SOAS Department of Economics

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Student Working paper
No. 06

March 2022

The SOAS Department of Economics Student Working Paper Series is published electronically by SOAS University of London.

Suggested citation
Bendixen, Weiwei (2022), "A Climate Minsky Moment in a Stock-Flow Consistent Model", SOAS Department of Economics Student Working Paper No. 06, London: SOAS University of London.

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A Climate Minsky Moment in a Stock-flow Consistent Model

Weiwei Bendixen*

Abstract

This paper examines the macroeconomic and financial effects of a green asset boom using a theoretical stock-flow consistent (SFC) model. The boom is fuelled by households' reallocation of wealth towards green equity driven by euphoria about the green returns. The paper follows Minsky's financial instability hypothesis in modelling the overvaluation of green equity and the process by which this leads to increased financial fragility. The SFC modelling approach permits the analysis of how financial instability crosses over into the real economy. In order to investigate the macroeconomic and financial effects under different strengths of responsiveness, I conduct simulations with different values for the responsiveness of investment to Tobin's q and the responsiveness of consumption to wealth. The sensitivity analysis shows that the build-up to a green asset boom requires a strong Tobin's q effect. When the propensity to consume out of wealth is high, a contractionary outcome is generated. I explain how the results of the simulations are in line with other research and stylised facts.

Keywords: Stock-flow consistent modelling; Climate change; Financial instability hypothesis.

JEL classification: E17, E12, E44, Q54

Acknowledgements: I would like to express my gratitude to my dissertation supervisor Dr Yannis Dafermos, who was incredibly supportive and provided careful attention to detail in my writing of this paper. Finally, many thanks to my family and friends for unconditional support throughout this Master's degree.

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1. Introduction

Climate change is one of the key challenges of our time. It will create structural changes in many parts of society. The economy and the financial system will face changes as well. Households, firms and governments will all feel the impact of climate change, and the uncertainty of the effects on the economy. There will be effects in terms of the physical risks from flooding, storms and other weather related incidences. But there will also be risks related to the transition or, the lack of it, to a low carbon economy. Significant transformations of the financial system are likely to be caused by new government policies that will try to tackle climate change as well as changes in market sentiment.

On the one hand, climate change can lead to changes in asset valuation of some of the largest companies resulting in stranded asset problems (NGFS, 2019). On the other end, the valuation of green companies could see a sharp rise in investment causing their valuation to rise way beyond their book value. The rise in stock prices of green investments has been captured in a recent Economist article (2021). The Economist has constructed a portfolio of a 100 firms that will benefit from the green transition. Since the start of 2020, the portfolio had risen by 58%, which is double compared to the S&P 500. This suggests that there is an increased interest in green investment. In this paper I examine if this newfound interest in green investment has the potential to lead to a green asset bubble, similar to the dot-com bubble.

To model this green asset boom I will use the theory of Minsky’s financial instability hypothesis (FIH). The green asset boom is driven by endogenously created instability of the financial system, as opposed to exogenous events such as climate-related natural disasters. Minsky argues that a capitalist economy is bound to create business cycles (Minsky, 1986, p. 173). These cycles are created by the debt-driven expansion of the economy, which leads to depression. I intend to show this debt-driven expansion through increased leverage ratios followed by an increase in green investment (Minsky, 1995). Thus, the model's aim is to show a “climate Minsky moment”, i.e. how an increase in asset price valuation exceeds the firm’s actual collateral. This is driven by households who increasingly buy more green stocks, driving up the price. This further makes the firms invest more and take out more debt. This causes financial fragility, and can result in a bursting of the green bubble when the firms cannot repay debt or household expectations of their market valuation changes.

I use a theoretical stock-flow consistent (SFC) modelling framework. I model the equity market and its effect on the rest of the economy. I do so by including the equity value in behavioural equations and including Tobin's q ratio in the investment functions and wealth in the consumption function. The model depends on parameters $\lambda_0 \, and \, \lambda_5$ in the portfolio choice equations, for which I impose a shock, to capture the change in liquidity preference of households towards green equity. I run the simulations with different values of the parameters $c_2 \, and \, \eta_2$ which represent the wealth effect and Tobin's q respectively. The value of Tobin's q is particularly important for the build-up in the bubble behaviour.

In the rest of the paper, I first provide a review of the literature on SFC models that have incorporated Minskyan and ecological aspects. In section 3, I cover the structure of the model including the transaction flow matrix and the balance sheet matrix. In section 4, the model equations are described in depth. In Section 5, I present the simulation results. In section 6, I discuss the limitations of the model and, finally, section 7 concludes.

2. Literature Review

In this literature review, I intended to review the SFC literature and how it has been used in combination with both Minsky's theories and ecological economics. I will also cover papers on the financial transition effects of climate change and previous examples of "sunrise" industries. I aim to establish the gap in which this paper finds itself, in combining Minsky's ideas with an SFC model that distinguishes between green and conventional investments, loans and equity.

The Stock-Flow Consistent macroeconomic modelling approach was formalised in Godley and Lavoie (2007). The approach follows a solid accounting framework. There are no black holes in SFC models, which means that all flows in the economy comes from somewhere and goes to somewhere. This is shown through a balance sheet and transaction flow matrix, for which each sector has its owns column which must sum to zero. This means that there is a budget constraint put in place by the zero-sum rule for each sector. Additionally, the different sectors add or subtract wealth and debt when there are borrowings/savings and capital movements between sectors. The model allows for the modelling of the impact of the financial sector on the real economy. SFC models capture well the endogenous creation of money associated with Post-Keynesian economics. Where banks are not intermediates, but can create money through bank lending (McLeay et al., 2014). Thus, using an SFC model to examine the equity market and its influence on the real economy is appropriate. This is done through the feedback from financial assets on the production and spending in the economy (Burgess et al., 2016). Lastly, using behavioural equations I can model the equity market more realistically.

Minsky’s financial instability hypothesis and Minskyan ideas have been incorporated in several SFC models, such as those developed by Ryoo (2010), Nikolaidi (2014) and Dafermos (2018). Moreover, Nikolaidi has written a paper which provides an overview of different Minsky models (2017). Following the great financial crisis (GFC), SFC modelling gained momentum as it is suitable to model monetary and financial dynamics in the economy (Burgess et al., 2016). Similarly, Minsky’s ideas gained popularity following the GFC. Dos Santos contributed to SFC models with Minskyan ideas both before and after the GFC in a 2005 and 2009 paper (Dos Santos, 2005; Dos Santos et al., 2009). In his 2005 paper, he argued how the FIH lacked a common ground and SFC modelling could be a solution to model Minsky’s ideas (Nikiforos & Zezza, 2017). Dafermos (2018) created a model combining Godley’s New Cambridge approach with some Minskyan ideas. The model includes a target net-assets-to-income ratio which by Minsky´s idea changes whenever a change in expectations and customs of both the borrower and lenders. Thus, the FIH can be incorporated in SFC models, to show how financial behaviours in times of economic stability can cause financial fragility. For the purpose of this paper, which is to model a green asset boom, following Minsky’s FIH provides a good framework to describe the build-up and the underlying process.

Moreover, many models have covered the formal Minskyan modelling. This is done by including the financial fragility factors in the investment function. Some of the papers doing this have been covered in an overview by Dos Santos (2005). He provides an overview of five papers (Lavoie, 1986-87; Franke, 1989; Gatti et al., 1994; Skott, 1994; Taylor & O'Connell, 1985). They all model the financial fragility through the investment function. Even if they all have different methods, they capture the main idea of internal financial availability in the economy. Regarding the early Lavoie paper, it is later specified in the Godley and Lavoie (2001-02) paper that the interest rate on loans negatively affects investment. My model uses a similar investment function as in Godley and Lavoie. Yet, I have made a distinction between green and conventional investment. The model also uses green and conventional interest rates for borrowing from the banking sector. Overall, the separation of green and conventional investments makes my model different from other Minskyan models.

There is a variety of literature exploring the transition to a low carbon economy and the financial implications of the transition. Semieniuk et al. (2020) covered the risk related to the low carbon economy transition. They discussed the risk from the rising "sunrise" industry such as the low carbon energy companies. They also covered previous sunrise industries to explain the potential of the bursting of a bubble in the low carbon industry. This is in line with what this paper is trying to model, by showing a green asset bubble. The paper also covers the "sunset" industries such as carbon-intensive energy firms. They compare to theories developed on previous "sunset" industries. On sunrise industries, the Dot-Com Bubble share some similar aspect to the aim of the model this paper develops. The Dot-Com Bubble described in the paper by Kraay & Ventura (2005) was largely fuelled by the stock market and investors change in sentiment was a reason behind the collapse of the bubble. Similar to my model the rising green asset prices are driven by the household' euphoria towards green stocks, and likely a burst of this bubble could stem from a sudden fall in interest from investors.

In recent years, including ecological aspects into modelling has been on the rise. Many models have been developed to incorporate environmental processes such as pollution or constraints on natural resources (Nikiforos & Zezza, 2017). Some of these SFC models includes papers by Dafermos et al., (2018) and Monasterolo and Raberto (2017), which both developed SFC models which examine the effects of the transition to a low carbon economy. The model by Nikolaidi, Dafermos, & Galanis (2018) covers how asset price deflation can be a result of financial behaviours. In the model, the physical flows are determined by the law of thermodynamics. The model also distinguishes between green and conventional investments making it able to determine how climate change and finance affects investment and demand (Nikiforos & Zezza, 2017). Naqvi (2015) developed a model which treated the energy sector specifically. The model is calibrated for the EU. The model can examine growth, distribution and environmental sustainability.

