Green fiscal policy in an empirical UK E-SFC model

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Abstract

Green fiscal policy is at the core of the net zero commitments of countries around the world. However, the exact macroeconomic, financial and environmental implications of the use of green fiscal policy tools within country-specific contexts are not sufficiently understood. This paper develops an empirical ecological stock-flow consistent (E-SFC) model for the UK economy that can analyse how the UK macrofinancial system and emissions can be affected by the implementation of green fiscal policy tools, such as carbon taxes, green subsidies and green public investment. The model synthesises the empirical SFC approach with ecological macroeconomic approaches and is designed to accurately reflect the accounting structure of the UK economy. Our scenario analysis sheds light on the direct and indirect channels by which the use of different fiscal policy tools can affect industrial and housing emissions, as well as the macrofinancial performance of the UK economy. The simulation results suggest that several trade-offs arise when green fiscal policies are implemented in isolation. However, these trade-offs are minimised when several green fiscal policies are introduced simultaneously.

Keywords

Ecological macroeconomics; Climate change; Green fiscal policy; Stock-flow consistent modelling

JEL classification

E12, E62, Q43, Q57, Q58

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1 Introduction

Governments' decarbonisation commitments around the world have increased in recent years. However, the gap between these commitments and the policies that need to be put in place to limit global warming to 1.5^{o}C or 2^{o}C above pre-industrial levels is still very large (IPCC 2023). On top of this, there is limited understanding of the country-specific macrofinancial implications of ambitious decarbonisation policies. This limited understanding acts as a barrier to the design of effective climate policy mixes at the national level.

Green fiscal policy is at the core of these decarbonisation commitments (Pigato 2019; GOV.UK 2021). Although economists have traditionally considered carbon pricing as the main fiscal policy that should be used to address the climate crisis, recent years have also seen growing attention to other green fiscal tools. For example, proposals for a new global 'Green New deal' have emphasised the crucial role of green public investment (Chomsky and Pollin 2020), which also forms the core of the Great British Energy scheme of the UK government (GOV.UK 2024). At the same time, the Inflation Reduction Act (IRA) in the US has drawn a lot of attention on the role of green subsidies (Kleimann et al. 2023). From a modelling perspective, the academic literature on green fiscal policy can be classified into three strands. First, there is a vast literature that has explored the implications of green fiscal policy within theoretical or global models. This literature includes Integrated Assessment Models (IAMs) that have largely drawn on Nordhaus' Dynamic Integrated Climate Economy (DICE) model in which carbon pricing is analysed within a framework that combines a growth analysis a la Ramsey with a climate module that captures how carbon pricing interacts with emissions and climate damage (Nordhaus 2018; Barrage and Nordhaus 2023). It also includes environmental Dynamic Stochastic General Equilibrium (E-DSGE) models that have analysed the implications of carbon pricing from a business cycle perspective (Golosov et al. 2014; Diluiso et al. 2021), as well as ecological stock-flow consistent (E-SFC) models that have analysed a wide range of green fiscal policies, paying attention both to transition and long-run effects from a macrofinancial perspective (Monasterolo and Raberto 2018; Dafermos and Nikolaidi 2019; Dafermos and Nikolaidi 2022).

Second, there are country-specific papers that rely on econometric models or input-output methods. For example, Batini et al. (2022) and Onaran and Oyvat (2023) have estimated country-specific output and employment effects of green public spending, while Pollin and Chakraborty (2015) and Pollin, Wicks-Lim, et al. (2022) have used input-output techniques to estimate the environmental and employment effects of green spending.

Third, there are some country-specific macromodels that have been used to analyse the implications of green fiscal policies. These include environmental computable general equilibrium (CGE) models that have been used to analyse carbon taxes (Meng et al. 2013), green subsidies (Kalkuhl et al. 2013) and feed-in tariffs (Wei et al. 2019), but also New Keynesian models, such as the National Institute of Economic and Social Research (NiESR) model that has been recently used to explore climate policy scenarios (Hantzsche et al. 2018; NGFS 2023).

Despite this vast literature, significant gaps remain. IAMs, CGE models, and DSGE models suffer from several key limitations when analysing climate policies. These models typically assume that agents make decisions under rational expectations, assume full employment in the economy, leading to interventionist policy being viewed purely as a cost, and have little to no role for finance or the financial system, ignoring the role of endogenous money. Econometric models and input-output models provide valuable insights, but cannot provide a holistic scenario-based analysis of the direct and indirect effects of green fiscal policies. E-SFC models address the limitations of equilibrium frameworks, but their use for country-specific evaluations of climate policies has been very limited.

The purpose of this paper is to address this gap by developing the first integrated country-specific E-SFC model that can be used to explore the environmental, macroeconomic, and financial effects of green fiscal policies in the UK within a holistic framework that is not constrained by the straitjacket of equilibrium analysis and pays particular attention to macrofinancial feedback loops. The UK economy has been selected for two reasons: first, the national accounting data for the UK is rich, permitting the development of detailed balance sheet and transaction matrices; second, the UK government has clear decarbonisation commitments, making it easier to develop a rich climate policy scenario analysis. However, the purpose of the paper goes beyond the UK: the methodology that we develop to build the E-SFC model can be applied to other countries as well.

The rest of the paper is structured as follows: Section 2 provides a brief overview of macroeconomic and environmental modelling approaches for the UK and justifies the use of the empirical E-SFC approach. Section 3 describes the overall structure and key features of the model, while Section 4 focuses in on the channels through which fiscal policies affect macroeconomic, financial, and environmental variables in the model. Section **??** shows the effects of several fiscal policy scenarios on key economic and environmental variables, with Section 6 summarising and concluding.

2 Macroeconomic and environmental modelling for the UK: the need for an E-SFC approach

2.1 Key UK macroeconomic models

While there are many macroeconomic models in the UK, all with different focusses and theoretical foundations, there are two that stand out, as both being used by key UK institutions for policy analysis and forecasting. These are the "Central Organising Model for Projection Analysis and Scenario Simulation" (COMPASS) model used by the Bank of England (BoE) and the "Office for Budget Responsibility (OBR) Macroeconomic Model" used by the OBR. Both models are data-driven and UK-specific.

The COMPASS model (Burgess, Fernandez-Corugedo, et al. 2013) is a New Keynesian DSGE model and is similar to the models used by other central banks. It is built on micro-foundations of representative utility maximising agents who make decisions under rational expectations. Exogenous stochastic stocks are included, which result in model fluctuations around a calibrated equilibrium position. The economic variables considered in the base model are limited to high-level economic variables, with the model generally being used to inform the BoE's monetary policy.

The OBR macroeconomic model (OBR 2013) is a large-scale macro-econometric model. Although it relies on the DSGE tradition, it drops some of the restrictive assumptions of DSGE models. For example, the representative utility optimising agent is replaced by econometric estimations of the behaviour of aggregated groups/sectors. The model employs a simplified representation of the economic activity recorded by the Office for National Statistics (ONS) with accounting identities forming the basis of the model, and econometrically estimated behavioural equations included, where required. There is also no reliance on general equilibrium in the OBR model with the model evolving according to the econometric equations. The OBR model has been specifically designed with government budgets in mind; as such, it has a highly disaggregated government sector and therefore includes a very large range of inputs to this sector.

Although these models differ in their focus, there are some key limitations. In particular, both models have a very limited treatment of the role of finance. Neither include an explicit financial sector with finance playing only an implicit role of intermediating funds between different sectors. This fundamentally ignores the role of banks in endogenously creating money (Lavoie 2014), with the problems that this creates for modelling being highlighted by Jakab and Kumhof (2018). Furthermore, the models do not consider financial balances extensively and focus primarily on monetary flows. This risks ignoring the structural and behavioural implications of phenomena, such as growing household indebtedness. Where financial balances are included, this is not done in a stock-flow consistent way, i.e. the stocks are not directly linked to flows, so their evolution in the model is not determined endogenously limiting the scope to analyse them. The fallout of the financial crisis made it clear that models should adopt a more integrated view of finance. This becomes even more important, with the role of finance and financial instability becoming increasingly clear for analysing ecological effects and policies. Therefore, this limited approach to finance represents a key weakness of these modelling approaches.

2.2 Macroeconomic modelling of UK climate policies

Several models have been used to analyse the effects of climate mitigation policies in the UK. One prominent model is the National Institute Global Econometric Model (NiGEM). This model was developed by the National Institute of Economic and Social Research (NiESR) and acts as a multi-country econometric model with different calibration for each country considered. The model is currently used in NiESR policy analysis, including specifically for the UK (e.g. King et al. (2022)). Additionally, NIGEM is the model currently used by the Network for Greening the Financial System (NGFS) as the economic side of their climate scenario analysis (NGFS 2023).

The NiGEM model is a New Keynesian model that incorporates energy use on the supply side. It relies on agents with rational expectations and general equilibrium to function and does not include any role for the financial system. As such, there is little role for financial assets and the interaction between stocks and flows. Furthermore, the UK-specific module is simply a general model calibrated with UK data as opposed to a model derived specifically around the structure of the UK economy. As such, the model may ignore important phenomena to the UK, although this is already evident through its lack of finance, which is known to play a key role in the functioning of the UK economy. Due to its theoretical limitations, the NiGEM model cannot incorporate key macro-financial effects which could be critical for analysing climate policy.

The next UK model is the Multisectoral Dynamic Model - Energy-Environment-Economy (MDM-E3) model developed by Cambridge Econometrics that has also developed the global Energy-Environment-Economy Macro-Econometric Model (E3ME) model (Dwesar et al. 2022). These models reject general equilibrium and incorporate some post-Keynesian principles, such as allowing demand to affect economic activity both in the short-run and in the long-run (Lavoie 2014). A key strength of these models is the high degree of dissagregation in terms of both sectors and geographic regions. The disaggregation of the model makes it suitable for analysing the sectoral effects of policies. However, finance still has little or no role to play, and the models do not pay attention to stock-flow consistency. This means that these models cannot be used to properly analyse the financial effects of policies and the impacts of green financial policy. Therefore, while the theoretical foundations of MDM-E3 are stronger than NiGEM, it is still limited by its treatment of finance.

Overall, although empirical macro-climate models exist in the UK, there are common gaps within these models, which suggest there would be a benefit to developing a UK focused empirical SFC model to assess climate policies. Since none of these models has a detailed view of finance, they are unable to assess the effects of climate policies on the financial system along with the role of climate financial policy. Empirical SFC models implicitly include finance and therefore represent a promising methodology for the construction of our desired model. Additionally, the inclusion of post-Keynesian characteristics in MDM-E3 suggests that there is a recognition of the importance of these post-Keynesian fundamentals when assessing climate policy, which lends support to adopting a post-Keynesian SFC modelling approach.

2.3 Towards an empirical E-SFC model for the UK

Stock-flow consistent modelling is an alternative macroeconomic modelling approach originating from post-Keynesian economics and first popularised by Godley and Lavoie (2012b). The models take a holistic approach to modelling, not relying on microfoundations, representative agents, or rational expectations, leading to more realistic behavioural equations. In particular, SFC models are well placed to analyse the role of finance in the economy, a key shortcoming of all models discussed so far, as financial balances are explicitly included in the model to ensure stock-flow consistency. Furthermore the structure of SFC models closely resembles the system of national accounts which makes them particularly useful for empirical modelling. Recently, SFC models have been extended to include ecological factors and used to analyse climate policies (Dafermos, Nikolaidi, and Galanis 2018; Monasterolo and Raberto 2018). Most SFC models are not country-specific and instead take a theoretical approach to general macroeconomic analysis (see Lavoie (2011), Godley and Lavoie (2012a), and Godley and Lavoie (2012b)). This limits the models abilities to consider the varied effects that different policies will have within different countries and any unique characteristics of certain countries, which should be modelled explicitly. There has, however, been work from the BoE to develop an SFC model for the UK economy.

Following the financial crisis Burgess, Burrows, et al. (2016), recognising the limitations of the DSGE approach to financial balances, developed an empirical SFC model for the UK (Burgess, Burrows, et al. 2016). This model is a relatively complex SFC model whose core structure is based heavily on Godley and Lavoie (2012a). Elements of the model are tailored to the UK, in particular, financial sectors are split between Banks and insurance companies and pension funds (ICPFs). Although not stated explicitly, it can be assumed that this separation is due to the important role the ICPF sector plays in the UK economy and that this role is sufficiently different from that of the traditional banking sector such that it warrants separate modelling. However, while the UK context is taken into account, the model structure is still theory-based rather than data-driven. This is to say that, while the data are used to calibrate the model, they are not explicitly used when deciding on how the model should be structured.

Most empirical SFC models are, like that of Burgess, Burrows, et al. (2016), theoretical SFC models with behavioural parameters calibrated to the available data. G. Zezza and F. Zezza (2019) propose an alternative approach in which real-world data flows, provided within the system of national accounts, are used as the foundation of the structure of the model. As most sectors hold almost all types of assets, this approach involves choices about what is considered significant enough to be modelled and what is not, usually based on the size of asset holdings or financial flows. The key advantage of this approach is that the model structure should, theoretically, be a good reflection of the economy it seeks to model, and there is little risk of ignoring highly relevant economic processes. The development of such a model for the UK would contribute to a growing literature on empirical SFC models with models being developed for Italy (F. Zezza and G. Zezza 2022), Denmark (Byrialsen and Raza 2020), and the Netherlands (Meijers and Muysken 2022) to name a few.

However, developing an empirical SFC model for the UK would not be sufficient to analyse green fiscal policies. It is also necessary to extend the standard SFC approach to explicitly account for ecosystem variables. To do so, we rely on the Dynamic Ecosystem-FINance-Economy (DEFINE) model developed by Dafermos, Nikolaidi, and Galanis (2017), Dafermos and Nikolaidi (2019) and Dafermos and Nikolaidi (2021). Drawing on the flow-of-funds model of Georgescu-Roegen (1971), the DEFINE model incorporates physical stocks and flows into the standard SFC model structure. This allows the model to analyse how ecological variables, such as material use, energy, emissions, and waste, interact with macroeconomic and financial variables. The model also formulates the connection between credit provision, green investment, and ecological efficiency indicators in a way that permits the analysis of environment-related macrofinancial feedback loops.

Hence, the general purpose of this paper is to synthesise the empirical SFC approach of G. Zezza and F. Zezza (2019) with the ecological macroeconomic modelling approach of DEFINE to develop a model of the UK economy, using ONS national accounting data. It will be shown that this approach leads to unique considerations for the UK economy and that the derived model, by taking this empirical approach, will differ in structure and scope when compared to current UK SFC models. Furthermore, this approach explicitly integrates ecological variables into the empirical SFC approach to derive a DEFINE-UK model that can be used to assess the impacts of fiscal policies for a low-carbon transition.

3 Model Structure

3.1 Derivation of accounting structure

Drawing on the approach of G. Zezza and F. Zezza (2019), the model's accounting structure is derived directly from UK national accounting data. The main source of this data is the ONS blue book (ONS 2022). As highlighted in G. Zezza and F. Zezza (2019), there are significant similarities between SFC models and the system of national account which make SFC models uniquely appropriate for applying national accounting data to model derivation. In fitting the model to national accounting data we have adopted the definition of "data consistency" described in George et al. (n.d.): "a model is data consistent if it has an accounting structure that allows a direct connection, across time, between the model's stocks and flows and the national accounting elements on which these stocks and flows are based".

In order to achieve a data consistent model without needing to explicitly model all stocks and flows in the UK national accounts we choose to introduce residual terms, as described in George et al. (n.d.) and F. Zezza and G. Zezza (2022). This means that we will introduce a *residual transaction*

Table 1: Transactions matrix after the use of net lending/borrowing data from the financial account (Step 8), UK data in percent (%) of GDP, 2000-2022 average

	Production	Households	Government	NFCs	FCs	RoW	Total
Consumption	+52.0%	-52.0%					0
Government Wages	+9.7%		-9.7%				0
Other Government Consumption	+8.2%		-8.2%				0
Gross capital formation	+17.6%	-4.3%	-2.6%	-10.7%			0
Exports	+28.2%					-28.2%	0
Imports	-29.7%					+29.7%	0
Taxes-subsidies	-11.2%		+11.2%				0
Private Wages	-39.6%	+39.6					0
Government Wages	-9.7%	+9.7%					0
GOS & mixed income	-25.5%	+5.9%		+19.6%			0
Interest paid by FCs		+1.4%	+0.5%	+0.9%	-10.3%	+7.5%	0
Interest paid to FCs		-4.6%	-2.8%	-2.8%	+15.9%	-5.7%	0
Dividends paid by FCs		+4.7%		+3.0%	-11.7%	+4.0%	0
Dividends paid to FCs				-7.5%	+11.8%	-4.3%	0
Income Taxes		-11.5%	+13.8%	-2.3%			0
Social Contributions		-15.6%	+7.6%		+8.0%		0
Social Benefits		+16.4%	-13.0%		-3.4%		0
Other Income		+6.3%			-6.3%		0
Pension Adjustment		+4.6%			-4.6%		0
Total: net lending (1)	0	+0.6%	-3.2%	+0.2%	-0.6%	+3.0%	0
Residual transaction (2)	0	+1.8%	-1.5%	-0.5%	-0.1%	+0.3%	0
Actual net lending: (1)+(2)	0	+2.4%	-4.7%	-0.3%	-0.7%	+3.3%	0

Notes: Pink colour illustrates flows that have been modified compared to the previous matrix. NFCs: Non-Financial Corporations; FC: Financial Corporations; RoW: Rest of the World; GOS: Gross Operating Surplus

that captures the net position of flows that are not explicitly included in the model.[2] In the case of stocks, we add a *residual financial instrument* that reflects the net asset position of stocks not explicitly included in the model. By defining these residuals precisely as the net position of all the national accounting items that we choose not to explicitly model, it is possible to still maintain data consistency when adopting this approach.[3]

These principles are applied in the derivation of a country-specific SFC model for the UK. This is done by following the same step-by-step process as described in George et al. (n.d.). Following this approach we derive three accounting matrices: the transactions flow matrix (Table 1), balance sheet matrix (Table 2), and the stock-flow matrix (Table 3 which links the two other matrices together. In these tables we present the actual average data values for the UK, in percentage of GDP averaged over the 2000-2022 period. This shows the different size of various stocks and flows for the UK model.

3.2 Model Estimation

The model presented is an empirical data driven model that has been built directly from national accounting data. The national accounting data will also form the basis for calibrating the model, it will inform the initial conditions of most variables, and will be used to estimate certain parameter values.

The UK model features three high-level equation categories:

- **Identities**: Equations that are directly derived from the transactions and balance sheet matrices such that stock-flow consistent principles are adhered to.
- **Behavioural equations**: These equations determine how certain variables depend on other variables in the model based on behavioural parameters.

[2]These are the so-called non-financial flows that impact each sector's net lending position

[3]While residuals as defined as the net position of all the national accounting items not explicitly modelled, for practical purposes they can be calculated as the difference between each sectors model determined net-lending/net-worth position and the actual net-lending/net-worth position given by national accounting data.

Table 2: Balance sheet matrix after adjusting government financial liabilities (Step 5), UK data in percent (%) of GDP, 2000-2022 average

		Households	Government	NFC	FC	RoW	Total
Housing Capital		+76.0%					+76.0%
NFC Capital				+91.0%			+91.0%
Government Capital			+28.3%				+28.3%
Total: real assets		+76.0%	+28.3%	+91.0%			+195.3%
Interest bearing assets		+73.4%	+15.4%	+45.6%	-428.2%	+293.8%	0
Interest bearing liabilities		-85.3%	-66.6%	-76.7%	+498.7%	-270.1%	0
Equity	Assets	+46.6%		+52.0%	-200.4%	+101.8%	0
	Liabilities			-138.5%	+259.3%	-120.8%	
Pensions & Insurance		+169.9%			-169.9%		0
Total: financial net worth		+204.6%	-51.2%	-117.6%	-40.5%	+4.7%	0
Residual financial instrument		+0.8%	+8.7%	-39.5%	+26.6%	+3.8%	0
Actual financial net worth		+205.4%	-42.5%	-157.1%	-13.9%	+8.5%	0

Notes: Pink colour illustrates stocks that have been modified compared to the previous matrix. NFCs: Non-Financial Corporations; FC: Financial Corporations; RoW: Rest of the World.

Table 3: Stock-flow matrix, percent (%) of GDP, 2000-2022 average, UK

		Households	Government	NFCs	FCs	RoW	Total
Gross Capital formation (2)		+4.3%	+2.6%	+10.7%			+17.6%
Depreciation of real assets (3)		-3.7%	-1.9%	-8.1%			-13.7%
Other changes in real assets (4)		+3.0%	+0.9%	+2.0%			+5.9%
Changes in real assets (5)=(2)-(3)+(4)		+3.6%	+1.6%	+4.6%			+9.8%
Change in net financial assets arising from financial transactions	Interest-bearing assets*	+3.7%	+0.8%	+2.3%	-18.2%	+11.4%	0
	Interest-bearing liabilities**	-4.4%	-5.2%	-3.7%	+23.8%	-10.5%	0
	Equity assets*	-1.2%		+3.7%	-6.1%	+3.6%	0
	Equity liabilities**			-2.1%	+5.1%	-3.0%	
	Pensions	+4.8%			-4.8%		0
	Residual FI	-0.5%	-0.3%	-0.5%	-0.5%	+1.8%	0
Actual net lending (6)		+2.4%	-4.7%	-0.3%	-0.7%	+3.3%	0
Other changes in net financial assets	Interest-bearing assets*	+0.2%	+0.2%	+0.1%	-2.7%	+2.2%	0
	Interest-bearing liabilities**	+0.4%	+0.1%	+0.8%	+2.4%	-3.7%	0
	Equity assets*	+1.8%		-1.1%	-3.9%	+3.2%	0
	Equity liabilities**			-2.3%	+6.7%	-4.4%	
	Pensions	+0.2%			-0.2%		0
	Residual FI	+0.5%	+0.5%	-0.3%	-0.8%	+0.1%	0
Total other changes in net financial assets (7)		+3.1%	+0.8%	-2.8%	+1.5%	-2.6%	0
Change in net financial assets (8)=(6)+(7)		+5.5%	-3.9%	-3.1%	+0.8%	+0.7%	0%

Notes: Financial transactions related to an increase in net financial assets are denoted by a plus sign, while financial transactions associated with a decline in net financial assets are denoted by a minus sign. NFCs: Non-Financial Corporations; FC: Financial Corporations; RoW: Rest of the World; FI: Financial Instrument.
*Liabilities for the financial corporations
**Assets for the financial corporations

- **Technical relationships**: These are calibrated equations that are neither identities nor behavioural equations. Some technical relationships are definitions, such as the definition of the wage share.

Therefore, the key focus of the estimation process is determining appropriate values for the parameters of the behavioural equations. A pragmatic approach to the estimation of behavioural equations within the model is taken. There are three distinct approaches taken for each behavioural equation:

- **Time series econometrics:** Where appropriate, the equations are calibrated using time series econometric methods, generally using autoregressive distributed lag models (ARDL) in the error correction model (ECM) form. This means that the parameter values are estimated from available past data. This requires that sufficiently long time series data are available for all variables in the equations. The form of the equations themselves are based on economic theory, although econometric results (such as a lack of significance of certain variables) will inform the structure of the equations. However, where data are not available, or there are limited significant econometric results, other approaches will need to be taken to estimate the parameters within the behavioural equation.

- **Existing Studies:** In some cases, the parameters of the behavioural equations will be based on existing studies. This is in part due to a lack of data or poor econometric results, although for some behavioural relationships, it is not appropriate to employ past data to estimate parameter values. This is particularly true for behavioural equations relating to green investment, where the past does not serve as a good predictor of future behaviour, due to the non-linear nature of technological progress in these areas and changes in government policies over time.

- **Exogenously Driven:** In cases where econometrics is not possible and other studies cannot be used, behavioural relationships can be set to be exogenously driven based on fixed relationships, such as assuming a variable maintains a steady relationship with GDP. Residual variables, which by definition include those variables that are not explicitly modelled, will generally be defined in this way. This effectively turns a behavioural equation into a technical relationship.

