ | $+\Delta B_s^B$ | $-\Delta B_{cb}^{BB}$ | 0 |
| **Σ** | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| *Memo: capital gains* | $-CG_b^G - CG_e^G$ | $+CG_{eG}^G$ | | $+CG_{bG}^G$ | | | $-CG_b^B - CG_e^B$ | $+CG_{eB}^B$ | | $+CG_{bB}^B$ | | |

Notes: A '+' before a magnitude denotes a receipt or a source of funds, whereas '–' denotes a payment or a use of funds. Floating exchange rates are assumed. Capitalists and workers are aggregated and consolidated in the household sector. [ · ] = capital account entry. $AF$ = amortisation funds (which are not explicitly modelled, as they are assumed to equal depreciation allowances). Subscript '$eG$' marks capital gains accruing on all shares issued by Greenland firms, regardless of the nationality of investors (similar considerations go for '$bG$', '$eB$' and '$Bb$').

Table 3. Physical stock-flow matrix of the two-area economy (consolidated)

| | **Worldwide material balance** | **Worldwide energy balance** |
|---|---|---|
| **Inputs** | | |
| Extracted matter | $+mat_G + mat_B$ | |
| Renewable energy | | $+er_G + er_B$ |
| Non-renewable energy | $+cen_G + cen_B$ | $+en_G + en_B$ |
| Oxygen | $+O_2^G + O_2^B$ | |
| **Outputs** | | |
| Industrial $CO_2$ emissions | $-emis_G - emis_B$ | |
| Waste | $-wa_G - wa_B$ | |
| Dissipated energy | | $-ed_G - ed_B$ |
| **Change in s.e.s.** | $-\Delta k_{se}^G - \Delta k_{se}^B$ | |
| **Σ** | 0 | 0 |

Notes: Matter is measured in Gt while energy is measure in EJ. A '+' sign denotes additions to the opening stock, whereas '–' denotes reduction. $G$ = Greenland; $B$ = Brownland.

Table 4. Physical flow matrix of the two-area economy (consolidated)

| | **Worldwide material reserves** | **Worldwide non-renewable energy reserves** | **Worldwide atmospheric CO2 concentration** | **Worldwide socio-economic stock** |
|---|---|---|---|---|
| **Initial stock** | $+k_{m,-1}^{G}+k_{m,-1}^{B}$ | $+k_{e,-1}^{G}+k_{e,-1}^{B}$ | $+CO_{2,-1}^{G}+CO_{2,-1}^{B}$ | $+k_{se,-1}^{G}+k_{se,-1}^{B}$ |
| Resources converted into reserves | $+conv_{m,}^{G}+conv_{m}^{B}$ | $+conv_{e}^{G}+conv_{e}^{B}$ | | |
| $CO_2$ emissions | | | $+emis_{G}+emis_{B}$ | |
| Production of material goods | | | | $+y_{mat}^{G}+y_{mat}^{B}$ |
| Extraction/use of matter/energy | $-mat_{G}-mat_{B}$ | $-en_{G}-en_{B}$ | | |
| Net transfer to oceans/biosph. | | | $-(1-\psi_{1})\cdot(CO_{2}^{G}+CO_{2}^{B})-1$ | |
| Destruction of socio-ec. stock | | | | $-dis_{G}-dis_{B}$ |
| **Final stock** | $+k_{m}^{G}+k_{m}^{B}$ | $+k_{e}^{G}+k_{e}^{B}$ | $+CO_{2}^{G}+CO_{2}^{B}$ | $+k_{se}^{G}+k_{se}^{B}$ |

Notes: Matter is measured in Gt while energy is measure in EJ. A ‘+’ sign denotes inputs in the socio-economic system, whereas ‘–’ denotes outputs. $G$ = Greenland; $B$ = Brownland.