The combination of Minsky's FIH and climate issues in SFC models have not been covered to a great extent. Most notably was the then governor of the Bank of England Mark Carney referring to the possibility of a "climate Minsky moment", referring to the financial instability stemming from climate change and the steps taken in the transition to a low carbon economy (Carney, 2016). In Nikolaidi's (2017) overview paper on modelling Minsky's ideas, she provides different scenarios in which a climate Minsky moment can occur. The first is that governments commit to reduce emissions. Investors would then realise that carbon-intensive companies would be a bad investment, causing them to sell off their bonds and stocks for these companies. This will result in a decrease in the asset prices of these companies, which could lead to stranded assets problems (Carbon Tracker Initiative 2011). It can also cause the carbon-heavy companies to default on loans and in the end causing financial instability (Battiston et al. 2017). The second potential "climate Minsky moment" is through green stock prices experiencing a boom in their asset price valuation, caused by a euphoria about green equity. It follows Minsky's FIH by generating a euphoria about green stocks. This leads to more green investment and loans. If firms end up with a higher asset valuation than they are worth, the fragility in the financial system is increased, because this valuation makes it possible for firms to take on more debt. This process is endogenous and renders itself well for analysis via a Minsky model as well as an SFC model. As other climate issues are often through exogenous shocks, this example is driven by endogenous forces (Nikolaidi, 2017).

The model equations follow the ones used in van Treeck (2009) Lavoie & Godley's (2001–2002), and Godley and Lavoie (2007, Ch. 5). Moreover, to develop the green and conventional sectors I have drawn on the equations given for the final assignment in the course Advanced Macroeconomics as well as model examples from an SFC summer school (Nikolaidi & Dafermos, 2016; Dafermos, 2021). I have used portfolio choice equations. This means that in the model the households have the option to use their money on deposits in the bank, or on green and conventional equities. This marks one of the main differences from those papers. Moreover, the investment function used is also divided between green and conventional investment, assuming the firms can make both kinds of investments. The model builds on these papers, yet is different by including ecological aspect into an SFC model which ties the financial system to the real economy, by using Minsky's FIH. This paper intends to explore a potential scenario in the transition to a low carbon economy. As the transition to a low carbon economy happens the uncertainty of the consequences for the financial system and economy are substantial. Therefore, it is important to explore different scenarios of what can happen.

3. Structure of the Model

This model consists of three sectors: households, firms and banks. The balance sheet matrix is shown in table 1 and the transaction flow matrix in table 2. The symbols of the model are in appendix 1. The list of equations can be found in appendix 2. The model distinguishes between conventional and green activities. The firms can issue green and conventional equity. Firms can make green and conventional investments. Similarly, firms can take out both green and conventional loans. However, firms can be both green and conventional so the model does not make a distinction in the firm sector. Portfolio equations are used to model the shift in household preferences from conventional to green stocks, which will drive the bubble behaviour given a strong effect of Tobin's q. Following a Minskyan perspective, the green equity comes on top of conventional equity: this is to show the euphoria developing for green equity, rather than showing a decline in conventional equity.

Table 1: Balance Sheet Matrix

	Households	Firms	Banks	Total
Deposit	$+D$		$-D$	0
Green Equity	$+p_{ge} * e_G$	$-p_{ge} * e_G$		0
Conventional Equity	$+p_{ce} * e_C$	$-p_{ce} * e_C$		0
Green Loans		$-L_G$	$+L_G$	0
Conventional Loans		$-L_C$	$+L_C$	0
Green Capital		$+K_G$		$+K_G$
Conventional Capital		$+K_C$		$+K_C$
Total	$+V$	$+K - (p_{ce} * e_C + p_{ge} * e_G + L_{G+} + L_C)$	0	+K

Table 2: Transaction Flow Matrix and Revaluation Matrix

	Households	Firms		Banks		Total
		Current	Capital	Current	Capital	
Consumption	$-C$	$+C$				0
Green Investment		$+I_G$	$-I_G$			0
Conventional investment		$+I_C$	$-I_C$			0
Wages	$+s_w Y$	$-s_w Y$				0
Firms profit	$+DP$	$-TP$	$+RP$			0
Banks profit	$+BP$			$-BP$		0
Interest on Green Loans		$-int_G L_{G-1}$		$+int_G L_{G-1}$		0
Interest on Conventional Loans		$-int_C L_{C-1}$		$+int_C L_{C-1}$		0
Interest on deposit	$+int_D D_{-1}$			$-int_D D_{-1}$		0
Change in deposit	$-\Delta D$				$+\Delta D$	0
Change in Green Loans			$+\Delta L_G$		$-\Delta L_G$	0
Change in Conventional Loans			$+\Delta L_C$		$-\Delta L_C$	0
Changes in green equity	$+p_{ge} * e_G$		$-p_{ge} * e_G$			

Changes in conventional equity	$+p_{ce} * e_C$		$-p_{ce} * e_C$		
Total	0	0	0	0	0

Revaluation Matrix

Showing the capital gains of green and conventional stocks when the price rises.

	Households	Firms	Banks	Total
Green Equity	$+\Delta p_{ge} * e_{G-1}$	$-\Delta p_{ge} * e_{G-1}$		0
Conventional Equity	$+\Delta p_{ce} * e_{C-1}$	$-\Delta p_{ce} * e_{C-1}$		0

4. Model Equations

4.1 Firms: Investment, Pricing and Financial Decisions

Tobin's Q: $q = \frac{(e_G * p_{ge} + e_C * p_{ce})}{K}$ (1)

The Tobin's q variable describes the market value of the firm's equity, given by the supply of equity times the price of equity. The market value of equity is over the book value of the firm. The book value is given by capital stock (*K*). The market value is the number of green and conventional equities multiplied by their prices (van Treeck, 2009; Tobin, 1969). The Tobin's q value is included in the investment function to capture the positive effect equity prices have on investment (Nikolaidi & Stockhammer, 2017)

Supply of new green equity: $e_G = e_{G-1} + \frac{(x_G * IG_{-1})}{p_{ge}}$ (2)

Supply of new conventional equity: $e_C = e_{C-1} + \frac{(x_C * IC_{-1})}{p_{ge}}$ (3)

The supply of equities is given by the previous period's equity supply, plus the parameters $x_G \; and \; x_C$, which determine how big a portion of the investment is from issuing new equity. This is divided by the price of equity. Loans are a residual meaning that the other parts of their investments are financed by taking loans or from retained profit (van Treeck, 2009, p. 475). I assume that $x_G \, and \, x_C$ are not controlled by the firm. Thus, firms don't control how big a share of investment is financed by issuing new equity. The supply of equity is also depending on the price of equity. The demand for equities is equal to supply. This means that the financial market clears through adjustments in prices. In the real economy the market does not necessarily clear: output is demand-led and no full employment is assumed. (Godley & Lavoie, 2007, p. 18).

Rate of return on conventional equities: $re_C = (1-\beta)\frac{DP}{p_{ce-1} * e_{C-1}} + g_{pce}$ (4)

Rate of return on green equities : $re_G = \beta \frac{DP}{p_{ge-1} * e_{G-1}} + g_{pge}$ (5)

The rate of return on equities for the firm is given by the distributed profit divided by the value of stocks lagged by one period, plus the growth rate of the price of equity (Lavoie & Godley, 2001–2002). The β variable accounts for the share of green investment in total investment. The return depends both on dividends payments as well as the value of equities.

Price of green equity: $p_{ge} = EG - \frac{x_G * I_{G-1}}{e_G}$ (6)

Price of conventional equity: $p_{ce} = EC - \frac{x_C * I_{C-1}}{e_C}$ (7)

The price of equities includes the portfolio choice variables, which means that the liquidity preferences of households directly affect the price of equity. The parameters x_G and x_C determines the portion of investment which is through issuing new stocks, these parameters are also included in the supply of equity equations. This is divided by the number of equities.

Output: $Y = C_D + I$ (8)

The output for firms is the consumption plus the investment. This shows that the supply in the goods market adjusts to demand each period (van Treeck, 2009).

Total profits of firms (identity): $TP = Y - s_W * Y - int_C * L_{C-1} - int_G * L_{G-1}$ (9)

The profit of the firm consists of output minus the share of output going to wages, minus interest on conventional loans and interest payment on green loans of the previous period (Dafermos, 2021).

Retained profits: $RP = s_F * TP_{-1}$ (10)

The retained profit is total profit of the previous periods multiplied by s_F, which is a parameter that determines the retention rate by the firm. The retained profit is used to finance a portion of the investment the firms undertake. The firms also finance investment by taking loans and issuing new equity (Dafermos, 2021).

Distributed profits (identity): $DP = TP - RP$ (11)

The distributed profit is the total profit minus the retained profit. The distributed profit is paid to the households in dividends. Distributed profit is a part of the return on equity.

Investment: $I = IG + IC$ (12)

The total investment is the green and conventional investment added together.

Rate of profit: $r = TP/K$ (13)

The profit rate is the total profit divided by the capital stock

Share of green investment in total investment: $\beta = \beta_0 - \beta_1 * (int_G - int_c)$ (14)

The β variables determines the share of green investment in total investment. β_0 is a parameter that determines the autonomous share of green investment in total investment. β_1 determines the sensitivity of green investment share to interest differential. The interest rate on green and conventional loans is also included in the equation (Dafermos, 2021).

Green capital stock: $K_G = K_{G-1} + I_G$ (15)

Conventional capital stock: $K_C = K_{C-1} + I_C$ (16)

Capital stock: $K = K_C + K_G$ (17)

The capital stock is determined by adding together green and conventional capital stock. The green capital stock is determined by the lagged capital stock and green investment; the same holds for conventional capital stock.