This pragmatic approach reflects that even for a country with relatively rich data, such as the UK, it will still not be possible, or even desirable, to estimate all behavioural equations from past data. This would become an even greater issue when attempting to build models for countries with more limited data. Given that it is desirable to be able to develop ecological SFC models in a broad range of country contexts, a strength of this flexible approach is that it is relatively straightforward to apply this process when data availability is more limited. The complete econometric results are shown in Appendix C and a complete list of parameter estimates and their sources is included in Appendix B Table 6.

3.3 Model overview

Having derived the model structure, along with estimating key equations, we now present the overview of the model, which is shown at a high level in Figure 1.

Many of the transactions in the model involve the production process, which is the combination of general production and power generation. GDP expenditure in the form of consumption ($CONS$), gross capital formation (GCF), and exports (EXP) less imports (IMP) flows into the production module. Meanwhile, GDP income in the form of wages, gross operating surplus (GOS_P), and indirect taxes on production ($INDTAX$) flows out of the production module. The separation of production in this way allows the model to reflect the fact that in the UK production occurs across many sectors to greater or lesser degrees. However, the productive module should not be confused with the other sectors: it does not have any assets or liabilities and simply serves as receiving productive "expenditure" and then distributing productive"income".

The industrial sectors in the model are split between the power sector (D35 in the European system of accounts NACE categorisation) and all other industrial sectors, which are then included in the production sector of the model. Final consumption is divided between the final consumption of general production products ($CONS_P$) and the final consumption of power sector products ($CONS_{PS}$) with the latter primarily being the consumption of electricity by households. Input-output interactions are included, in the form of intermediate consumption between the production and power sectors. Intermediate consumption of the production sector for products of the power sector (IC_{PSP}) accounts primarily for electricity consumption of industrial sectors, while intermediate consumption of the power sector for products of the production sector (IC_{PPS}) accounts for inputs into the electricity generation process, notably fossil fuels. Both the production and power sectors also have internal intermediate consumption that completes the input-output structure.

On the transaction side, all sectors receive interest from the MFI sector based on their holding of interest bearing assets and pay interest to the MFI sector based on their holding of interest bearing liabilities. Dividend payments occur between many sectors, and dividend payments are administered through the NMFI sector. Social contributions are paid by households to the government and NMFI sectors, which social benefits paid to households by those same sectors. Other income (OI) and pension adjustment ($PENS_{ADJ}$) are paid by NMFIs to the household sector. A residual transaction for each sector is used to bring model-determined net lending in line with the net lending level from national accounts.

Emissions constitute the only ecosystem variable that is included in the model at this stage. Emissions are driven by several stock variables, such as green and conventional capital levels and non-fossil power capital, which affect the emission intensity of the economy. However, emissions tend to increase when there is an increase in economic activity.

Although much of this structure is standard to macroeconomic models, and particularly SFC models, it can be seen how the empirical SFC approach has led to different considerations to other models. Some examples that illustrate this: the separation of production is non-standard, but is necessary to reflect that production does not occur uniquely in one national accounting sector; pensions are not always included in SFC models but are found to be a highly significant household asset within the UK so are included in the model; social contributions and social benefits are rarely modelled but are found to be highly significant flows within the UK national accounts and therefore need to be included in the model.

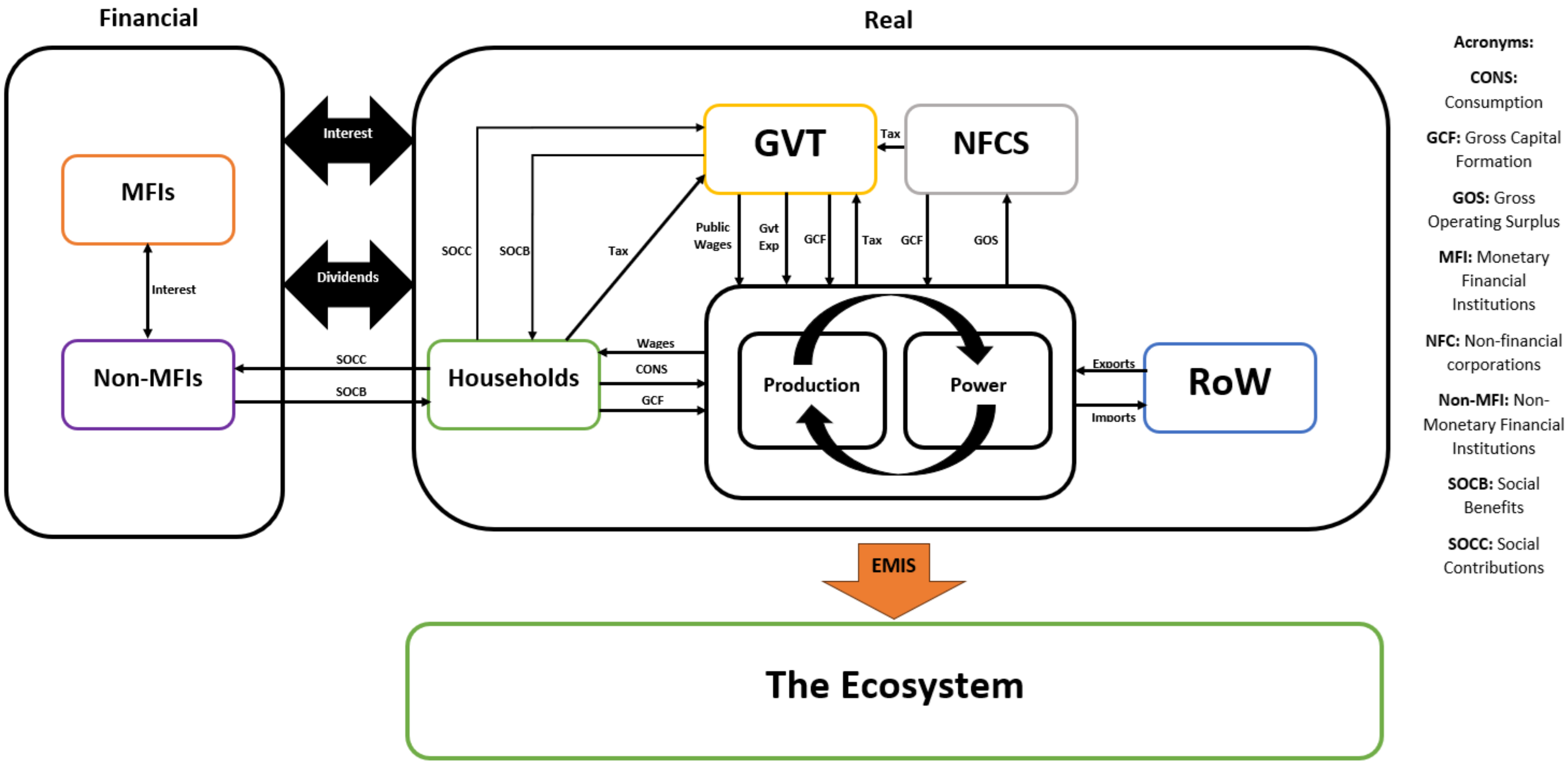


Figure 1: Simplified Model Overview

Baseline scenario

The combination of econometrically estimated behavioural equations, identities, and technical relationships results in a model that generates a baseline projection. However, there are significant uncertainties around the parameter values, particularly with regard to some of the environmental parameters in the model. To set reasonable estimates for these parameters, the model draws on a range of external data sources to estimate a baseline scenario, which can be used as the basis for policy scenario analysis. The baseline of the model and the scenarios will run until 2035, this reflects the focus of scenarios on medium-term energy transition goals, as opposed to the longer-term environmental and ecological scenarios covered in models such as the global DEFINE,(Dafermos and Nikolaidi 2022), which runs until 2100, or EUROGREEN, which has projections until 2050 (D'Alessandro, Cieplinski, et al. 2020).

For macroeconomic data, the model relies mainly on estimates from the UK Office for Budgetary Responsibility OBR (2025). The OBR, set up in 2010 produces detailed forecasts for the economy and public finances and is intended to serve as an independent evaluator of government policy. The OBR uses various tools to generate their economic and fiscal outlook, including their macroeconomic model (OBR 2013). OBR economic forecasts are short-term with a five-year horizon, therefore, data are available until 2030 for calibrating the baseline. It is assumed that economic variables after 2030 follow a similar growth rate as later years in the forecast.[4] Initial values and parameters are adjusted to achieve similar trajectories as the OBR for variables such as headline GDP growth, the debt-GDP ratio, and the rate of price inflation. As the OBR forecasts feature detailed projections for various forms of government spending, this data will be used to calibrate the technical relationships in the model related to government spending such as forms of government consumption and investment.

For environmental variables, in particular territorial emissions, the objective is to establish a reasonable "current policies" baseline where existing environmental policy commitments are included but no additional policies or unexpected behaviour change occurs. The emission pathway of the model is close to the current policy projection of the National Energy System Operator (NESO 2025), who provide independent forecasts of net zero pathways within a specific UK context. Other sources are also used, such as the Network for Greening the Financial System (NGFS) scenario data (NGFS 2025), although their projections only include emission data at 5-year intervals and take a more global perspective. This means that there is a reduction in emissions in the model; however, the emission reduction falls significantly short of the UK's 2035 NDC target (GOV.UK 2025) to reduce greenhouse gas emissions by at least 81% by 2035 compared to 1990 levels.

Although other studies are used to calibrate the baseline, this should not be taken as an endorsement of any particular projections. Rather, this is a pragmatic approach in order that the model develops in a way more or less consistent with future expectations for the macroeconomy and environmental systems for the UK. The baseline of the model should also not be seen as a prediction or forecast; What is of primary interest in this research is the effect of different scenarios on the model. Therefore, this thesis is primarily concerned with how various scenarios change variables from the baseline as opposed to making any predictive forecasts for specific variables.

Several key baseline variables are shown in Table 4. Most variables are relatively steady; growth projections are modest, but in line with the overall trend in real GDP growth in the UK. Unemployment is fairly consistent over the baseline period. The population and labour force increase steadily, in line with UK projections. The proportion of non-fossil fuel electricity production increases, but falls far short of the goal of fully non-fossil fuel production by 2030. Total emissions do fall, due to higher electrical energy use and green investment and efficiency improvements, but again this falls short of UK emission reduction targets. The emission price is set to increase modestly during the baseline period. Green investment, as a percentage of GDP, also increases modestly over the period. NFC default rates and credit rationing decrease slightly over the baseline period; this is mainly due to the fact that the start of the baseline scenario is still being affected by the high inflation, low growth, and high interest rates of the early 2020s. The variables that change the most in the baseline are the financial variables, default rate, and credit rationing rate of the power sector, with both of these

[4]The OBR forecasts mostly converge to a steady growth rate by the end of the forecast period so for the baseline it is assumed that this steady rate can be extrapolated.

increasing over the period. This will be discussed in more detail in the results section. However, in short, this occurs mainly due to the marginal price electricity system within the model. As electricity use becomes increasingly non-fossil based, electricity prices fall due to more “fully non-fossil” electricity hours. This reduces the profits of the private power sector and has a negative impact on their ability to service debt, which is required to undertake the high levels of investment required for the non-fossil fuel energy transition. This is consistent with recent discussions around the “cannibalisation” effect (see Peña et al. (2022)), whereby increasing renewable energy use negatively impacts the profits of electricity-generating firms.

Table 4: Key characteristics of the baseline scenario

Variable	2025	2035	Mean	St. deviation
Real GDP growth (%)	1.64	1.73	2.02	3.02
Unemployment (%)	4.36	4.32	4.45	0.07
Population (millions)	55.66	59.66	57.70	1.32
Labour Force (millions)	34.68	36.39	35.60	0.57
Proportion of non-fossil electricity generation (%)	67.35	84.55	77.63	5.60
Total emissions ($MTCO_{2e}$/year)	358.71	283.20	323.78	26.68
Emission price (£/TCO_{2e})	8.01	13.14	10.6	0.17
Green investment investment (% of GDP)	1.34	1.72	1.55	0.13
NFC default rate (%)	2.02	1.75	1.81	0.11
NFC credit rationing (%)	17.98	15.55	16.81	1.25
Power Sector default rate (%)	2.53	4.53	3.78	0.67
Power Sector credit rationing (%)	27.93	43.51	38.68	5.72

Notes: All quarterly values are annualised and the mean and standard deviation are calculated from 2025-2035.

4 Green Fiscal Policy: Key Model Channels

There are several key green fiscal policy channels present within the model with green fiscal policies that impact macroeconomic, financial, and environmental variables. Due to the integrated nature of the model, there will be several feedback loops and dynamic effects that should be considered before running policies. In this section, the key environmental and macroeconomic channels for each fiscal policy scenario will be discussed along with some of the key subsystems in the model around price formation, government debt, and financial constraints. As the model is system-based and fully integrated technically, every endogenous variable has at least some indirect impact on every other variable, so while the figures in this section will present what appear to be closed systems, this is not the case in reality. However, the systems presented reflect the most important channels for certain policies or effects and will be useful in showing how these channels operate within the model. In the description of channels below, we will refer to model equations which are available in Appendix A.

4.1 Carbon Pricing Channels

The key impacts of an increase in the carbon price are shown in Figure 2. Carbon pricing has a direct behavioural impact on the investment decisions of agents within the model. NFC green investment is increased by the higher relative cost of fossil fuel energy through Eq. (161) and households also respond to higher non-electric energy prices by investing more in green home improvements through Eq. (323). This increase in “Green Investment (non-power)” (as named in Figure 2) leads to a moderate reduction in the intensity of emissions from the use of non-fossil fuel energy through Eq. (19), a fall in energy intensity through Eq. (16) and an increase in the electricity share of energy use through Eq. (18). An increase in the carbon price also increases the proportion of power investment in non-fossil fuel electricity generation through Eqs. (97 & 98). This leads to a reduction in the fossil intensity of electricity production and overall lower emissions from the electricity generating process.

The carbon price also has direct and indirect impacts on the overall price level in the UK. As carbon prices are included within indirect taxes, they directly increase the cost of production in Eq.

(48), higher marginal costs are passed through to prices directly through Eq. (30), although the degree of pass through will depend on the behavioural changes that result from a carbon tax. However, the increase in non-fossil fuel electricity capital leads to a fall in the electricity price. As electricity is part of intermediate consumption in the production sector, lower electricity prices will reduce costs, resulting in a deflationary effect. The inflationary impacts of carbon pricing are empirically discussed by Konradt and Weder di Mauro (2023) with reference to the EU and Canada, where the net inflationary impacts were found to be neutral in the past, although the authors acknowledge that more ambitious future carbon pricing policies could have greater macroeconomic impacts than have been seen in the past. Furthermore, the New-Keynesian modelling approach of Ferrari and Nispi Landi (2022) finds that the short-term impacts of carbon pricing are deflationary due to households with rational expectations anticipating a fall in future income and reducing their spending accordingly, however, the authors do find inflation in the first period when they relax the expectation structure and allow households to not anticipate the future fall in incomes. With the expectation structure of an SFC model, it is more likely that inflationary impacts will occur as households do not have rational expectations, although their fall in income related to higher carbon prices will likely reduce spending. Therefore, the overall impact of carbon pricing on inflation is unclear. It is likely to be initially inflationary, with deflationary pressures appearing as the higher price passes through to economic activity and green investments.

The impact of the carbon price on GDP is both direct and indirect. Directly carbon prices are a cost for firms and households (indirectly in the latter case), this reduces the disposable income of these sectors and results in lower spending through less household consumption in Eq. (310) and lower firm investment in Eq. (160), the latter effect being an indirect impact of lower creditworthiness of firms with lower incomes. This will directly reduce GDP through a fall in the components of final-demand. If there are inflationary pressures, this will result in a further fall in economic activity as wages lag behind rising prices, resulting in further lower demand. Furthermore, the Bank of England, following their Taylor rule in Eq. (382), are likely to increase the base rate in response to inflation, this leads to higher debt-service ratio for firms, lower disposable income for households and acts to further depress demand.[5]

The overall effect on emissions of a higher carbon price is, as expected, an overall reduction in emissions. More investment in non-fossil power capital will reduce the emissions from electricity generation, while greater general green investment increasing the electricity share while reducing energy and emission intensities will lead to lower energy use in general and lower emissions from the energy that is used, resulting in a fall in non-electric emissions and overall emission reduction. The negative impacts on economic activity further reduce energy use through Eq. (2) and lead to further falls in emissions. This is consistent with insights from the Degrowth literature (see Kallis (2011), Hickel (2019), and Mastini et al. (2021)) where the link between economic activity and ecological damage, including emissions, is highlighted. However, it must be stressed that carbon pricing is not a "degrowth policy", but rather that lower economic activity is a side effect. For an analysis of degrowth policies, such as sufficiency-based approaches, within a post-Keynesian modelling framework, see D'Alessandro, Cieplinski, et al. (2020) and Dafermos and Nikolaidi (2022). Although not shown in the figure, the increase in carbon prices provide income for the government sector and can be considered a fiscal contractionary policy.

[5]While there is a negative macroeconomic impacts of rising interest rates within the model it should be highlighted that the effect is often smaller than what is seen within the New-Keynesian macro modelling literature.

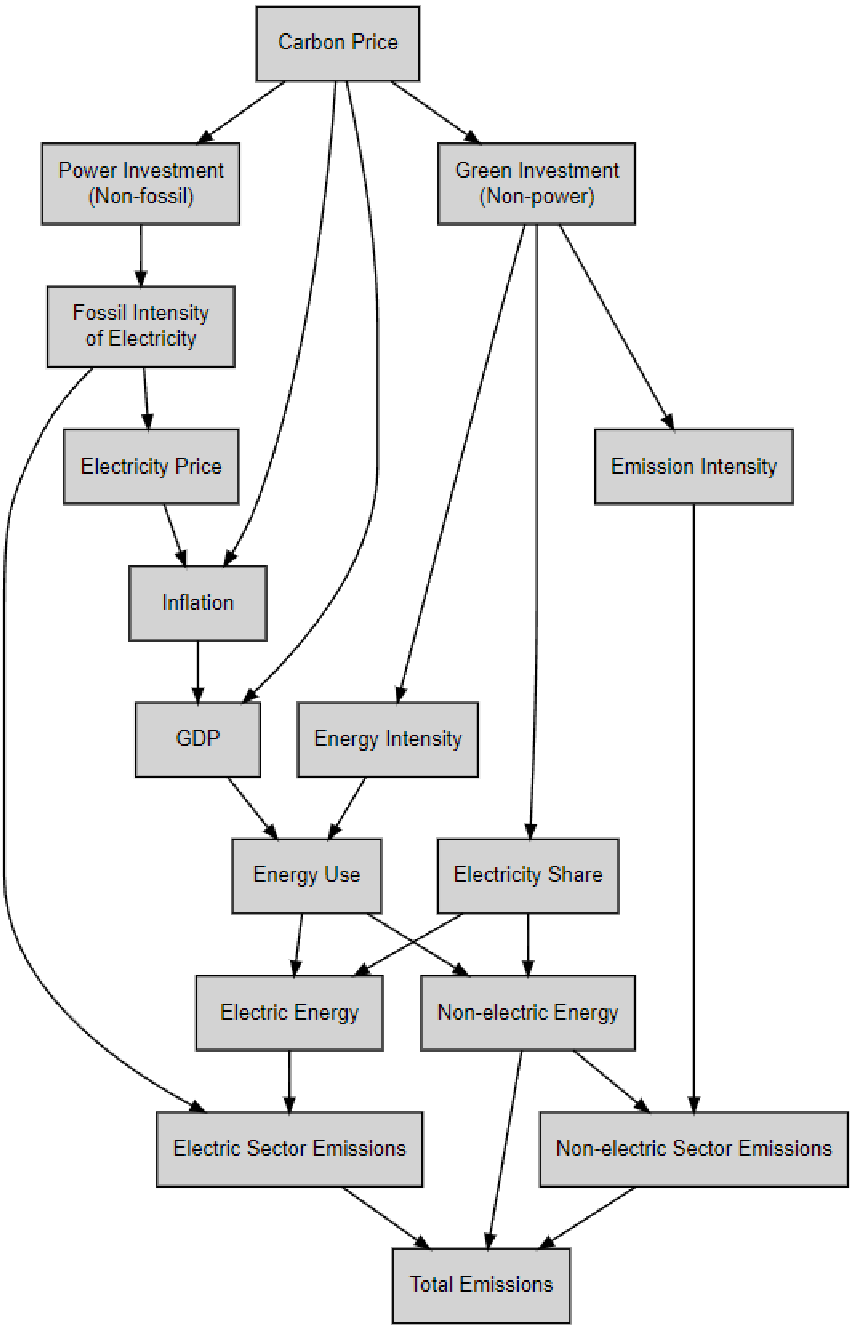


Figure 2: Carbon pricing channels within the model

4.2 Non-fossil Fuel Subsidy Channels

The key impacts of the implementation of a non-fossil power subsidy are shown in Figure 3. In the first instance, the subsidy increases the income of the power sector; however, the subsidy is conditional on the sector carrying out non-fossil power investment and so is channelled directly into this investment activity. However, it is assumed that a portion of the planned non-fossil power investment that would have been carried out by the power sector in the absence of the subsidy is now instead covered by the subsidy. Crucially, this means that the subsidy does not increase non-fossil fuel investment directly by the subsidy amount, although in the scenarios the increase is still substantial. This also means that the subsidy increases the net-lending position of the power sector, as the sector now does not need to self fund as much of its investment activity. This increases the net worth of the power sector, which further increases income through increasing the income that the sector derives from financial stocks.

Greater power sector income also increases power sector creditworthiness, by reducing the debt-service ratio of the power sector (Eq. (130) which leads to lower credit rationing in Eq. (131). Lower credit rationing further supports power sector investment by making it easier for these firms to access credit in order to support their investments. This further increases power investment in non-fossil fuel capital, creating a positive financial feedback loop.

Greater power investment in non-fossil fuels, as in the Carbon Price scenario, will directly reduce electricity-based emissions. It will also lower the price of electricity due to the lower marginal cost of non-fossil fuel electricity, and this latter effect is likely to be considerably larger in this case due to the direct nature of this policy in targeting the power sector. A lower electricity price will also increase green non-power investments, with NFC green investment being increased by the lower relative cost of electrical energy Eq. (161) and households also respond to lower electricity prices by investing more in green home improvements through Eq. (323).

However, there is an important feedback loop around electricity prices. Although the subsidy supports the income of the power sector, the lower price of electricity has the opposite effect. With lower marginal-cost electricity production, the power sector receives increasingly lower income from selling electricity. This is a result of the cannibalisation effect (Peña et al. 2022), where a non-fossil fuel transition reduces the income of the firms selling power. This negative feedback effect will constrain future non-fossil investment in the model by reducing the income of the power sector and reducing the sectors credit-worthiness.

In terms of the policies impact on overall economic activity and GDP, this is now expected to be broadly positive. Unlike the carbon tax, which reallocated investment from conventional to green activity, the subsidy is expected to increase power sector investment, which will directly increase GDP. Furthermore, lower electricity prices reduce costs in the rest of the economy, reducing inflation and further supporting economic activity. There is a feedback loop here as well, with higher economic activity increasing inflationary pressures such that in the long run this could balance out. However, in the short run the expectation is that this would be an economically expansionary policy. Again, although not shown in the figure, this policy is funded by the government sector and will, at least in the short run, reduce the governments net-lending position and can be considered as a fiscal expansionary policy.