Fig. 1. Baseline: selected variables

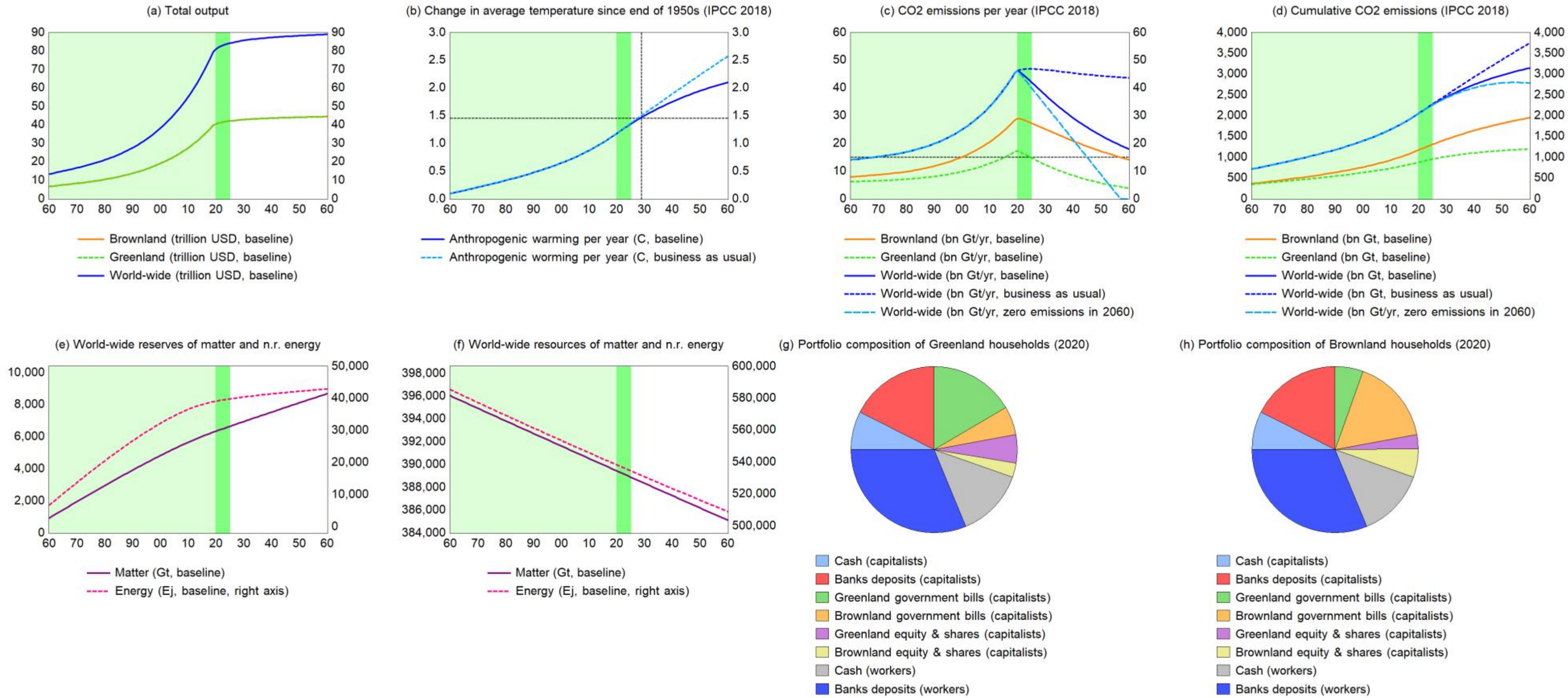


Fig. 2. Increase in risk aversion in both areas

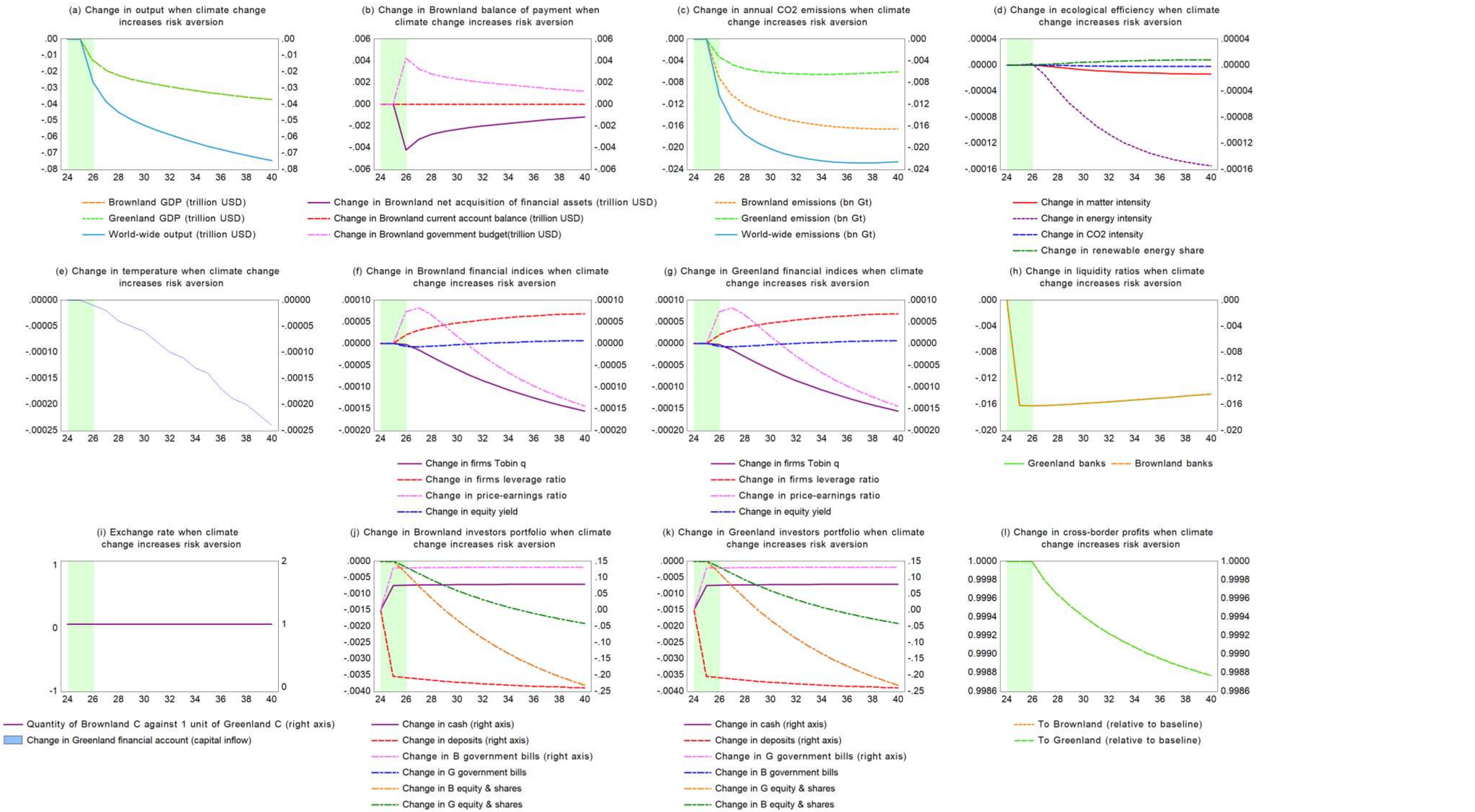


Fig. 3. Preference for 'greener' financial assets

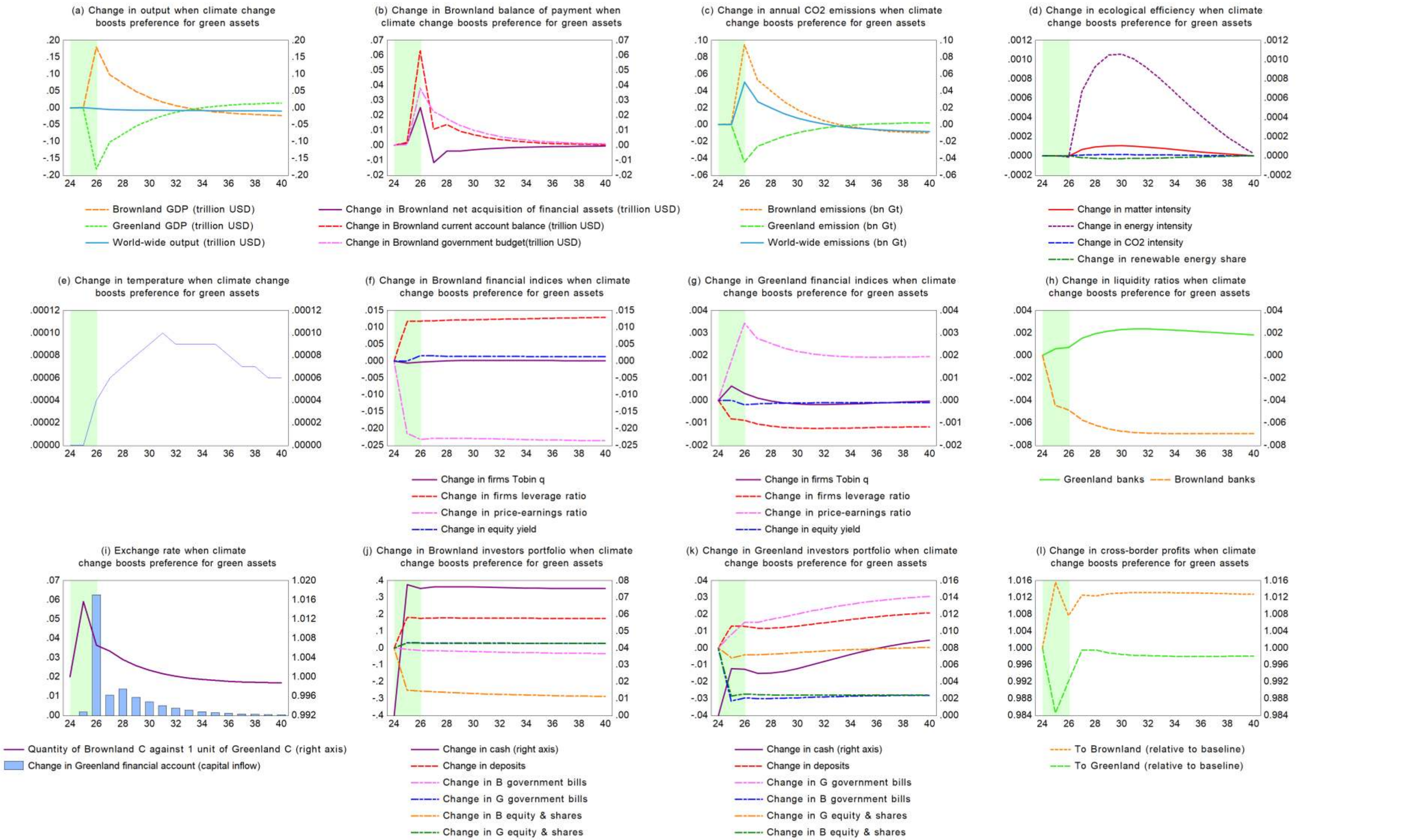


Fig. 4. Preference for ‘greener’ products

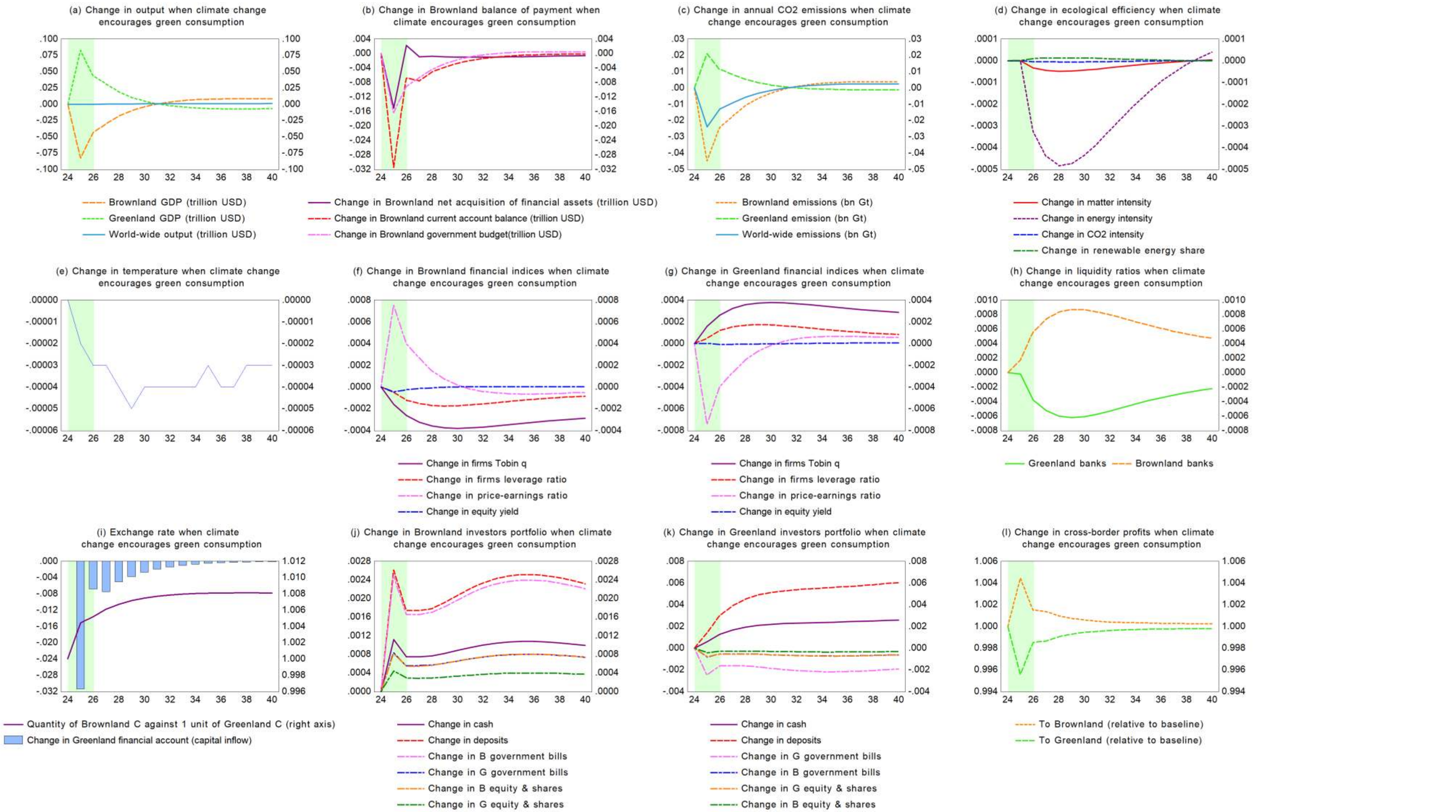


Fig. 5. Brownland government cuts green incentives, affecting import from Greenland