Green loans: $L_G = L_{G-1} + I_G - \beta RP$-$p_{Ge} * (e_G - e_{G-1})$ (18)

Conventional loans (identity): $L_C = L_{C-1} + I_C + I_G - RP - (LG - LG_{-1}) - p_{ce} * (e_C - e_{C-1}) - p_{ge} * (e_G - e_{G-1})$ (19)

Total loans: $L = L_C + L_G$ (20)

It is assumed that the firm can make both green and conventional investments, so they can also take out both kind of loans. Therefore, the model distinguishes between green and conventional loans. The loans are determined based on previous periods loans. Investment is included because this is what the loans are used on. The retained profit is negatively factored in, since this can be used on investments as well. Importantly, the equity value is also considered, this is because the firms can finance investment through issuing new equity as well (Dafermos, 2021).

Green investment: [1]

$$I_G = (\eta_0 + \eta_1 * r_{-1} + \eta_2 * q + \eta_3 * u_{-1} - \eta_4 * int_G * levG_{-1}) * KG_{-1} \quad (21)$$

Conventional investment:

$$I_C = (\eta_5 + \eta_6 * r_{-1} + \eta_7 * q + \eta_8 * u_{-1} - \eta_9 * int_C * levC_{-1}) * KC_{-1} \quad (22)$$

The investment functions are similar to the ones used in the papers by Lavoie & Godley (2001–2002) and van Treeck (2009). First, the parameters $\eta_0\ and\ \eta_4$ are exogenous and referred to as “animal spirits” to state the confidence in the investment (Lavoie & Godley, 2001–2002). The second set of parameters $\eta_1\ and\ \eta_5$ relates to the profit rate of the previous period. The rate of profit has a positive effect on investment. Importantly, the third set of parameters $\eta_2\ and\ \eta_6$ are for Tobin’s q. Tobin’s q has been used in some Post-Keynesian economics papers to determine investment (Lavoie & Godley, 2001–2002). This model uses the ratio to model Minsky’s FIH causing the market value of green stocks to increase way beyond its

[1] (Lavoie & Godley, 2001–2002, p. 286)

book value, for which Tobin's q ratio is suitable. This is because it models the effects of overvaluation, leading to increases in investment and debt of the firms. The parameters for Tobin's q will be used for simulation to see the effects of a stronger Tobin's q ratio for green investment (Skott & Ryoo, 2007). By including Tobin's q variable in the investment function, I will be able to analyse the macroeconomic effects of the financial side of the economy on the real economy. Including Tobin's q value into the investment function means that the asset prices affect the investment decisions of firms (a Tobin's q value over one means the asset prices are higher than the book value). This is in line with Minsky's two price' theory, which states that asset inflation affects the economy and investment in a positive way (Nikolaidi & Stockhammer, 2017).

I added the negative effect of interest rate to the investment functions. This is multiplied by the respective leverage ratios of the two different investment options. The interest rate on loans has a negative effect on investment directly and indirectly. Indirectly, it enters the function by reducing cash flow (r_{-1}) which decrease the ability to finance investment with its own profit. Moreover, the direct inclusion of the negative effect on interest rate is shown through high-interest payment, which is the decreased creditworthiness and increased change of insolvency (Lavoie & Godley, 2001–2002). By including this addition to the investment function, the model can capture the Minskyan ideas of financial fragility on aggregated investment (Dos Santos, 2005). By this, the fragility enters the financial system through higher interest rates on loans, which might lead to less expansion and the firm having a harder time financing loans as they have a higher debt commitment (Lavoie & Godley, 2001–2002).

4.2 Households

Portfolio choice conventional equity: [2]

$$EC = (\lambda_0 + \lambda_1 re_{C-1} + \lambda_2 re_{C-1} + \lambda_3 int_D + \lambda_4 \left(\frac{Y_{D-1}}{V_{-1}}\right)) * V_{-1} \quad (23)$$

Portfolio choice green equity:

$$EG = (\lambda_5 + \lambda_6 re_{C-1} + \lambda_7 re_{G-1} + \lambda_8 int_D + \lambda_9 \left(\frac{Y_{D-1}}{V_{-1}}\right)) * V_{-1} \quad (24)$$

Two of the main equations in this model are the portfolio choice equations. The household makes decisions on how to allocate their wealth. They can choose between green or conventional equity and deposit. The choice depends on the return on different assets. The deposit is a residual. Therefore, there are only two equations which are for green and conventional equities. For green equities, the return of green equities has a positive effect, whilst the return on conventional equities has a negative effect. The same idea holds for conventional equities. Instead of showing the negative and positive effects through the equations signs I have used the parameter values instead. The parameters $\lambda_0 \, and \, \lambda_5$ are an exogenous target portion of the wealth given to the asset. These parameters will be used in the simulation to see what an increase in preference for green equity will lead to. The parameters in the equations have certain constraints it needs to hold[3]. The last term in the equations is the income scaled by wealth (Godley & Lavoie, 2007, p. 105). The portfolio choice variables are included in the equations for price of equity, so household's decisions have an effect on financial assets in this model. Having wealth included in the consumption function, the value of financial assets affects consumption and wealth is affected by asset values. Investment is affected by including Tobin´s q in the investment functions (Dafermos, 2021).

The portfolio choice functions used have three equations in principal, but the third option for the households is to put their money as deposits in the bank. This option is just the residual, given the green and conventional equity equations, it is not included. Therefore, the last equation: $D = (\lambda_{10} + \lambda_{11} re_{C-1} + \lambda_{12} re_{G-1} + \lambda_{13} int_D +$

[2] (Godley & Lavoie, 2007, p. 103)

(Godley & Lavoie, 2007, p. 141-146)

[3] $\lambda_0 + \lambda_5 + \lambda_{10} = 1,\ \lambda_1 + \lambda_6 + \lambda_{11} = 0,\ \lambda_2 + \lambda_7 + \lambda_{12} = 0,\ \lambda_3 + \lambda_8 + \lambda_{13} = 0,\ \lambda_4 + \lambda_9 + \lambda_{14} = 0$
$\lambda_2 = \lambda_6,\ \lambda_3 = \lambda_{11},\ \lambda_8 = \lambda_{12}$
$\lambda_1 + \lambda_2 + \lambda_3 = 0,\ \lambda_6 + \lambda_7 + \lambda_8 = 0\ ,\ \lambda_{11} + \lambda_{12} + \lambda_{13} = 0$

$\lambda_{14}\left(\frac{Y_{D-1}}{V_{-1}}\right)) * V_{-1}$ is excluded in the model, but the parameter constraint described above holds for this equation as well (Godley & Lavoie, 2007, s. 141).

Disposable income of households: $Y_D = s_w Y + DP + BP + int_D D_{-1}$ (25)

The equation consists of a fixed portion of the firm's output paid to the household as wages, distributed profit and bank profit as well as interest rate times the deposit the household has in the bank (Dafermos, 2021).

Consumption expenditures: $C_D = c_1 Y_{D-1} + c_2 V_{-1}$ (26)

The consumption consists of a fixed portion of the disposable income and a fixed portion of household wealth. Wealth is included in the equation as the model is based on the portfolio choice of households. Thus, the household decides how to allocate wealth between green and conventional equities. This follows Godley & Lavoie's model (2007) whereby households' decision making process is characterised by two stages: The household starts by deciding how much of their income to save and then decides how to allocate it. The decision is made simultaneously, yet the consumption decision is necessary to determine the size of wealth (Godley & Lavoie, 2007). Wealth is included in the consumption function since wealth is affected by price and number of equities. This means that the link between the financial system and the real economy is there. In the simulation, if the wealth increases, it could lead to either higher consumption or higher stock investment due to the high return, this represents the wealth effect. The parameters C_2 and C_1 represent the propensity to consume out of wealth and disposable income respectively. An increase in either parameter would lead to an increase in consumption. Moreover, an increase in wealth also leads to higher consumption, thus including the wealth effect in this model.

Household wealth:

$$V = V_{-1} + Y_D - C_D + e_{C-1} * (p_{ce} - p_{ce-1}) + e_{G-1} * (p_{ge} - p_{ge-1}) \quad (27)$$

The wealth of households is determined by the wealth of the last period, disposable income minus consumption. Their holding of equities in both conventional and green factor into the equation positively. The wealth of the household is key in this model. The first decision households make is about the allocation of disposable income between consumption and wealth. Wealth is then allocated between the assets green equity, conventional equity and deposits (Godley & Lavoie, 2007, p. 395). The value of equity is included in the wealth function, making wealth determined by the financial market. As mentioned, wealth is a part of the consumption function, which is a way in which the financial sector affects the real economy through consumption and by that firm's output.

Deposits (identity): $D = D_{-1} + Y_D - C_D - p_{ce}(e_C - e_{C-1}) - p_{ge}(e_G - e_{G-1})$ (28)

Deposits are given by previous period's deposits plus disposable income minus consumption. The value of the number of equities held by households is deducted from deposits, as what they invest they don't hold as deposits.

4.3 Banks

Profits of banks (identity): $BP = int_C\, L_{C-1} + int_G\, L_{G-1} - int_D\, D_{-1}$ (29)

The profit of the bank is determined by the interest paid from the firm to the bank on both green and conventional loans. The interest on deposit which is paid to the households is deducted (Dafermos, 2021).

Deposits (redundant identity): $D_{red} = L$ (30)

This is a redundant equation since it is logically implied by the transactional and balance sheet matrix.

4.4 Auxiliary Equations

Potential output: $Y^* = v * K$ (31)

Potential output is shown through the capital stock and *v* which is a parameter for capital productivity.

Capacity utilisation: $u = Y/Y^*$ (32)

Capacity utilisation shows how much of the productive capital of the firms are being used. It is the firm's output over potential output.

Growth rate of output: $g_Y = (Y - Y_{-1})/Y_{-1}$ (33)

This equation shows how the growth rate of the firm's output changes from period to period. The growth rate of output can give an indication of if the economy is growing or declining.