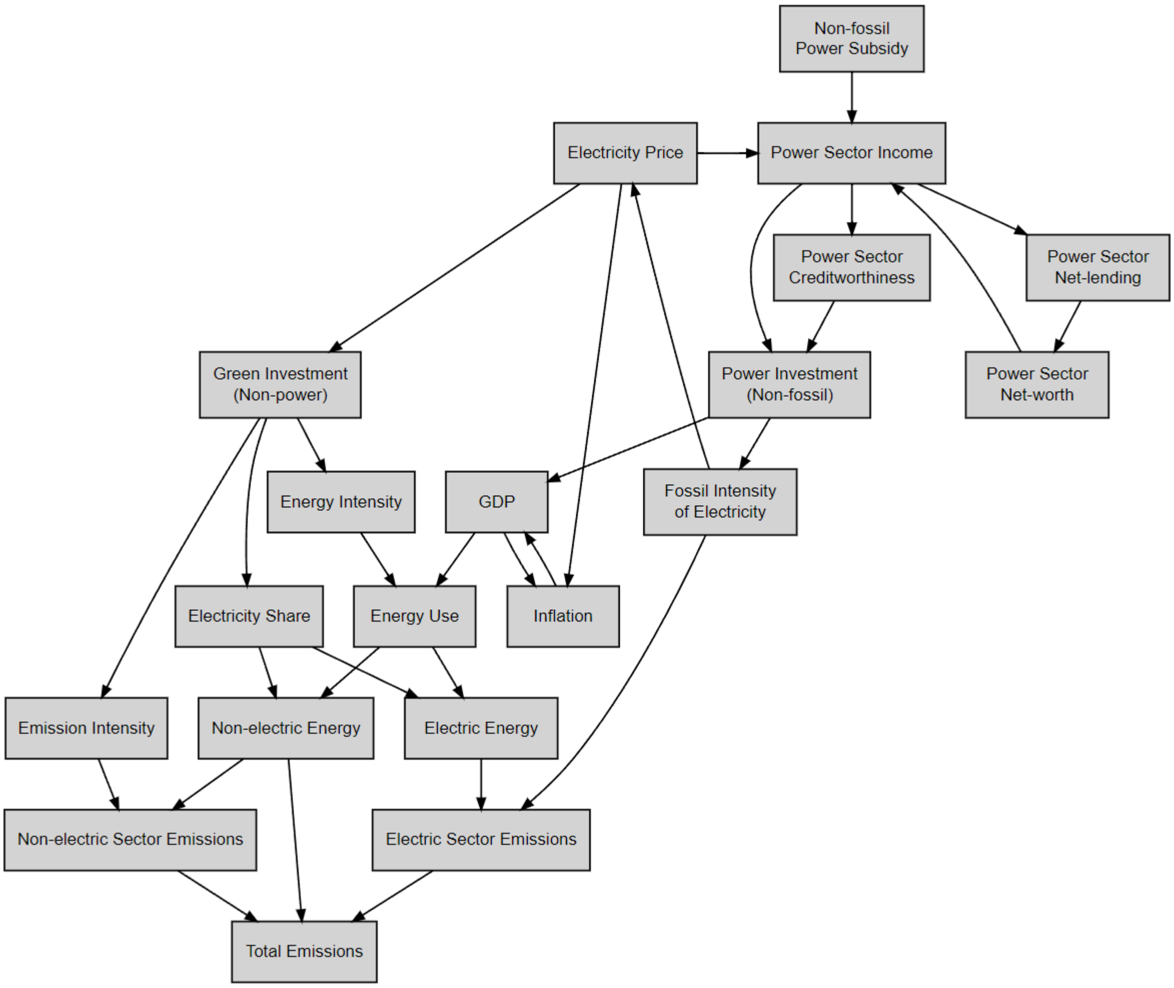


Figure 3: Non-fossil fuel channels within the model

4.3 Green Housing Subsidy

The key impacts of the implementation of a green housing subsidy are shown in Figure 4. As with the power sector subsidy, the green subsidy is received as sectoral income of households; however, this income is not accessible and must be spent on household green home improvements. In terms of whether the subsidy increases or decreases the household sectors own spending on green home improvements, there are two competing effects. On the one hand, the reduced costs of green home improvements are likely to incentivise some households who would not have been able to undertake these improvements to do so now. On the other hand, the subsidy will be used to cover some of the spending on green home improvements that certain households would have carried out anyway without the subsidy being in place. For the initial projections, it is assumed that the overall effect is neutral in terms of household spending, that is, households spend the same on green home improvements when the subsidy is in place. As the subsidy effectively reduces the cost of green home improvements for households, this leads to an increase in total green home improvement spending, the remainder being covered by the subsidy. Therefore, unlike for the power sector subsidy, there is no immediate positive impact on households net lending position.

An increase in green home improvements leads to a greater number of efficient and electric houses within the overall housing stock through Eqs. (351 - 353). Greater efficient, housing stock serves to reduce household energy intensity, while an increase in the number of fully electric houses increases households electricity share. Household energy use falls leading to a reduction in the non-electric energy use of households, the impact on electric energy is less certain as the rise in the electricity share increases household electric energy demand while efficiency gains serve to reduce it. This means that it is possible for household electric emissions to increase in this scenario, particularly if the power sector still uses considerable fossil-based electricity generation. Nevertheless, as the electricity system is generally less emission intensive than non-electric household energy, the expectation is that the net impact of home improvements is a reduction in total emissions.

The subsidy would also have a modest impact on economic activity. The increase in overall household home improvements leads to a rise in household gross capital formation and thus directly increases GDP. In addition, the reduction in the energy intensity of houses and increase in the electricity share reduce the cost of energy for households and reduce the amount that households need to spend on their energy. This increases households post-energy disposable income and means that they have more income available for other spending such as household consumption and investment. As GDP is a measure of monetary flows, this latter effect does not increase GDP as it is mostly a reallocation of household consumption from energy spending to other spending; however, in terms of households satisfying their needs, they are effectively receiving the same energy while enjoying a greater degree of other consumption. The muted impact on GDP in this scenario highlights the issue of using GDP as a proxy for general welfare when, in reality, it is only a measure of a part of the marketable output of the economy (Aitken 2019).

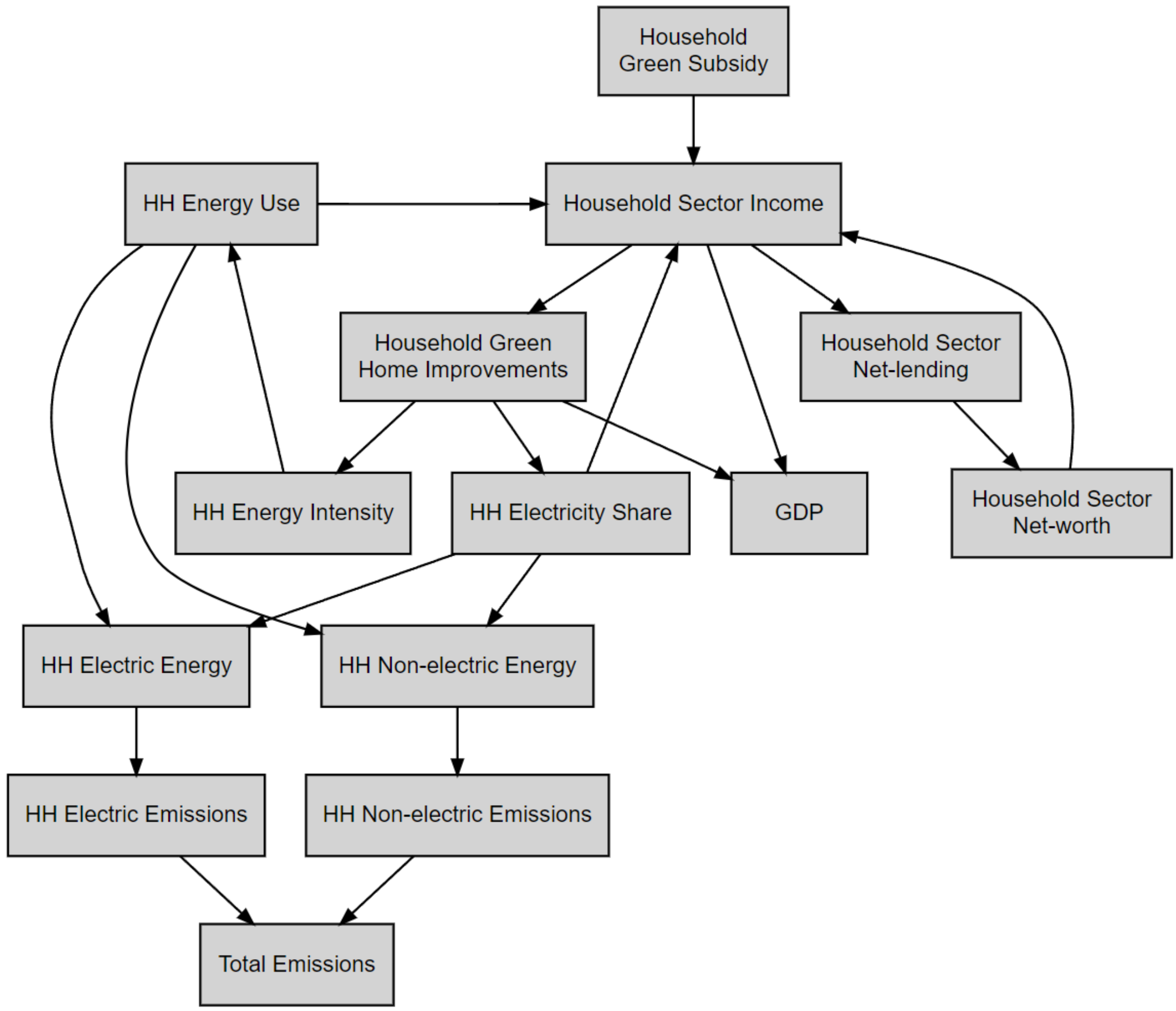


Figure 4: Green Housing Subsidy channels within the model

4.4 Price Channels

The key internal channels related to economy-wide prices are presented in Figure 5. In this figure, green arrows describe an increasing effect and red arrows describe a decreasing effect. Price inflation will have a positive impact on nominal wages due to a direct increase in nominal GDP, and total wages being set to tend to a portion of the nominal GDP in Eq. (52). As wages are a cost to the production process, this increases the nominal costs of the production module. Nominal costs are also impacted by a variety of other input costs, such as imports, energy costs, and indirect taxation as described in Eq. (48). On the other hand, inflation, at least in the short term, leads to a fall in real wages as the wage-setting process is dynamic and when prices rise, wages will not immediately adjust to the higher price level. Price inflation also increases interest rates through the central banks' Taylor rule in Eq. (382) which propagates through to other interest rates through Eq. (383-386). Both real wages falling and higher interest rates will have a negative impact on real output, which is demand-led, as household consumption falls due to lower income from wages, and many other sectors are impacted by higher borrowing costs, reducing both income and the availability of credit for investment. Lower real output will reduce the level of employment in Eq. (33) which in turn leads to lower wages as workers' bargaining power is reduced, leading to a further negative impact on real output. A fall in real output also reduces the utilisation of capital within the model.

As the equation for price inflation is a mark-up on unit costs in Eq. (49) the increase in nominal costs will have a positive impact on inflation, while the fall in real output will have a negative one. Furthermore, as the mark-up is driven by the level of capacity utilisation, a fall in the utilisation of capital results in further deflationary effects. Therefore, the model does have a form of wage price spiral, as shown by the interaction between nominal wages and inflation. However, this spiral is dampened by the impacts of inflation on demand, both directly through real wages and indirectly through interest rates. The wage price spiral is emphasised as a key driver of inflation in the new Keynesian macroeconomic literature, such as for the new Keynesian model of Bernanke and Blanchard (2025). However, unlike Bernanke and Blanchard (2025), wage bargaining is based on actual current prices rather than inflation expectations[6] and the ability for workers to demand higher wages through bargaining is constrained with it taking time for workers to be able to increase their wages to match inflation. The inclusion of post-Keynesian insights relating to the impact of the utilisation of capital on mark-ups serves to further dampen the wage price spiral within the model. This is more consistent with the criticism of Bernanke and Blanchard (2025) presented by Storm (2024) and results in the impacts of the tightening of the labour market on prices being considerably smaller than in the new Keynesian literature. Instead, other variables that affect the costs of production, such as imports, energy prices, and levels of production taxation, play a greater role.

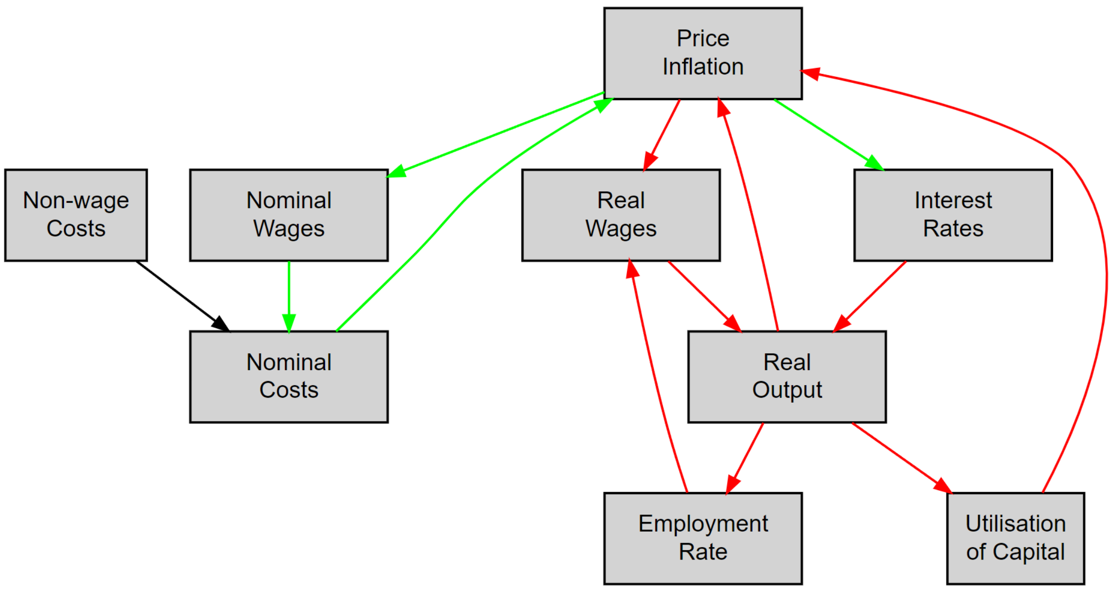


Figure 5: Price Channels within the model

[6]This is more in line with recent empirical literature on inflation expectations being based on past and current inflation levels (Rudd 2022; Fair 2022).

4.5 Fiscal Channels

All the policies being analysed here are fiscal policies and are either expansionary in the case of government subsidies or contractionary in the case of carbon taxes. The impacts of a general reduction in government spending are shown in Figure 6. The impacts of increasing spending would be the opposite of this. Reduction in government spending leads to an immediate fall in GDP, as government spending is a part of total demand in the economy, while increasing net-government income through lower expenditure. A fall in GDP, as already discussed, leads to a fall in the employment rate. It also reduces most forms of government taxation, reducing indirect taxes on production directly through lower output in Eq. (247) and indirectly through falling GDP, depressing wages, and therefore also reducing income taxes in Eqs. (254 & 255). The higher unemployment rate also leads to the government increasing social benefit spending, which includes out-of-work benefits, through Eq. (262). Higher social benefit spending and lower tax revenue both reduce net-government income with the overall impact of the policy on this variable depending on whether the reduction in spending is greater than the reduction in income. The change in net income impacts the government debt levels which combined with the reduction in GDP lead to changes in the government debt to GDP ratio, the primary variable of interest when assessing the sustainability of government debt. Therefore. depending on how large the reduction in GDP is, it is possible that even if the policy reduces overall government debt, it may increase the debt-GDP ratio.

This is in line with post-Keynesian analysis, such as Botta (2020), where it is highlighted that spending reduction (austerity) policies can be self-defeating in terms of improving the government debt-GDP ratio. This is broadly consistent with the experience within the UK where austerity policies in the aftermath of the global financial crisis were unable to reduce the debt-GDP ratio of the UK, which remained elevated until the Covid-19 crisis, where they once again increased.[7]. This is not to say that the model will always generate this paradoxical effect, as this will depend on the state of the model when policies are implemented.[8] This description of fiscal channels mainly serves to demonstrate that there are multiple interacting processes and feedback effects such that the impact of fiscal policies may not always be easy to predict.

[7]Not to mention that these same austerity policies in the UK had broad reaching negative socio-economic impacts, such as increasing inequalities (Nunn 2016) and worsening health outcomes (Stuckler et al. 2017)

[8]For example expansionary policies tend to be more effective when resources in the economy are relatively under-utilised in line with the classic argument of Keynes (1937)

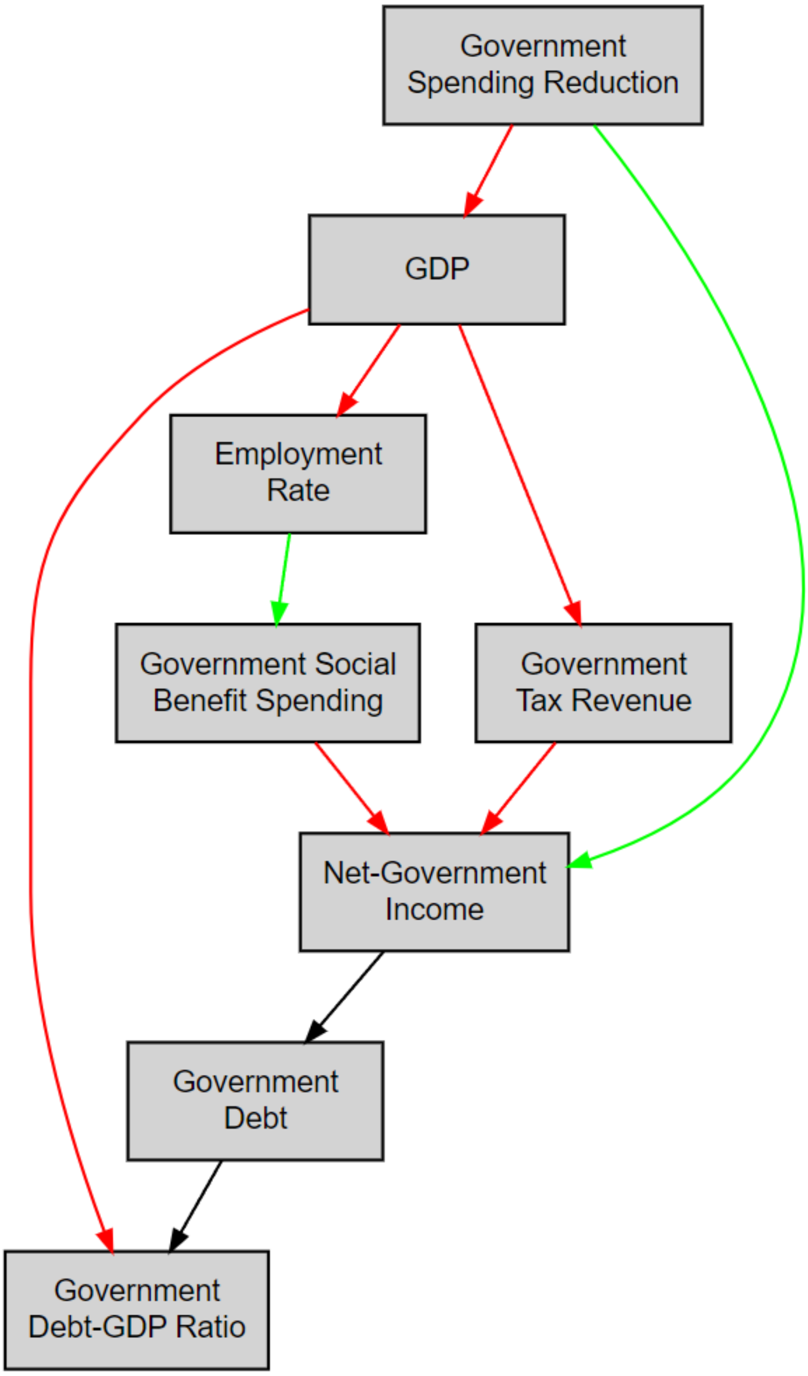


Figure 6: Government Spending Reduction Channels

4.6 Credit-Investment Feedback Channels

Finally, the key interactions between credit, income, and the investment of firms are shown in Figure 7. These channels are broadly similar for general non-financial corporations and firms in the power sector except around the drivers of prices. The income of firms impacts the numerator of firms' debt-service ratio Eqs. (199 & 130) such that a higher firm income leads to greater availability of credit with which forms can carry out investment (capital formation) as in Eq. (160). The amount of loans taken out by firms to cover this investment is driven by the amount of investment that occurs along with firm net income; if firms' income is higher, then they are able to fund more investment from retained profits rather than loans. The taking out of loans increases the interest paid on loans, impacting the denominator of the debt-service ratio and increasing the rate of credit rationing. This is a key financial stabiliser in the model, if firms invest heavily by taking out credit, while their incomes do not expand sufficiently, then they become less credit worthy, and it becomes more difficult for them to raise credit for future investments.

Capital formation has a direct impact on GDP, and it is a component of final demand. The formation of capital, all else equal, also reduces capital utilisation by increasing the total stock of capital. Rising GDP, on the other hand, increases capital utilisation from the demand side. This small system also acts as a stabilising force in the model. If investment occurs without sufficient increase in GDP, then the utilisation of firm capital reduces and firms are less incentivised to carry out additional investment; in this way investment responds to the demand environment within the economy.

Changes in capital utilisation also impact prices,[9] with higher utilisation leading to price increases. Higher prices increase the net income of firms and have a positive impact on firms' ability to borrow to invest. On the other hand, higher prices lead to an increase in the interest rate on loans due to the central bank responding by increasing the base interest rate, thus constraining investment. Furthermore, as described in the price channel section, higher prices will tend to reduce real GDP. As can be seen, this system has a high level of interdependencies and multiple channels acting in opposition to each other. However, it is crucial in determining the degree of private investment that is necessary in many scenarios to achieve environmental transition goals.

[9]This is not the case for the power sector where prices are set based on marginal costs.