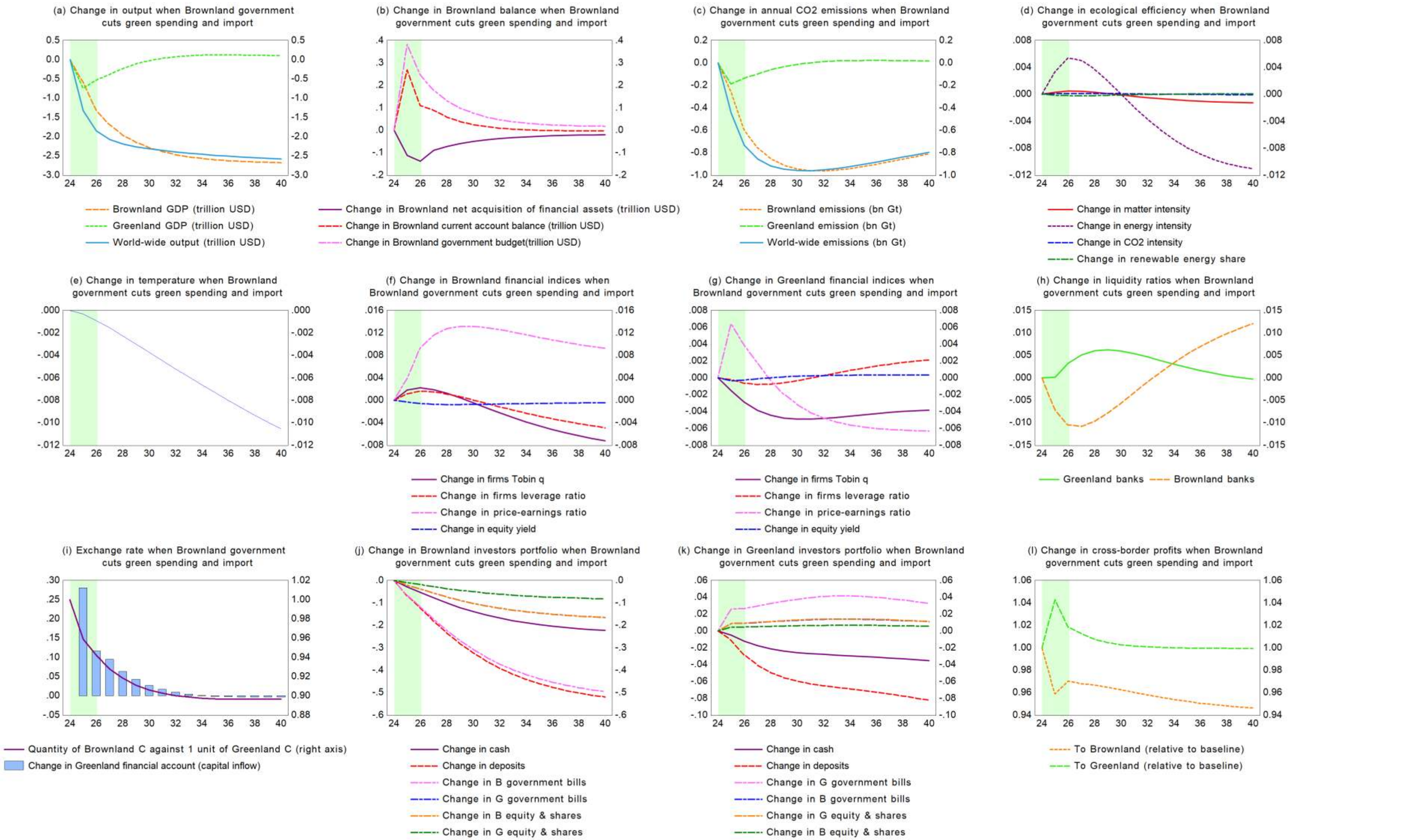


Fig. 6. Credit rationing in Brownland

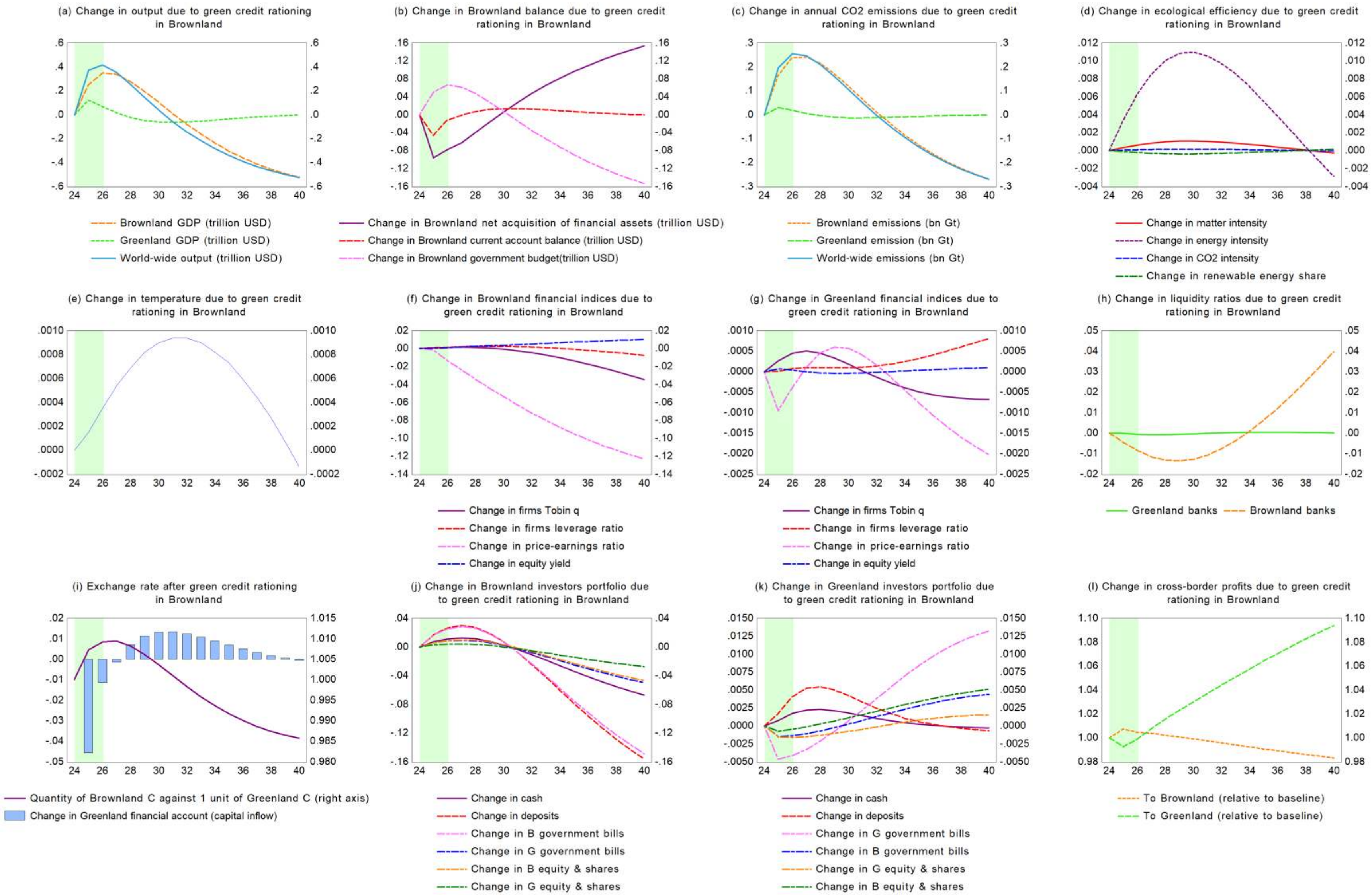


Fig. 7. Greenland government undertakes mission-oriented green spending

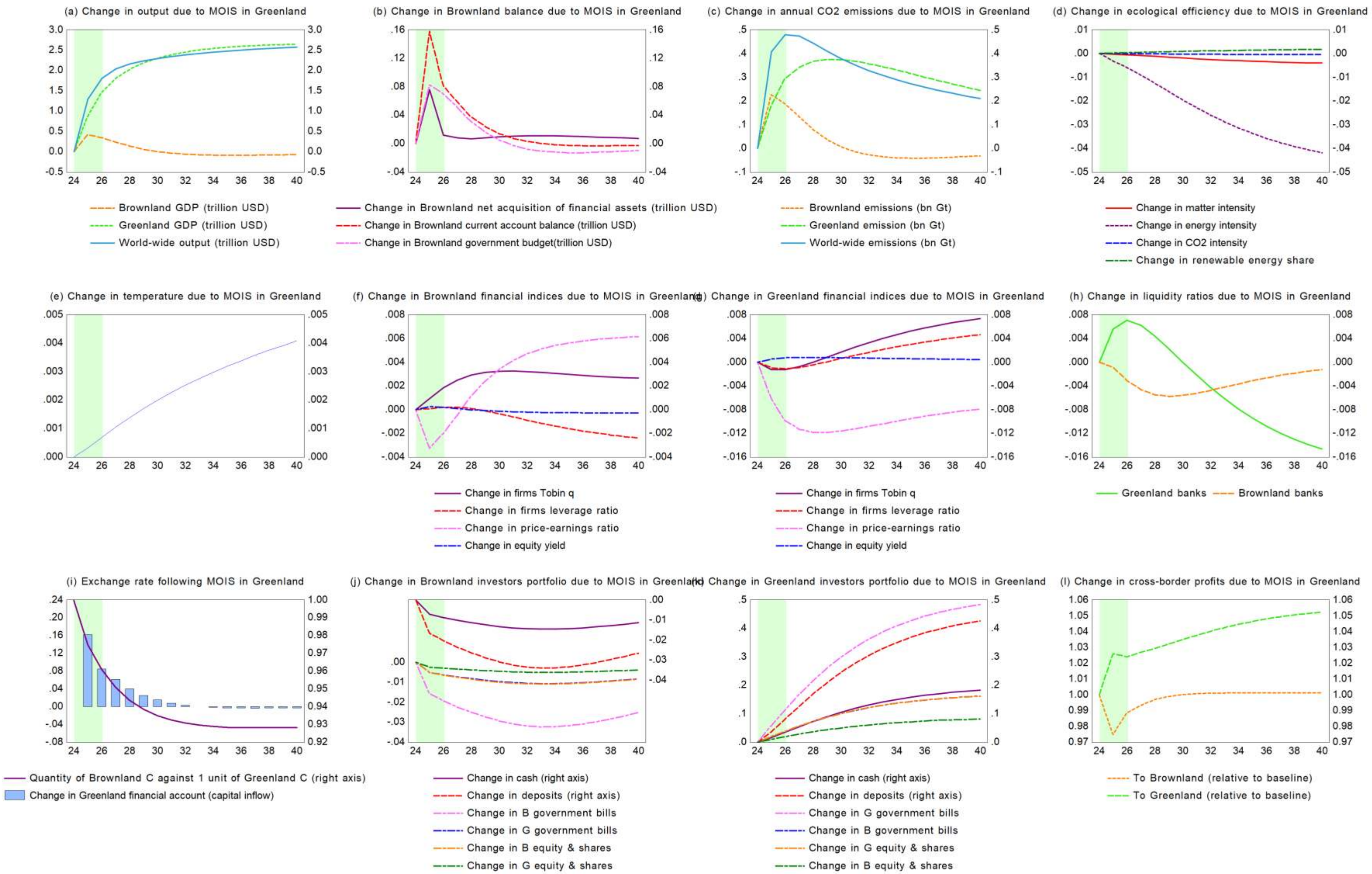


Fig. 3b. Preference for 'greener' financial assets under a fixed exchange rate regime

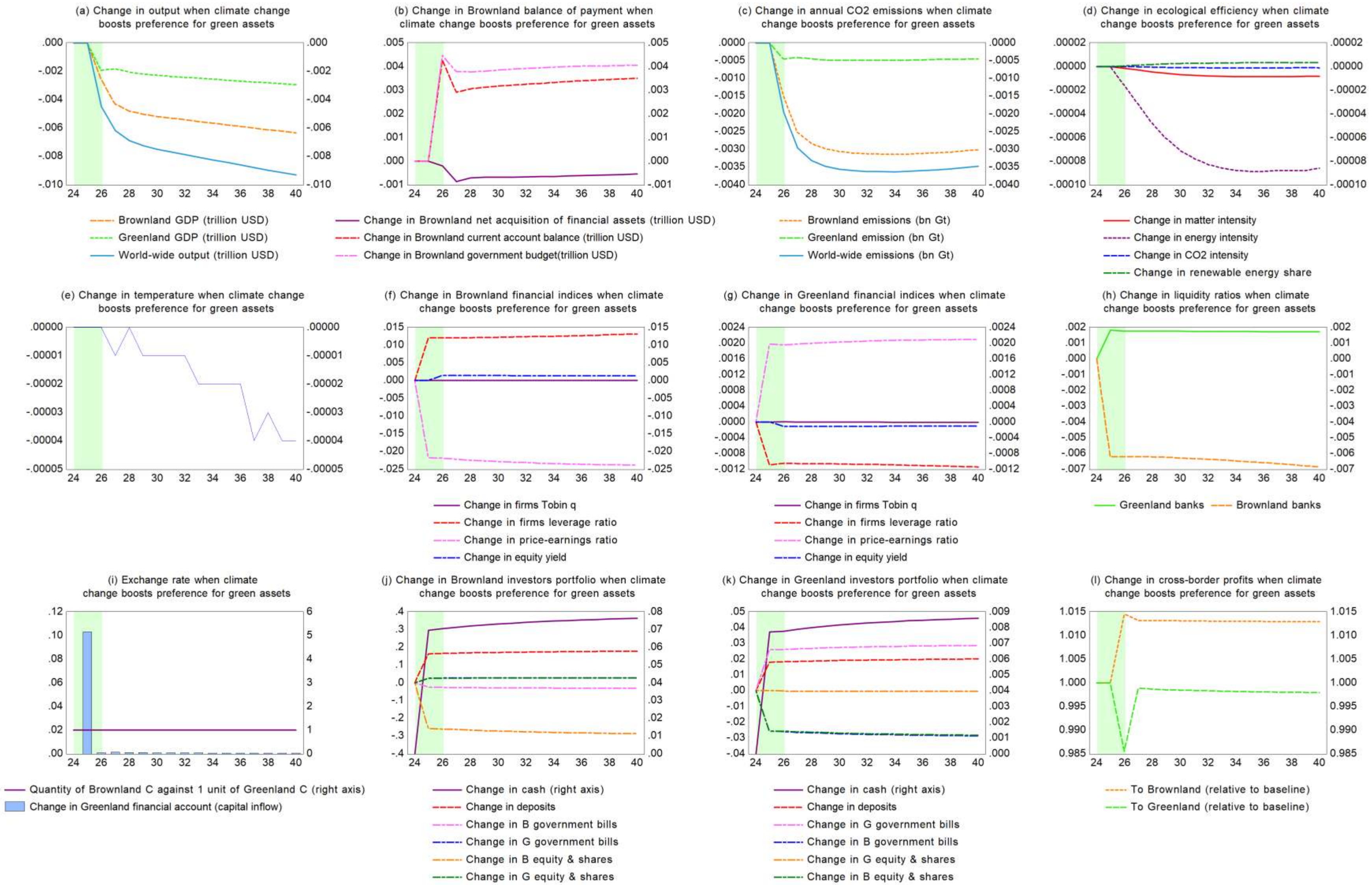


Fig. 4b. Preference for ‘greener’ products under a fixed exchange rate regime

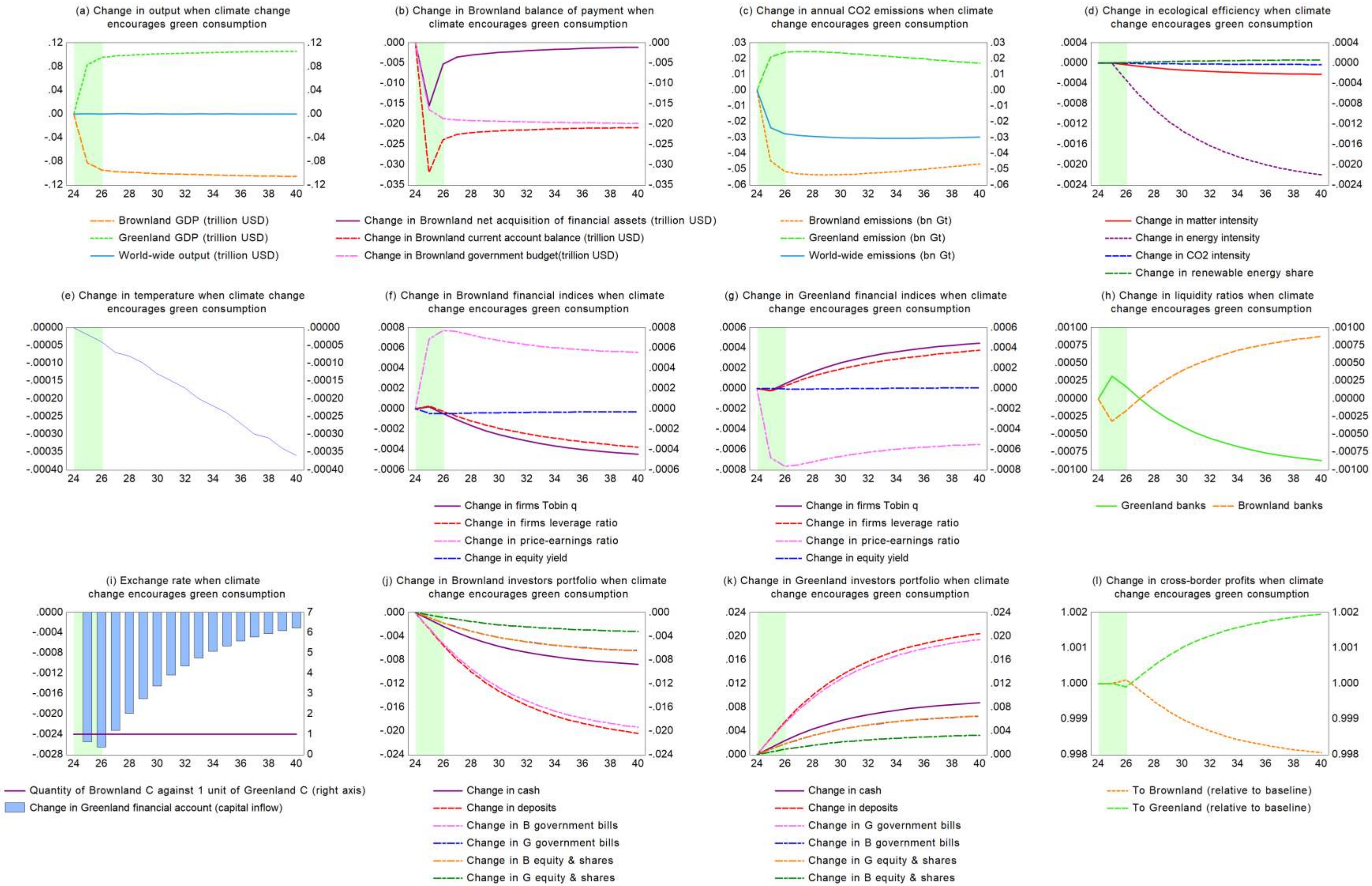


Fig. 5b. Brownland government cuts green incentives, affecting import from Greenland under a fixed exchange rate regime