Leverage ratio: $lev = \frac{L}{K}$ (34)

The leverage ratio is used to look into how much debt the companies are in. It consists of loans over capital stock. This is a good indicator in examining if Minsky's FIH holds, meaning that if we see an increase in leverage of the firms, it could indicate a build-up of debt (Minsky, 1992).

Growth rate of green equity prices: $g_{pge} = \frac{(p_{ge} - p_{ge-1})}{p_{ge-1}}$ (35)

Growth rate of conventional equity prices: $g_{pce} = \frac{(p_{ce} - p_{ce-1})}{p_{ce-1}}$ (36)

The growth rate of the prices on conventional and green equity determines how the prices grow compared to previous periods. This variable can indicate that a higher household valuation of the asset can lead to growth in prices. Modelling a green credit boom, I would expect a rise in the green equities that is higher than the conventional.

Growth rate of number of green equity: $g_{eg} = \frac{(e_G - e_{G-1})}{e_{G-1}}$ (37)

Growth rate of number of conventional equity: : $g_{ec} = \frac{(e_C - e_{C-1})}{e_{C-1}}$ (38)

The growth rate of the number of equity is used to determine the growth in number of each kind of equity issued. If the household prefers green assets over conventional, it could cause a rise in firms issuing green equity, since the price is likely to rise and the demand would be higher.

Green Investment ratio: $IR_G = \frac{I_G}{K_G}$ (39)

Conventional Investment ratio: $IR_C = \frac{I_C}{K_C}$ (40)

The investment ratio is the green or conventional investment over the green and conventional capital stock. This ratio can contribute to determining the expansion of investment.

Money-to-wealth ratio: $mw = \frac{D}{V}$ (41)

The money to wealth ratio is deposit over wealth. This can determine how much wealth the households hold as opposed to deposits. If the return of equity increases, then the households would prefer to reduce deposits relative to their overall wealth (Lavoie & Godley, 2001–2002).

Investment to profit ratio: $ip = \frac{I}{TP}$ (42)

This is determined by investment over total profit. This ratio can measure if the investment out of total profit is declining or rising over time. This also ties into the investment profit puzzle, which from empirical research shows a decline in investment to profit from the 1970s onwards. This trend was however broken with the "New Economy" boom, which interestingly shows many similarities in the kind of bubble behaviour this model seeks to examine (Stockhammer, 2005-2006). Therefore, I expect the investment-profit ratio to increase in the build-up to a green bubble.

5 Simulations

The model described above have been put into the R programming language for running the simulations. But first, the model was solved for the steady-state. The steady-state is defined as a state where the key variables in the model are in a constant relationship to each other (this refers to both stocks and flows). The aim is to use it as a starting point to perform the simulations. A comparison is then made between variables before and after a shock has been imposed (Godley & Lavoie, 2007, p. 71). For instance, in my model, the growth rate of the variables for loans, capital stock and output growth are all at 2.5% which is chosen for this model. Furthermore, the ratios for leverage, capacity utilisation and Tobin's q are constant. To find the steady-state some of the key variables have had to be stabilised. These includes $c_1, s_F, \lambda_0, \lambda_5, x_G, x_C, g_{eg}$ and g_{ec}. The R code of the steady-state solution is available upon request.

The main simulation of this model is to increase the parameter λ_5 in the green equity portfolio choice function. By doing so, I want to show how a change in the household liquidity preference towards green equity affects the economy − more precisely, how it affects equity prices, the number of equities, leverage and loans of the firm, household consumption and in turn the output of companies and growth rate of the economy. In line with Minsky's FIH when the economy is growing, the firms gradually take on more risk. In this model, it is the increasing preferences for green equity from households that drive up the green equity prices. This leads to firms being more willing to take loans to finance riskier investments. Banks are also more willing to issue these loans due to the success in the equity market. The firms take on more debt to finance green investment. At the same time, the asset prices start to rise even more, due to an increasing optimism, which further makes households invest in green equity. The firms are more in debt which makes them more financially fragile. This affects the whole economy because of the way the firms finance their investment through liabilities which is paid back at a later time, since the loans are given depending on expected profit (Minsky, 1992). Initially, the loans would be to finance investment, whilst moving along the firms might take loans to repay prior commitments. Minsky distinguishes between three financing schemes called hedge, speculative and ponzi. He argues how, to begin with the economy is dominated by hedge scheme which are firms which can fulfil all contractual repayment by their cash flow. However, the capitalist economy moves towards speculative and ponzi schemes, where they take out more debt to finance repayment of loans or interest payments. As the shift towards the ponzi and speculative schemes happens, it causes financial fragility (Minsky, 1992). If there is a burst of this increase, it starts with some kind of expectation deterioration. The households realise that in fact, the green stocks are valued way beyond their book value. The households start to sell stocks and it leads to asset price deflation. This makes it harder for the firms to refinance their debt payments, banks are also likely to be affected by the negative view. The firms cannot repay debt and would have to default on debt payment.

I expect that in line with Lavoie & Godley (2001–2002), that when the liquidity preferences are increasing towards holding green stocks over conventional stocks, it will increase stock demand and in turn drive up the price. It will also create capital gains modelled through *W* which factor into consumption, and also capacity utilization increase. The increase in consumption affects the output of the firms. The investment increases, caused by an increase in capacity utilisation, but also by the Tobin's q ratio. The bubble behaviour will start with the equity market, but cross over to the real economy as well. In table 3, I have outlined the different simulations I ran. I started with implementing a shock in the 11th period, which is to the portfolio choice parameters to increase the preference of households for green equity. I then ran this shock with a small and big increase in the Tobin's q parameter in the investment function. Then I changed the parameter for consumption out of wealth in the consumption equation to see what happens if households start to consume more. I also ran this scenario with different Tobin´s q values.

Table 3: Simulation Overview

	Liquidity preference	**Weak Tobin's q**	**Strong Tobin's q**	**Higher propensity to consume out of wealth, weak q**	**Increase in consumption, strong q**
	A.	**B.**	**C.**	**D.**	**E.**
λ_5	0.5	0.5	0.5	0.5	0.5
λ_0	0.4	0.4	0.4	0.4	0.4
η_2	0.03	0.04	0.095	0.03	0.095
c_2	0.1	0.1	0.1	0.2	0.2

5.1 Simulation of Portfolio Choice Behavior

In this section, I will examine an increase in the "animal spirit" parameter in the green investment function. To simulate the change in liquidity preference on green equity, the simulation will include the preference for conventional equity staying the same, whilst the green equity come on top of the conventional equity. This means the households also shift away from holding money deposit. According to Lavoie and Godley, this shift also means a shift from holding short term deposits to long term assets in the form of equity (Lavoie & Godley, 2001–2002). Additionally, having the green equity euphoria following Minsky's FIH, where there is no change to preferences for conventional stocks, but the green euphoria makes the household invest more in equity as opposed to holding deposit (Nikolaidi, 2017). Conventional equity is being held constant, as the model is not intended to model the downturn for the carbon-heavy industry, which could happen especially if the governments start to implement policies to offset this shift.

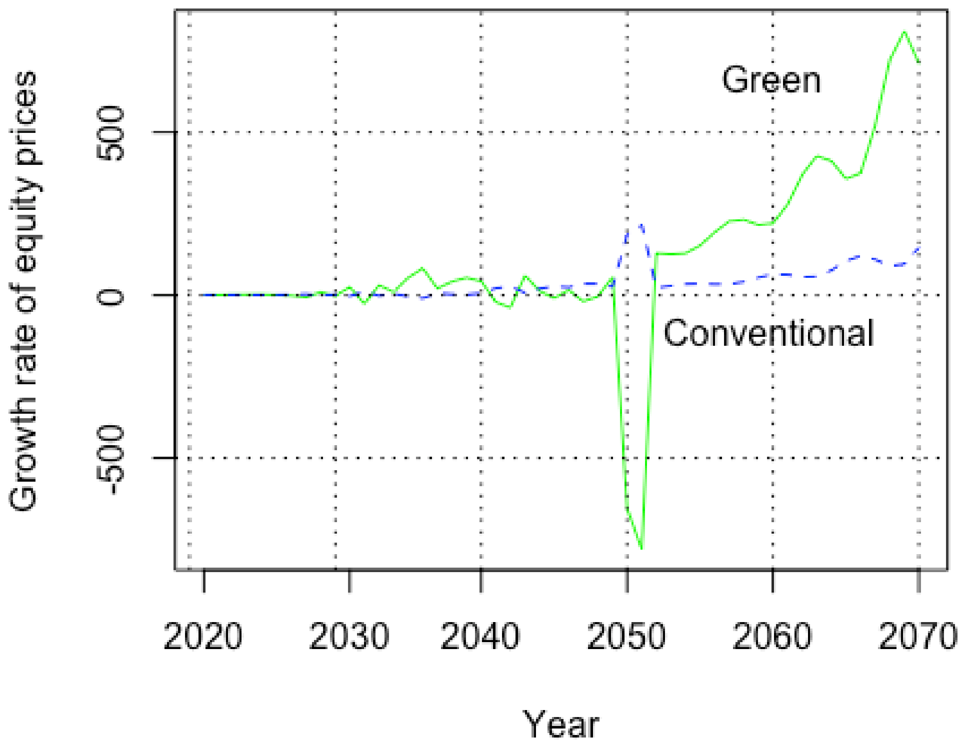

Figure 1: Growth Rate of Green and Conventional Equity Prices

In figure 1, I have plotted the growth rate of green and conventional equity prices. Both assets experience an increase in prices. However, the green equity prices grow more than conventional, this is to be expected given the increase in preferences by the households. The prices increase due to the increase in demand following the household preference for equity (Lavoie & Godley, 2001–2002). From table 4 lines 1-4 (found on page 27) it can be seen that capacity utilisation, leverage, rate of profit and Tobin's q have increased from the steady-state. These variables are all included in the investment function. Thus, there is an increase in green and conventional investment. Yet, the change in liquidity preferences for households have not been enough to offset a Minsky cycle where a green asset boom will happen. This is shown through figure 2 where it can be seen that even if green investment increases, it is still lower compared to conventional investment. Furthermore, looking at lines 7-8 in table 4, the ratio of investments by firms is the same for both categories, making conventional loans and investment more than green loans and investment. Furthermore, it is given that in the steady-state conventional starts above green loans and investments.