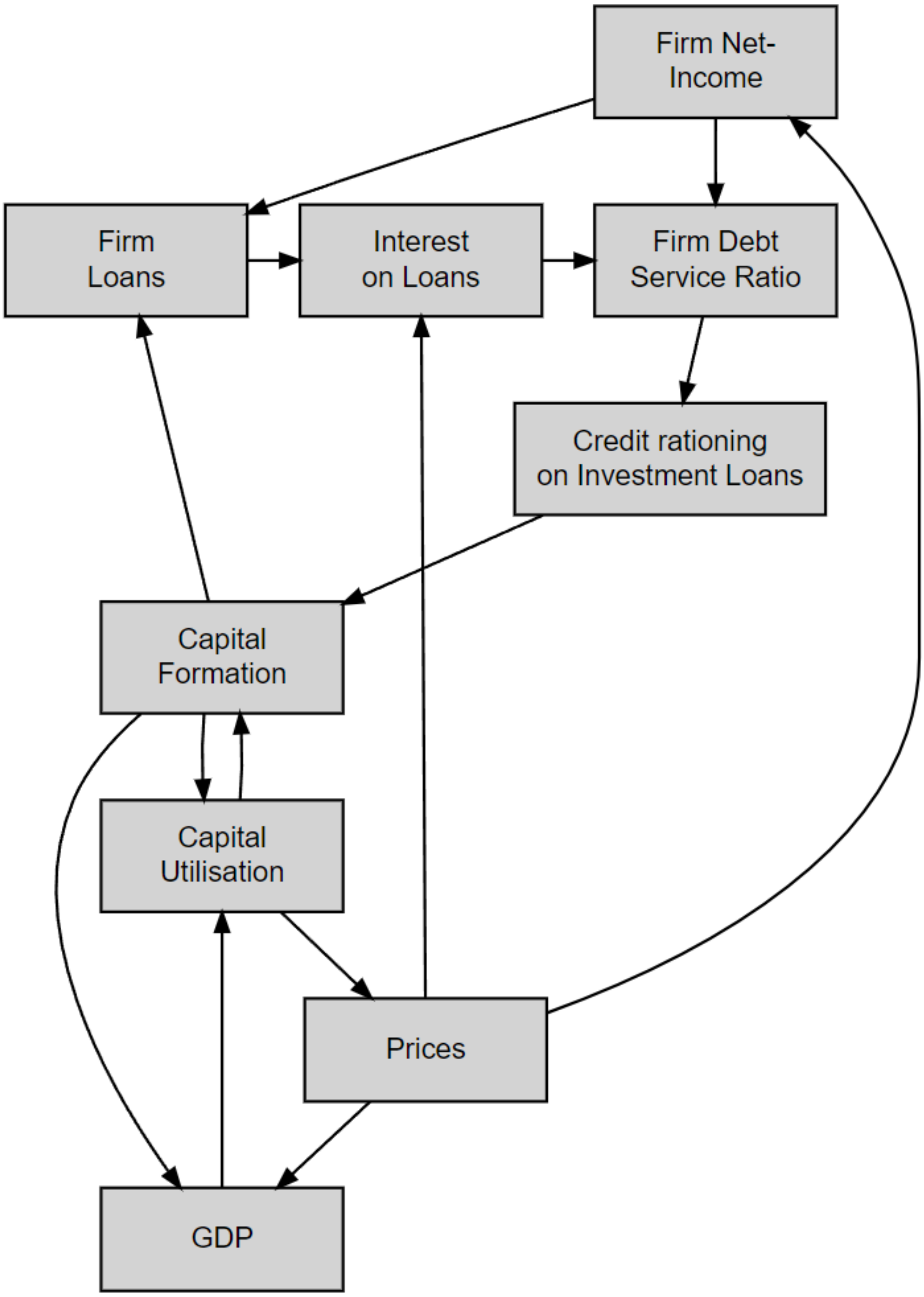


Figure 7: Investment-Credit Channels

5 Scenario analysis

5.1 Green fiscal policy scenarios

The model will be run under several different green policy scenarios in order to assess the environmental and macroeconomic outcomes of a variety of different policy approaches. The focus in this paper will be on fiscal policies. Additionally, we choose to focus primarily on fiscal policy approaches which are already somewhat in place in the UK, and analyse the impacts of strengthening said policies.

The fiscal policy scenarios that will be assessed are the following; all policies are implemented in 2026 Q1:

- **Carbon Tax Increase:** The tax on emissions is increased initially from around £10/$MTCO_{2e}$

to £30/$MTCO_{2e}$ and then steadily increases to almost £200 /$MTCO_{2e}$ by 2035. In this scenario, the coverage of the emission price is also increased, so a greater proportion of emissions are covered by the carbon price. The carbon price must be paid by the emitting firms and provided revenue for the government sector.

- **Green Power Subsidy:** The government increases the scale of its "Great British Energy" power sector subsidy from £8.3 bn to £50 bn over the next parliament (until 2030). It is assumed that this subsidy remains in place until the end of the simulations or until the power sector fully transitions to non-fossil fuel power generation.
- **Housing Subsidy:** The government provides subsidies to households for green home improvements reducing the cost of energy efficiency and electrification improvements by 40% and this is then paid for by the government sector.
- **Combined Scenario:** All above policies are run simultaneously.

These scenarios capture a range of quite different green fiscal policy approaches, which allow the model to consider the differentiated impacts that different policy packages could have and the potential trade-offs between them. The combined scenario further allows the model to explore the complementarities between policies and explore how they might interact with each other.

Full results for the 5 scenarios: Baseline, Carbon Price Increase, Green Power Subsidy and all policies together are presented in Figure 8. Starting with the direct environmental impact of policies, Figure 8a shows the increase in emission pricing in various scenarios, the emission price increases only in the carbon price and all policy scenarios. Figures 8b, 8c, and 8d show, respectively, the proportion of green non-power capital investment, green power capital investment, and green home improvement investment. The carbon price increase has a significant impact on general green non-power investment, although it's effect appears to diminish over time, even as the carbon tax continues to rise. The higher emission price also has a moderate impact on green energy investment, although it has almost no impact on green home improvement investment. The proportion of green power investment increases in 2026 in the baseline due to the establishment of Great British Energy. For the green public investment scenario, this increase is considerably greater. For both the green power subsidy and all policy scenario, green power investment becomes entirely non-fossil fuel based by the end of the projections. An increase in green power investment also has a positive behavioural impact on both green non-power and green home improvement investment, predominantly through lower electricity prices. Finally, the proportion of investments in green home improvements is significantly increased by the green housing subsidy; however, this increase does not have a major impact on the other forms of green investment.

Figure 8e shows the mix of non-fossil energy in electricity production. In the baseline, the grid becomes increasingly non-fossil based; however, the pace of transition slows and the electricity grid ends up at around 75% non-fossil generation by the end of the period. The green power subsidy, by significantly increasing green power investment, results in a non-fossil transition by the end of 2032 when applied alone and slightly earlier in 2031 when all policies are applied simultaneously. Once the non-fossil power transition is achieved, the government stops subsidising power sector investment and the impact on other forms of investment stagnates as seen in figures Figures 8b and 8d.

The impact on total greenhouse gas emissions is shown in Figure 8f. None of the individual scenarios achieve the UK's target by 2035. Even when all policies are applied together, the targets are not met.[10] This may reflect that targeted policies may be required in other areas, such as transport, which are not included in these scenarios, or that broader policy approaches beyond fiscal policies should be considered. The greatest emission reduction is achieved by the green power subsidy, followed by the increase in carbon prices, and finally by the green housing subsidy. The energy use across the economy, under the different scenarios, is shown in 8g. The trajectory of this variable is similar to that of emissions, which is understandable given that these variables are strongly linked within the model. However, there are some key differences, in that while the power sector subsidy reduces emissions the

[10] A reduction in emissions of 81% in the model would imply total emissions need to fall to 155MtCo2e, all policies result in emissions reducing to 189MtCo2e

most of each individual policy, it reduces energy use the least, with the carbon tax being more effective here. Although by the end of the simulation the reduction in energy is similar for all policies. This again highlights the indirect impacts of the power sector subsidy; by reducing electricity prices, this policy has a behavioural impact on other green investment decisions; however, this takes time to be achieved, whereas the carbon price increase has a more immediate behavioural effect.

The real GDP levels are shown in Figure 8h. Increasing carbon prices on their own are contractionary, as seen in other post-Keynesian environmental and ecological models (Dafermos and Nikolaidi 2019; An 2024). These taxes reflect a direct increase in costs for firms and households, and are therefore likely to constrain output. The reduction in GDP, in the carbon price scenario, has a positive impact on environmental variables by reducing energy use. In fact, around 60% of the reduction in energy use from a carbon tax is due to the negative impact this policy has on economic activity, while the remaining 40% are due to green investments carried out due to the change in relative energy costs. The green power subsidy is, on the other hand, expansionary when applied in isolation. Again, this is to be expected as this policy leads to a direct increase in power sector investments. The increase in GDP in this scenario is further supported by positive spillover effects from power sector investment, such as increasing average labour productivity and reducing electricity prices and thus reducing costs for other sectors in the economy. However, this expansion does lead to environmental rebound effects, where an expansion of economic activity leads to greater energy use and some forms of emissions. The green housing subsidy is, on the other hand, fairly neutral in terms of overall GDP, only resulting in a very marginal increase in economic activity. This is due to the gross investment numbers being fairly marginal in the housing case and also a lack of the same spillover effects seen in the case of investment within the power sector. When all policies are applied together, initially there is a small increase in GDP; however, once the behavioural impacts of the carbon price kick in, this turns negative, finally increasing towards the end of the projection period and ending up with slightly lower GDP than the baseline scenario. There are several interactions that occur when all policies are run together. Firstly, investment within the power sector is partly counteracting the contractionary effects of the increase in the carbon price. Furthermore, the reduction in emissions from other policies reduces the costs resulting from the carbon price, with the total receipts from the carbon price scheme being approximately 40% higher at the end of the projections for the government in the scenario of the pure carbon price compared to the scenario with all policies. This highlights that there are some key interactions between the policies, and some undesirable policy outcomes can be addressed when policies are implemented together.

Two key components of GDP, total consumption and total investment, are shown in Figures 8i & 8j. The expansionary power subsidy increases investment directly and also has a positive impact on overall consumption. Notice that overall investment falls at the end of the period due to the non-fossil power transition being achieved, and hence the subsidy no longer being provided. The rise in carbon prices reduces both consumption and investment, and the negative impact on total investment also impacts green investment in this scenario, so that while the proportion of green investment increases (Figures 8b) this is counteracted by falling overall investment levels such that the gross real investment in green capital in the carbon price increase scenario is only marginally higher than the baseline. The increase in carbon price has a neutral impact on consumption, as while household energy consumption falls and this counteracts the increase in other forms of consumption, although as highlighted in Section 4, from a wellbeing perspective, households are receiving the same electrical energy while simply paying less for it. In the all policy scenario, total investment is more or less maintained, due to the expansionary fiscal policies counteracting the contractionary impacts from the carbon price rise. On the other hand, under "all policies", total consumption still falls below the baseline, recovering slightly toward the end of the period.

The impact on overall price inflation (CPI) is shown in Figure 8k and the corresponding increase in the Bank of England base rate is shown in Figure 8 l. Initially, CPI inflation is high, due to higher inflation in the post Covid-19 period, although this falls in the baseline to slightly higher than 2% inflation for most of the period. The most notable impact of scenarios occurs in scenarios with increased carbon prices. These cause an immediate and pronounced spike in the inflation rate followed by a corresponding increase in the base rate. This is because the higher operating costs of firms are mostly passed through to prices. As described in Section 4, higher inflation and interest rates will have a negative impact on economic activity and this is another key reason for the contractionary impacts of the carbon price increase scenario. Although initially the spike in inflation is controlled through contractionary policies, towards the end of the scenario inflation begins to rise again in the carbon price increase scenario, as the rise in carbon prices, without sufficient decarbonisation, leads to a significant rise in the costs of production. The green power subsidy is initially slightly inflationary due to the rise in demand; however, rapidly becomes deflationary due to the impact of electricity prices which reduce overall costs (electricity itself being an input into production). When all policies are applied together, the initial inflation spike is even more severe; however, this is partially balanced out by lower prices in the electricity market leading to only modestly higher price inflation, compared to be baseline, by the end of the scenario period. In all cases, the Bank of England increases interest rates in response to rises in inflation, although the dynamics of interest rates is smoother than inflation reflecting rigidities in the central banks' decision-making process.

The impact on the public debt-GDP ratio is shown in Figure 8m. Initially, most policy scenarios cause an initial fall in the Debt-GDP ratio; however, this rises later in the projects, leading to all policies resulting in a slightly higher Debt-GDP position compared to the baseline. Perhaps counter-intuitively, the increase in carbon prices does not lead to a long-term improvement in the debt-GDP ratio. This is due to fiscal channels described in Section 4, where the negative impact on GDP and other forms of government income is greater than the increased revenue from the policy itself. The all-policy scenario leads to the greatest increase in the debt-GDP ratio due to multiple fiscal spending increases and the contraction in GDP from the carbon tax.

Changes in the unemployment rate are shown in Figure 8n. Policies where carbon prices are increased have the largest negative impact on unemployment, due to their negative impact on overall output in the economy. The power sector subsidy minorly reduces long-run unemployment, with this effect being reduced in scale due to the positive impact of higher overall investment on productivity, with higher productivity, all else equal, leading to higher unemployment, due to how employment in derived in Eq. (33). The all policy scenario leads to an initial rise in unemployment but this is reduced by the end of the period to be only marginally higher than the baseline unemployment projection.

Figures 8o and 8p show the default rate and credit rationing rate for non-financial corporations (private non-financial firms excluding the power sector). These figures show the financial feedback effects of certain policies. The largest financial impacts come from the increase in carbon prices, where defaults are increased compared to the baseline initially, and the credit rationing rate rises. The increase in credit rationing will further constrain firms investment on top of the other negative effects that have already been covered in relation to carbon pricing. However, the green power subsidy reduces credit rationing marginally compared to the baseline, which will lead to additional investment on top of the investment activity already supported by the subsidy. Toward the end of the period, NFC default rates reduce compared to the baseline for the carbon price scenarios; this is mainly driven by the lower access to credit, reducing the stock of NFC loans, and thus lowering their interest payments and illiquidity ratio in Eq. (198) thus reducing the defaults in Eq. (179).

Figures 8q and 8r show the default rate and the credit rationing rate for the power sector. These figures show the financial feedback loops specifically for the power sector. The largest impacts here come from the green power subsidy, where this significantly reduces both the default rate and credit rationing compared to the baseline projections. However, once a full transition is achieved the power sector default rate increases significantly, this is due to a sudden fall in the liquidity of the sector, which up to that point has been receiving a significant portion of income from the subsidy. Furthermore, due to the lower electricity prices resulting from a non-fossil fuel power transition, the income of the power sector is reduced in these scenarios, which is what leads to the higher default rate and rising credit rationing rates at the end of the projection period. In fact, this impact of lower electricity prices plays out, to a lesser or greater degree, in every scenario, including the baseline. The lower marginal cost of electricity production from the move to greater non-fossil fuel electricity generation, leads to lower income and a lower debt service ratio (Eq. (130) resulting in an increase to power sector credit rationing (Eq. (131) during the simulation period. Perhaps unexpectedly, the carbon price increase reduces both the power sector default rates and power sector credit rationing. This is because the carbon price increases the marginal cost of fossil fuel electricity production which is the driver of overall electricity prices in the UK. This increases the electricity price and makes all forms of electricity production (fossil and non-fossil) more profitable. This benefits the power sector, with the biggest winners being non-fossil fuel electricity generation firms, who will be able to increase their income with no impact on their costs.

5.2 Discussion

The results highlight several interesting impacts and feedback effects from the green fiscal policies scenarios. A summary of the main results and trade-offs is provided in Table 5. Firstly, the model highlights several macroeconomic feedback effects. In particular, the macroeconomic rebound effect (as described in Barker et al. (2009)) is present in the model, where policies that reduce energy costs and/or increase disposable income lead to higher demand and energy use throughout the economy. Although the net impact on emissions may still be negative, such rebound effects will reduce the effectiveness of certain policies. This is particularly true for the expansionary green power subsidy, where greater economic activity occurs along with lower electricity costs. The reverse effect is seen for carbon prices, where the policy reduces incomes and constrains economic activity. In terms of emission reduction, this leads to the so-called "double dividend", as in Li et al. (2022), where higher carbon prices reduce sectoral output and energy use beyond the initial impact of the carbon price itself. Of course, the carbon tax also constrains firms investments including in green capital, so even the second-order effects are somewhat mixed. This highlights the importance of macroeconomic feedback effects when analysing the impacts of climate policy, as outcomes are significantly impacted by these feedback effects.

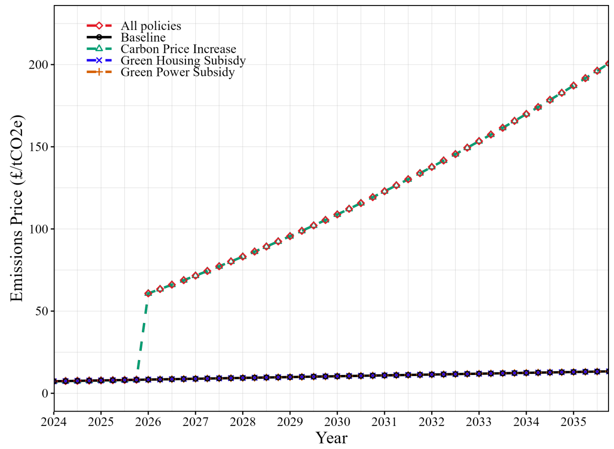
Table 5: Summary of scenario results. *Note*: single and double arrows reflect small and large changes respectively, SR (short run) refers to the period before 2030 and LR (long run) to the period after 2030.

Indicator	Carbon Price		Power Subs		Housing Subs		All Policies	
Time Period	SR	LR	SR	LR	SR	LR	SR	LR
Emissions	↓	↓	↓	↓	↓	↓	↓↓	↓↓
Electricity Share	↑	↑	↑↑	-	-	-	↑↑	-
GDP	↓	↓↓	-	↑	↑	↑	↓	↓
Inflation	↑↑	↑	↑	↓	-	-	↑↑	-
Public debt-GDP	↓	↑	↓	↑	-	↑	↓	↑↑
NFC Defaults	↑	↓	-	↓	-	-	↑	↓
PS Defaults	↓	↓	↓↓	↓↑	-	-	↓↓	↓↑

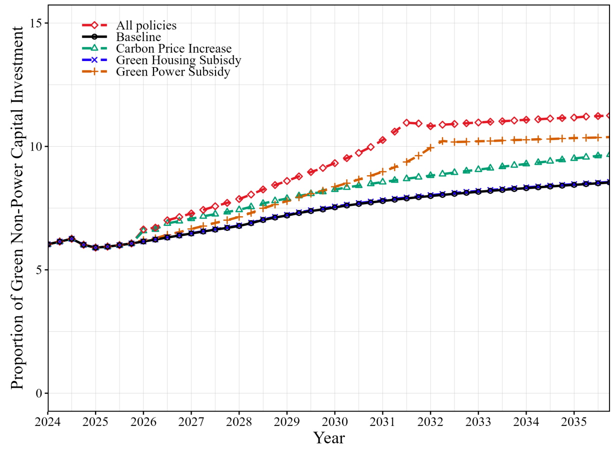
Partially linked to the macroeconomic feedback effects is the role of prices in the model, with price channels being particularly important for the model results. Inflationary pressures exacerbate the negative macroeconomic effects of carbon prices, while price reduction from the fossil fuel subsidy exacerbates the expansionary effects of the subsidy. Recent country level models are increasingly incorporating price dynamics into their analysis. The price impacts of carbon pricing/taxation are consistent with recent modelling results such as the CGE for Japan of Yoshino et al. (2021) and the SFC models for China and Denmark of An (2024) and Thomsen et al. (2025). Following the high inflationary environment of the early 2020s, more models have begun incorporating prices more explicitly in their analysis. These results suggest that prices are indeed important, both as an outcome and as a driver of model behaviour, and that incorporating the price impacts of policies changes the effectiveness of environmental policies.

The impact of financial constraints, both on the power sector and firms in general, also has a material impact on model outcomes. Finance can exacerbate the first-order impacts of policies by increasing credit rationing for NFCs in the scenario of a carbon price rise, leading to a contraction in overall investment. This is in line with the arguments of Dafermos and Nikolaidi (2022) on the role of financial feedback effects and the negative financial impacts of different environmental policy

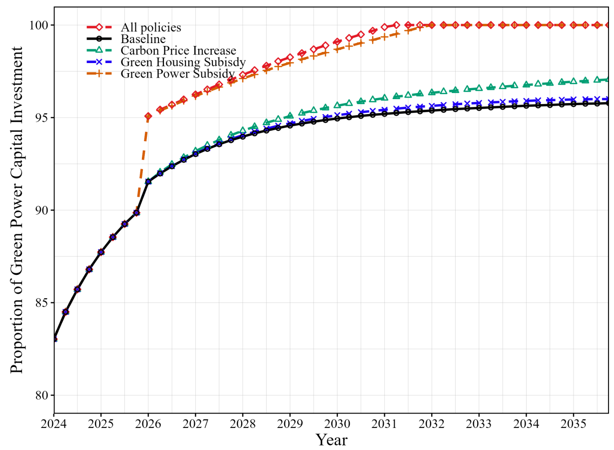
Figure 8: Effects of green fiscal policies on UK macroeconomic, financial and environmental variables



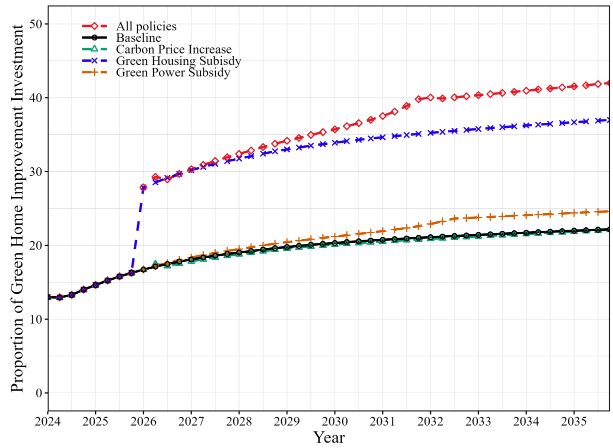
(a) Emission Price



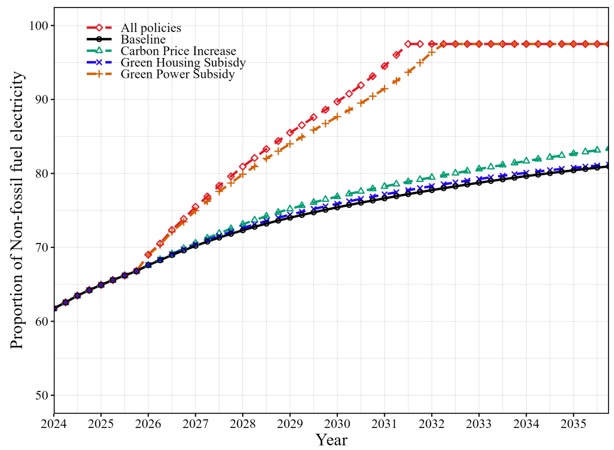
(b) Proportion of Green Non-Power Capital Investment



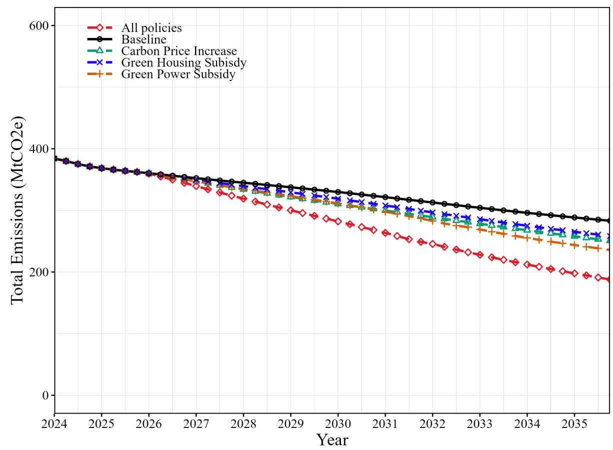
(c) Proportion of Green Power Investment



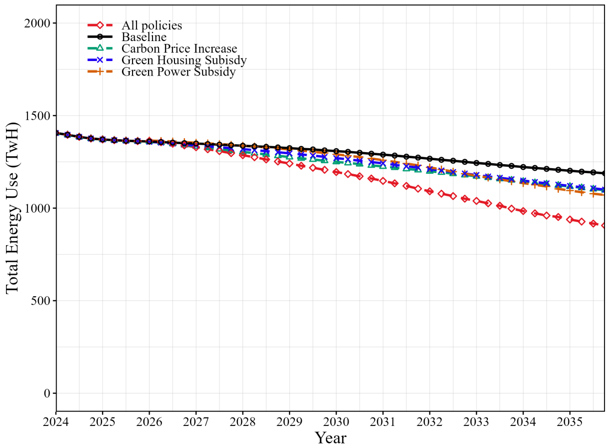
(d) Proportion of Green Home Improvement Investment



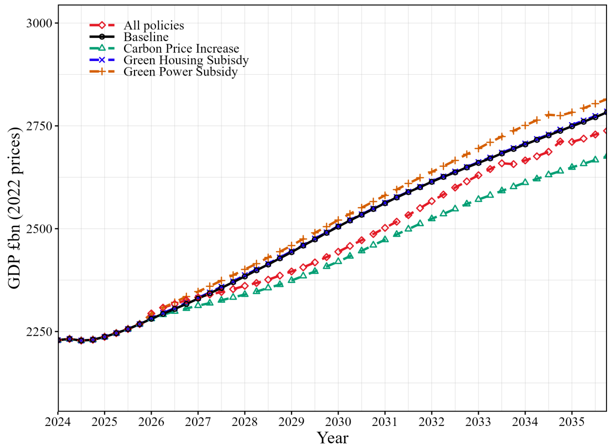
(e) Share of Non-Fossil Electricity Generation