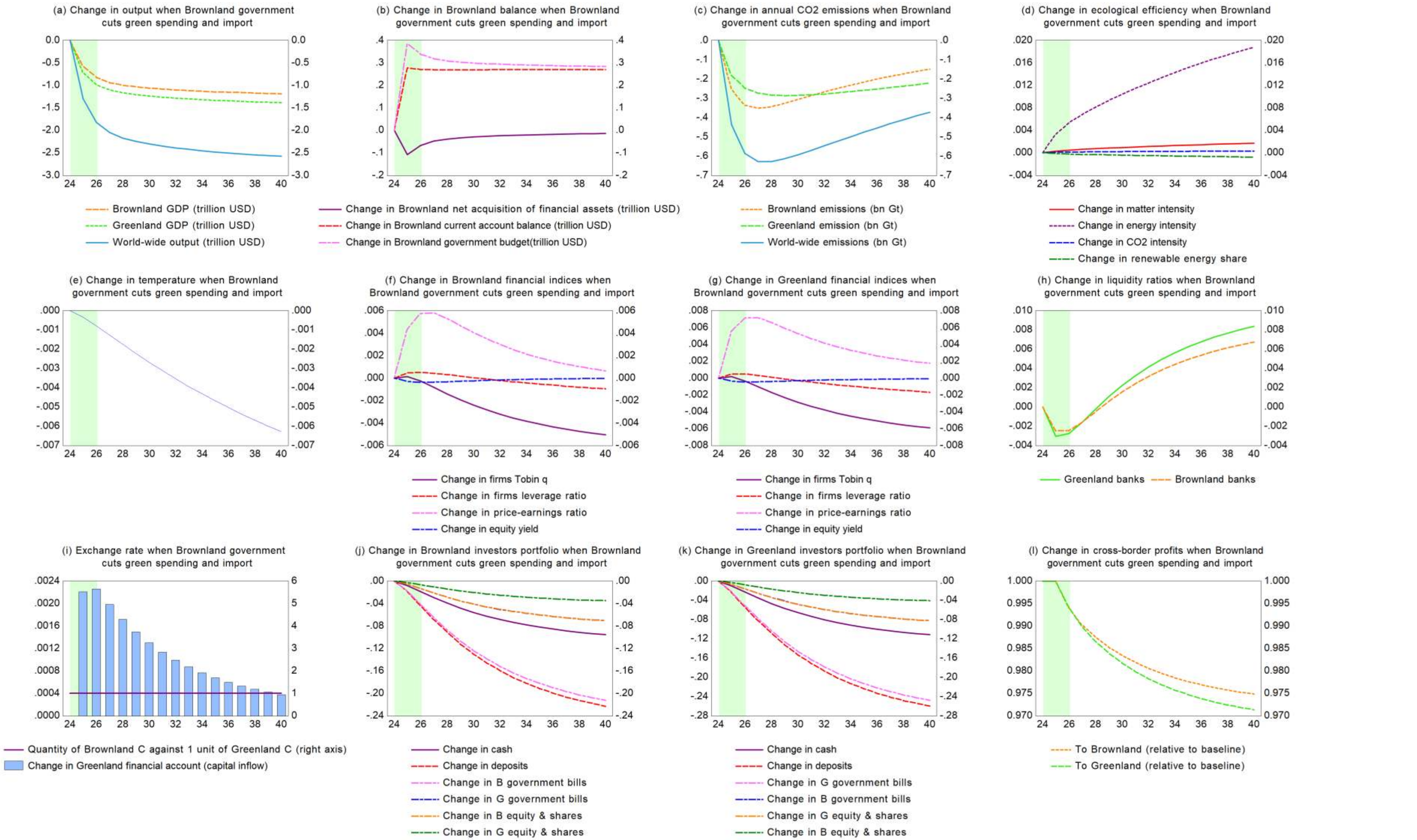


Fig. 7b. Greenland government undertakes mission-oriented green spending under a fixed exchange rate regime

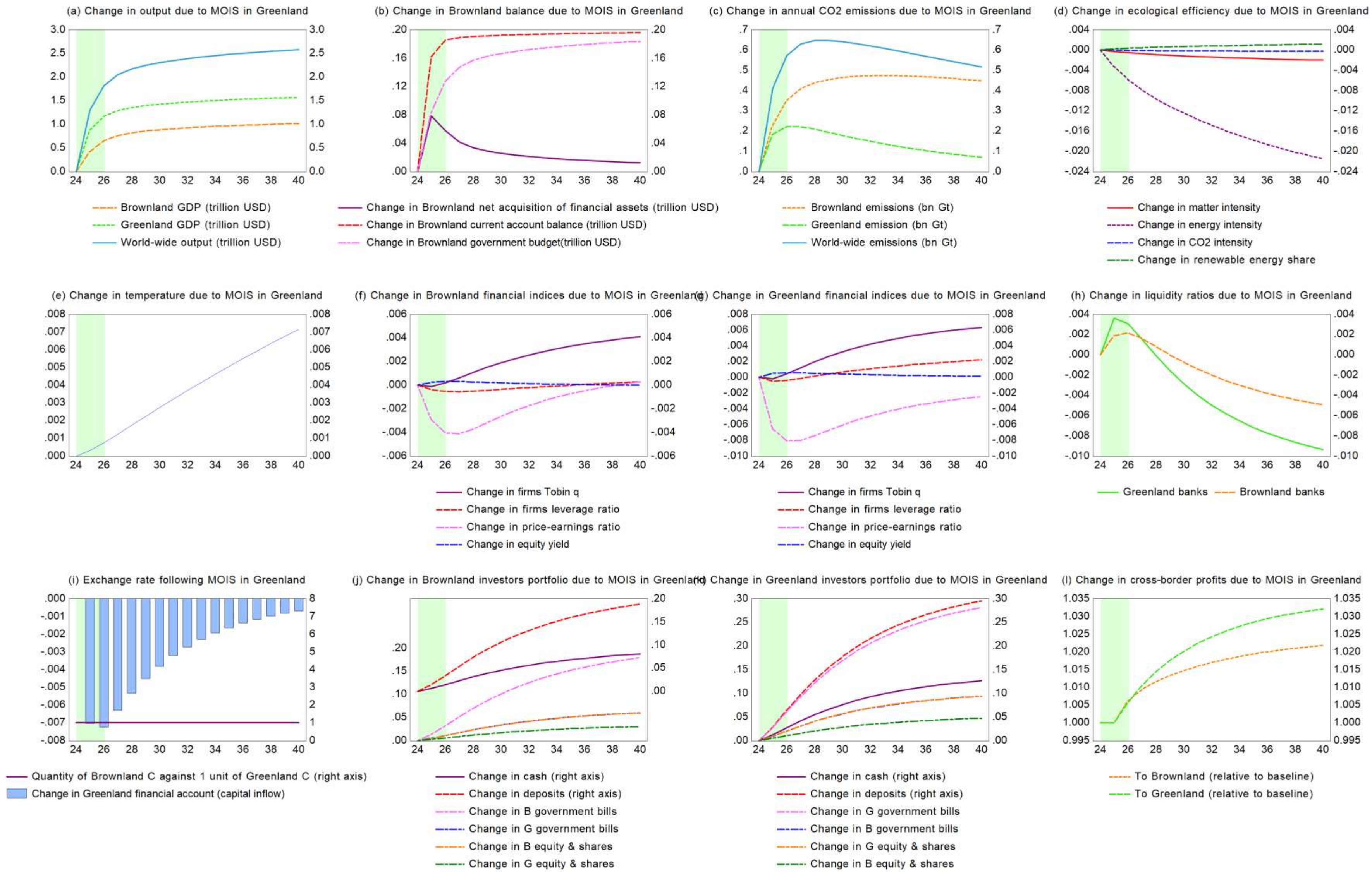
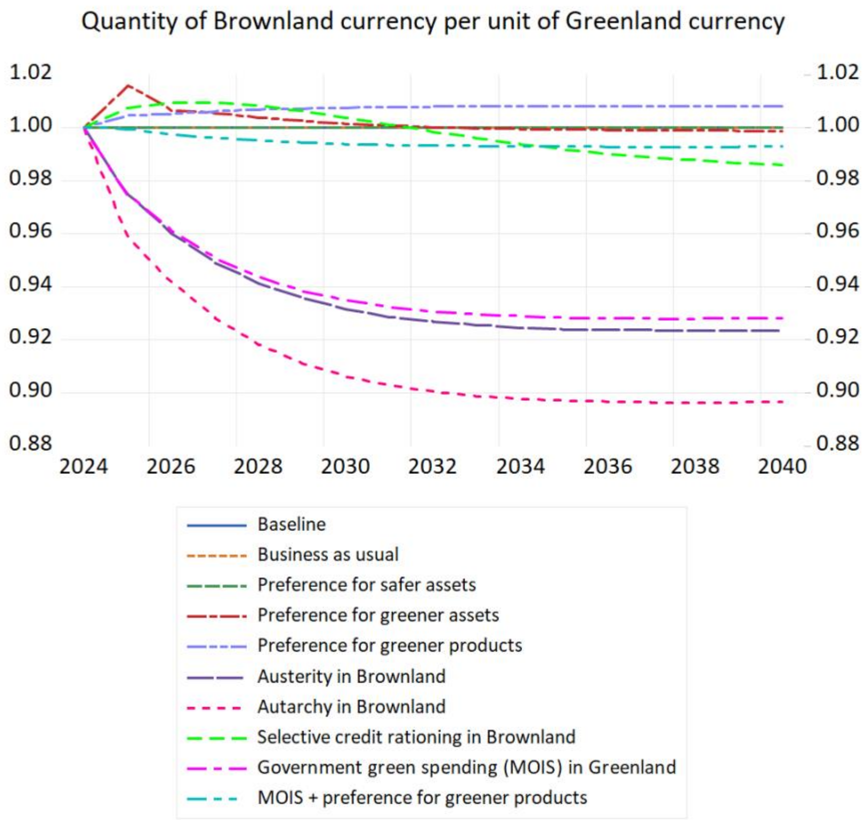


Fig. 8. Floating exchange rate: all scenarios



## Appendix: the complete model

The basic model is made up of 225 equations. Exogenous variables and coefficients are more than one hundred and thirty.[19] Superscript '$B$' stands for Brownland, while superscript '$G$' marks Greenland's variables and parameters. Government conventional spending, $GOV_{con}^{B[G]}$, grows at rate $g_{GOV,con}^{B[G]} > 0$ up until 2020 and 0 afterwards.

**Block I. Disposable income, wealth and taxes**

| | |
|---|---|
| $YD_r^B = Y_r^B \cdot (1-\theta_B)$ | Disposable income capitalists in Brownland – eq. 1 |
| $YD_w^B = Y_w^B \cdot (1-\theta_B)$ | Disposable income workers in Brownland – eq. 2 |
| $YD_{hs,r}^B = YD_r^B + CG_b^B + CG_e^B$ | Haig-Simons disposable income capitalists in Brownland – eq. 3 |
| $CG_b^B = d(xr_G) \cdot B_{s,-1}^{BG}$ | Revaluation of foreign bills held by Brownland capitalists – eq. 4 |
| $CG_e^B = d(xr_G) \cdot E_{s,-1}^{BG}$ | Revaluation of foreign shares held by Brownland capitalists – eq. 5 |
| $V_r^B = V_{r,-1}^B + YD_{hs,r}^B - C_r^B$ | Wealth accumulation capitalists in Brownland – eq. 6 |
| $V_w^B = V_{w,-1}^B + YD_w^B - C_w^B$ | Wealth accumulation workers in Brownland – eq. 7 |
| $YD_r^G = Y_r^G \cdot (1-\theta_G)$ | Disposable income capitalists in Greenland – eq. 8 |
| $YD_w^G = Y_w^G \cdot (1-\theta_G)$ | Disposable income workers in Greenland – eq. 9 |
| $YD_{hs,r}^G = YD_r^G + CG_b^G + CG_e^G$ | Haig-Simons disposable income capitalists in Greenland – eq. 10 |
| $CG_b^G = d(xr_B) \cdot B_{s,-1}^{GB}$ | Revaluation of foreign bills held by Greenland capitalists – eq. 11 |
| $CG_e^G = d(xr_B) \cdot E_{s,-1}^{GB}$ | Revaluation of foreign shares held by Greenland capitalists – eq. 12 |
| $V_r^G = V_{r,-1}^G + YD_{hs,r}^G - C_r^G$ | Wealth accumulation capitalists in Greenland – eq. 13 |
| $V_w^G = V_{w,-1}^G + YD_w^G - C_w^G$ | Wealth accumulation workers in Greenland – eq. 14 |
| $T_B = (Y_r^B + Y_w^B) \cdot \theta_B$ | Taxes paid in Brownland – eq. 15 |
| $T_G = (Y_r^G + Y_w^G) \cdot \theta_G$ | Taxes paid in in Greenland – eq. 16 |

**Block II. Consumption and income shares**

| | |
|---|---|
| $C_r^B = \alpha_{1r}^B \cdot YD_r^B + \alpha_{2r}^B \cdot V_{r,-1}^B$ | Consumption of capitalists in Brownland – eq. 17 |
| $C_w^B = \alpha_{1w}^B \cdot YD_w^B + \alpha_{2w}^B \cdot V_{w,-1}^B$ | Consumption of workers in Brownland – eq. 18 |
| $Y_B = C_r^B + C_w^B + GOV_{tot}^B + X_B - IM_B + INV_B$ | Total income in Brownland – eq. 19 |
| $C_r^G = \alpha_{1r}^G \cdot YD_r^G + \alpha_{2r}^G \cdot V_{r,-1}^G$ | Consumption of capitalists in Greenland eq. – 20 |

[19] The model we simulated is slightly bigger, as it includes some checks and additional calculations. It amounts to 239 endogenous variables and 132 exogenous variables and parameters, overall. We are happy to provide the program file upon request.