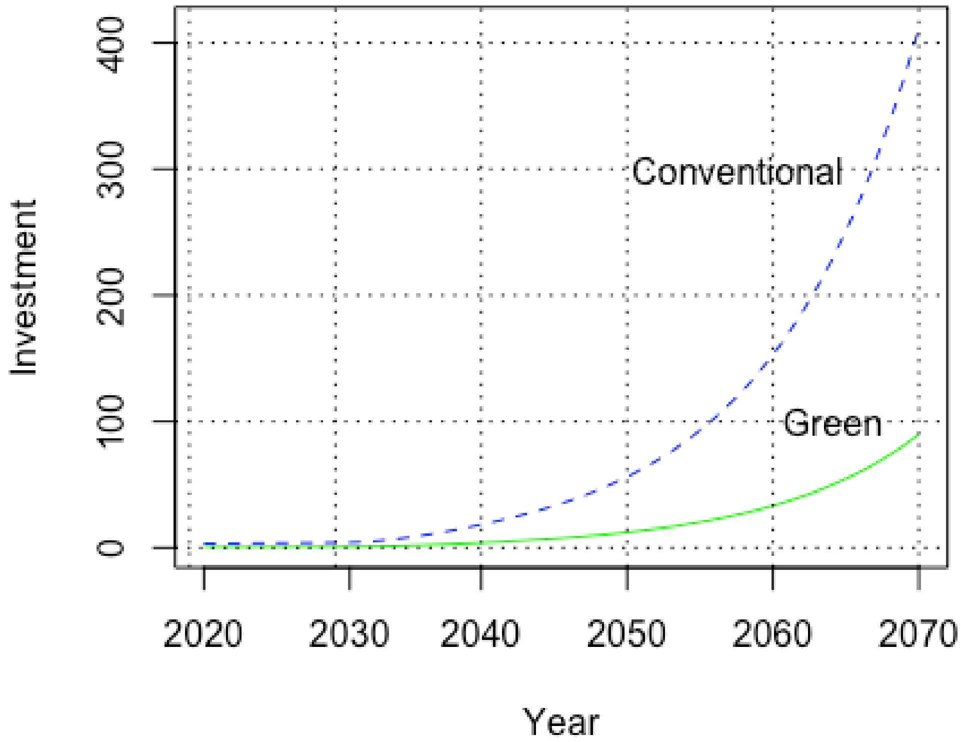

Figure 2: Green and Conventional Investment for Firms

From the above graphs, it is clear that even if the preference from households shifts towards green equity, it is not enough to create a green asset bubble that affects more than the financial sector, since figure 2 still shows much higher conventional investment.

5.2 Simulation of Tobin's q

While inserting the shock to the portfolio choice equations. I also tried 2 different values for the parameter η_2 which represent the parameter for Tobin's q in the green investment function. For the first simulation η_2 was increased from 0.03 to 0.04 (see simulation B. in table 3). This did not affect the influence green investment and loans much. In fact, even with household preferences being changed and a larger q parameter, the conventional stocks were still higher than the green stocks.

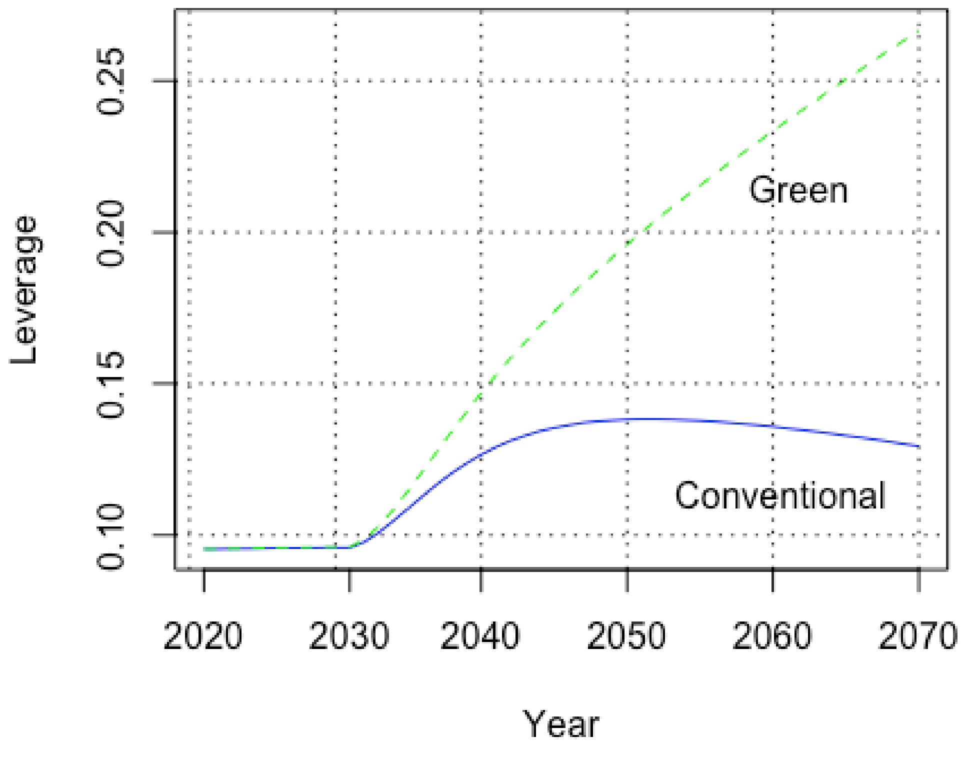

Figure 3: Leverage Ratio of Firms

In figure 3, I used the small increase in Tobin's q (Simulation B.). This resulted in the green leverage increase beyond the conventional leverage. As from table 4 lines 5-6 and 9-10, total conventional loans and investments are still more than green. But it is worth noticing that the growth rates of green investment and loans are slightly larger than the conventional. This indicates that raising Tobin´s q parameter further is necessary which is what the next part is examining. In the next part of the simulation, I raised Tobin´s q to 0.095 referring to table 3 simulation C. This creates a strong response coupled with the initial shock of the change in liquidity preferences.

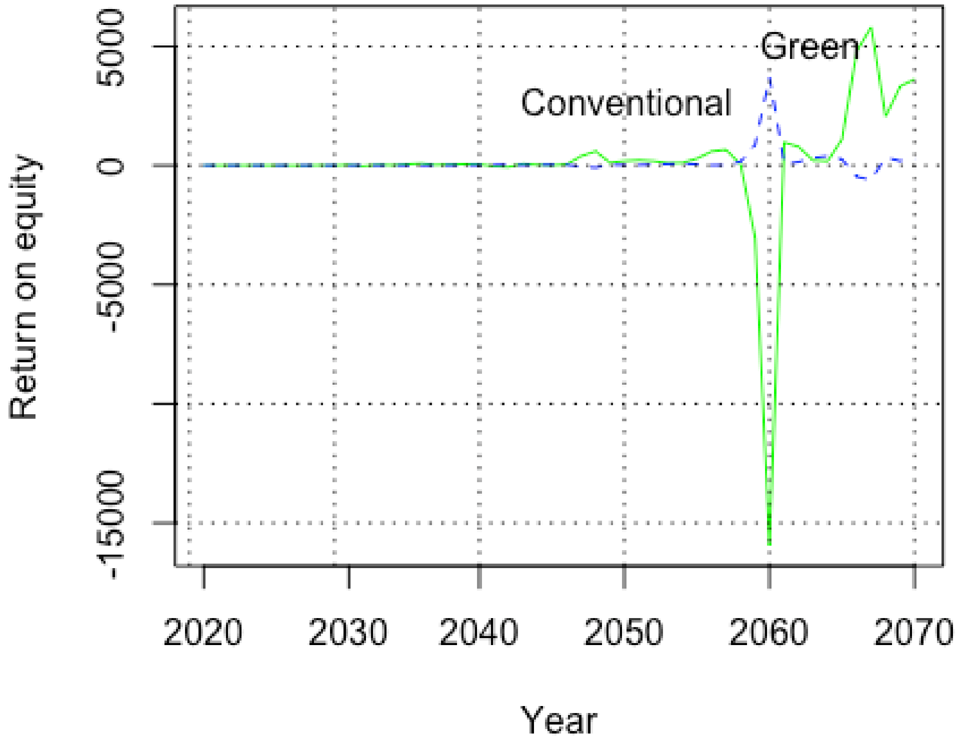

Figure 4: Return on Green and Conventional Equity, q Parameter = 0.95

Figure 4 shows that after a period of some instability in 2060 the return on green equity ends up being above that of conventional equity. I believe the initial instability in 2060 is related to the fact that the return on equity equation uses lagged variables of equity price and equity demand. When a shock occurs the economy needs to adjust. Initially, the shock starts a feedback loop because the growth rate of the economy and the capacity utilisation increases which is seen in lines 11 and 1, in table 4. This is because the return on investment depends on the distributed profit of firms, which increases with an increase in profit of the firm. This effect further induces the households to hold more green equity, as the return is larger (Lavoie & Godley, 2001–2002). The figure shows a dynamic evolution of the variable as opposed to a static movement. This is due to the model being a dynamic macroeconomic model. As described above it means that the different sectors in the economy have a feedback loop between each other. For this model especially the financial sector and real economy have an effect on each other.