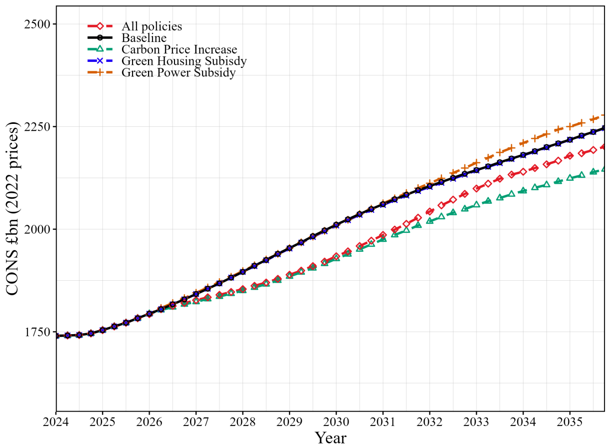
(f) Total Emissions



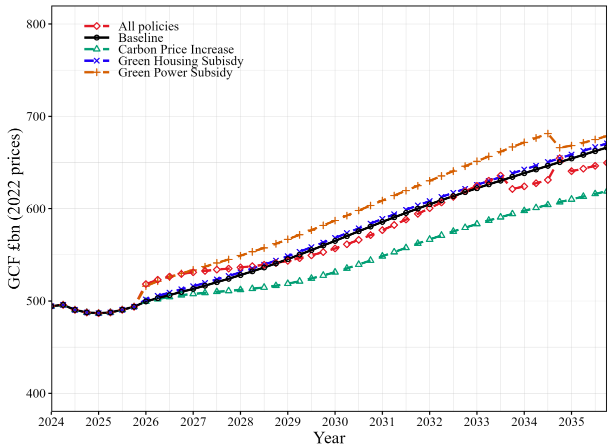
(g) Total Energy Use



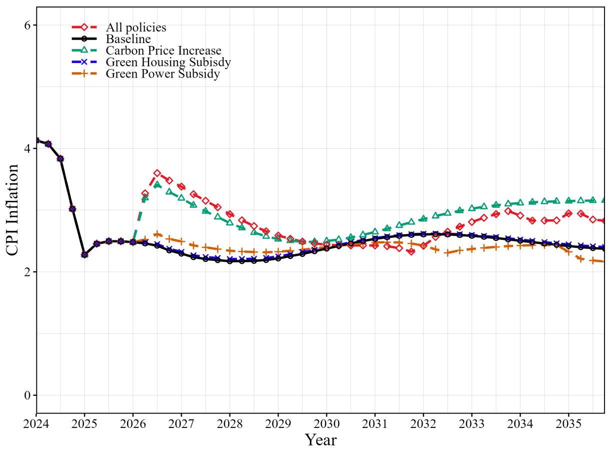
(h) GDP



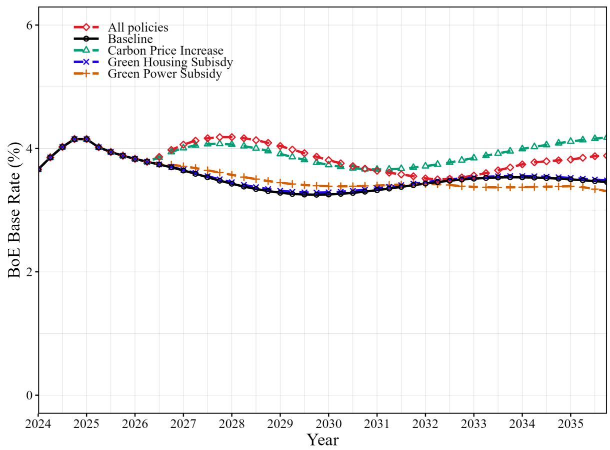
(i) Total Consumption



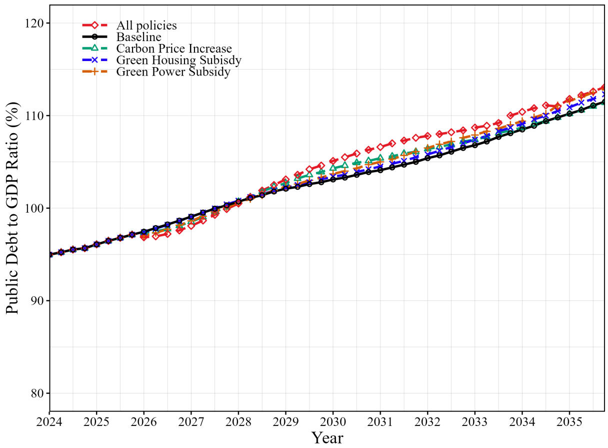
(j) Total Investment



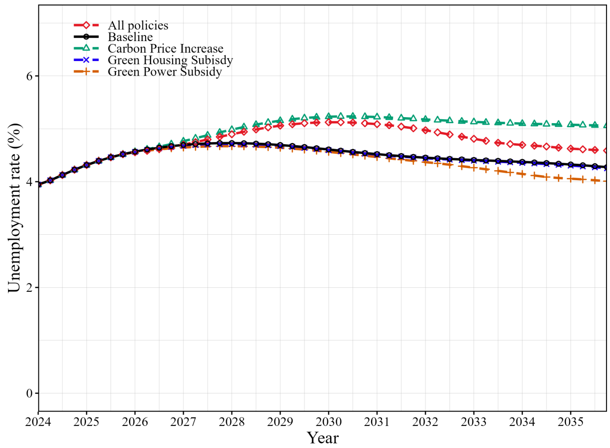
(k) Price Inflation



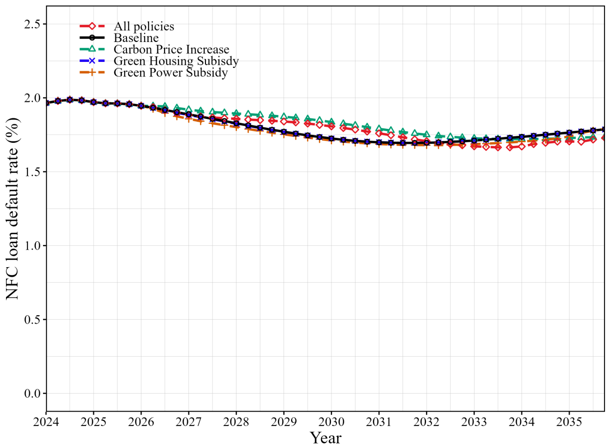
(l) Bank of England Base Rate



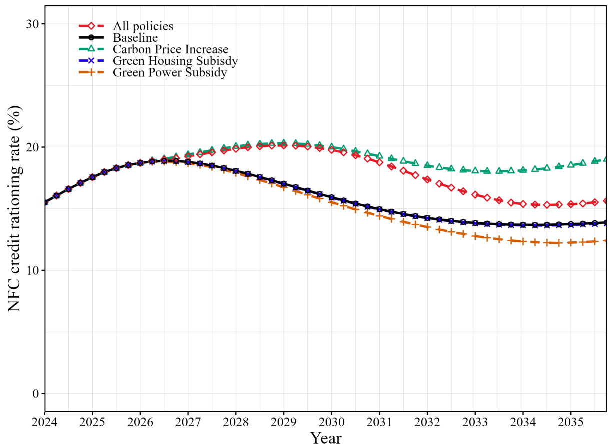
(m) Gross Public Debt-GDP Ratio



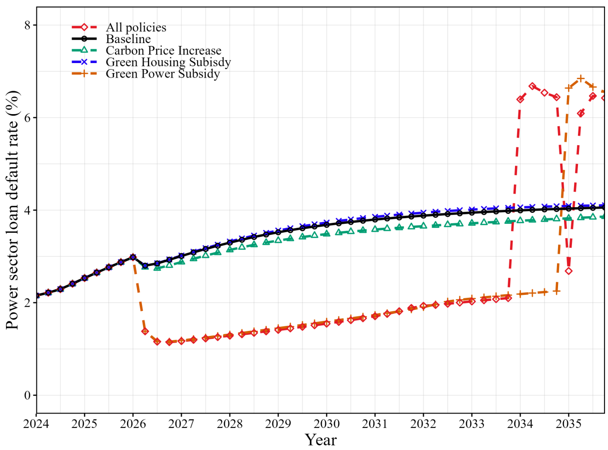
(n) Unemployment Rate



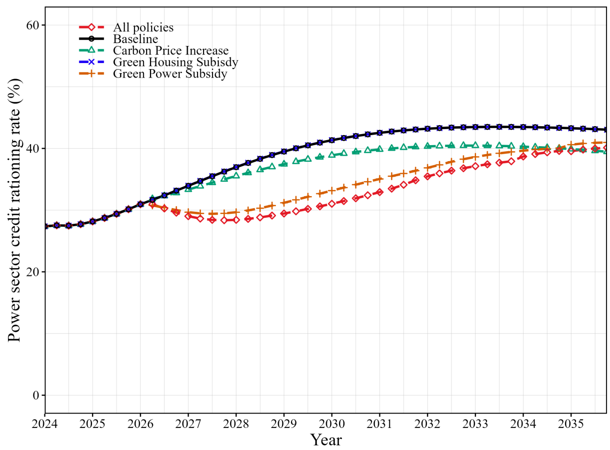
(o) NFC Default Rates



(p) NFC Credit Rationing



(q) PS Default Rates



(r) PS Credit Rationing

approaches. The long-term rise in the credit rationing of the power sector, even at baseline, highlights how finance acts as a constraining force in the model. As electricity prices fall, due to the greater use of non-fossil electricity, financial corporations are less willing to lend to the power sector, expecting that lower sectoral incomes will reduce their capacity to repay their loans, and indeed default rates even in the baseline do rise for the power sector. This result shows how the power sector may require greater guarantees in terms of it's future income in order to finance a transition to non-fossil energy as this constraint is one of the factors which leads to a slow down in non-fossil electricity capital investment within all model scenarios where the power sector is not explicitly subsidised.

When comparing policy scenarios, the spillover effects or lack thereof become evident. This is particularly the case when contrasting the power sector and housing subsidy. Both policies are highly targeted, the first supporting the investment in the power sector and the latter supporting the investment of households in green home improvements. The green power subsidy has many spillover effects already discussed, such as a fall in electricity prices, increasing investment demand, and leading to broader behavioural change across the economy, including increased levels of general green investment. The green housing subsidy, on the other hand, has far fewer spillover effects. This can be broadly explained by the fact that green housing investment is downstream of investment in the power sector. While lower electricity prices act to encourage households to invest in green home improvements, the effect does not play out in the opposite direction. Greater investment in green home improvements can increase the electricity demand of households; however, the electricity can be fossil or non-fossil based and therefore household investment has limited impacts on other forms of green investment in the model. This also explains why the green housing subsidy has fairly neutral effects on many of the variables in Figure 8. This is an observation, rather than a criticism of the green housing subsidy. While it's lack of spillover effects could be seen as a disadvantage there are many reasons to pursue such a policy, such as households being unable to fund improvements themselves along with the positive effect on household wellbeing from lower energy costs and better insulated housing stock.[11]

Looking at the "all policies" scenario, the results show several complementarities and interactions between policies. Both general green investment and household investment in home improvements result in increased electricity use. The degree to which this electrification reduces emissions is directly related to the electrification of the power sector itself. Therefore, the power sector subsidy increases the effectiveness of both other policies in reducing emissions by making electrical energy less emission intensive. Another interaction is between the carbon price and all other policies, as the carbon price is based on total emissions, when other policies are applied alongside the carbon price, the reduction in emissions from these policies reduces the scale of the carbon pricing policy. This mitigates some of the negative long-term impacts of the carbon price, such as high levels of inflation, by reducing the amount sectors need to pay due to their lower emission levels. The carbon price and power subsidy also both effect non-electric and electric energy prices in opposing directions, with the carbon price increasing non-electric energy prices while the subsidy reduces the price of electricity, this has a compounding effect on the behavioural choice of firms looking at green investment and further incentivised firms to make these green investments and electrify their capital stock. The complimentary Being able to model the interactions between policies is a strength of an integrated systems-based modelling approach. The positive interactions between policies highlight that a mix of complementary policies will be necessary to achieve decarbonisation goals and that models need to be designed to analyse multiple policies that interact with each other.

The fiscal policy results are broadly in line with other post-Keynesian models of fiscal policy generally and green fiscal policies, however, there are some differences. The macroeconomic impact of a carbon price is fairly large in the model, as along with increasing the price of emissions, this scenario also broadens the scope of emissions that are subject to carbon pricing. This may explain the strong negative macroeconomic impacts of increasing carbon prices within the model compared to other post-Keynesian models such as D'Alessandro, Dittmer, et al. (2018), where the scope of emissions covered by a carbon price is more limited and the impact of carbon pricing is more marginal. The

[11] It is also likely, provided such a policy was well designed, that it could have a positive distributional impact by supporting the poorest households who are overly represented within low energy efficient houses in the UK. As the model does not include distributional effects, this is not currently captured but is nonetheless relevant to assessing policies.

greater impact of carbon price increases is also driven by the policies impact on prices which are not always explicitly modelled. As in Bovari et al. (2018) and Dafermos and Nikolaidi (2019), the combination of fiscal policies leads to a reduction in emissions; however,our model does not capture the additional macroeconomic benefit of lower environmental damages. This leads to an additional positive macroeconomic effect in these models which is not present in mine and may lead to more pessimistic macroeconomic results.

An important point to highlight is that this system-based analysis does not result in a specific policy recommendation. Unlike the cost-benefit analysis approach and the so-called "policy optimisation models", the model and results presented here do not generate an optimal policy result. All the policies presented thus far feature certain advantages and disadvantages within the model. This is further complicated by the interactions between policies. Furthermore, we believe that what policy is considered optimal is fundamentally a political choice. If, as is the case for many cost-benefit models, one chooses to equate societal wellbeing and GDP output, then certain policies, such as high carbon prices, may be undesirable. However, as has already been discussed here and elsewhere, GDP is not very reflective of general welfare, particularly in a high income country such as the UK. There may be other macroeconomic targets, such as limiting unemployment or inflation, that could be considered more important than GDP. Income and wealth inequality may also be areas of interest, and these are not explicitly explored in the model. Therefore, no specific recommendation of policies is made here; rather, the results should be interpreted as highlighting some potential unintended consequences of certain policies, such as rebound effects or persistent inflation. If there were to be a specific recommendation stemming from these results, it would be that the interdependencies and complementarities between policies should be considered actively when designing fiscal policy mixes and that while there are costs to undertaking climate policies, there are also certain opportunities and potential positive macroeconomic outcomes.

The results highlight some interesting outcomes; however, they are based on certain structures and parametrisations within the model. Carbon prices have a very strong and swift pass through to general prices, and this may be less severe in reality. Households reaction to the housing subsidy is fairly moderate and households may be more (or even less) responsive in reality. Furthermore, electricity prices are allowed to fall rapidly in the power sector, harming the profits of this sector, whereas it might be the case that power sector firms are provided electricity price guarantees to protect their income, and this is already happening in a limited way within the UK. As these results are based on relatively uncertain parameters we have carried out sensitivity analysis, which can be seen in Appendix D. While the sensitivity analysis does show that different configurations can change the effectiveness of policies, the overall policy results are not qualitatively changed.

6 Conclusion

This paper presents a novel empirical E-SFC model for the UK economy that is used to analyse the effectiveness of several green fiscal policies. Using the empirical SFC approach, the paper explicitly takes into account the individual country context when making modelling choices. The model structure is derived directly from UK national accounting data, with those same data then forming the basis for calibrating behavioural equations and integrating ecological factors.

We use the model to conduct a policy scenario analysis until 2035. We analyse three green fiscal policies: a carbon tax policy, green public investment, and a green housing subsidy. The results highlight certain problems when policies are applied in isolation, including the recessionary impacts of a carbon tax and the diminishing returns of green power investment. Many of these problems can be addressed and mitigated against when policies are applied simultaneously, and for environmental goals, these benefits can be greater than the sum of the benefits from individual policies. The results highlight the importance of designing effective fiscal policy mixes that can achieve climate targets without undermining macrofinancial stability.

Several extensions of the model of this paper are in order. First, a more complete integration of ecological variables beyond carbon emissions would be crucial to allow the model to properly analyse the wider effects of policies on the ecosystem. Second, the role of non-banks, which constitute a significant part of the UK financial system, needs to be explored in more detail. Third, since a key strength of SFC modelling is the full integration of finance, the model would be well placed to analyse the effects of green financial policies, such as green differentiated capital requirements, green asset purchases, and green refinancing operations. Finally, extensions to consider a wider range of policies, such as regulatory changes, would allow the model to explore the implications of a broader set of environmental policies.

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A Full Model Description

A.1 Ecosystem

The ecological side of the model considers primarily the role of energy use, electric or non-electric and emissions derived from the generation of said energy. Energy is an input to the production process, so economic activity always leads to greater energy use, which then can lead to higher emissions. Unlike the global DEFINE model of Dafermos and Nikolaidi (2022) we do not include matter or climate damages and instead focus on power generation and transition policy. Climate damage could be considered, but unlike a global model, the stock of greenhouse gases is not an endogenous variable, with UK emissions only making up a small fraction of global emissions[12]. Therefore, damages would be driven exogenously based on the predicted level of global emissions. Such an analysis would be valuable for exploring the UKs medium to long term exposure to climate risk however currently the model focuses on the short to medium term analysis of the effectiveness of transition policy. The inclusion of matter is also an area of interest; however, much matter in the UK is imported and the global stock of materials is not going to be heavily impacted by the UK material use.[13] The current environmental structure of the model is well placed to analyse the impacts of policies targeting the expansion of non-fossil fuel energy generation and investment in greening the UK housing stock. These are areas that are high on the green policy agenda in the UK.

A.1.1 Energy

Energy is considered in an aggregate way, similar to the DEFINE-GLOBAL model. However, unlike the global DEFINE, a distinction is made between the energy produced by households from activities within the home, such as heating and the use of electrical appliances, and the energy used in production, which includes all other final energy use. This distinction helps us isolate energy use in homes,

[12]UK territorial emissions make up approximately 1% of global emissions (ONS 2025)

[13]This will be something to include in future extensions of the model.

which is mostly independent of economic activity from other energy use. Household energy use in homes is a relatively large proportion of final energy use within the UK, so this extension allows us to consider more directly the role of households in UK energy use and also allows us to look at policy scenarios that directly target the household sector.

Rather than directly distinguishing between fossil fuel and non-fossil fuel energy, as is the case within the global DEFINE model, the model instead distinguishes between electric and non-electric energy. This distinction is consistent with country-specific ecological models such as EUROGREEN (D'Alessandro, Cieplinski, et al. 2020). Electric energy refers to all energy drawn from the electricity grid, whereas non-electric energy refers to all other energy use such as the direct burning of fossil fuels in vehicles or houses. Electric energy can be provided by either fossil fuel or non-fossil fuel sources, whereas non-electric energy is assumed to be entirely fossil fuel based. This allows the model to more directly assess the transition of the electricity grid towards non-fossil fuel sources and the impact of electricity, including the price of electricity, on the wider economy.

The total energy use (E) is calculated as the sum of the energy use from production (E_P) and the energy use from housing (E_H) (Eq.(1)). The energy use for production (E_P) is the product of overall economic activity, represented by the real gross output of production (GO_{PR}) and the energy efficiency of production (ϵ). The total use of household energy (E_H) is given by the sum of household electrical energy (E_{ELECH}) and non-electrical energy (E_{NELECH}).

$$E_t = E_{Pt} + E_{Ht} \tag{1}$$

$$E_{Pt} = \epsilon_t GO_{PRt} \tag{2}$$

$$E_{Ht} = E_{ELECHt} + E_{NELECHt} \tag{3}$$

The total electrical energy (E_{ELEC}) is the sum of the electrical energy related to production (E_{ELECP}) and electrical energy related to housing (E_{ELECH}) (9). The maximum electrical energy ($E_{ELECMAX}$) that can be generated is given as the sum of the capital efficiency of the fossil fuel and non-fossil fuel energy (EFF_{FF} & EFF_{NFF}) multiplied by the respective real capital of fossil fuel and non-fossil fuel power capital (K_{PSFFR} & K_{PSNFFR}) (Eq. (5)). In this context, the efficiency parameters capture several properties, including the average capacity factor, defined as the ratio between average electricity production to maximum electricity production (Bolson et al. 2022), technological improvements to electricity production, the conversion between monetary capital value and electrical energy production and implicitly the operating hours of power plants. Fossil fuel efficiency is set as a constant; this is due to UK fossil fuel sources being almost entirely gas-fired power plants which have limited scope for further energy efficiency improvements, with these plants already operating at almost 80% of Carnot efficiency[14] Non-fossil fuel efficiency can and will change over time and this process is described by Equation (17). It is worth highlighting that in general, the non-fossil fuel capital efficiency is lower than the fossil fuel capital efficiency, mainly due to the variable nature of renewable energy production, leading to a lower capacity factor for non-fossil fuel capital. This means that, as is common in the environmental literature (Hirth and Steckel 2016), non-fossil fuel electricity production is more capital intensive than fossil fuel production.

$$E_{ELECt} = E_{ELECPt} + E_{ELECHt} \tag{4}$$

$$E_{ELECMAXt} = EFF_{FF}K_{PSFFRt} + EFF_{NFFt}K_{PSNFFRt} \tag{5}$$

Non-fossil fuel electricity is assumed to be used prior to fossil fuel electricity to meet electricity demand. This is due to the cost of non-fossil fuel energy production being primarily the initial cost of capital Timilsina (2021), such that the marginal cost of non-fossil fuel power production is low resulting in it always being able to offer a competitive price to energy markets when compared with fossil fuel electricity generation . Therefore, the output of non-fossil fuel electricity ($E_{ELECNFF}$) is equal to its maximum generation capacity (i.e. $EFF_{NFFt}K_{PSNFFR}$) until the point where its capacity is greater than the total electricity demand (E_{ELECt}) (Eq. 6). The constant σ_{ELEC} is included in Eq. (6) , where this constant is slightly lower than one, in order to capture the effect that even in a full

[14] Carnot efficiency refers to the theoretical maximum efficiency of a heat engine.

non-fossil fuel energy transition scenario it is likely that a small proportion of electricity will not be able to be provided by non-fossil fuel sources due to weather effects or unexpected short-term increases in electricity demand. Fossil fuel electricity (E_{ELECFF}) then covers the remainder of electrical energy demand (Eq. 7), this means that even though the efficiency of fossil fuel generation is higher than that of non-fossil fuel generation, fossil fuel capital tends to be underutilised, with fossil fuel sources only being used when electricity demand cannot be satisfied by non-fossil fuel sources.

$$E_{ELECNFFt} = min(E_{ELECt}\sigma_{ELEC}, EFF_{NFFt}K_{PSNFFRt}) \tag{6}$$

$$E_{ELECFFt} = E_{ELECt} - E_{ELECNFFt} \tag{7}$$

The demand for electrical energy from production (E_{ELECP}) is based on the intensity of the electricity demand for the production energy (θ_P) multiplied by the total energy demand for production (E_P). The electric energy of houses (E_{ELECH}) defined in Eq. (9) is based on the number of houses under different classifications: inefficient houses (H_I) efficient non-electric houses (H_{EN}) and efficient fully-electric houses (H_{EE}). These different house classifications have been constructed in the UK based on Energy Performance Certificate (EPC) data (UK Department for Levelling UP, Housing & Communities 2025). Inefficient houses have an EPC rating of D or below, reflecting low energy efficiency within these houses. The other two categorisations are houses with an EPC rating of C or above, reflecting much higher energy efficiency and fully-electric houses are those where the primary energy source of the house is electric as opposed to a gas boiler as is common in most UK houses. Therefore, in Eq. 9 only a portion of the energy demand of inefficient and efficient non-electric houses is electricity based, whereas all energy demand of efficient electic houses will be electricity based. In this equation, the θ's represent the energy efficiency of houses of each type, while the value β_{ELECHH} reflects the proportion of use of electric energy in non-fully electric houses[15].

$$E_{ELECPt} = \theta_{Pt}E_{Pt} \tag{8}$$

$$E_{ELECHt} = (\theta_{HI}H_{It} + \theta_{HEN}H_{ENt})\beta_{ELECH} + \theta_{HEE}H_{EEt} \tag{9}$$

The total non-electrical energy (E_{NELEC}) is the sum of the non-electrical energy related to production (E_{NELECP}) and the electrical energy related to housing (E_{NELECH}) (12). The demand for non-electrical energy from production (E_{NELECP}) is defined as the proportion of energy for production not provided by electric sources ($1 - \theta_P$) multiplied by the total energy demand for production (E_P). The non-electric energy of houses (E_{NELECH}) defined in Eq. 12 is calculated similarly to Eq. 9 with the remainder of inefficient (H_I) and efficient non-electric (H_{EN}) energy demand being drawn from non-electric sources.

$$E_{NELECt} = (E_{NELECPt} + E_{NELECHt}) \tag{10}$$

$$E_{NELECPt} = (1 - \theta_{Pt})E_{Pt} \tag{11}$$

$$E_{NELECHt} = (\theta_{HI}H_{It} + \theta_{HEN}H_{ENt})(1 - \beta_{ELECH}) \tag{12}$$

A.1.2 Emissions

The total greenhouse gas emissions ($EMIS$) are split into emissions from non-electric sources ($EMIS_{NELEC}$) and electric ($EMIS_{ELEC}$) sources (Eq. (13)). Emissions from non-electric energy, which is assumed to be entirely fossil fuel based, is calculated as the product of non-electric emission efficiency (ω_{NELEC}) and total non-electrical energy use (E_{NELEC}) (Eq. (14)). The emissions of the use of electric energy is then calculated as the product of the efficiency of electric emissions (ω_{ELEC}) and the provision of fossil fuel-based electrical energy (E_{ELECFF}) (Eq. (15)).

$$EMIS_t = EMIS_{NELECt} + EMIS_{ELECt} \tag{13}$$

$$EMIS_{NELECt} = \omega_{NELECt}E_{NELECt} \tag{14}$$

[15] Relating to common electrical uses from household white goods etc.

$$EMIS_{ELECt} = \omega_{ELECt} E_{ELECFFt} \tag{15}$$

These equations are highly aggregated, so the model cannot look at changes within the non-electrical energy mix nor changes to the fossil fuel electricity energy mix. The latter is justified for the UK somewhat by the dominance of gas generation and little scope to green fossil fuel electricity production (aside from moving to non-fossil fuel sources). On non-electric energy, again the model cannot look at changes to the energy mix, in the time period of the model scenarios (around 10 years) this is somewhat justifiable; however, there are important technological changes that could be ignored here such as low carbon hydrogen which is a focus of UK government policy (UK Department for Energy Security and Net Zero 2021). Such technologies are still in their infancy in the UK and there is limited reliable data or projections to assess them directly at this stage; if this changes then the model could be expanded to consider hydrogen and other non-electric energy use more explicitly. Therefore, for the purposes of this model, the aggregated form of non-electric and electric emissions is sufficient and it is possible to implicitly capture technological improvement through efficiency parameters, which will be described in the next set of equations.