$C_w^G = \alpha_{1w}^G \cdot YD_w^G + \alpha_{2w}^G \cdot V_{w,-1}^G$ Consumption of workers in Greenland – eq. 21

$Y_G = C_r^G + C_w^G + GOV_{tot}^G + X_G - IM_G + INV_G$ Total income in Greenland – eq. 22

$Y_w^B = \omega \cdot Y_B$ Total income of Brownland workers – eq. 23

$Y_w^G = \omega_G \cdot Y_G$ Total income of Greenland workers – eq. 24

$F_f^B = Y_B - Y_w^B - DA_B - r_{l,-1}^B \cdot L_{f,-1}^B$ Gross profit of Brownland firms – eq. 25

$F_u^B = F_f^B \cdot ret_B$ Profit retained by Brownland firms – eq. 26

$F_d^B = r_{e,-1}^B \cdot (E_{s,-1}^{BB} + E_{s,-1}^{GB})$ Profit distributed by Brownland firms – eq. 27

$F_m^B = F_f^B - F_u^B - F_d^B$ Compensations of Brownland firms' managers – eq. 28

$Y_r^B = F_m^B + F_b^B + r_{B,-1} \cdot B_{s,-1}^{BB} + xr_G \cdot r_{G,-1} \cdot B_{s,-1}^{BG} + F_{d,-1}^{BB} + F_{d,-1}^{BG}$ Total income of Brownland capitalists – eq. 29

$F_d^{BG} = xr_G \cdot r_e^G \cdot E_s^{BG}$ Dividends paid by Greenland firms to Brownland shareholders – eq. 30

$F_d^{BB} = r_e^G \cdot E_s^{BB}$ Dividends paid by Brownland firms to Brownland shareholders – eq. 31

$F_f^G = Y_G - Y_w^G - DA_G - r_{l,-1}^G \cdot L_{f,-1}^G$ Gross profit of Greenland firms – eq. 32

$F_u^G = F_f^G \cdot ret_G$ Profit retained by Greenland firms – eq. 33

$F_d^G = r_{e,-1}^G \cdot (E_{s,-1}^{GG} + E_{s,-1}^{BG})$ Profit distributed by Greenland firms – eq. 34

$F_m^G = F_f^G - F_u^G - F_d^G$ Compensations of Greenland firms' managers – eq. 35

$Y_r^G = F_m^G + F_b^G + r_{G,-1} \cdot B_{s,-1}^{GG} + xr_B \cdot r_{B,-1} \cdot B_{s,-1}^{GB} + F_{d,-1}^{GB} + F_{d,-1}^{GG}$ Total income of Greenland capitalists – eq. 36

$F_d^{GB} = xr_B \cdot r_e^B \cdot E_s^{GB}$ Dividends paid by Brownland firms to Greenland shareholders – eq. 37

$F_d^{GG} = r_e^G \cdot E_s^{GG}$ Dividends paid by Greenland firms to Greenland shareholders – eq. 38

**Block III. Firms' investment plans**

$K_B = K_{gr}^B + K_{con}^B$ Total accumulation capital in Brownland – eq. 39

$K_{gr}^B = K_{gr,-1}^B + INV_{gr}^B - DA_{gr}^B$ Accumulation of green capital in Brownland – eq. 40

$K_{con}^B = K_{con,-1}^B + INV_{con}^B - DA_{con}^B$ Accumulation of conventional capital in Brownland – eq. 41

$DA_B = DA_{gr}^B + DA_{con}^B$ Total depreciation allowances in Brownland – eq. 42

$DA_{gr}^B = \delta_B \cdot K_{gr,-1}^B$ Depreciation allowances of green capital in Brownland – eq. 43

$DA_{con}^B = \delta_B \cdot K_{con,-1}^B$ Depreciation allowances of conventional capital in Brownland – eq. 44

$K_B^t = \kappa \cdot Y_{-1}^B$ Capital stock target in Brownland – eq. 45

$INV_B = \gamma_B \cdot (K_B^t - K_{B,-1}) + DA_{gr}^B + DA_{con}^B$ Demand for investment goods in Brownland – eq. 46

$INV_{gr}^B = \min[(\chi_1^B \cdot GOV_{gr}^B + \chi_2^B \cdot Y_B - \chi_3^B \cdot r_l^B), INV_B)$ Demand for green investment in Brownland – eq. 47

$INV_{con}^B = INV_B - INV_{gr}^B$ Conventional investment in Brownland – eq. 48

$L_f^B = L_{f,-1}^B + INV_B - DA_B - F_u^B - d(E_s^{GB}) - d(E_s^{BB})$ Demand for bank loans by Brownland firms – eq. 49

$K^G = K_{gr}^G + K_{con}^G$ Total accumulation of capital in Greenland – eq. 50

$K_{gr}^G = K_{gr,-1}^G + INV_{gr}^G - DA_{gr}^G$ Accumulation of green capital in Greenland eq. 51

$K_{con}^G = K_{con,-1}^G + INV_{con}^G - DA_{con}^G$ Accumulation of conventional capital in Greenland – eq. 52

$DA_G = DA_{gr}^G + DA_{con}^G$ Total depreciation allowances in Greenland – eq. 53

$DA_{gr}^G = \delta_G \cdot K_{gr,-1}^G$ Depreciation allowances of green capital in Greenland – eq. 54

$DA_{con}^G = \delta_G \cdot K_{con,-1}^G$ Depreciation allowances of conventional capital in Greenland – eq. 55

$K_G^t = \kappa \cdot Y_{-1}^G$ Capital stock target in Brownland – eq. 56

$INV_G = \gamma_B \cdot (K_G^t - K_{G,-1}) + DA_{gr}^G + DA_{con}^G$ Demand for investment goods in Greenland – eq. 57

$INV_{gr}^G = \min[(\chi_1^G \cdot GOV_{gr}^G + \chi_2^G \cdot Y_G - \chi_3^G \cdot r_l^G), INV_G)$ Demand for green investment in Greenland – eq. 58

$INV_{con}^G = INV_G - INV_{gr}^G$ Conventional investment in Greenland – eq. 59

$L_f^G = L_{f,-1}^G + INV_G - DA_G - F_u^G - d(E_s^{BG}) - d(E_s^{GG})$ Demand for bank loans by Greenland firms – eq. 60

**Block IV. International trade**

$\log(X_B) = \varepsilon_0 - \varepsilon_1 \cdot \log(xr_{B,-1}) + \varepsilon_2 \cdot \log Y_G$ Exports of Brownland – eq. 61

$\log(IM_B) = \mu_0 + \mu_1 \cdot \log(xr_{B,-1}) + \mu_2 \cdot \log(Y_B)$ Imports of Brownland – eq. 62

$X_G = IM_B \cdot xr_B$ Exports of Greenland – eq. 63

$IM_G = x_B \cdot xr_B$ Imports of Greenland – eq. 64

**Block V. Demand for financial assets (portfolio equations)**

$\frac{B_d^{BB}}{V_r^B} = \lambda_{10} + \lambda_{11} \cdot r_B - \lambda_{12} \cdot r_G - \lambda_{13} \cdot r_e^B - \lambda_{14} \cdot r_e^G$ Nominal demand for Brownland bills by Brownland capitalists – eq. 65

$\frac{B_d^{BG}}{V_r^B} = \lambda_{20} - \lambda_{21} \cdot r_B + \lambda_{22} \cdot r_G - \lambda_{23} \cdot r_e^B - \lambda_{24} \cdot r_e^G$ Nominal demand for Greenland bills by Brownland capitalists – eq. 66

$\frac{E_d^{BG}}{V_r^B} = \lambda_{70} - \lambda_{71} \cdot r_B - \lambda_{72} \cdot r_G - \lambda_{73} \cdot r_e^B + \lambda_{74} \cdot r_e^G$ Nominal demand for Greenland shares by Brownland capitalists - eq. 67

$\frac{E_d^{BB}}{V_r^B} = \lambda_{90} - \lambda_{91} \cdot r_B - \lambda_{92} \cdot r_G + \lambda_{93} \cdot r_e^B - \lambda_{94} \cdot r_e^G$ Nominal demand for Brownland shares by Brownland capitalists - eq. 68

$M_r^B = (V_r^B - B_s^{BB} - E_s^{BB} - (B_s^{BG} + E_s^{BG}) \cdot xr_G) \cdot \nu_B$ Holding of money in bank deposits by capitalists in Brownland – eq. 69

$H_r^B = V_r^B - B_s^{BB} - E_s^{BB} - (B_s^{BG} + E_s^{BG}) \cdot xr_G - M_r^B$ Holding of money in cash by capitalists in Brownland – eq. 70

$M_w^B = V_W^B \cdot \nu_B$ Holding of money in bank deposits by workers in Brownland – eq. 71

$H_w^B = V_w^B - M_w^B$ Holding of money in cash by workers in Brownland – eq. 72

$H_h^B = H_w^B + H_r^B$ Total holding of money in cash in Brownland – eq. 73

| | |
|---|---|
| $\frac{B_d^{GG}}{V_r^G} = \lambda_{40} - \lambda_{41} \cdot r_B + \lambda_{42} \cdot r_G - \lambda_{43} \cdot r_e^B - \lambda_{44} \cdot r_e^G$ | Nominal demand for Greenland bills by Greenland capitalists – eq. 74 |
| $\frac{B_d^{GB}}{V_r^G} = \lambda_{50} + \lambda_{51} \cdot r_B - \lambda_{52} \cdot r_G - \lambda_{53} \cdot r_e^B - \lambda_{54} \cdot r_e^G$ | Nominal demand for Brownland bills by Greenland capitalists – eq. 75 |
| $\frac{E_d^{GB}}{V_r^G} = \lambda_{80} - \lambda_{81} \cdot r_B - \lambda_{82} \cdot r_G + \lambda_{83} \cdot r_e^B - \lambda_{84} \cdot r_e^G$ | Nominal demand for Brownland shares by Greenland capitalists - eq. 76 |
| $\frac{E_d^{GG}}{V_r^G} = \lambda_{100} - \lambda_{101} \cdot r_B - \lambda_{102} \cdot r_G - \lambda_{103} \cdot r_e^B + \lambda_{104} \cdot r_e^G$ | Nominal demand for Greenland shares by Greenland capitalists - eq. 77 |
| $M_r^G = (V_r^G - B_s^{GG} - E_s^{GG} - (B_s^{GB} + E_s^{GB}) \cdot xr_B) \cdot \nu_G$ | Holding of money in bank deposits by capitalists in Greenland – eq. 78 |
| $H_r^G = V_r^G - B_s^{GG} - E_s^{GG} - (B_s^{GB} + E_s^{GB}) \cdot xr_B - M_r^G$ | Holding of money in cash by capitalists in Greenland – eq. 79 |
| $M_w^G = V_W^G \cdot \nu_G$ | Holding of money in bank deposits by workers in Greenland – eq. 80 |
| $H_w^G = V_w^G - M_w^G$ | Holding of money in cash by workers in Greenland – eq. 81 |
| $H_h^G = H_w^G + H_r^G$ | Total holding of money in cash in Greenland – eq. 82 |

**Block VI. Supplies and prices of financial assets (equilibrium conditions)**

| | |
|---|---|
| $B_s^{BB} = B_d^{BB}$ | Supply of Brownland bills to Brownland households (capitalists) – eq. 83 |
| $B_s^{GG} = B_d^{GG}$ | Supply of Greenland bills to Greenland households (capitalists) – eq. 84 |
| $B_s^{GB} = B_d^{GB} \cdot xr_G$ | Supply of Brownland bills to Greenland households (capitalists) – eq. 85 |
| $B_s^{BG} = B_d^{BG} \cdot xr_B$ | Supply of Greenland bills to Brownland households (capitalists) – eq. 86 |
| $E_s^{BG} = E_d^{BG} \cdot xr_B$ | Nominal supply of Greenland shares to Brownland capitalists - eq. 87 |
| $E_s^{GG} = E_d^{GG}$ | Nominal supply of Greenland shares to Greenland capitalists - eq. 88 |
| $e_s^G = e_{s,-1}^G + \xi_G \cdot \frac{INV_{G,-1}}{p_{e,-1}^G}$ | Quantity of shares issued by Greenland firms - eq. 89 |
| $p_e^G = \frac{E_d^{GG} + E_d^{BG}}{e_s^G}$ | Unit price of shares issued by Greenland firms - eq. 90 |
| $E_s^{GB} = E_d^{GB} \cdot xr_G$ | Nominal supply of Brownland shares to Greenland capitalists - eq. 91 |
| $E_s^{BB} = E_d^{BB}$ | Nominal supply of Brownland shares to Brownland capitalists - eq. 92 |
| $e_s^B = e_{s,-1}^B + \xi_B \cdot \frac{INV_{B,-1}}{p_{e,-1}^B}$ | Quantity of shares issued by Greenland firms - eq. 93 |
| $p_e^B = \frac{E_d^{BB} + E_d^{GB}}{e_s^B}$ | Unit price of shares issued by Brownland firms - eq. 94 |
| $r_e^G = \left(1 - \pi_{dy}^G\right) \cdot r_G + \pi_{dy}^G \cdot r_e^{GT}$ | Dividend yield on Greenland firms' shares - eq. 95 |
| $r_e^{GT} = \frac{F_f^G}{e_{s,-1}^G \cdot p_{e,-1}^G}$ | Return rate on Greenland firms' equity - eq. 96 |

| | |
|---|---|
| $r_e^B = \left(1 - \pi_{dy}^B\right) \cdot r_B + \pi_{dy}^B \cdot r_e^{BT}$ | Dividend yield on Brownland firms' shares - eq. 97 |
| $r_e^{BT} = \frac{F_f^B}{e_{s,-1}^B \cdot p_{e,-1}^B}$ | Return rate on Brownland firms' equity - eq. 98 |