I wanted to check if the instability would continue or the variable would come to a steady-state. For this, I tried to run the model for more periods and impose the shock to liquidity preference later. When I ran the model for more periods and moved the shock I again looked at return on equity. The results implied that both green and conventional return on equity starts to move towards the initial steady-state without fully stabilising. For it to be in line with Minsky's FIH, the economy has these cycles caused by periods of stability which causes risk-taking behaviour. The instability occurs when the risks are realised, but the risk-taking behaviour decreases as more losses are incurred and a return to stability happens. Therefore, what could be expected of this model is a return to stability after a period of instability.

Figure 5 shows that after the shock in period 11 is imposed the money to wealth ratio falls, meaning the household wealth is increased and Tobin's q is rising. Tobin's q is rising due to the increase in the price of equities mainly green equities, which also increase investment. These effects are contributing to the confidence of firms and households to take out more loans and investments.

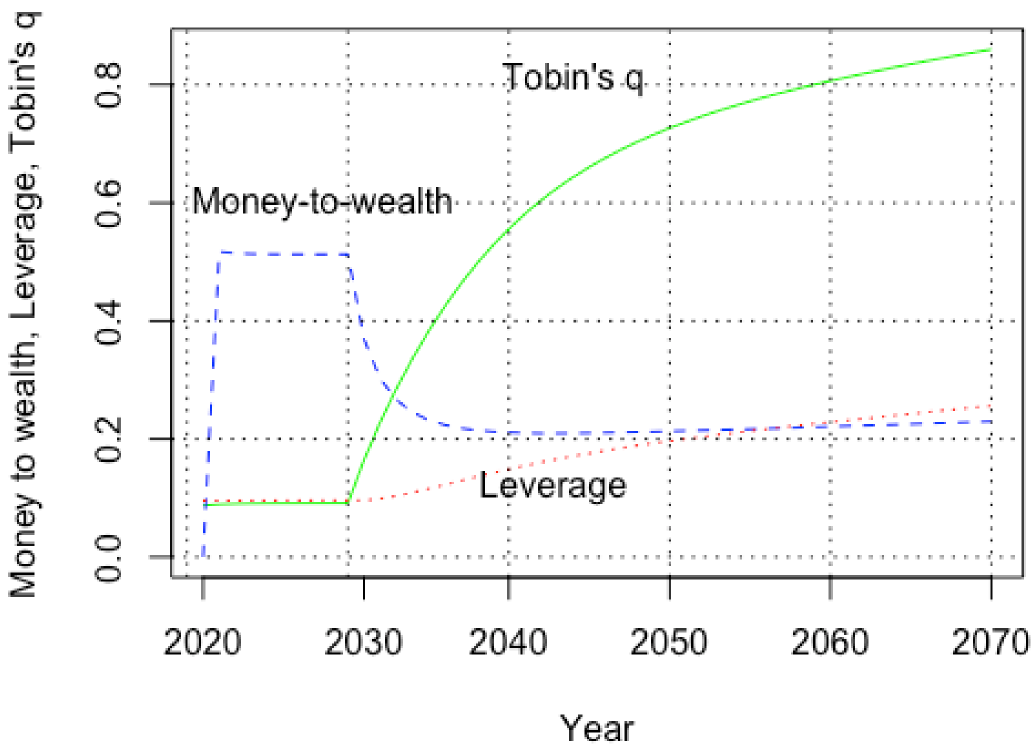

Figure 5: Money to Wealth Ratio, leverage ratio and Tobin's q

Following the FIH the increase in asset prices leads to more loans and riskier investment. The banks are willing to give out loans, and firms are willing to take higher risks as they are confident in the riskier projects (Dafermos, 2021). This is shown through the investment and loans ratios in figure 6. Both green and conventional loans and investments are shown. It is clear that following the shock in period 11, the green loans and investments increases. This is in line with the FIH, whereas firms experience increased risk towards green investments, in this model it is because households experience this green euphoria which makes them invest more in green stocks. This affects the investment of firms since Tobin's q value rises. Firms choose to invest more in green investments. Following the FIH, the increase in confidence of green investment makes it easier for firms to get loans for their investment. This is done through either bank loans but could also be through issuing equity. This makes firms become more indebted and thus more fragile.

The variables in the model evolve dynamically. This is because there is a feedback loop between the financial sector consisting of the bank and equity market on one side and the real sector consisting of the firm and household on the other side. This can be seen in the equations for investment which includes Tobin's q a variable for the valuation of stocks. Similarly, wealth is determined by equity value, and wealth is a part of the consumption function, again linking the real and financial sector.

From figure 5, it is seen how the leverage ratio is rising from this simulation. Thus, having household liquidity preferences change and having a strong Tobin's q effect, the model does show results in line with the FIH. The firms are in a financial fragile situation. For example, it could be through a bottleneck problem in the supply of resources for the green transition. This could drive up the production cost and again cause the households to change expectations and sell off their green stocks, driving down the asset prices. In the end, some firms would face repayment problems since it would be harder to refinance loans (Hutchinson et al., 2021).

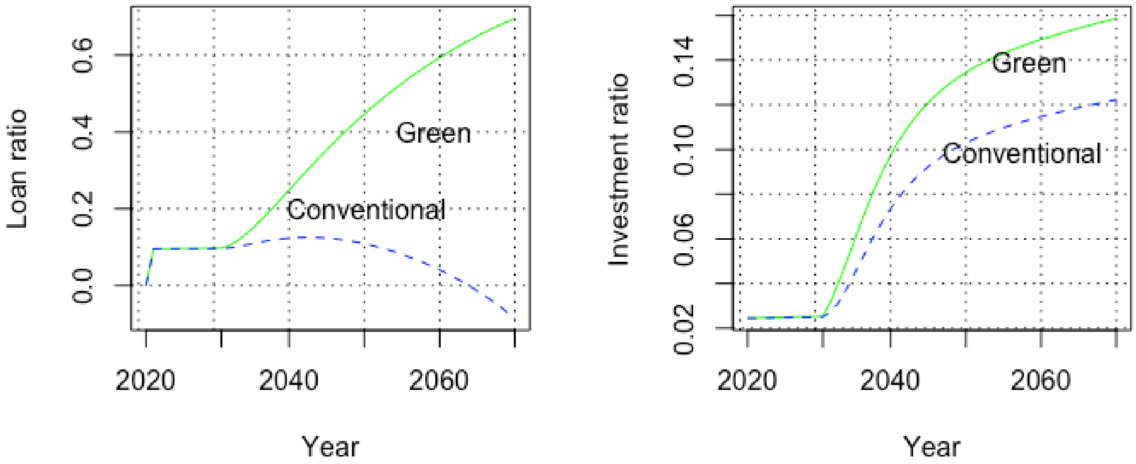

Figure 6: Loans and Investment Ratios

Although a high Tobin's q is required for the model to show results resembling the build-up to a green asset boom, it is not too far from empirical evidence of Tobin´s q value. From van Treeck's paper, he calculated Tobin's q from the market value of equity of private non-financial corporations from 1960 to 2005 (2009, p. 471). The Tobin's q ratio peaked at 1.8 around the early 2000s and declines down towards 0.8 in 2005. This result is similar to what this model with Tobin's q ratio of 0.85 when the parameter for q is 0.095 and liquidity prefers are changed towards green equity.

Table 4: Long-run Variables for the Simulations

		Steady State	**A. Liquidity preference**	**B. Weak Tobin´s q**	**C. Strong Tobin's q**	**D. Increased consumption weak q**	**E. Increased consumption strong q**
1	**Capacity utilisation (*u*)**	0.78	2.73	2.84	3.68	2.63	3.6343
2	**Rate of profit (*r*)**	0.03	0.1490	0.1548	0.1978	0.1447	0.1971
3	**Firm's leverage ratio (*lev*)**	0.09	0.1468	0.1576	0.2562	0.1244	0.2233
4	**Tobin's q (*q*)**	0.08	0.6472	0.6748	0.8597	0.5648	0.7714
5	**Convention**	42.12	644.55	616.61	-688.95	525.65	-602.744

	al loans (L_C)						
6	**Green loans (L_G)**	9.1851	140.55	329.29	4355.71	114.62	3597.88
7	**Green investment ratio (IR_G)**	0.02	0.0938	0.1020	0.1587	0.0892	0.1517
8	**Conventional investment ratio (IR_C)**	0.02	0.0938	0.0974	0.1223	0.0982	0.1191
9	**Conventional investment (I_C)**	10.76	412.02	464.32	984.32	376.97	946.98
10	**Green investment (I_G)**	2.34	89.85	125.99	984.32	82.20	828.69
11	**Growth rate of capital (g_K)**	0.025	0.1035	0.1091	0.1603	0.0980	0.1526
12	**Growth rate of output (g_Y)**	0.025	0.1041	0.1101	0.1675	0.0983	0.1597
13	**Money to Wealth ratio (MW)**	0.5222	0.1848	0.1893	0.2296	0.1805	0.2245
20	**Investment to profit (IP)**	2.04	80.54	94.81	306.93	73.50	287.13

*Key variables in the end of the 50 periods the model is running

5.3 Simulations of Propensity to Consume out of Wealth

On top of the portfolio choice shock, I also ran the simulation with a different propensity to consume out of wealth parameter represented in the consumption function (see table 3, simulation D. and E.). This means the household would consume more rather than invest in stocks if c_2 is increased. However, consumption also benefits the economy so some of the variables which are expected to decrease with lower investment in stocks could still rise given the increased consumption. One could further say that an increase in c_2 represents a stronger wealth effect in the model, making people consume more (van Treeck, 2009).