A.1.3 Ecological efficiency and technology

This section now presents the ecological efficiency and technology parameters that are the key channels through which macroeconomic variables and policies impact the ecological side of the model. For the following five equations, logistic equations have been employed in all cases. The use of logistic functions here allows the model to account for learning processes and positive spillover effects while also allowing the setting of theoretical maximum and minimum values for many of these efficiency-based parameters, in line with UK projections[16] in a way similar to the global DEFINE model (Dafermos and Nikolaidi 2022).

The energy efficiency of production (ϵ) is driven by the ratio of green productive capital to conventional productive capital, the higher the use of green capital, the less energy is required per unit of real output, reflected by a reduction in the value of ϵ (Eq. (16)). The efficiency of non-fossil fuel electricity production (EFF_{NFF}) is variable and is reduced according to the ratio between non-fossil fuel and fossil fuel energy production (defined as β_{NFF}) (Eq. (17)). It may seem counter-intuitive that this efficiency value falls as electric energy production rises, in reality there are two effects occurring at the same time, a positive technological effect and a negative capacity volatility effect. For technological change, greater use of non-fossil capital, along with general exogenous efficiency improvements to the technology, would be expected to increase non-fossil fuel efficiency over time. However, in the short term this is likely to be smaller than the negative impact of higher non-fossil fuel electricity production resulting from non-fossil fuel energy sources including renewable energy which generates intermittent electricity based on weather conditions; as the prevalence of non-fossil fuel electricity increases, it is expected that this intermittence will result in a higher frequency of periods where non-fossil electricity is effectively wasted, thus reducing the average capacity factor of non-fossil fuel electricity production. This is calibrated based on recent data on non-fossil fuel electricity production in the UK which suggests a negative relationship between the proportion of non-fossil fuel capital in the energy mix and it's efficiency level. This implicitly assumes no major technological changes to electrical energy storage in the UK, which could mitigate against this effect. Furthermore, changes to the non-fossil fuel energy mix, such as an increase in nuclear electricity generation, would mitigate against this issue. Within the period of the model scenarios, the nuclear plant "Hinkley Point C" is set to become operational, although it should be noted that this plant has already been delayed by over 5 years and may face further delays. Although the model will not explicitly look at the shift in energy mix resulting from this nuclear project, Eq. (17) has been parametrised to be less pessimistic than past UK data would suggest, in order to partially account for this development.

The proportion of electrical energy used in the production process (θ_P) is driven by the ratio of green productive capital to conventional productive capital, the higher the use of green capital, the greater the use of electricity in the productive process, reflected by an increase in the value of ϵ (Eq.

[16]For the importance of these processes in energy systems and renewable energy technologies, see Kahouli-Brahmi (2009) and Tang and Popp (2016)

(18)). The intensity of emissions from non-electric energy production (ω_{NELEC}) is driven similarly by the ratio of green productive capital to conventional productive capital with a greater use of green capital resulting in a lower intensity of emissions (Eq. (19)).[17] Finally, the emission intensity of electric energy production (ω_{ELEC}) reduces based on the ratio between non-fossil fuel and fossil fuel energy production (β_{NFF}) (Eq. (20)). This captures the merit-order effect[18] resulting in a fall in average emissions of fossil fuel electricity production as their is greater non-fossil fuel penetration in energy markets.

$$\epsilon_t = \epsilon_{min} + \frac{(\epsilon_{max} - \epsilon_{min})}{(\pi_1 e^{\kappa_1 (K_{PGt-1}/K_{PCt-1})})} \tag{16}$$

$$EFF_{NFFt} = EFF_{min} + \frac{EFF_{max} - EFF_{min}}{\pi_2 e^{\kappa_2 \beta_{NFFt-1}}} \tag{17}$$

$$\theta_{Pt} = \frac{1}{\pi_3 e^{-\kappa_3 K_{PGt-1}/K_{PCt-1}}} \tag{18}$$

$$\omega_{NELECt} = \omega_{nemin} + \frac{\omega_{nemax} - \omega_{nemin}}{\pi_4 e^{\kappa_4 K_{PGt-1}/K_{PCt-1}}} \tag{19}$$

$$\omega_{ELECt} = \omega_{emin} + \frac{\omega_{emax} - \omega_{emin}}{\pi_5 e^{\kappa_5 \beta_{NFFt-1}}} \tag{20}$$

A.2 High level macroeconomic variables

The macroeconomy in the model is made up of several sectors that interact with each other through monetary and financial relationships. The sum of these interactions generates high-level macroeconomic variables, in particular the gross domestic product (GDP) and the total level of employment. This section will describe these high-level variables before looking at the individual sectors in the following sections.

Total GDP is defined following the expenditure approach as consumption ($CONS$), plus gross capital formation (GCF), plus exports (EXP) minus imports (IMP) (Eq. (21)), with consumption being the sum of household ($CONS_{HH}$) and government ($CONS_{GVTt}$) consumption (Eq. (22)) and gross capital formation being the sum of the capital formation of households (GCF_{HH}), non-financial corporations (GCF_{NFC}), the power sector (GCF_{PS}) , and the government (GCF_{GVT}) (Eq.(23)). By defining GDP in this way, it is implicitly assumed that the economy's output is driven by demand, in line with post-Keynesian tradition (Palley 1996; Lavoie 2014; Hein 2023). Total gross output in the economy[19] (GO) is defined as the sum of gross output for the two input-output sectors in the model; gross output from production (GO_P) and gross output from the power sector (GO_{PS}).

While high level macroeconomic variables are demand determined there are supply constraints in the model. The role of supply in post-Keynesian analysis is often under-emphasised when compared to demand. This may be in part in opposition to the fully supply-determined approach of many main macroeconomic models such as DSGE and CGE approaches, although it is also due to the post-Keynesian argument that supply-side factors, such as technology and productivity, will respond to some extent to demand pressures (Stockhammer 2023). Setterfield (2023) argue that supply side constraints can and should be integrated into post-Keynesian macroeconomic models and Stockhammer (2008) show how post-Keynesian inflation theory introduces a form of labour supply constraint. Furthermore, ecological macroeconomic models such as EUROGREEN and DEFINE (D'Alessandro, Cieplinski, et al. 2020; Dafermos, Nikolaidi, and Galanis 2017) both include a form of supply constraints. There are several areas where supply will constrain the model, most notably through the relationship between prices and employment. However, the model does not feature a non-accelerating

[17] This effect is however relatively small and there are only marginal reductions in non-electric emission intensity possible within the model, this is in line with past UK data and the current UK energy mix which is predominantly oil (petrol) and gas based.

[18] As lower cost non-fossil fuel energy sources expand this changes the order in which power plants are dispatched to meet energy demand with the least efficient, most costly, plants ceasing their operations first

[19] Including intermediate inputs to production.

inflation rate of unemployment (NAIRU), which is often assumed in mainstream macroeconomic approaches. As output can also expand the supply constraint, lower unemployment, despite leading to higher wages, is not necessarily inflationary. This is in line with criticisms of the NAIRU by Storm and Naastepad (2011), with the model rejecting the binary trade-off between unemployment reduction and controlling inflation.

$$GDP_t = CONS_t + GCF_t + EXP_t - IMP_t \tag{21}$$

$$CONS_t = CONS_{HHt} + CONS_{GVTt} \tag{22}$$

$$GCF_t = GCF_{NFCt} + GCF_{PSGt} + GCF_{GVTt} + GCF_{HHt} \tag{23}$$

$$GO_t = GO_{Pt} + GO_{PSt} \tag{24}$$

Real GDP (GDP_R) is defined as real consumption ($CONS_R$), plus real gross capital formation (GCF_R), plus real exports (EXP_R) minus real imports (IMP_R) (Eq. (25)). Real consumption, gross capital formation, and gross output are all defined as their nominal values divided by the overall production price deflator (P_P) (Eqs. (26), (27) & (28)). A point to highlight here is that in general the model behavioural equations are presented in nominal terms and then converted to real values through prices. There are several reasons for taking this approach, the first is pragmatic, the "raw" national accounting data is nominal and requires the calculation of some deflator to convert to a real series, this approach allows us to work more with actual observed data and rely less on price calculations. However, there is also a theoretical reason to do this, based on the post-Keynesian tradition, money is not neutral and nominal changes will impact real outcomes (Asensio et al. 2012; Lavoie 2014). This is particularly important for the implementation of supply constraints in the model, where the distinction between nominal and real variables allows real variables to be constrained through prices. This interaction facilitates a model that is demand-determined, in line with post-Keynesian tradition, while also being supply constrained through prices, which better reflects the structure of individual economies.

$$GDP_{Rt} = CONS_{Rt} + GCF_{Rt} + EXP_{Rt} - IMP_{Rt} \tag{25}$$

$$CONS_{Rt} = \frac{CONS_t}{P_{Pt}} \tag{26}$$

$$GCF_{Rt} = \frac{GCF_t}{P_{Pt}} \tag{27}$$

$$GO_{Rt} = \frac{GO_t}{P_t} \tag{28}$$

Overall (quarterly) GDP growth (g) is then defined based on its change between period t and $t-1$ (Eq. (29)). While the overall GDP price deflator (P) is defined as the ratio between nominal (GDP) and real (GDP_R) GDP (Eq. (30)).

$$g_t = \frac{GDP_t}{GDP_{t-1}} \tag{29}$$

$$P_t = \frac{GDP_t}{GDP_{Rt}} \tag{30}$$

Turning to supply within the model, the model employs a Leontief-type production function for both labour and capital. Therefore, the productivity of both labour and capital must be defined within the model. Labour productivity per worker (λ) is set as a function of real growth GDP_R as a Kaldor-Verdoorn relationship (Kaldor 1975), while also including the growth of real productive investment (excluding housing investment) as an additional factor of productivity growth a la Thirlwall (2007) (Eq. (31)). This allows the model to account for demand-driven productivity growth as per the post-Keynesian tradition, while allowing productive investment to have an additional positive impact on the growth of productivity through capital deepening. Real capital productivity (ν) is defined as a constant based on it's initial value (Eq. (32)), this is a reasonable assumption as the implied value of real; capital productivity in the UK is mostly constant over past data. This implies that the capital constraint in the model can only be moved through investment in new capital.

$$\Delta \mathbf{L}\lambda_t = \alpha_{0lambda} + \alpha_{1lambda}\Delta(\mathbf{L}(GDP_{Rt})) + \alpha_{2lambda}\Delta(\mathbf{L}(GCF_{Rt} - GCF_{HHRt}))) \tag{31}$$

$$\Delta\nu_t = 0 \tag{32}$$

Employing the Leontief-type production function for labour leads to the definition of total employment (EMP) as equal to real GDP (GDP_R) divided by labour productivity per worker (Eq. (33)). Employment is then split between public- and private-sector employment. Public sector employment (EMP_{PUB}) is effectively a policy variable, for the model it is assumed that the size of public sector employment, relative to the size of the labour force (LF), is constant and therefore public sector employment grows based on the growth rate of the labour force (Eq. (34)). The remaining employment is covered by the private sector such that private sector employment (EMP_{PRI}) is defined as total employment minus public sector employment (Eq. (34)).

$$EMP_t = \frac{GDP_{Rt}}{\lambda_t} \tag{33}$$

$$EMP_{PUBt} = \frac{LF_t}{LF_{t-1}} EMP_{PUBt-1} \tag{34}$$

$$EMP_{PRIt} = EMP_t - EMP_{PUBt} \tag{35}$$

Now to define the supply constraint explicitly, real full employment GDP (GFP_{RFE})[20] is equal to the total labour force (LF) multiplied by labour productivity (λ) (Eq. (36)). Real full capital utilisation GDP (GDP_{RFK})[21] is equal to the total real productive capital (K_{PR}) multiplied by capital productivity (ν) (Eq. (36)). Taken together, these two constraints generate the maximum real GDP (GDP_{RMAX}) which is defined as the minimum of these supply constraints (Eq. (38)). This is similar to the approach taken in the DEFINE model (Dafermos, Nikolaidi, and Galanis 2017), where maximum GDP is the minimum of several seperate supply side constraints.

$$GDP_{RFEt} = \lambda_t LF_t \tag{36}$$

$$GDP_{RFKt} = \nu_t K_{PRt} \tag{37}$$

$$GDP_{RMAXt} = min(GDP_{RFEt}, GDP_{RFKt}) \tag{38}$$

Both the labour force (LF)[22] and the total population (POP) are driven exogenously based on data from the Office for Budget Responsibility (OBR 2025) (Eqs. (39) & (40)). The employment rate (re) is defined as the total number of people employed (EMP) divided by the labour force (LF) (Eq. (41)) with the unemployment rate (ru) being defined as the remainder (Eq. (42)). The utilisation rate of capital (u) is then defined as the ratio between real GDP (GDP_R) and capital determined maximum GDP (GDP_{RFK}) (Eq. (43)).

$$LF_t = g_{LFOBR} LF_{t-1} \tag{39}$$

$$POP_t = POP_{OBRt} \tag{40}$$

$$re_t = \frac{EMP_t}{LF_t} \tag{41}$$

$$ru_t = 1 - re_t \tag{42}$$

$$u_t = \frac{GDP_{Rt}}{GDP_{RFKt}} \tag{43}$$

[20] This is the labour supply constraint.

[21] This is the capital supply constraint.

[22] The labour force is defined as adults who are willing and able to work and is the sum of all employed and unemployed people.

A.3 Production

This section will focus on how the production modules behaves within the model. A key challenge that is faced is that production is not isolated to a single sector with this problem exacerbated by a lack of sufficient whom-to-whom data.[23] To address this, the production module is defined separately from any one model sector. The production module is therefore initially defined as the destination of all GDP expenditure flows and the origin of all GDP income flows.[24]

This would be sufficient if were there no input-output relationships to model; however, we have chosen to separate the power generation sector in order to better consider it's relationship with the rest of the economy and it's role in a green transition. This again raises a similar issue to that of production; industries, as defined within input-output tables can span across multiple accounting sectors and are not only based within the non-financial corporation sector. This issue is highlighted by Thomsen et al. (2025) where the authors find that a third of agricultural gross value added is attributed to the household sector in Denmark. Fortunately, in the case of the UK, the power generation sector is largely privatised and thus can be assumed to be a part of the wider non-financial corporation sector. Therefore, when separating the power sector, it is possible to simply reduce values within the non-financial corporation sector to account for the removal of power sector firms from the wider non-financial corporation sector and this is the approach that will be taken for this model.

Separating the power sector now also means that the production module no longer contains all GDP income and expenditure flows as consumption of electricity will now be an inflow to the power generation sector. In this simple input-output extension the production module and power sector are considered as two industries where the production module, by definition, contains all industries apart from the power sector.

A.3.1 Domestic production module

The majority of production occurs within the domestic production module. The final demand for production products (F_P) is equal to the household consumption of production products ($CONS_{HHP}$), the total consumption of the government ($CONS_{GVT}$) and the exports (EXP) minus imports (IMP) (Eq. (44)). The real final demand for production products (F_{PR}) is then given as the sum of the real components of the final demand (Eq. (45)). The real gross output of the production (GO_{PR}) sector is then calculated from the coefficients of the Leiontief inverse matrix multiplied by the real final demand for the two input output sectors in the model (Eq. (46)). Nominal gross output from production (GO_P) is then derived by multiplying the real gross output of production (GO_{PR}) by the production price deflator (P_P) (Eq. (47)). Total input costs of the production module ($COST_P$) are defined as the sum of total wages (W), indirect taxation on production ($ITAX_P$), intermediate consumption of production products (IC_{PP}) and intermediate consumption of power sector products (IC_{PSP}) which is predominately electricity used for production (Eq. (48)).

$$F_{Pt} = CONS_{HHPt} + CONS_{GVTt} + GCF_t + EXP_t - IMP_t \tag{44}$$

$$F_{PRt} = CONS_{HHPRt} + CONS_{GVTRt} + GCF_{Rt} + EXP_{Rt} - IMP_{Rt} \tag{45}$$

$$GO_{PRt} = L_{PPt}F_{PRt} + L_{PPSt}F_{PSRt} \tag{46}$$

$$GO_{Pt} = GO_{PRt}P_{Pt} \tag{47}$$

$$COST_{Pt} = W_t + ITAX_{Pt} + IC_{PPt} + IC_{PSPt} \tag{48}$$

The production price deflator (P_P) is defined based on a simple mark-up (MU) over the unit costs (UC) in the previous period (Eq. (49)).[25] Unit costs (UC) are defined as the total nominal

[23]For example there is data for both household and government consumption outflows but a lack of data for consumption inflows. In national accounts final consumption includes the purchase of goods and services from the private sector but also includes items such as governments consumption of its own products or households derived services from owner-occupied dwellings. For a similar assumption, see F. Zezza and G. Zezza (2022).

[24]it is important to note that the production module is not a sector in the traditional sense, it does not hold any financial assets or liabilities.

[25]This is consistent with the post-Keynesian approach of analysing prices as primarily a mark up on costs (see Lavoie (2014))

cost of production divided by the real output of production (GO_{PR}) (Eq. (50)). The mark-up (MU) itself varies according to the capital capacity utilisation rate (u) (Eq. (51)). This partially addresses a common critique of fixed mark-up pricing[26] which posits that the mark should vary based on macroeconomic conditions. Capacity utilisation serving as a driver of price mark-ups is similar to country models such as EUROGREEN (D'Alessandro, Cieplinski, et al. 2020). However, unlike EUROGREEN, the definition of the mark up means that if capacity utilisation falls, firms will reduce their mark-ups in an attempt to attract more customers and restore their rate of capacity utilisation.

$$P_{Pt} = (1 + MU_t)UC_{t-1} \tag{49}$$

$$UC_t = \frac{COST_{Pt}}{GO_{PRt}} \tag{50}$$

$$MU_t = \alpha_{MU}(u_{t-1}) \tag{51}$$

The production sector is the source of all wage payments to workers in the model, including all public sector and private sector wages. A part of government consumption ($CONS_GVT$) includes public sector wages and this is simply distributed through the production module. Power sector wages are also paid through the production module as these are relatively small, this means that part of the intermediate consumption of the power sector for production products is made up by power sector wage payments to their employees.

The wage share (W_S) is defined as the total wage bill divided by GDP. The wage share evolves based on an econometrically calibrated equation where it depends negatively on the unemployment rate (ru) in the long run while also having a negative short-run relationship with recent changes in the wage share and a positive short-run relationship with changes in the unemployment rate, these two short-run parameters capture a wage stickiness and acceleration effect, respectively (Eq. (52)). The dynamics of the wage share follow the approach of the global DEFINE model (Dafermos, Nikolaidi, and Galanis 2017) although build on this approach by allowing for wage rigidities through the dynamics of Eq. (52). This is consistent with the analysis of Stirati and Paternesi Meloni (2021) where a 'structural' Phillips-type relationship is found between the unemployment rate and the wage share. The wage rate (W_R), or wage per employee, is defined as the total wage (W_SGDP) divided by the total number of employees (EMP) (Eq. (52)). The wage rate is marginally different for public and private sector employees, with employees in the private sector receiving slightly more on average in the UK. Therefore, the respective public (WR_{PUB}) and private (WR_{PRI}) wage rates are defined as multiples of the total wage rate (Eqs. (54) & (55).[27]

$$\Delta W_{St} = \alpha_{0WS} - \epsilon_{WR}(W_{St-1} - \alpha_{1WS}ru_{t-1}) - \delta_{1WS}\Delta W_{St-1} + \delta_{2WS}\Delta ru_{t-1} \tag{52}$$

$$WR_t = \frac{W_{St}(GDP_t}{EMP_t)} \tag{53}$$

$$WR_{PRIt} = \beta_{WRPRI}WR_t \tag{54}$$

$$WR_{PUBt} = \beta_{WRPUB}WR_{t-1} \tag{55}$$

$$W_{PRIt} = WR_{PRIt}EMP_{PRIt} \tag{56}$$

$$W_{PUBt} = WR_{PUBt}EMP_{PUBt} \tag{57}$$

$$W_t = W_{PRIt} + W_{PUBt} \tag{58}$$

Non-electrical energy prices and costs are also defined within the production module, as the power sector only covers electrical energy, with these values having a behavioural impact on proportions of green investment within the model. The price of non-electric energy (P_{NELEC}) is defined as a fixed mark-up over the prices of gas (P_{GAS}) and oil (P_{OIL}), with the proportion of these different fuels in the non-electric energy mix being assumed to remain constant during the simulation period (Eq. (59)).

[26] Such as Halevi (2016)

[27] Note that the public wage rate is based on the lag of the overall wage rate, this is due to public wage rates directly determining the level of government consumption, which is a component of GDP, therefore this must be lagged to avoid a circular dependency between equations.