**Block VII. The banking sector**

| | |
|---|---|
| $M_s^B = M_w^B + M_r^B$ | Supply of deposits in Brownland (liabilities of Brownland banks) – eq. 99 |
| $L_s^B = L_f^B$ | Supply of loans to firms in Brownland - eq. 100 |
| $B_{b,not}^B = M_s^B - L_s^B$ | Brownland bills notionally bought by Brownland banks – eq. 101 |
| $\zeta_B = 1\ iff\ \ B_{b,not}^B > 0$ | Trigger for notional Brownland bills bought by Brownland banks – eq. 102 |
| $B_b^B = B_{b,not}^B \cdot \zeta_B$ | Brownland bills actually bought by Brownland bank – eq. 103 |
| $A_d^B = -B_{b,not}^B \cdot (1 - \zeta_B)$ | Advances needed by Brownland banks from Brownland central bank – eq. 104 |
| $A_s^B = A_d^B$ | Advances provided to Brownland banks by Brownland central bank – eq. 105 |
| $F_b^B = r_{B,-1} \cdot B_{b,-1}^B + r_l^B \cdot L_{s,-1}^B$ | Profits of banks in Brownland – eq. 106 |
| $M_s^G = M_w^G + M_r^G$ | Supply of deposits in Greenland (liabilities of Brownland banks) – eq. 107 |
| $L_s^G = L_f^G$ | Supply of bank loans to firms in Greenland – eq. 108 |
| $B_{b,not}^G = M_s^G - L_s^G$ | Greenland bills notionally bought by Greenland banks – eq. 109 |
| $\zeta_G = 1\ iff\ B_{b,not}^G > 0$ | Trigger for notional Greenland bills bought by Greenland bank – eq. 110 |
| $B_b^G = B_{b,not}^G \cdot \zeta_G$ | Greenland bills actually bought by Greenland banks – eq. 111 |
| $A_d^G = -B_{b,not}^G \cdot (1 - \zeta_G)$ | Advances needed by Greenland banks from Greenland central bank – eq. 112 |
| $A_s^G = A_d^G$ | Advances provided to Greenland banks by Greenland central bank – eq. 113 |
| $F_b^G = r_{G,-1} \cdot B_{b,-1}^G + r_l^G \cdot L_{s,-1}^G$ | Profits of banks in Greenland – eq. 114 |

**Block VIII. The central bank and the government sector**

| | |
|---|---|
| $B_{cb}^{BB} = B_s^B - B_s^{BB} - B_s^{GB} - B_b^B$ | Brownland bills purchased by Brownland central bank – eq. 115 |
| $H_s^B = B_{cb}^{BB} + A_s^B$ | Supply of cash in Brownland – eq. 116 |
| $F_{cb}^B = r_{B,-1} \cdot B_{cb,-1}^{BB}$ | Profits of central bank in Brownland – eq. 117 |
| $B_{cb}^{GG} = B_s^G - B_s^{GG} - B_s^{BG} - B_b^G$ | Greenland bills purchased by Greenland central bank – eq. 118 |
| $H_s^G = B_{cb}^{GG} + A_s^G$ | Supply of cash in Greenland – eq. 119 |
| $F_{cb}^G = r_{G,-1} \cdot B_{cb,-1}^{GG}$ | Profits of central bank in Greenland – eq. 120 |
| $GOV_{tot}^B = GOV_{con}^B + GOV_{gr}^B$ | Total government expenditure in Brownland – eq. 121 |

$GOV_{tot}^{G} = GOV_{con}^{G} + GOV_{gr}^{G}$ Total government expenditure in Greenland – eq. 122

$B_{s}^{B} = B_{s,-1}^{B} + GOV_{tot}^{B} + r_{B,-1} \cdot B_{s,-1}^{B} - T_{B} - F_{cb}^{B}$ Government budget constraint in Brownland – eq. 123

$B_{s}^{G} = B_{s,-1}^{G} + GOV_{tot}^{G} + r_{G,-1} \cdot B_{s,-1}^{G} - T_{G} - F_{cb}^{G}$ Government budget constraint in Greenland – eq. 124

**Block IX. The exchange rates**

$xr_{G} = \frac{r_{B,-1} \cdot B_{S,-1}^{GB} + r_{e,-1}^{B} \cdot E_{S,-1}^{GB} - d(B_{S}^{GB}) - d(E_{S}^{GB}) - X_{B} + IM_{B}}{r_{G,-1} \cdot B_{S,-1}^{BG} + r_{e,-1}^{G} \cdot E_{S,-1}^{BG} - d(B_{S}^{BG}) - d(E_{S}^{BG})}$ Brownland exchange rate[20] – eq. 125

$xr_{B} = \frac{1}{xr_{G}}$ Greenland exchange rate – eq. 126

**Block X. The ecosystem: material resources and reserves**

$y_{mat}^{B} = \mu_{B} \cdot Y_{B}$ Production of material goods in Brownland – eq. 127

$y_{mat}^{G} = \mu_{G} \cdot Y_{G}$ Production of material goods in Greenland – eq. 128

$mat_{B} = y_{mat}^{B} - rec_{B}$ Extraction of matter in Brownland – eq. 129

$mat_{G} = y_{mat}^{G} - rec_{G}$ Extraction of matter in Greenland – eq. 130

$rec_{B} = \rho_{B} \cdot dis_{B}$ Recycled socio-economic stock in Brownland – eq. 131

$rec_{G} = \rho_{G} \cdot dis_{G}$ Recycled socio-economic stock in Greenland – eq. 131

$dis_{B} = \mu_{B} \cdot (DA_{B} + C_{w,-1}^{B} + C_{r,-1}^{B} - X_{B,-1} + IM_{B,-1})$ Discarded socio-economic stock in Brownland – eq. 133

$dis_{G} = \mu_{G} \cdot (DA_{G} + C_{w,-1}^{G} + C_{r,-1}^{G} - X_{G,-1} + IM_{G,-1})$ Discarded socio-economic stock in Greenland – eq. 134

$k_{se}^{B} = k_{se,-1}^{B} + y_{mat}^{B} - \mu_{B} \cdot (X_{B,-1} - IM_{B,-1}) - dis_{B}$ Socio-economic stock in Brownland – eq. 135

$k_{se}^{G} = k_{se,-1}^{G} + y_{mat}^{G} - \mu_{G} \cdot (X_{G,-1} - IM_{G,-1}) - dis_{G}$ Socio-economic stock in Greenland – eq. 136

$wa_{B} = mat_{B} - d(k_{se}^{B})$ Waste generated by production activities in Brownland – eq. 137

$wa_{G} = mat_{G} - d(k_{se}^{G})$ Waste generated by production activities in Greenland – eq. 138

$k_{m}^{B} = k_{m,-1}^{B} + conv_{m}^{B} - mat_{B}$ Stock of material reserves in Brownland – eq. 139

$k_{m}^{G} = k_{m,-1}^{G} + conv_{m}^{G} - mat_{G}$ ' Stock of material reserves in Greenland – eq. 140

$k_{m} = k_{m}^{B} + k_{m}^{G}$ ' World-wide stock of material reserves – eq. 141

$conv_{m}^{B} = \sigma_{m}^{B} \cdot res_{m,-1}^{B}$ Material resources converted to reserves in Brownland – eq. 142

$conv_{m}^{G} = \sigma_{m}^{G} \cdot res_{m,-1}^{G}$ Material resources converted to reserves in Greenland – eq. 143

$res_{m}^{B} = res_{m,-1}^{B} - conv_{m}^{B}$ Stock of material resources in Brownland – eq. 144

$res_{m}^{G} = res_{m,-1}^{G} - conv_{m}^{G}$ Stock of material resources in Greenland – eq. 145

$res_{m} = res_{m}^{B} + res_{m}^{G}$ World-wide stock of material resources – eq. 146

[20] Quantity of Brownland currency per unit of Greenland currency (e.g. USD).

| | |
|---|---|
| $cen_B = \frac{emis_B}{car}$ | Carbon mass of (non-renewable) energy in Brownland – eq. 147 |
| $cen_G = \frac{emis_G}{car}$ | Carbon mass of (non-renewable) energy in Greenland – eq. 148 |
| $o2_B = emis_B - cen_B$ | Mass of oxygen in Brownland – eq. 149 |
| $o2_G = emis_G - cen_G$ | Mass of oxygen in Greenland – eq. 150 |

**Block XI. The ecosystem: energy resources and reserves**

| | |
|---|---|
| $e_B = \epsilon_B \cdot Y_B$ | Energy required for production in Brownland – eq. 151 |
| $er_B = \eta_B \cdot e_B$ | Renewable energy in Brownland – eq. 152 |
| $en_B = e_B - er_B$ | Non-renewable energy in Brownland – eq. 153 |
| $ed_B = er_B + en_B$ | Dissipated energy at the end of the period in Brownland – eq. 154 |
| $e_G = \epsilon_G \cdot Y_G$ | Energy required for production in Greenland – eq. 155 |
| $er_G = \eta_G \cdot e_G$ | Renewable energy in Greenland – eq. 156 |
| $en_G = e_G - er_G$ | Non-renewable energy in Greenland – eq. 157 |
| $ed_G = er_G + en_G$ | Dissipated energy at the end of the period in Greenland – eq. 158 |
| $k_e^B = k_{e,-1}^B + conv_e^B - en_B$ | Stock of energy reserves in Brownland – eq. 159 |
| $k_e^G = k_{e,-1}^G + conv_e^G - en_G$ | Stock of energy reserves in Greenland – eq. 160 |
| $k_e = k_e^B + k_e^G$ | World-wide stock of energy reserves – eq. 161 |
| $conv_e^B = \sigma_e^B \cdot res_e^B$ | Energy resources converted to reserves in Brownland – eq. 162 |
| $conv_e^G = \sigma_e^G \cdot res_e^G$ | Energy resources converted to reserves in Greenland – eq. 163 |
| $res_e^B = res_{e,-1}^B - conv_e^B$ | Stock of energy resources in Brownland – eq. 164 |
| $res_e^G = res_{e,-1}^G - conv_e^G$ | Stock of energy resources in Greenland – eq. 165 |
| $res_e = res_e^B + res_e^G$ | World-wide stock of energy resources – eq. 166 |

**Block XII. The ecosystem: emissions and climate change**

| | |
|---|---|
| $emis_B = \beta_B \cdot en_B$ | Industrial emissions of $CO_2$ in Brownland – eq. 167 |
| $emis_G = \beta_G \cdot en_G$ | Industrial emissions of $CO_2$ in Greenland – eq. 168 |
| $emis = emis_b + emis_g$ | World-wide industrial emissions of $CO_2$ – eq. 169 |
| $co2_B = \psi_b \cdot co2_{B,-1} + emis_B$ | Cumulative emissions of CO2 in Brownland – eq. 170 |
| $co2_G = \psi_G \cdot co2_{G,-1} + emis_G$ | Cumulative emissions of CO2 in Greenland – eq. 171 |
| $co2 = co2_B + co2_G$ | World-wide cumulative emissions of CO2 – eq. 172 |
| $temp = temp_{-1} + \tau_B \cdot emis_B + \tau_G \cdot emis_G$ | Average atmospheric temperature – eq. 173 |

**Block XIII. The ecosystem: ecological efficiency**

$\mu_B = \mu_{gr}^B \cdot \frac{k_{gr}^B}{k_B} + \mu_{con}^B \cdot \frac{k_{con}^B}{k_B}$ Matter intensity coefficient in Brownland – eq. 174

$\mu_B = \mu_{gr}^G \cdot \frac{k_{gr}^G}{k_G} + \mu_{con}^G \cdot \frac{k_{con}^G}{k_G}$ Matter intensity coefficient in Greenland – eq. 175

$\epsilon_B = \epsilon_{gr}^B \cdot \frac{k_{gr}^B}{k_B} + \epsilon_{con}^B \cdot \frac{k_{con}^B}{k_B}$ Energy intensity coefficient in Brownland – eq. 177

$\epsilon_G = \epsilon_{gr}^G \cdot \frac{k_{gr}^G}{k_G} + \epsilon_{con}^G \cdot \frac{k_{con}^G}{k_G}$ Energy intensity coefficient in Greenland – eq. 178

$\beta_B = \beta_{gr}^B \cdot \frac{k_{gr}^B}{k_B} + \beta_{con}^B \cdot \frac{k_{con}^B}{k_B}$ $CO_2$ intensity coefficient in Brownland – eq. 179

$\beta_G = \beta_{gr}^G \cdot \frac{k_{gr}^G}{k_G} + \beta_{con}^G \cdot \frac{k_{con}^G}{k_G}$ $CO_2$ intensity coefficient in Greenland – eq. 180

$\eta_B = \eta_{gr}^B \cdot \frac{k_{gr}^B}{k_B} + \eta_{con}^B \cdot \frac{k_{con}^B}{k_B}$ Renewable energy share in Brownland – eq. 181

$\eta_G = \eta_{gr}^G \cdot \frac{k_{gr}^G}{k_G} + \eta_{con}^G \cdot \frac{k_{con}^G}{k_G}$ Renewable energy share in Greenland – eq. 182