I tried to combine an increase in η_2 and c_2. This is to see the effect of the increase together. Moreover, I can test whether or not the paradox of saving holds given different values of Tobin's q parameter. This is in line with how Lavoie and Godley distinguish between a normal and puzzling regime, the normal regime the q parameter is below the rate of utilisation in the investment function (2001–2002). In the puzzling regime, the q parameter is above the rate of utilisation. Whereas, increased consumption leads to a higher rate of accumulation in the normal regime. I can run a similar simulation for my model using an increase in consumption with high and low Tobin's q parameter. Following the Lavoie and Godley paper, I expected the increase in consumption to yield a fall in the q ratio, whilst also having a fall in equity prices due to falling demand. On the other side, I expected the increase in consumption to lead to higher utilisation and profit rates, which could make firms reduce their dependence on debt, thus, reducing the leverage of the firms. This process of higher consumption leading to a decrease in leverage is to be considered. Especially because I am modelling Minsky's FIH where the increase in leverage causes instability. On top of this, the increase in consumption caused by rising equity values also referred to as the wealth effect should be considered as it can result in countering the increase in leverage which is instrumental in Minsky's FIH (van Treeck, 2009).

On to the simulations, I examine the results of the change in liquidity preferences with a different C_2 value, which is a parameter in the consumption function representing the consumption out of wealth. Also, by increasing the parameter, the wealth effect is deemed stronger in the model. The paradox of saving occurs in the model when a higher propensity to consume leads to faster economic growth. Additionally, the effect of the consumption varies depending on the value of the q ratio. Therefore, I try to increase consumption with different q ratios. According to Lavoie and Godley, with a small q value, the investment increases due to higher capacity utilisation and profit rates, these two variables are in the investment function. However, from my model capacity utilization, profit rate and investment are all lower when c_2 is increased regardless of Tobin's q parameter (see table 4 line 1, 2, 7, 8). In the paper by van Treeck, there is an explanation for this: He argues that the reason behind the differences of result could be the low value of parameters c_2 and γ_3, which in my model would be η_2 and c_2. He also covers the wealth effect on consumption which indicate that households spend more when they see an increase in the value of their assets.

From the simulation, it is clear that with both q values of 0.03 and 0.095, the effects are that the various indicators in the economy such as capacity utilisation, rate of profit, leverage and Tobin's q all decline following an increase in consumption, producing a contractionary outcome for the economy. The reason for my model behaving like this can be found by examining the equations. For consumption (eq. 26), it is the disposable income and wealth which determines it. Moreover, consumption factors into the wealth equation (eq. 27) negatively whilst stock value has a positive impact on wealth. Since consumption increases, it causes a decrease in wealth. In my model, wealth is used by the household to invest in equity or put as deposits. It follows that the households first determine how much to consume and then how much to put towards wealth. Afterwards, they decide what the wealth should be spend on, these decisions are taken simultaneously (Godley & Lavoie, 2007). From eq. 23 and 24 it is found that household portfolio choice is dependent on wealth. Therefore, with the decrease in wealth less equity is held by households. This means a decrease in the value of equity, as from eq. 6 and 7 price of equity is determined partially by the portfolio choice equations, which also leads to a lower Tobin's q value. Tobin's q is one of the variables determining the firm's investment when it declines then the investment is lower. It shows how the financial sector plays a big role in this model and that the value of equity factors into many of the behavioural equations such as wealth, loans, portfolio choice and deposit. Moreover, as a part of the consumption function, we have wealth, meaning that an increase in wealth will lead to higher consumption, so the wealth effect is incorporated in the model through that.

What is interesting from this is the effect the increase in consumption has on the economy. As from the simulations, an increase in consumption seems to cause a contradictory case for the economy. Also, if the wealth effect is quite strong, the households sees their assets increase in value they increase their consumption. Then from a Minskyan perspective, the expansionary period for which the model has been in, in simulation C. and E. where the leverage ratio and investment have been rising, especially in the green investment. It suggests that this period could be a long-run cycle driven by endogenous financial behaviour (van Treeck, 2009). But that at some point, the strong wealth effect could kick in when households realise the asset value is rising and start consuming more. This would cause a slowdown in the financial sector as described above. Thus, there could in fact be endogenous factors through the wealth effect and consumption which curbs a potential asset boom. Given that there is not any bursting of the build-up before the wealth effect could slowly curb the financial sector. As it shows through table 4 lines 7-10, even in the cases with the same Tobin's q, with an increase in consumption, investment is lower. A potential burst could happen, if for example, household has a sudden change in expectation or an exogenous shock happens. I think it is interesting to consider how strong the different variables are in this theoretical model compared to empirical evidence. In the end, it could also be a question of adjusting some of the variables in the investment function, it could be for Tobin's q to have a smaller effect on investment decisions of the firms.

6 Limitations of the Model

The model used in this paper suffers from some limitations. In this section I will basically discuss issues related with the green asset boom and Minsky's FIH. I will also cover some of the drawbacks of modelling of the green and conventional sectors.

Minsky's FIH has often been criticised because of the fact that it neglects the household sector as the source of financial fragility. By including the household's financial decision making through the portfolio choice equations, this is not a limitation for the model of this paper (Ryoo, 2010). However, what is a limitation is the fact that the model does not incorporate household debt. Minsky's arguments can be used in different ways depending on what one wants to show. In my model, I wanted to focus on how the financial sector through asset prices can affect the real economy. I want to show this effect through equity prices, which is why it appears in the investment function that equity prices have a positive effect on investment. This model has many similarities with many Minskyan equity models. A common feature in many equity models is the inclusion of the government and central bank and by that the bonds market, bonds would be another option for household's portfolio choice (Nikolaidi & Stockhammer, 2017). Modelling the difference between the green and conventional economy, it could have been useful to distinguish between green and conventional bonds; the issue of green bonds were recently discussed in a BOE discussion paper (Bank of England, 2021). It could have been interesting to add more portfolio choices. Yet, the complexity of including the government sector was not necessary for what I wanted to show.

Furthermore, the model does not include expectations. Expectations are often included through variables such as expected output or expected disposable income in the model. If this had been included, then an increase in expectation could lead to a positive effect on investment, or net borrowing (Nikolaidi & Stockhammer, 2017). Expectations of future profit are mentioned in Minsky's FIH, for when firms borrow in the bank, expectations of future profits is what the loans are based on (Minsky, 1992). One could also include the expected disposable income of households into the portfolio choice equations, as this would influence how the households spend their money.

The last drawback I want to cover by using Minsky is the idea of "paradox of debt", which means that when firms increase indebtedness by increasing investment financed by debt, it can lead to lower debt in the end. This is because there is a positive effect of investment which could lead to more sales for firms. In a Minskyan framework, this is not considered, which means more debt would lead to higher fragility (Dafermos, 2021). The simulations of my model do not capture such an outcome.

Tobin's q plays an important role in this model as one of the key variables in the investment functions. However, in empirical studies, there is weak evidence for

Tobin's q having a big effect on investment on its own. At best, it is one of a few variables that can determine investment (Ndikumana, 1999). Therefore, to make the model more realistic I could have made Tobin's q parameter lower than the initial 0.03, for example in the paper by Ndikumana, it was estimated to range from 0.003-0.012 (1999). Yet, as van Treeck argues *"during the US 'New Economy' boom, rising share prices were accompanied by euphoric expectations about future profit opportunities in an allegedly completely new technological era, and this apparently contributed to the remarkable, though only temporary, hike in investment spending."* (van Treeck, 2009, p. 487). This situation is very much in line with what I wanted to model, which is euphoria for green equity.

The distinction between green and conventional equity, investment and loans was something I particularly found challenging. In the model, some simplifying assumptions were made, such as the fact that an investment is purely green or conventional. However, by not dividing the firm sector into a conventional and green sector, a firm can still do both kinds of investments making it more realistic. It can be a limitation to have to make such simplifying assumptions about the different sectors in the economy.

Lastly, I consider the fact that an increase in consumption having a contractionary effect on the economy a sign that the model places much emphasis on the financial sector. This is in line with the above argument that the q parameter might be too high. In the paper by van Treeck, the wealth effect is tied into the discussion on consumption and increase in asset prices (van Treeck, 2009). As mentioned, the wealth effect factor into this model since consumption is given by disposable income and wealth. However, it is not entirely realistic in my model, as I have only one kind of household whereas van Treeck has both workers and rentiers, with the rentiers owning equity and workers having zero wealth. The rentiers hold all household wealth, which means the wealth effect is only applicable for them, whereas in my model this effects applies to all households. This could mean the effect might be too strong. Moreover, the wealth effect has been criticised since it is often rich households holding assets. Rich households might not have the same propensity to consume when they have an increase in perceived wealth. They could even invest in more stock as opposed to consuming real assets. Also, an argument is that investment might expand less due to unproductive consumption of luxury goods (Davanzati & Pacella, 2013). Additionally, a problem with including wealth effects in the consumption is that wealth from the stock market is “virtual wealth”, which means that if everyone suddenly decides to sell off their stock the value will decrease substantially. This makes the institutional setup particularly important in an overdraft economy where the expansion is debt lead (Riese, Laski, & Bhaduri, 2006). For instance, it means that borrowing from the bank should be possible for households against collateral in the form of assets.

7 Conclusion

In this paper, the aim was to build an SFC model to examine the possibility of a green asset boom following Minsky’s FIH. In the simulations, the change in household liquidity preference was the main driver of the build-up of a green asset boom. This euphoria was captured by an increase in household liquidity preference toward green equity. The model at its initial state has been modelled to have the conventional sector being larger. The simulation results showed that households' euphoria about green equity is not enough for the green asset boom to build up. However, once a strong Tobin’s q parameter was introduced in the green investment function, the model was able to generate a debt-driven expansion of the green sector. The second set of simulations was to increase consumption which leads to a contraction in the economy, including a decrease in investment. From this I was able to conclude that the equity value has a big influence on investment through Tobin’s q and wealth on the consumption. It also leads to the discussion of why the increase in wealth induced consumption did not lead to an expansion of the economy. To this, I found studies suggesting the wealth lead consumption has less impact on the economy due to mostly well off people owning assets and their specific spending patterns.