Gas and oil prices are assumed to be based on global prices and are therefore exogenous to the model, growing according to OBR forecasts (OBR 2025). The price of non-electric energy including taxes (P_{NELECT}) is given by adding the indirect tax per unit of non-electric energy ($ITAX_{NELEC}/E_{NELEC}$) to the non-taxed price of non-electric energy (Eq.(60)). The price of fuel (P_{FUEL}) which the production sector sells to the power sector is set as proportional to the wholesale price of gas, reflecting that fossil fuel electricity generation in the UK is now entirely gas-based (Eq. (61)). The total cost of non-electric energy ($COST_{NELEC}$) is given as the price of non-electric energy (P_{NELEC}) multiplied by total non-electric energy use (E_{NELEC}) (Eq. (62)). The real total cost of all energy use in the economy, including energy taxes, is given as the sum of the cost of non-electric energy ($COST_{NELEC}$), the total tax paid on non-electric energy use ($ITAX_{NELEC}$), the final consumption of electricity by households ($CONS_{HHPS}$ and the intermediate consumption of electricity by the production module (IC_{PSP}); all divided by the level of production price (P_P) (Eq. (63).

$$P_{NELECt} = \alpha_{NELEC}(\beta_{NELECGAS}P_{GASt} + \beta_{NELECOIL}P_{OILt}) \tag{59}$$

$$P_{NELECTt} = P_{NELECt} + \frac{ITAX_{NELECt}}{E_{NELECt}} \tag{60}$$

$$P_{FUELt} = \alpha_{PFUEL}P_{GASt} \tag{61}$$

$$COST_{NELECt} = P_{NELECt}E_{NELECt} \tag{62}$$

$$COST_{ERt} = \frac{COST_{NELECt} + ITAX_{NELECt} + CONS_{HHPSt} + IC_{PSPt}}{P_{Pt}} \tag{63}$$

Productive capital (K_P) in the model is defined as all non-housing capital so is given by the total capital stock of non-financial corporations (K_{NFC}) and the government (K_{GVT}) (Eq. (64)). For both NFCs and the government, the productive capital is divided into green and conventional capital stocks with the total green (K_{PG}) and conventional (K_{PC}) defined as the sum of the respective green and conventional NFC and government capital stocks (Eqs. (65) & (66)). Real productive capital levels are defined similarly on the basis of the real NFC and government capital stocks (Eqs. (67), (68) & (66)). The depreciation of productive capital (δ_{KP}), which is assumed to be the same rate for NFC and government capital, is constant (Eq. (70)). As described in the Energy Efficiency and Technology Section, the ratio between green and conventional capital is a key driver of energy efficiency and emission reduction within the model. This follows the approach of Dafermos, Nikolaidi, and Galanis (2017) and means that decarbonisation requires a certain level of investment. However, there is no explicit innovation process that governs energy efficiency, as is the case for the EUROGREEN model (D'Alessandro, Cieplinski, et al. 2020).

$$K_{Pt} = K_{NFCt} + K_{GVTt} \tag{64}$$

$$K_{PGt} = K_{NFCGt} + K_{GVTGt} \tag{65}$$

$$K_{PCt} = K_{NFCCt} + K_{GVTCt} \tag{66}$$

$$K_{PRt} = K_{NFCRt} + K_{GVTRt} \tag{67}$$

$$K_{PGRt} = K_{NFCGRt} + K_{GVTGRt} \tag{68}$$

$$K_{PCRt} = K_{NFCCRt} + K_{GVTCRt} \tag{69}$$

$$\delta_{KPt} = \delta_{kpc} \tag{70}$$

A.3.2 The power generation sector

The power generation sector is the other input output sector outside of the production sector, which is involved in the input-output system. This sector is defined as the industry 'Electricity, gas, steam and air conditioning supply (D.35)' in the ONS input output tables. The final demand for products from the power sector, which is assumed to be completely electricity demand (F_{PS}) is equal to the household consumption of electricity ($CONS_{HHPS}$) (Eq. (71)). The real final demand for power sector products (F_{PR}) is then given as the sum of the real value of household consumption (Eq. (72)).

The real gross output of the power (GO_{PSR}) sector is then calculated from the coefficients of the Leiontief inverse matrix multiplied by the real final demand for the two input output sectors in the model (Eq. (73)). Nominal gross output of the power sector (GO_PS) is then derived by multiplying the real gross output of the power sector (GO_{PSR}) by the price of electricity (P_{ELEC}) (Eq. (74)). The total input costs of the power sector ($COST_{PS}$) are defined as the sum of indirect taxation on the power sector ($ITAX_P$), intermediate consumption of production products (IC_{PSP})[28] and intermediate consumption of products of the power sector (IC_{PSPS}) which is predominantly electricity used within the electricity production process (Eq. (75)).

$$F_{PSt} = CONS_{HHPSt} \tag{71}$$

$$F_{PSRt} = CONS_{HHPSRt} \tag{72}$$

$$GO_{PSRt} = L_{PSPt}F_{PRt} + L_{PSPSt}F_{PSRt} \tag{73}$$

$$GO_{PSt} = GO_{PSRt}P_{ELECt} \tag{74}$$

$$COST_{PSt} = ITAX_{PSt} + IC_{PPSt} + IC_{PSPSt} \tag{75}$$

$$GOS_{PSt} = GO_{PSt} - COST_{PSt} \tag{76}$$

The power sector generates electricity from both fossil fuel (E_{ELECFF}) and non-fossil fuel ($E_{ELECNFF}$) sources. The ratio between non-fossil fuel electricity and total electricity (β_{NFF}) is defined in Eq. (77). The total operating cost for non-fossil fuel energy production ($COST_{PSNFF}$) is defined as the total indirect taxes on non-fossil fuel energy production ($ITAX_{PSNFF}$), a share of the non-fossil fuel based intermediate consumption, with the share assumed to be proportional to the amount of non-fossil fuel energy in the energy mix (β_{NFF}) and the total depreciation of non-fossil fuel capital ($\delta_{KPS}K_{PSNFF}$). (Eq. 78). The total operating cost for fossil fuel energy production ($COST_{PSFF}$) is defined similarly except all intermediate consumption for fuel production (IC_{FUELPS}) is attributed to fossil fuel generation costs (Eq. (78)). The average costs of non fossil (AC_{NFF}) and fossil (AC_{FF}) electricity are then defined based on their total costs divided by the share of the respective energy source multiplied by the real output of the power sector (GO_{PSR}) (Eqs. (80) & (81)).

$$\beta_{NFFt} = \frac{E_{ELECNFFt}}{E_{ELECt}} \tag{77}$$

$$COST_{PSNFFt} = ITAX_{PSNFFt} + (IC_{PSPSt} + IC_{OPPSt})\beta_{NFFt-1} + \delta_{KPSt}K_{PSNFFt-1} \tag{78}$$

$$COST_{PSFFt} = ITAX_{PSFFt} + IC_{FUELPSt} + (IC_{PSPSt} + IC_{OPPSt})(1 - \beta_{NFFt-1}) + \delta_{KPSt}K_{PSFFt-1} \tag{79}$$

$$AC_{NFFt} = \frac{COST_{PSNFFt}}{GO_{PSRt}\beta_{NFFt}} \tag{80}$$

$$AC_{FFt} = \frac{COST_{PSFFt}}{GO_{PSRt}(1 - \beta_{NFFt})} \tag{81}$$

Although average costs are tracked in the model, electricity prices are set on the basis of marginal costs, where the electricity price is driven by the cost of producing an additional unit of electricity. This better replicates how electricity is priced in reality within the UK (Stirati and Paternesi Meloni 2021) and has a significant impact on the behaviour of the model. Therefore, the marginal cost of fossil fuel electricity production (MC_{FF}) is defined based on the variable costs of fossil fuel production: the cost of fuel input IC_{FUELPS} and the cost of emissions due to emission pricing $COV_{ETSPS}P_{ETS}EMIS_{ELEC}$ divided by the total fossil fuel electrical energy E_{ELECFF}, where COV_{ETSPS} is the coverage of the carbon price over the sectoral fossil fuel output[29] and P_{ETS} is the carbon price (Eq. (82)).[30] For

[28]This includes wages paid to employees in the power sector and any imports of the power sector.

[29]This is generally less than one due to exemptions and free carbon credits provided to firms.

[30]This equation form assumes that the relationship between fossil fuel inputs and fossil fuel electrical output is constant, while this is unlikely to be the case in reality it is a fair assumption for modelling purposes.

non-fossil fuel generation, there is no fuel input or emission tax, so it is assumed that the marginal cost of non-fossil fuel electricity production is effectively zero, as pointed out by Heal (2022).[31]

Now, these two marginal costs must be used to define the total marginal cost of electricity that will drive the electricity price. Given that the marginal cost of fossil fuels is always higher than that of non-fossil fuels, one approach would be to define the marginal cost of electricity as equal to that of fossil fuels until a full non-fossil fuel transition is achieved. However, this would be misleading for several reasons. The first reason is that energy demand and the energy mix vary significantly over time, this volatility means that at around 60-70% non-fossil energy production it becomes likely that, at least temporarily, the electricity grid will be supplied by entirely non-fossil sources. This is supported in the case of the UK by Carbon Brief (2024) where it is observed that the share of electricity in the UK generated from fossil fuels fell to a record low of 2.4% on April 15th, 2024, this is despite average yearly fossil fuel electricity generation still accounting for around 40% of total electricity generation. This brings the UK National Grid Electricity System Operator (NGESO) closer to their goal of running the UK electricity network without fossil fuels, for short periods, by 2025 a goal they are confident of reaching (Carbon Brief 2024). Given that wholesale electricity prices in the UK adjust every 30 minutes, even an hour of fully non-fossil electricity production could significantly lower electricity prices temporarily. To account for this the model employs a non-linear relationship where, as the proportion of non-fossil fuel electricity provision rises, the marginal cost of electricity production falls, accounting for greater frequency of fully non-fossil fuel based electricity production, this non-linear relationship is described in Eq. (83).The price of electricity (P_{ELECLR}) is then set based on a fixed mark up over the marginal cost of electricity production (Eq. (84)).

$$MC_{FFt} = \frac{IC_{FUELPSt} + COV_{ETSPSt}P_{ETSt}EMIS_{ELECt}}{E_{ELECFFt}} \tag{82}$$

$$MC_{ELECt} = MC_{FFt}(1 - \beta_{NFFt})^{\mu_{MCELEC}} \tag{83}$$

$$P_{ELECt} = (1 + MU_{ELEC})MC_{ELECt} \tag{84}$$

Unlike the production module, the power sector is an asset holding sector with a sectoral net-lending and net worth positions, it therefore holds assets, has property income and it's own fixed capital formation. This reflects one the innovations of this model, as most models with input-output sectors, even when they follow a stock-flow consistent approach (such as D'Alessandro, Cieplinski, et al. (2020) and Thomsen et al. (2025)), generally do not include financial balances for the individual input-output sectors, choosing instead to consider these balances at the aggregate firm level. This is due mainly to data availability issues as financial balance data is far less disaggregated than the input-output flow data. This is an issue in the UK as well, however by using available data on the loans to the power sector, and assuming the power sector stocks are a fixed proportion, based on said loans, it is possible to approximate a financial structure for this sector. While such an approximation is unlikely to be fully accurate, it does allow the model to consider changes to financial balances for this sector and financial constraints at the sectoral level. However, it does increase model complexity and following this approach makes it more difficult to expand the input-output structure of the model which, for full SFC-IO models, can include a large number of different input-output sectors.

Interest payments to the power sector are based on respective rates of return on interest bearing assets (IBA^{PS}) and interest bearing liabilities (IBL^{PS}) (Eqs.(85)&(86)). Disposable income of the power sector (YD_{PS}) is then defined as the gross operating surplus of the sector plus it's net interest payments (Eq. (87)). Dividends received by the power sector ($DIVR_{PS}$) are a proportion of the dividends paid by NMFIs multiplied by the share of PS equity assets among all equity assets (Eq. (88)). Dividends paid by the power sector are set as a fixed proportion of their gross output (Eq. (89)). This leaves the retained profit of the power sector (RP_{PS}), to be used for investment, as their disposable income after accounting for dividend transactions (Eq. (90)ou.

$$INTR_{PSt} = r_{IBAPSt}IBA_{PSt-1} \tag{85}$$

[31] However, as already discussed, capital intensity and capital costs for non-fossil fuel generation are higher than for fossil fuels, this has practical implications which will be explored in the scenarios and results discussion.

$$INTP_{PSt} = r_{IBLPSt} IBL_{PSt-1} \tag{86}$$

$$YD_{PSt} = GOS_{PSt} + INTR_{PSt} - INTP_{PSt} \tag{87}$$

$$DIVR_{PSt} = \beta_{dps} \frac{EQA_{PSt}}{EQL_{NMFIt}} DIVP_{NMFIt} \tag{88}$$

$$DIVP_{PSt} = \alpha_{DIVPPS} GO_{PSt} \tag{89}$$

$$RP_{PSt} = YD_{PSt} + DIVR_{PSt} - DIVP_{PSt} \tag{90}$$

The desired investment in fossil fuel (GCF_{PSFFD}) and non-fossil fuel (GCF_{PSNFFD}) power capital is based on adjustment processes where there is assumed to be a consistent positive relationship between real desired investment and overall electricity use. Therefore, following the post-Keynesian tradition, electricity supply will adjust to meet demand, although investment does take time and sudden changes in electricity demand can still put pressure on electricity supply. For both non-fossil and fossil desired investment there is an exogenous component related to the α_{1GCFPS} terms which reflect the level of investment that would occur in the absence of significant cost differences between non-fossil and fossil electricity provision. The second α_{2GCFPS} term shows how higher fossil costs relative to the cost of non-fossil fuel electricity production reduce desired fossil fuel investment while increasing desired non-fossil fuel investment. Therefore, the decision of whether to invest in non-fossil or fossil based electricity generation is driven by costs. This is once again consistent with a post-Keynesian and classical political economy perspective that, ultimately, firms make decisions to minimise costs (Lavoie 2014; Shaikh 2016) and lower costs result in the anticipation of higher returns (Qadir et al. 2021). For both forms of investment, the level of investment is based on the share of each energy type in the energy mix, such that if there is a particularly low share of fossil fuel electricity production there would be less investment in fossil fuel electricity capital (Eqs. (91) & (92)).

$$\Delta \frac{GCF_{PSFFDt}}{E_{ELECt} P_{Pt}} = \epsilon_{GCFPSFF} \Bigg(\alpha_{1GCFPSFF} (1 - \beta_{NFFt-1}) - \alpha_{2GCFPSFF} \frac{AC_{FFt-1}}{AC_{NFFt-1}} (1 - \beta_{NFFt-1}) - \frac{GCF_{PSFFDt-1}}{E_{ELECt-1} P_{Pt-1}} \Bigg) \tag{91}$$

$$\Delta \frac{GCF_{PSNFFDt}}{E_{ELECt} P_{Pt}} = \epsilon_{GCFPSNFF} \Bigg(\alpha_{1GCFPSNFF} \beta_{NFFt-1} + \alpha_{2GCFPSNFF} \frac{AC_{FFt-1}}{AC_{NFFt-1}} \beta_{NFFt-1} - \frac{GCF_{PSNFFDt-1}}{E_{ELECt-1} P_{Pt-1}} \Bigg) \tag{92}$$

Actual fossil fuel (GCF_{PSFF}) and non-fossil fuel (GCF_{PSNFF}) gross capital formation are subject to credit rationing where it is assumed that firms seek finance to cover their desired level of investment and that only a portion of this finance is provided based on the level of power sector credit rationing (CR_{PS}) (Eqs. (93) & (94)). This allows the model to capture that the availability of credit is a major barrier to investment in non-fossil fuel energy (Taghizadeh-Hesary and Yoshino 2020) and reflects the importance of credit constraints highlighted by Dafermos and Nikolaidi (2022). The sum of these two gross capital formations gives the overall gross capital formation for the power sector (GCF_{PS}) (Eq. (95)). Real gross capital formation levels are defined by dividing the nominal gross capital formation by the production price deflator (P_P) (Eqs. (96), (97) & (98)). The net-lending position of the power sector ($LEND_{PS}$) is then defined as the retained profits of the sector minus actual sectoral investment (Eq. (99)).

$$GCF_{PSFFt} = (1 - CR_{PSt}) GCF_{PSFFDt} \tag{93}$$

$$GCF_{PSNFFt} = (1 - CR_{PSt}) GCF_{PSNFFDCOt} \tag{94}$$

$$GCF_{PSt} = GCF_{PSNFFt} + GCF_{PSFFt} \tag{95}$$

$$GCF_{PSRt} = GCF_{PSFFRt} + GCF_{PSNFFRt} \tag{96}$$

$$GCF_{PSFFRt} = \frac{GCF_{PSFFt}}{P_{Pt}} \tag{97}$$

$$GCF_{PSNFFRt} = \frac{GCF_{PSNFFGt}}{P_{Pt}} \tag{98}$$

$$LEND_{PSt} = RP_{PSt} - GCF_{PSt} \tag{99}$$

Interest bearing ($IBATR_{PS}$) and equity asset ($EQATR_{PS}$) transfers are assumed to equal a fixed proportion of the gross output (GO_{PS}) of the power sector (Eqs. (100) & (101)). Equity liability transfers ($EQLTR_{PS}$) equal a portion of the equity acquisitions of the NMFI sector which is assumed to hold the counterpart equity assets to all equity liabilities within the model (Eq. (102)). Interest bearing liability transfers ($IBLTR_{PS}$) serve as the residual stock transfer and equal the net transfers of all other financial assets (Eq. (103)). The residual financial instrument transaction of the power sector ($RESTR_{PS}$) grows exogenously as a fixed proportion of GDP (Eq. (104)).

$$IBATR_{PSt} = \alpha_{IBAPS} GO_{PSt} \tag{100}$$

$$EQATR_{PSt} = \alpha_{EQAPS} GO_{PSt} \tag{101}$$

$$EQLTR_{PSt} = \theta_{psb} EQATR_{NMFIt} \tag{102}$$

$$IBLTR_{PSt} = (IBATR_{PSt} + EQATR_{PSt} + RESTR_{PSt}) - (LEND_{PSt} + EQLTR_{PSt}) \tag{103}$$

$$RESTR_{PSt} = \eta_{PSB} GDP_{t-1} \tag{104}$$

Other transfers, which include price revaluations and other changes in asset value, are driven in a variety of ways within the model (Eqs. (105) - (108)). Other transfers relating to interest-bearing assets (OT_{IBAPS}) are assumed to follow a fixed exogenous rate, reflecting these assets include safe assets such as deposits that do not vary significantly based on other model variables (Eq. (105)). Other transfers relating to equity assets (OT_{EQAPS}) are given as a portion of the other transfers of NMFI equity liabilities ($OT_{EQANMFI}$) (Eq. (106). Other transfers relating to equity liabilities are assumed to be set such that equity prices are positively related to dividend payments by the power sector while being reduced by the current interest rate on interest bearing liabilities of the government, which serves as an approximation for the so-called 'risk-free interest rate (Eq. (107)). Other transfers relating to interest-bearing liabilities (OT_{IBLPS}) are relatively large and require some individual attention. Other transfers of interest-bearing liabilities are mostly made up of defaults on loans, it is therefore assumed that it's rate of change is entirely driven by defaults (Eq. (109)). The default rate of the power sector (DEF_{PS}) is then proportional to the illiquidity ratio ($ILLIQ_{PS}$) where the higher the illiquidity of the power sector leads to higher defaults (Eq. (110)).

$$OT_{IBAPSt} = \delta_{IBAPS}(IBA_{PSt-1}) \tag{105}$$

$$OT_{EQAPSt} = \beta_{dps} \frac{EQA_{PSt-1}}{EQL_{NMFIt-1}} OT_{EQLNMFIt} \tag{106}$$

$$OT_{EQLPSt} = \frac{DIVP_{PSt}}{r_{IBLGVTt} + \beta_{EQLPS}} - EQL_{PSt-1} \tag{107}$$

$$OT_{RESPSt} = \delta_{RESPS}(RES_{PSt-1}) \tag{108}$$

$$OT_{IBLPSt} = -DEF_{PSt}(IBL_{PSt-1}) \tag{109}$$

$$DEF_{PSt} = \alpha_{DEFPS} ILLIQ_{PSt-1} \tag{110}$$

The financial stocks of the power sector develop according to their respective financial transfers and other transfers (Eqs. (111) - (114)). Total financial assets and liabilities are defined in Eqs. (115) & (116). Financial assets minus liabilities give the power sector model determined financial net worth (FNW_{PSM}) (Eq. (117)). The residual financial instrument develops similarly to other financial assets (Eq. (118)) and is then added to the model determined financial net worth to give the overall power sector financial net-worth FNW_{PS} (Eq. (119)).

$$IBA_{PSt} = IBA_{PSt-1} + IBATR_{PSt} + OT_{IBAPSt} \tag{111}$$

$$IBL_{PSt} = IBL_{PSt-1} + IBLTR_{PSt} + OT_{IBLPSt} \tag{112}$$

$$EQA_{PSt} = EQA_{PSt-1} + EQATR_{PSt} + OT_{EQAPSt} \tag{113}$$

$$EQL_{PSt} = EQL_{PSt-1} + EQLTR_{PSt} + OT_{EQLPSt} \tag{114}$$

$$FA_{PSt} = IBA_{PSt} + EQA_{PSt} \tag{115}$$

$$FL_{PSt} = IBL_{PSt} + EQL_{PSt} \tag{116}$$

$$FNW_{PSMt} = FA_{PSt} - FL_{PSt} \tag{117}$$

$$RES_{PSt} = RES_{PSt-1} + RESTR_{PSt} + OT_{RESPSt} \tag{118}$$

$$FNW_{PSt} = FNW_{PSMt} + RES_{PSt} \tag{119}$$

The capital stock of the power sector is split into fossil fuel and non-fossil fuel capital stock, with the real value of power capital being used as a proxy for the energy electricity production capacity of both fossil and non-fossil electricity. The real value of fossil fuel (K_{PSFFR}) and non-fossil fuel (K_{PSNFFR}) are increased through real gross capital formation, while a portion of the previous periods real capital stock is lost to depreciation (Eqs. (120) & (121). These stocks are summed to give the overall real capital stock (K_{PSR}) of the power sector (Eq. (122)). Nominal capital stock values are then calculated by multiplying real capital by the production price deflator (Eqs. (124) - (126)). Power sector net worth is defined as the sum of net financial and real assets (Eq. (127)).

$$K_{PSFFRt} = (1 - \delta_{KPSt})K_{PSFFRt-1} + GCF_{PSFFRt} \tag{120}$$

$$K_{PSNFFRt} = (1 - \delta_{KPSt})K_{PSNFFRt-1} + GCF_{PSNFFRt} \tag{121}$$

$$K_{PSRt} = K_{PSFFRt} + K_{PSNFFRt} \tag{122}$$

$$\delta_{KPSt} = \delta_{KPSt-1} \tag{123}$$

$$K_{PSt} = K_{PSNFFt} + K_{PSFFt} \tag{124}$$

$$K_{PSFFt} = K_{PSFFRt}P_{Pt} \tag{125}$$

$$K_{PSNFFt} = K_{PSNFFRt}P_{Pt} \tag{126}$$

$$NW_{PSt} = FNW_{PSt} + K_{PSt} \tag{127}$$

The leverage ratio of the power sector (LEV_{PS}) is defined as the ratio between the interest-bearing liabilities of the sector and the total capital stock of the sector (Eq. (128)). The illiquidity ratio of the power sector ($ILLIQ_{PS}$) captures the ratio between cash outflows to cash inflows for the sector (Eq. (129)). The debt-service ratio of the power sector (DSR_{PS}) is the ratio of disposable income less depreciation of capital and before interest payments to total interest payments (Eq. (130)). The level of credit rationing (CR_{PS}), which constrains the level of investment of the power sector, depends negatively on the sectors debt service ratio and positively on the ratio of MFI liabilities to MFI assets (Eq. (131)). Therefore, credit is constrained both when power sector firms lack sufficient income to cover their interest payments and also when MFIs (i.e. the traditional banking sector) financial position worsens.

$$LEV_{PSt} = \frac{IBL_{PSt}}{K_{PSt}} \tag{128}$$

$$ILLIQ_{PSt} = \begin{pmatrix} INTP_{PSt} + ITAX_{PSt} + DIVP_{PSt} + GCF_{PSt} + \delta_{KPSt}K_{PSt} \\ + IBATR_{PSt} + EQATR_{PSt} + IC_{PPSt} + IC_{PSPSt} \end{pmatrix} \Big/ (GO_{PSt} + INTR_{PSt} + DIVR_{PSt} + EQLTR_{PSt} + IBLTR_{PSt}) \tag{129}$$

$$DSR_{PSt} = \frac{YD_{PSt} - \delta_{KPSt}K_{PSt-1} + INTP_{PSt}}{INTP_{PSt}} \tag{130}$$

$$CR_{PSt} = \alpha_{0CRPS} + \alpha_{1CRPS}CR_{PSt-1} - \alpha_{2CRPS}DSR_{PSt-1} + \alpha_{3CRPS}\frac{FL_{MFIt-1}}{FA_{MFIt-1}} \tag{131}$$

A.3.3 Input-Output Calculations

This section will describe the simple two sector input output system present within the model.[32] The approach taken to input-output relationships is standard, see Miller and Blair (2009) for more information on input output data and modelling.