**Block XIV. The ecosystem: ecological feedbacks**

$dep_m^B = \frac{mat_B}{k_{m,-1}^B}$ Matter depletion ratio in Brownland – eq. 183

$dep_m^G = \frac{mat_G}{k_{m,-1}^G}$ Matter depletion ratio in Greenland – eq. 184

$dep_e^B = \frac{en_B}{k_{e,-1}^B}$ Energy depletion ratio in Brownland – eq. 185

$dep_e^G = \frac{en_G}{k_{e,-1}^G}$ Energy depletion ratio in Greenland – eq. 186

$\delta_B = \delta_{B,-1} + \delta_{11} \cdot d(dep_m^B) + \delta_{12} \cdot d(depl_e^B) + \delta_{13} \cdot d(temp)$ Depreciation of capital stock in Brownland – eq. 187

$\delta_G = \delta_{G,-1} + \delta_{21} \cdot d(dep_m^G) + \delta_{22} \cdot d(depl_e^G) + \delta_{23} \cdot d(temp)$ Depreciation of capital stock in Greenland – eq. 188

$\alpha_{1w}^B = \alpha_{1w,-1}^B + \alpha_{11} \cdot d(depl_m^B) + \alpha_{12} \cdot d(depl_e^B) + \alpha_{13} \cdot d(temp)$ Propensity to consume of workers in Brownland – eq. 189

$\alpha_{1w}^G = \alpha_{1w,-1}^G + \alpha_{21} \cdot d(depl_m^G) + \alpha_{22} \cdot d(depl_e^G) + \alpha_{23} \cdot d(temp)$ Propensity to consume of workers in Greenland – eq. 190

**Block XV. Auxiliary equations for domestic and foreign balances**

$DEF_B = GOV_{tot}^B + r_{B,-1} \cdot B_{s,-1}^B - T_B - F_{cb,-1}^B$ Government deficit in Brownland – eq. 191

$DEF_G = GOV_{tot}^G + r_{G,-1} \cdot B_{s,-1}^G - T_G - F_{cb,-1}^G$ Government deficit in Greenland – eq. 192

$NAFA_B = DEF_B + CAB_B$ Net accumulation of financial assets in Brownland – eq. 193

$NAFA_G = DEF_G + CAB_G$ Net accumulation of financial assets in Greenland - eq. 194

$CAB_B = TB_B + xr_G \cdot \left(r_{G,-1} \cdot B^{BG}_{s,-1} + r^G_{e,-1} \cdot E^{BG}_{s,-1}\right) - r_{B,-1} \cdot B^{GB}_{s,-1} - r^B_{e,-1} \cdot E^{GB}_{s,-1}$ Current account balance of Brownland – eq. 195

$CAB_G = TB_G + xr_B \cdot \left(r_{B,-1} \cdot B^{GB}_{s,-1} + r^B_{e,-1} \cdot E^{GB}_{s,-1}\right) - r_{G,-1} \cdot B^{BG}_{s,-1} - r^G_{e,-1} \cdot E^{BG}_{s,-1}$ Current account balance of Greenland – eq. 196

$KAB_B = -d(B^{BG}_S) \cdot xr_G + d(B^{GB}_S) - d(E^{BG}_S) \cdot xr_G + d(E^{GB}_S)$ Financial account balance of Brownland – eq. 1907

$KAB_G = -d(B^{GB}_S) \cdot xr_B + d(B^{BG}_S) - d(E^{GB}_S) \cdot xr_B + d(E^{BG}_S)$ Financial account balance of Greenland – eq. 198

$TB_B = X_B - IM_B$ Trade balance of Brownland – eq. 199

$TB_G = X_G - IM_G$ Trade balance of Greenland – eq. 200

$BP_B = CAB_B + KAB_B$ Balance of payment of Brownland – eq. 201

$BP_G = CAB_G + KAB_G$ Balance of payment of Greenland – eq. 202

**Block XVI. National product and inequality indices**

$GNP_B = Y_B + xr_G \cdot (r_{G,-1} \cdot B^{BG}_{s,-1} + r^G_{e,-1} \cdot E^{BG}_{s,-1}) - r_{B,-1} \cdot B^{GB}_{s,-1} - r^B_{e,-1} \cdot E^{GB}_{s,-1}$ Gross National product of Brownland – eq. 203

$GNP_G = Y_G + xr_B \cdot (r_{B,-1} \cdot B^{GB}_{s,-1} + r^B_{e,-1} \cdot E^{GB}_{s,-1}) - r_{G,-1} \cdot B^{BG}_{s,-1} - r^G_{e,-1} \cdot E^{BG}_{s,-1}$ Gross National product of Greenland – eq. 204

$YD^B_{tot} = YD^B_w + YD^B_r$ Total disposable income in Brownland – eq. 205

$gini^B_{YD} = \frac{YD^B_r}{YD^B_{tot}}$ Income inequality index in Brownland – eq. 206

$YD^G_{tot} = YD^G_w + YD^G_r$ Total disposable income in Greenland – eq. 207

$gini^G_{YD} = \frac{YD^G_r}{YD^G_{tot}}$ Income inequality index in Greenland – eq. 208

$V^B_{tot} = V^B_r + V^B_w$ Total net wealth in Brownland – eq. 209

$gini^B_V = \frac{V^B_r}{V^B_{tot}}$ Wealth inequality index in Brownland – eq. 210

$V^G_{tot} = V^G_r + V^G_w$ Total net wealth in Greenland – eq. 211

$gini^G_V = \frac{V^G_r}{V^G_{tot}}$ Wealth inequality index in Brownland – eq. 212

**Block XVII. Additional financial variables and indices**

$q_G = \frac{e^G_{s,-1} \cdot p^G_{e,-1} + L^G_f}{K_G}$ Tobin's q of Greenland firms - eq. 213

$q_B = \frac{e^B_{s,-1} \cdot p^B_{e,-1} + L^B_f}{K_B}$ Tobin's q of Brownland firms - eq. 214

$lev^G_f = \frac{L^G_f}{e^G_{s,-1} \cdot p^G_{e,-1} + L^G_f}$ Leverage ratio of Greenland firms - eq. 215

$lev^B_f = \frac{L^B_f}{e^B_{s,-1} \cdot p^B_{e,-1} + L^B_f}$ Leverage ratio of Brownland firms - eq. 216

| | |
|---|---|
| $per_G = \frac{p_e^G}{F_G / e_{s,-1}^G}$ | Price-earnings ratio of Greenland firms' shares - eq. 217 |
| $per_B = \frac{p_e^B}{F_B / e_{s,-1}^B}$ | Price-earnings ratio of Brownland firms' shares - eq. 218 |
| $liq_b^G = \frac{A_s^G + M_s^G - L_s^G}{M_s^G}$ | Liquidity ratio of Greenland banks - eq. 219 |
| $liq_b^B = \frac{A_s^B + M_s^B - L_s^B}{M_s^B}$ | Liquidity ratio of Brownland banks - eq. 220 |

**Block XVIII. Credit rationing and other shocks**

| | |
|---|---|
| $\gamma_G = \gamma_{10} - \gamma_{11} \cdot r_{G,-1} - \gamma_{12} \cdot lev_{f,-1}^G + \gamma_{13} \cdot liq_{b,-1}^G + \gamma_{14} \cdot \frac{INV_{gr,-1}^G}{INV_{G,-1}}$ | Speed of adjustment of capital to target level in Greenland - eq. 221 |
| $r_l^G = r_{l,-1}^G - \gamma_{15} \cdot \frac{INV_{gr,-1}^G}{INV_{G,-1}}$ | Interest rate on bank loans in Greenland - eq. 222 |
| $\gamma_B = \gamma_{20} - \gamma_{21} \cdot r_{B,-1} - \gamma_{22} \cdot lev_{f,-1}^B + \gamma_{23} \cdot liq_{b,-1}^B + \gamma_{24} \cdot \frac{INV_{gr,-1}^B}{INV_{B,-1}}$ | Speed of adjustment of capital to target level in Brownland - eq. 223 |
| $r_l^B = r_{l,-1}^B - \gamma_{25} \cdot \frac{INV_{gr,-1}^B}{INV_{B,-1}}$ | Interest rate on bank loans in Brownland - eq. 224 |
| $\mu_2 = \mu_{2,-1} + \gamma_3 \cdot d(GOV_{gr}^B)$ | Propensity to import of Brownland - eq. 225 |

**Redundant equations**

| | |
|---|---|
| $H_s^B = H_h^B$ | Supply of cash matches demand for cash in Brownland |
| $H_s^G = H_h^G$ | Supply of cash matches demand for cash in Greenland |

Table 5. Initial values of variables and coefficient values for the baseline and the experiments