In the limitations section, I argued how Tobin´s q and the wealth effect do not hold the strongest empirical evidence. But for this particular case, it is acceptable to put a strong emphasis on those values as the aim of the model is to show a particular expansion in the economy driven by the equity market. Minsky’s FIH has been followed in terms of the different “steps” leading to a green asset boom. However, in the limitation section, some drawbacks of the model were identified which, if they had been addressed, could have made the model more in line with Minsky’s FIH. These were the inclusion of expectations into the equations, as well as the inclusion of a government sector and a central bank. That being said, the model was able to produce results in line with Minskyan ideas. By showing how the increased preferences towards green equity could start the Minsky cycle, where firms gradually experience higher optimism which leads them to take out debt to finance riskier invest.

Future research could focus on the development of models which can capture the effects of climate change on the economy. Furthermore, this line of research must be expanded to produce different models showing all sorts of scenarios that could potentially materialise. From a Minskyan perspective, for a green asset bubble bursting not to happen, thwarting mechanisms need to counter it. Therefore, it is important to recognize all these different implications of transitioning to a low carbon economy and to assess whether the institutional structures are appropriate in order to stabilise the macro-financial system.

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9 Appendices

9.1 Appendix 1: Parameter and Variable Description

Parameters

Symbol	Description
s_W	Wage share
s_F	Retention rate of firms
g_K	Growth rate of capital
v	Capital productivity
int_C	Interest rate on conventional loans
int_G	Interest rate on green loans
int_D	Interest rate on deposit
x_G	Proportion of investment financed by green equity
x_C	Proportion of investment financed by conventional equity
c_1	Propensity to consume out of disposable income
c_2	Propensity to consume out of wealth
λ_0	Portfolio choice parameter for “Animal Spirit”
λ_1	Portfolio choice parameter for return on conventional equity
λ_2	Portfolio choice parameter for return on green equity
λ_3	Portfolio choice parameter for interest on deposit
λ_4	Portfolio choice household parameter for disposable income over wealth
λ_5	Portfolio choice parameter for “Animal Spirit”
λ_6	Portfolio choice parameter for return on conventional equity
λ_7	Portfolio choice parameter for return on green equity
λ_8	Portfolio choice parameter for interest on deposit
λ_9	Portfolio choice household parameter for disposable income over

	wealth
η_0	Investment function exogenous parameter
η_1	Investment function parameter for rate of profit
η_2	Investment function parameter for Tobin's q
η_3	Investment function parameter for capacity utilisation
η_4	Investment function parameter for green debt
η_5	Investment function exogenous parameter
η_6	Investment function parameter for rate of profit
η_7	Investment function parameter for Tobin's q
η_8	Investment function parameter for capacity utilisation
η_9	Investment function parameter for conventional debt
β_0	Sensitivity of the green investment share to the interest rate differential
β_1	Autonomous share of green investment in total investment

Variables

Symbol	**Description**
q	Tobin's q ratio
EC	Household portfolio choice of green equity
EG	Household portfolio choice conventional equity
e_G	Number of new green equity
e_C	Number of new conventional equity
p_{ge}	Price of green equity
p_{ce}	Price of conventional equity
re_G	Rate on return on Green equites
re_C	Rate on return on conventional equites

g_{pge}	Growth rate of green equity prices
g_{pce}	Growth rate of conventional equity prices
g_{ec}	Growth rate of number of conventional equity
g_{eg}	Growth rate of number of green equity
Y_D	Disposable income of households
C_D	Consumption expenditures
D	Deposits (identity)
V	Wealth of households
r	Rate of profit
β	Share of green investment in total investment
Y	Output
TP	Total profits of firms (identity)
RP	Retained profits
DP	Distributed profits (identity)
I	Total investment
K_G	Green capital stock
K_C	Conventional capital stock
K	Capital stock
L_G	Green loans
L_C	Conventional loans (identity)
L	Total loans
I_G	Green Investment
I_C	Conventional investment
lev	Leverage ratio
lev_C	Conventional leverage ratio
lev_G	Green leverage ratio

BP	Profits of banks (identity)
D_{red}	Deposits (redundant identity)
Y^*	Potential output
u	Capacity utilisation
g_y	Growth rate of output
IR_G	Green investment rate
IR_G	Conventional investment rate
mp	Money to wealth ratio
ip	Investment to profit ratio

9.2 Appendix 2: Equations of the Model

Firms: Investment, Pricing and Financial Decisions

Tobin's Q: $q = \frac{(e_G * p_{ge} + e_C * p_{ce})}{K}$ (1)

Supply of new green equity: $e_G = e_{G-1} + \frac{(x_G * IG_{-1})}{p_{ge}}$ (2)

Supply of new conventional equity: $e_C = e_{C-1} + \frac{(x_C * IC_{-1})}{p_{ge}}$ (3)

Rate on return of green equities: $re_C = (1-\beta)\frac{DP}{p_{ce-1} * e_{C-1}} + g_{pce}$ (4)

Rate on return of green equities : $re_G = \beta \frac{DP}{p_{ge-1} * e_{G-1}} + g_{pge}$ (5)

Price of green equity: $p_{ge} = EG - \frac{x_G * I_{G-1}}{e_G}$ (6)

Price of conventional equity: $p_{ce} = EC - \frac{x_C * I_{C-1}}{e_C}$ (7)

Output: $Y = C_D + I$ (8)

Total profits of firms (identity): $TP = Y - s_W * Y - int_C * L_{C-1} - int_G * L_{G-1}$ (9)

Retained profits: $RP = s_F * TP_{-1}$ (10)

Distributed profits (identity): $DP = TP - RP$ (11)

Investment: $I = IG + IC$ (12)

Rate of profit: $r = TP/K$ (13)

Share of green investment in total investment: $\beta = \beta_0 - \beta_1 * (int_G - int_c)$ (14)

Green capital stock: $K_G = K_{G-1} + I_G$ (15)

Conventional capital stock: $K_C = K_{C-1} + I_C$ (16)

Capital stock: $K = K_C + K_G$ (17)

Green loans: $L_G = L_{G-1} + I_G - \beta RP - p_{Ge} * (e_G - e_{G-1})$ (18)

Conventional loans (identity):

$L_C = L_{C-1} + I_C + I_G - RP - (LG - LG_{-1}) - p_{ce} * (e_C - e_{C-1}) - p_{Ge} * (e_G - e_{G-1})$ (19)

Total loans: $L = L_C + L_G$ (20)

Green Investment:

$I_G = (\eta_0 + \eta_1 * r_{-1} + \eta_2 * q + \eta_3 * u_{-1} - \eta_4 * int_G * levG_{-1}) * KG_{-1}$ (21)

Conventional investment:

$I_C = (\eta_5 + \eta_6 * r_{-1} + \eta_7 * q + \eta_8 * u_{-1} - \eta_9 * int_C * levC_{-1}) * KC_{-1}$ (22)

Households

Portfolio choice green equity:

$EC = (\lambda_0 + \lambda_1 re_{C-1} + \lambda_2 re_{C-1} + \lambda_3 int_D + \lambda_4 \left(\frac{Y_{D-1}}{V_{-1}}\right)) * V_{-1}$ (23)

Portfolio choice conventional equity:

$EG = (\lambda_5 + \lambda_6 re_{C-1} + \lambda_7 re_{G-1} + \lambda_8 int_D + \lambda_9 \left(\frac{Y_{D-1}}{V_{-1}}\right)) * V_{-1}$ (24)

Disposable income of households: $Y_D = s_w Y + DP + BP + int_D D_{-1}$ (25)

Consumption expenditures: $C_D = c_1 Y_{D-1} + c_2 V_{-1}$ (26)

Household wealth:

$V = V_{-1} + Y_D - C_D + \left(e_{C-1} * (p_{ce} - p_{ce-1})\right) + \left(e_{G-1} * \left(p_{ge} - p_{ge-1}\right)\right)$ (27)

Deposits (identity): $D = D_{-1} + Y_D - C_D - (p_{ce}(e_C - e_{C-1}) - \left(p_{ge} * (e_G - e_{G-1}\right)$ (28)

Banks

Profits of banks (identity): $BP = int_C L_{C-1} + int_G L_{G-1} - int_D D_{-1}$ (29)

Deposits (redundant identity): $D_{red} = L$ (30)

Auxiliary equations

Potential output: $Y^* = vK$ (31)

Capacity utilisation: $u = Y / Y^*$ (32)

Growth rate of output: $g_Y = (Y - Y_{-1}) / Y_{-1}$ (33)

Leverage ratio: $lev = \frac{L}{K}$ (34)

Growth rate of green equity prices: $g_{pge} = \frac{(p_{ge} - p_{ge-1})}{p_{ge-1}}$ (35)

Growth rate of conventional equity prices: $g_{pce} = \frac{(p_{ce} - p_{ce-1})}{p_{ce-1}}$ (36)

Growth rate of number of green equity: $g_{eg} = \frac{(e_G - e_{G-1})}{e_{G-1}}$ (37)

Growth rate of number of conventional equity: : $g_{ec} = \frac{(e_C - e_{C-1})}{e_{C-1}}$ (38)

Green Investment ratio: $IR_G = \frac{I_G}{K_G}$

(39)

Conventional Investment ratio: $IR_C = \frac{I_C}{K_C}$ (40)

Money-to-wealth ratio: $mw = \frac{D}{V}$ (42)

Investment to profit ratio: $ip = \frac{I}{TP}$ (43)