| Starting values of parameters of the two open economies | Symbols and baseline values | Values under alternative scenarios | | | | | |
|---|---|---|---|---|---|---|---|
| | | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 |
| Brownland capitalists’ propensity to consume out of income | $\alpha_{1r}^{B} = 0.65$ | | | | | | |
| Brownland workers’ propensity to consume out of income | $\alpha_{1w}^{B} = 0.85$ | | | | | | |
| Greenland capitalists’ propensity to consume out of income | $\alpha_{1r}^{G} = 0.65$ | | | | | | |
| Greenland workers’ propensity to consume out of income | $\alpha_{1w}^{G} = 0.85$ | | | | | | |
| Brownland capitalists’ propensity to consume out of wealth | $\alpha_{2r}^{B} = 0.13333$ | | | | | | |
| Brownland workers’ propensity to consume out of wealth | $\alpha_{2w}^{B} = 0.13333$ | | | | | | |
| Greenland capitalists’ propensity to consume out of wealth | $\alpha_{2r}^{G} = 0.13333$ | | | | | | |
| Greenland workers’ propensity to consume out of wealth | $\alpha_{2w}^{G} = 0.13333$ | | | | | | |
| Parameter in Brownland export equation | $\varepsilon_0 = -2.1$ | | | | | | |
| Parameter in Brownland export equation | $\varepsilon_1 = 0.5$ | | | | | | |
| Parameter in Brownland export equation | $\varepsilon_2 = 1.228$ | | | 1.226 | | | [1.226] |
| Portfolio parameter defining demand for Brownland bills by Brownland capitalists | $\lambda_{10} = 0.3$ | 0.305 | 0.299 | | | | |
| Portfolio parameter defining demand for Brownland bills by Brownland capitalists | $\lambda_{11} = 1$ | | | | | | |
| Portfolio parameter defining demand for Brownland bills by Brownland capitalists | $\lambda_{12} = 1$ | | | | | | |
| Portfolio parameter defining demand for Brownland bills by Brownland capitalists | $\lambda_{13} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland bills by Brownland capitalists | $\lambda_{14} = 0$ | | | | | | |
| Portfolio parameter defining demand for Greenland bills by Brownland capitalists | $\lambda_{20} = 0.1$ | | 0.101 | | | | |
| Portfolio parameter defining demand for Greenland bills by Brownland capitalists | $\lambda_{21} = 1$ | | | | | | |
| Portfolio parameter defining demand for Greenland bills by Brownland capitalists | $\lambda_{22} = 1$ | | | | | | |
| Portfolio parameter defining demand for Greenland bills by Brownland capitalists | $\lambda_{23} = 0$ | | | | | | |
| Portfolio parameter defining demand for Greenland bills by Brownland capitalists | $\lambda_{24} = 0$ | | | | | | |
| Portfolio parameter defining demand for Greenland bills by Greenland capitalists | $\lambda_{40} = 0.3$ | 0.305 | 0.301 | | | | |
| Portfolio parameter defining demand for Greenland bills by Greenland capitalists | $\lambda_{41} = 1$ | | | | | | |
| Portfolio parameter defining demand for Greenland bills by Greenland capitalists | $\lambda_{42} = 1$ | | | | | | |
| Portfolio parameter defining demand for Greenland bills by Greenland capitalists | $\lambda_{43} = 0$ | | | | | | |
| Portfolio parameter defining demand for Greenland bills by Greenland capitalists | $\lambda_{44} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland bills by Greenland capitalists | $\lambda_{50} = 0.1$ | | 0.099 | | | | |
| Portfolio parameter defining demand for Brownland bills by Greenland capitalists | $\lambda_{51} = 1$ | | | | | | |
| Portfolio parameter defining demand for Brownland bills by Greenland capitalists | $\lambda_{52} = 1$ | | | | | | |
| Portfolio parameter defining demand for Brownland bills by Greenland capitalists | $\lambda_{53} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland bills by Greenland capitalists | $\lambda_{54} = 0$ | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Portfolio parameter defining demand for Greenland shares by Brownland capitalists | $\lambda_{70} = 0.05$ | 0 | 0.051 | | | | |
| Portfolio parameter defining demand for Greenland shares by Brownland capitalists | $\lambda_{71} = 0$ | | | | | | |
| Portfolio parameter defining demand for Greenland shares by Brownland capitalists | $\lambda_{72} = 0$ | | | | | | |
| Portfolio parameter defining demand for Greenland shares by Brownland capitalists | $\lambda_{73} = 0.01$ | | | | | | |
| Portfolio parameter defining demand for Greenland shares by Brownland capitalists | $\lambda_{74} = 0.01$ | | | | | | |
| Portfolio parameter defining demand for Greenland shares by Brownland capitalists | $\lambda_{75} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Greenland capitalists | $\lambda_{80} = 0.05$ | 0 | 0.049 | | | | |
| Portfolio parameter defining demand for Brownland shares by Greenland capitalists | $\lambda_{81} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Greenland capitalists | $\lambda_{82} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Greenland capitalists | $\lambda_{83} = 0.01$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Greenland capitalists | $\lambda_{84} = 0.01$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{90} = 0.1$ | 0 | 0.09 | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{91} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{92} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{93} = 0.01$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{94} = 0.01$ | | | | | | |
| Portfolio parameter defining demand for Greenland shares by Greenland capitalists | $\lambda_{100} = 0.1$ | 0 | 0.101 | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{101} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{102} = 0$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{103} = 0.01$ | | | | | | |
| Portfolio parameter defining demand for Brownland shares by Brownland capitalists | $\lambda_{104} = 0.01$ | | | | | | |
| Shares issues to investment ratio in Greenland | $\xi_G = 0.01$ | | | | | | |
| Shares issues to investment ratio in Brownland | $\xi_B = 0.01$ | | | | | | |
| Real supply of shares in Brownland | $e_s^B = 1$ | | | | | | |
| Real supply of shares in Greenland | $e_s^G = 1$ | | | | | | |
| Unit price of shares in Brownland | $p_e^B = 1$ | | | | | | |
| Unit price of shares in Greenland | $p_e^G = 1$ | | | | | | |
| Parameter in Brownland import equation | $\mu_0 = -2.1$ | | | | | | |
| Parameter in Brownland import equation | $\mu_1 = 0.5$ | | | | | | |
| Parameter in Brownland import equation | $\mu_2 = 1.228$ | | | 1.23 | | | [1.23] |
| Average tax rate in Brownland | $\theta_B = 0.2$ | | | | | | |
| Average tax rate in Greenland | $\theta_G = 0.2$ | | | | | | |
| Depreciation rate in Brownland | $\delta_B = 0.08$ | | | | | | |
| Depreciation rate in Greenland | $\delta_G = 0.08$ | | | | | | |
| Parameter of capital adjustment speed in Greenland | $\gamma_{10} = 0.1603$ | | | | | | |
| Parameter of capital adjustment speed in Greenland | $\gamma_{11} = 0.1$ | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Parameter of capital adjustment speed in Greenland | $\gamma_{12} = 0.01$ | | | | | |
| Parameter of capital adjustment speed in Greenland | $\gamma_{13} = 0.01$ | | | | | |
| Parameter of capital adjustment speed in Greenland | $\gamma_{14} = 0$ | | | | | |
| Sensitivity of loan interest rate to green investment share in Greenland | $\gamma_{15} = 0$ | | | | | |
| Parameter of capital adjustment speed in Brownland | $\gamma_{20} = 0.1603$ | | | | | |
| Parameter of capital adjustment speed in Brownland | $\gamma_{21} = 0.1$ | | | | | |
| Parameter of capital adjustment speed in Brownland | $\gamma_{22} = 0.01$ | | | | | |
| Parameter of capital adjustment speed in Brownland | $\gamma_{23} = 0.01$ | | | | | |
| Parameter of capital adjustment speed in Brownland | $\gamma_{24} = 0$ | | | | | 0.1 |
| Sensitivity of loan interest rate to green investment share in Brownland | $\gamma_{25} = 0$ | | | | | 0.08 |
| Sensitivity of Brownland import to government spending | $\gamma_3 = 0$ | | | | 0.015 | |
| Target capital to output ratio | $\kappa = 0.85$ | | | | | |
| Parameter of Brownland green investment function | $\chi_1^B = 0.2$ | | | | | |
| Parameter of Brownland green investment function | $\chi_2^B = 0.02$ | | | | | |
| Parameter of Brownland green investment function | $\chi_3^B = 0$ | | | | | |
| Parameter of Greenland green investment function | $\chi_1^G = 0.2$ | | | | | |
| Parameter of Greenland green investment function | $\chi_2^G = 0.02$ | | | | | |
| Parameter of Greenland green investment function | $\chi_3^G = 0$ | | | | | 0.08 |
| Wage share to total income in Brownland | $\omega_B = 0.62$ | | | | | |
| Wage share to total income in Greenland | $\omega_G = 0.62$ | | | | | |
| Profit retention rate of Brownland firms | $ret_B = 0.02$ | | | | | |
| Profit retention rate of Greenland firms | $ret_G = 0.02$ | | | | | |
| Percentage of money held in Brownland deposits | $\nu_B = 0.7$ | 0.69 | | | | |
| Percentage of money held in Greenland deposits | $\nu_G = 0.7$ | 0.69 | | | | |
| Parameter defining dividend yield in Greenland | $\pi_{dy}^G = 0.00555$ | | | | | |
| Parameter defining dividend yield in Brownland | $\pi_{dy}^B = 0.00555$ | | | | | |
| **Starting values of variables and parameter values for the ecosystem** | | | | | | |
| Material intensity of green capital in Brownland (Kg/USD) | $\mu_{gr}^B = 0.71$ | | | | | |
| Material intensity of green capital in Greenland (Kg/USD) | $\mu_{gr}^G = 0.51$ | | | | | |
| Material intensity of conventional capital in Brownland (Kg/USD) | $\mu_{con}^B = 0.86$ | | | | | |
| Material intensity of conventional capital in Greenland (Kg/USD) | $\mu_{con}^G = 0.66$ | | | | | |
| Energy intensity of green capital in Brownland (Ej/USD) | $\epsilon_{gr}^B = 7.65$ | | | | | |
| Energy intensity of green capital in Greenland (Ej/USD) | $\epsilon_{gr}^G = 5.65$ | | | | | |
| Energy intensity of conventional capital in Brownland (Ej/USD) | $\epsilon_{con}^B = 9.32$ | | | | | |

| | |
|---|---|
| Energy intensity of conventional capital in Greenland (Ej/USD) | $\epsilon_{con}^{G} = 7.32$ |
| $CO_2$ intensity of green capital in Brownland (Gt/Ej | $\beta_{gr}^{B} = 0.045$ |
| $CO_2$ intensity of green capital in Greenland (Gt/Ej) | $\beta_{gr}^{G} = 0.025$ |
| $CO_2$ intensity of conventional capital in Brownland (Gt/Ej) | $\beta_{con}^{B} = 0.085$ |
| $CO_2$ intensity of conventional capital in Greenland (Gt/Ej) | $\beta_{con}^{G} = 0.065$ |
| Rate of decline of $CO_2$ intensity in Brownland after 2020 | $g_{\beta}^{B} = 0.02$ |
| Rate of decline of $CO_2$ intensity in Greenland after 2020 | $g_{\beta}^{G} = 0.04$ |
| Initial value of $CO_2$ emissions in Brownland | $\beta_{0}^{B} = 4.5$ |
| Initial value of $CO_2$ emissions in Greenland | $\beta_{0}^{G} = 4.5$ |
| Autoregressive parameter of cumulative $CO_2$ emissions in Brownland (accounting for carbon cycle) | $\psi_{B} = 0.999$ |
| Autoregressive parameter of cumulative $CO_2$ emissions in Greenland (accounting for carbon cycle) | $\psi_{G} = 0.999$ |
| Approximate value of cumulative $CO_2$ emissions of Brownland in 1950s (billion tonnes $CO_2$, Gt) | $co2_{B} = 300$ |
| Approximate value of cumulative $CO_2$ emissions of Greenland in 1950s (billion tonnes $CO_2$, Gt) | $co2_{G} = 300$ |
| Initial value of average atmospheric temperature (C) | $temp = 13$ |
| Sensitivity of temperature to Brownland emissions | $\tau_{B} = 7.69e-4$ |
| Sensitivity of temperature to Greenland emissions | $\tau_{G} = 7.69e-4$ |
| Recycling rate in Brownland | $\rho_{B} = 0.2$ |
| Recycling rate in Greenland | $\rho_{G} = 0.28$ |
| Conversion rate of material resources into reserves in Brownland | $\sigma_{m}^{B} = 0.00028$ |
| Conversion rate of material resources into reserves in Greenland | $\sigma_{m}^{G} = 0.00028$ |
| Conversion rate of non-renewable energy resources into reserves in Brownland | $\sigma_{e}^{B} = 0.0014$ |
| Conversion rate of non-renewable energy resources into reserves in Greenland | $\sigma_{e}^{G} = 0.0014$ |
| Initial value of matter resources of Brownland (Gt) | $res_{m}^{B} = 198{,}526.$ |
| Initial value of matter resources of Greenland (Gt) | $res_{m}^{G} = 198{,}526.4$ |
| Initial value of non-renewable energy resources of Brownland (Ej) | $res_{e}^{B} = 296{,}421.3$ |
| Initial value of non-renewable energy resources of Greenland (Ej) | $res_{e}^{G} = 296{,}421.3$ |
| Initial value of socio-economic stock of Brownland (Gt) | $k_{se}^{B} = 380$ |
| Initial value of socio-economic stock of Brownland (Gt) | $k_{se}^{G} = 380$ |
| Coefficient converting Gt of carbon into Gt of $CO_2$ | $car = 3.67$ |
| Init. val. of sensitivity of capital depreciation rate of Brownland firms to matter depletion | $\delta_{11} = 0$ |
| Initial value of sensitivity of capital depreciation rate of Brownland firms to energy depl. | $\delta_{12} = 0$ |
| Init. val. of sensitivity of capital depreciation rate of Brownland firms to climate change | $\delta_{13} = 0$ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Init. val. of sensitivity of capital depreciation rate of Greenland firms to matter depletion | $\delta_{21} = 0$ | | | | | | |
| Init. val. of sensitivity of capital depreciation rate of Greenland firms to energy depletion | $\delta_{22} = 0$ | | | | | | |
| Init. val. of sensitivity of capital depreciation rate of Greenland firms to climate change | $\delta_{23} = 0$ | | | | | | |
| Init. val. of sensitivity of propensity to consume of Brownland workers to matter depletion | $\alpha_{11} = 0$ | | | | | | |
| Init. val. of sensitivity of propensity to consume of Brownland workers to energy depletion | $\alpha_{12} = 0$ | | | | | | |
| Init. val. of sensitivity of propensity to consume of Brownland workers to climate change | $\alpha_{13} = 0$ | | | | | | |
| Init. val. of sensitivity of propensity to consume of Greenland workers to matter depletion | $\alpha_{21} = 0$ | | | | | | |
| Init. val. of sensitivity of propensity to consume of Greenland workers to energy depletion | $\alpha_{22} = 0$ | | | | | | |
| Init. val. of sensitivity of propensity to consume of Greenland workers to climate change | $\alpha_{23} = 0$ | | | | | | |
| Share of renewable energy to total energy in Brownland, conventional capital | $\eta_{con}^{B} = 0$ | | | | | | |
| Share of renewable energy to total energy in Greenland, conventional capital | $\eta_{con}^{G} = 0.05$ | | | | | | |
| Share of renewable energy to total energy in Brownland, green capital | $\eta_{gr}^{B} = 0.075$ | | | | | | |
| Share of renewable energy to total energy in Greenland, green capital | $\eta_{gr}^{G} = 0.15$ | | | | | | |
| | | | | | | | |
| **Starting values of exogenous variables for the two open economies** | | | | | | | |
| Government green spending in Brownland | $GOV_{gr}^{B} = 1$ | | | | 0.05 | | 1.1 |
| Government green spending in Greenland | $GOV_{gr}^{G} = 1$ | | | | | | |
| Government conventional spending in Brownland | $GOV_{con}^{B} = 0.25$ | | | | | | |
| Government conventional spending in Greenland | $GOV_{con}^{G} = 0.25$ | | | | | | |
| Growth rate of government conventional spending in Brownland up until 2020 | $g_{GOV,con}^{B} = 0.0495$ | | | | | | |
| Growth rate of government conventional spending in Brownland up until 2020 | $g_{GOV,con}^{G} = 0.0495$ | | | | | | |
| Return rate on government bonds in Brownland | $r_B = 0.03$ | | | | | | |
| Return rate on government bonds in Greenland | $r_G = 0.03$ | | | | | | |
| Interest rate on loans in Brownland | $r_l^B = 0.03$ | | | | | | |
| Interest rate on loans in Greenland | $r_l^G = 0.03$ | | | | | | |
| | | | | | | | |
| **Starting values for endogenous variables with lag for the two open economies** | | | | | | | |
| Exchange rate | $xr_B = xr_G = 1$ | | | | | | |
| Return rate on equity & shares in Brownland | $r_e^G = 0.03$ | | | | | | |
| Return rate on equity & shares in Greenland | $r_e^B = 0.03$ | | | | | | |

Notes: narrowly-defined economic and financial parameters of each area are taken from SFC modelling literature or calibrated to obtain a realistic baseline. Ecological coefficients are based on Dafermos et al. (2017, 2018) and IPCC (2018). Simulations are run beginning from 1952. Starting values of financial stocks and all remaining lagged endogenous variables are set to zero.