The technical coefficients of real intermediate consumption are defined such that some are constant and assumed to follow a long-term stable relationship, while some vary based on changes in environmental variables (Eqs. (132)-(137)). In particular, the technical coefficient of electrical energy use by production ($alpha_{PSP}$) decreases through lower energy intensity (ϵ_t) and increases through greater electrification of production (θ_P) (Eq. (133)). The technical coefficient for fuel input into electricity production (α_{FUELPS}) is directly related to the share of fossil fuel electricity production in the electricity generation process (Eq. (136)). The use of technical coefficients for power that vary according to the energy mix and technological change is similar to the approach taken by the EUROGREEN model for the energy supply industries (D'Alessandro, Cieplinski, et al. 2020).

$$\alpha_{PPt} = \alpha_{PPLR} \tag{132}$$

$$\alpha_{PSPt} = \epsilon_t \theta_{Pt} \tag{133}$$

$$\alpha_{PSPSt} = \alpha_{PSPSLR} \tag{134}$$

$$\alpha_{OPPSt} = \alpha_{OPPSLR} \tag{135}$$

$$\alpha_{FUELPSt} = (1 - \beta_{NFFt-1})\alpha_{FUELPSR} \tag{136}$$

$$\alpha_{PPSt} = \alpha_{FUELPSt}\frac{P_{FUELt}}{P_{Pt}} + \alpha_{OPPSt} \tag{137}$$

These technical coefficients are then used to calculate the intermediate consumption levels of the sectors, inter-sectoral intermediate consumption is calculated in real terms and then converted to nominal intermediate consumption through the respective product price (Eqs. (138)-(146)).

$$IC_{PSPRt} = \alpha_{PSPt} GO_{PRt} \tag{138}$$

$$IC_{FUELPSRt} = \alpha_{FUELPSt} GO_{PSRt} \tag{139}$$

$$IC_{OPPSRt} = \alpha_{OPPSt} GO_{PSRt} \tag{140}$$

$$IC_{PPt} = \alpha_{PPt} GO_{Pt} \tag{141}$$

$$IC_{PSPt} = IC_{PSPRt} P_{ELECt} \tag{142}$$

$$IC_{PSPSt} = \alpha_{PSPSt} GO_{PSt} \tag{143}$$

$$IC_{PPSt} = IC_{FUELPSt} + IC_{OPPSt} \tag{144}$$

$$IC_{FUELPSt} = IC_{FUELPSRt} P_{FUELt} \tag{145}$$

$$IC_{OPPSt} = IC_{OPPSRt} P_{Pt} \tag{146}$$

Finally, the Leiontief coefficients, which are used to calculate real output of each sector are calculated by taking the inverse of the matrix of technical coefficients. As there are only two input-output sectors, this can be presented this directly below[33] (Eqs: (147)-(151)).

$$det_{IAt} = ((1 - \alpha_{PPt})(1 - \alpha_{PSPSt})) - ((\alpha_{PPSt})(\alpha_{PSPt})) \tag{147}$$

$$L_{PPt} = \frac{(1 - \alpha_{PSPSt})}{det_{IAt}} \tag{148}$$

$$L_{PPSt} = \frac{\alpha_{PPSt}}{det_{IAt}} \tag{149}$$

[32] In this section and elsewhere subscripts are ordered such that the product appears first and the sector receiving the product is second, therefore α_{FUELPS} refers to the technical coefficient for the power sector purchasing fuel products.

[33] These equations describe a simple 2X2 matrix inversion.

$$L_{PSPt} = \frac{\alpha_{PSPt}}{det_{IAt}} \quad (150)$$

$$L_{PSPSt} = \frac{(1 - \alpha_{PPt})}{det_{IAt}} \quad (151)$$

Although the two-sector input-output system presented here is simple, it would be possible to extend this to other sectors by adding relevant technical coefficients and then inverting a larger Leiontief matrix.

A.4 Sectoral Equations

A.4.1 Non-financial corporations

The model utilises a consolidated version of the non-financial corporation sector with the exception of private firms which are involved in the electricity generation process, which are moved to the power sector.

The primary income of non-financial corporations (YP_{NFC}) is the sum of the gross operating surplus of the production module (GOS_P), interest received ($INTR_{NFC}$) minus interest paid ($INTP_{NFC}$) (Eq.(152)). The equations for interest payments are based on respective rates of return on interest-bearing assets (IBA_{NFC}) and interest-bearing liabilities (IBL_{NFC}) (Eqs.(153)&(154)). NFC disposable income (YD_{NFC}) is then given as primary income minus income tax (Eq.(155)).

$$YP_{NFCt} = GOS_{Pt} + INTR_{NFCt} - INTP_{NFCt} \quad (152)$$

$$INTR_{NFCt} = r_{IBANFCt} IBA_{NFCt-1} \quad (153)$$

$$INTP_{NFCt} = r_{IBLNFCt} IBL_{NFCt-1} \quad (154)$$

$$YD_{NFCt} = YP_{NFCt} - INTAX_{NFCt} \quad (155)$$

Dividends received by firms ($DIVR_{NFC}$) are a proportion of the dividends paid by NMFIs multiplied by the share of NFC equity assets (Eq. (157)). Dividends paid by firms ($DIVP_{NFC}$) are given as a fixed proportion of their disposable income (Eq. (157)). This leaves NFCs retained profit (RP_{NFC}), to be used for investment, as their disposable income after accounting for dividend transactions (Eq. (158)).

$$DIVR_{PSt} = \frac{\beta_{dnfc} EQA_{NFCt}}{EQL_{NMFIt} DIVP_{NMFIt}} \quad (156)$$

$$DIVP_{NFCt} = \alpha_{DIVPNFC} YD_{NFCt} \quad (157)$$

$$RP_{NFCt} = YD_{NFCt} + DIVR_{NFCt} - DIVP_{NFCt} \quad (158)$$

NFC gross capital formation demand (GCF_{NFCD}), captures the desired investment level of the firm sector (Eq. (159)). A Kaleckian approach is followed when estimating this equation, as described by Blecker (2002) where investment depends positively on both the profit rate and the rate of capacity utilisation. However, for desired NFC investment, the profit rate of firms was not found to have a significant impact on desired investment, therefore the investment equation is driven primarily by the rate of capacity utilisation (u).[34] This effectively means that firms will seek to increase investment levels whenever capital is highly utilised as this is a signal that they require more capital to satisfy future demand. The actual level of NFC gross capital formation (GCF_{NFC}) is subject to credit rationing where it is assumed that firms seek finance to cover their desired level of investment and that only a portion of this finance is provided based on the level of NFC credit rationing (CR_{NFC}) (Eq. (160).

$$\frac{GCF_{NFCDt}}{K_{NFCt}} = \alpha_{0GCFNFC} + \alpha_{1GCFNFC} u_{t-1} + \alpha_{2GCFNFC} \frac{GCF_{NFCDt-1}}{K_{NFCt-1}} \quad (159)$$

[34]It should be highlighted that, while desired investment is not impacted by profits, lower income will reduce NFC debt-service ratio and increasing the level of credit constraints on the sector, effectively reducing investment through the financial channel

$$GCF_{NFCt} = (1 - CR_{NFCt})GCF_{NFCDt} \tag{160}$$

The NFC gross capital formation is divided between green and conventional capital, with β_{nfc} representing the portion of the gross capital formation allocated to green capital. Green capital is assumed to be both less energy intensive and favour electricity over direct fuel sources, therefore, the proportion of green investment is driven by the relative price of electric versus non-electric energy along with the total cost of energy relative to energy use (Eq. (161)). So, the decision between green and conventional technologies is primarily based on relative costs along with the overall cost of energy. The relative cost term that relates non-electic to electric energy prices uses a sigmoid function, in this case the hyperbolic tangent (**Tanh**) to reflect that the price elasticity effect is unlikely to be linear, and as one energy price diverges significantly from the other the impact on the proportion of green investment would be expected to decline. This ratio then defines the level of green and conventional capital investment (Eqs. (165) & (166).

$$\beta_{nfct} = \alpha_{0betaNFC} + \alpha_{1betaNFC}\mathbf{Tanh}(\frac{P_{NELECTt}}{P_{ELECt}}) + \alpha_{2betaNFC}\frac{COST_{ERt-1}}{E_{t-1}} \tag{161}$$

$$GCF_{NFCGt} = \beta_{nfct}GCF_{NFCt} \tag{162}$$

$$GCF_{NFCCt} = GCF_{NFCt} - GCF_{NFCGt} \tag{163}$$

The real levels of gross capital formation are then defined by dividing the nominal levels by the production price deflator (P_P) (Eqs. (166) - (166)).

$$GCF_{NFCRt} = GCF_{NFCGRt} + GCF_{NFCCRt} \tag{164}$$

$$GCF_{NFCGRt} = \frac{GCF_{NFCGt}}{P_{Pt}} \tag{165}$$

$$GCF_{NFCCRt} = \frac{GCF_{NFCCt}}{P_{Pt}} \tag{166}$$

Non-financial corporation model determined net lending ($LEND_{NFCM}$) is defined as their retained profits less gross capital formation spending (Eq. (167)). The lending discrepancy is driven exogenously as a portion of GDP (Eq. (168)) with the actual NFC net lending position defined as the model determined net lending plus the lending discrepancy (Eq. (169)).

$$LEND_{NFCMt} = RP_{NFCt} - GCF_{NFCt} \tag{167}$$

$$DISC_{NFCt} = \eta_{NFCT}GDP_{t-1} \tag{168}$$

$$LEND_{NFCt} = LEND_{NFCMt} + DISC_{NFCt} \tag{169}$$

Interest bearing ($IBATR_{NFC}$) and equity asset ($EQATR_{NFC}$) transfers are assumed to equal a fixed proportion of the gross output (GO_P) of the production module (Eqs. (170) & (171)). Equity liability transfers ($EQLTR_{NFC}$) equal a portion of the equity acquisitions of the NMFI sector which is assumed to hold the counterpart equity assets to all equity liabilities within the model (Eq. (172)). Interest-bearing liability transfers ($IBLTR_{NFC}$) serve as the residual stock transfer and equal the net transfers of all other financial assets (Eq. (173)). The residual transaction of the financial instruments of the NFC sector ($RESTR_{NFC}$) grows exogenously as a fixed proportion of GDP (Eq. (174)).

$$IBATR_{NFCt} = \alpha_{IBANFC}GO_{Pt} \tag{170}$$

$$EQATR_{NFCt} = \alpha_{EQANFC}GO_{Pt} \tag{171}$$

$$EQLTR_{NFCt} = (1 - \theta_{psb})(EQATR_{NMFIt}) \tag{172}$$

$$IBLTR_{NFCt} = (IBATR_{NFCt}+EQATR_{NFCt}+RESTR_{NFCt})-(LEND_{NFCt}+EQLTR_{NFCt}) \tag{173}$$

$$RESTR_{NFCt} = \eta_{NFCB}GDP_{t-1} \tag{174}$$

Other transfers, which include price revaluations and other changes in asset value, are driven in a variety of ways within the model (Eqs. (175) - (180)), similar to the power sector. Other transfers relating to interest-bearing assets (OT_{IBANFC}) are assumed to follow a fixed exogenous rate, reflecting that these assets include safe assets such as deposits that do not vary significantly based on other model variables (Eq. (175)). Other transfers relating to equity assets (OT_{EQANFC}) are given as a portion of the other transfers of NMFI equity liabilities ($OT_{EQANMFI}$) (Eq. (176). Other transfers relating to equity liabilities are assumed to be set such that equity prices are positively related to dividend payments by the NFC sector while being reduced by the current interest rate on interest bearing liabilities of the government, which serves as an approximation for the so-called 'risk-free interest rate (Eq. (177)). Other transfers relating to interest-bearing liabilities (OT_{IBLNFC}) are relatively large and require some individual attention. Other transfers of interest-bearing liabilities are mostly made up of defaults on loans, it is therefore assumed that it's rate of change is entirely driven by defaults (Eq. (178)). The default rate of the power sector (DEF_{NFC}) is then proportional to the illiquidity ratio ($ILLIQ_{NFC}$) where the higher the illiquidity of the power sector leads to higher defaults (Eq. (179)).

$$OT_{IBANFCt} = \delta_{IBANFC}(IBA_{NFCt-1}) \tag{175}$$

$$OT_{EQANFCt} = OT_{EQLNMFIt} - (OT_{EQAHHt} + OT_{EQAPSt}) \tag{176}$$

$$OT_{EQLNFCt} = \frac{DIVP_{NFCt}}{r_{IBLGVTt} + \beta_{EQLNFC}} - EQL_{NFCt-1} \tag{177}$$

$$OT_{IBLNFCt} = DEF_{NFCt} IBL_{NFCt-1} \tag{178}$$

$$DEF_{NFCt} = -0.002371(ILLIQ_{NFCt-1}) \tag{179}$$

$$OT_{RESNFCt} = \delta_{RESNFC}(RES_{NFCt-1}) \tag{180}$$

The financial stocks of the NFC sector develop according to their respective financial transfers and other transfers (Eqs. (181) - (184)). Total financial assets and liabilities are defined in Eqs. (185) & (186). Financial assets minus liabilities give the NFC sector model determined financial net worth (FNW_{NFCM}) (Eq. (187)). The residual financial instrument develops similarly to other financial assets (Eq. (188)) and is then added to the model determined financial net worth to give the overall NFC sector financial net-worth FNW_{NFC} (Eq. (189)).

$$IBA_{NFCt} = IBA_{NFCt-1} + IBATR_{NFCt} + OT_{IBANFCt} \tag{181}$$

$$EQA_{NFCt} = EQA_{NFCt-1} + EQATR_{NFCt} + OT_{EQANFCt} \tag{182}$$

$$IBL_{NFCt} = IBL_{NFCt-1} + IBLTR_{NFCt} + OT_{IBLNFCt} \tag{183}$$

$$EQL_{NFCt} = EQL_{NFCt-1} + EQLTR_{NFCt} + OT_{EQLNFCt} \tag{184}$$

$$FA_{NFCt} = IBA_{NFCt} + EQA_{NFCt} \tag{185}$$

$$FL_{NFCt} = IBL_{NFCt} + EQL_{NFCt} \tag{186}$$

$$FNW_{NFCMt} = FA_{NFCt} - FL_{NFCt} \tag{187}$$

$$RES_{NFCt} = RES_{NFCt-1} + RESTR_{NFCt} + OT_{RESNFCt} \tag{188}$$

$$FNW_{NFCt} = FNW_{NFCMt} + RES_{NFCt} \tag{189}$$

The capital stock of the NFC sector is split into conventional and green capital stock. The real value of conventional (K_{NFCCR}) and green (K_{NFCGR}) are increased through real gross capital formation, while a portion of the previous periods real capital stock is lost to depreciation (Eqs. (190) & (191). These stocks are summed to give the overall real capital stock (K_{NFCR}) of NFC sector (Eq. (192)). The nominal capital stock values are then calculated by multiplying the real capital by the production price deflator (Eqs. (193) - (195)). NFC sector net worth is defined as the sum of net financial and real assets (Eq. (196)).

$$K_{NFCCRt} = (1 - \delta_{KPt})K_{NFCCRt-1} + GCF_{NFCCRt} \tag{190}$$

$$K_{NFCGRt} = (1 - \delta_{KPt})K_{NFCGRt-1} + GCF_{NFCGRt} \tag{191}$$

$$K_{NFCRt} = K_{NFCCRt} + K_{NFCGRt} \tag{192}$$

$$K_{NFCt} = K_{NFCCt} + K_{NFCGt} \tag{193}$$

$$K_{NFCCt} = K_{NFCCRt} P_{Pt} \tag{194}$$

$$K_{NFCGt} = K_{NFCGRt} P_{Pt} \tag{195}$$

$$NW_{NFCt} = FNW_{NFCt} + K_{NFCt} \tag{196}$$

The leverage ratio of the power sector (LEV_{NFC}) is defined as the ratio between the interest-bearing liabilities of the sector and the total capital stock of the sector (Eq. (197)). The illiquidity ratio of the power sector ($ILLIQ_{NFC}$) captures the ratio between cash outflows and cash inflows for the sector (Eq. (198)). The debt-service ratio of NFCs (DSR_{NFC}) is defined in the same way as the power sector as the ratio of disposable income less depreciation of capital and before interest payments to total interest payments (Eq. (199)). The level of credit rationing (CR_{NFC}), which constrains the level of investment of the NFC sector, depends negatively on the sectors debt service ratio and positively on the ratio of MFI liabilities to MFI assets (Eq. (200)). Therefore, as with the power sector, credit is constrained both when firms lack sufficient income to cover their interest payments and also when MFIs (i.e. the traditional banking sector) financial position worsens.

$$LEV_{NFCt} = \frac{IBL_{NFCt}}{K_{NFCt}} \tag{197}$$

$$ILLIQ_{NFCt} = \begin{pmatrix} INTP_{NFCt} + INTAX_{NFCt} + DIVP_{NFCt} + GCF_{NFCt} + \delta_{KPt} K_{NFCt} \\ + IBATR_{NFCt} + EQATR_{NFCt} \end{pmatrix} \Big/ \\ (GOS_{Pt} + INTR_{NFCt} + DIVR_{NFCt} + EQLTR_{NFCt} + IBLTR_{NFCt}) \tag{198}$$

$$DSR_{NFCt} = \frac{YD_{NFCt} - \delta_{NFCSt} K_{NFCt-1} + INTP_{NFCt}}{INTP_{NFCt}} \tag{199}$$

$$CR_{NFCt} = \alpha_{0CRNFC} + \alpha_{1CRNFC} CR_{NFCt-1} - \alpha_{2CRNFC} DSR_{NFCt-1} + \alpha_{3CRNFC} \frac{FL_{MFIt-1}}{FA_{MFIt-1}} \tag{200}$$

A.4.2 Monetary financial Institutions

The monetary financial institution (MFI), sector represents traditional banks whose primary role is to hold the interest bearing assets (Deposits etc.) of the sectors in the model and provide interest bearing liabilities (Loans etc.) to these same sectors. MFIs play a relatively passive role in the model, although they do ration credit to the power sector and NFC sector through Eqs. (131) & (200). Therefore, banks are not simply intermediaries of loanable funds, consistent with the arguments of Jakab and Kumhof (2018) and the MFI sector creates money endogenously when it provides loans to the rest of the institutional sectors, consistent with post-Keynesian theory (Lavoie 2014).

For MFIs, the model net lending position ($LEND_{MFIM}$) is the net of interest received by MFIs ($INTR_{MFI}$) and interest paid by MFIs ($INTP_{MFI}$) (Eq.(201)). MFI Interest received and paid is the sum of respective rates of returns and stock levels (Eqs.(202)&(203)). The lending discrepancy is driven exogenously as less the sum of all the other exogenously driven discrepancies within the model (Eq. (204)) with the actual NFC net lending position defined as the model determined net lending plus the lending discrepancy (Eq. (205)).

$$LEND_{MFIMt} = INTR_{MFIt} - INTP_{MFIt} \tag{201}$$

$$INTR_{MFIt} = INTP_{NFCt} + INTP_{PSt} + INTP_{NMFIt} + INTP_{GVTt} + INTP_{HHt} \tag{202}$$

$$INTP_{MFIt} = INTR_{NFCt} + INTR_{PSt} + INTR_{NMFIt} + INTR_{GVTt} + INTR_{HHt} + INTN_{RoWt} \tag{203}$$

$$DISC_{MFIt} = -(DISC_{NFCt} + DISC_{NMFIt} + DISC_{GVTt} + DISC_{HHt} + DISC_{RoWt}) \tag{204}$$

$$LEND_{MFIt} = LEND_{MFIMt} + DISC_{MFIt} \tag{205}$$

The total MFI financial assets (FA_{MFI}) are given as the sum of all other sectors' interest-bearing liabilities, while the total MFI financial liabilities are given as the sum of all other sectors' interest-bearing assets (Eqs. (206) & (207)). Financial assets minus liabilities give the MFI sector model determined financial net worth (FNW_{MFIM}) (Eq. (208)). The residual financial instrument is given as less the sum of all the other residual financial instruments in the model[35](Eq. (209)) and is then added to the model determined financial net worth to give the overall MFI financial net-worth FNW_{MFI} (Eq. (210)).

$$FA_{MFIt} = IBL_{NFCt} + IBL_{PSt} + IBL_{NMFIt} + IBL_{GVTMFIt} + IBL_{HHt} + IBL_{RoWt} \tag{206}$$

$$FL_{MFIt} = IBA_{NFCt} + IBA_{PSt} + IBA_{NMFIt} + IBA_{GVTt} + IBA_{HHt} + IBA_{RoWt} \tag{207}$$

$$FNW_{MFIMt} = FA_{MFIt} - FL_{MFIt} \tag{208}$$

$$RES_{MFIt} = -(RES_{HHt} + RES_{NFCt} + RES_{NMFIt} + RES_{PSt} + RES_{GVTt} + RES_{RoWt}) \tag{209}$$

$$FNW_{MFIt} = FNW_{MFIMt} + RES_{MFIt} \tag{210}$$

A.4.3 Non-monetary financial Institutions

Non-monetary financial institutions (NMFIs) represent all non-bank financial institutions, including investment funds and pension funds. The separation of this sector from traditional banks reflects the importance of non-monetary financial activity in the UK and a similar separation is made by Burgess, Burrows, et al. (2016) in their SFC model for the UK. This sector acts as the counterpart for all dividend transfers in the model, and it's asset position has a direct impact on the value of pension and insurance assets held by households. In the UK, the NMFI sector is particularly large with almost the same total financial assets/liabilities as the traditional banking (MFI) sector. Including it as a separate sector in this way allows the model to look at a wider range of financial effects and is prudent due to the differing role MFIs and NMFIs have in the economy.

NMFIs disposable income (YD_{NMFI}) is defined as the sum of their interest and dividend receipts minus their interest and dividend payments (Eq. (211). The interest received and the interest paid are equal to the sum of the relevant rates multiplied by the associated stock values (Eqs. (212) & (213)). NMFI dividends received are equal to the sum of the dividend payments of the other model sectors as it is assumed that the NMFI sector is the destination of all dividend payments and the source of all dividend flows (Eq.(214)). The dividends paid by NMFIs are then given as a fixed proportion of their available net-income prior to dividend payments, where ($\alpha_{DIVPNMFI}$) is between 0 and 1 (Eq. (215)).[36]

$$YD_{NMFIt} = (INTR_{NMFIt} + DIVR_{NMFIt}) - (INTP_{NMFIt} + DIVP_{NMFIt}) \tag{211}$$

$$INTR_{NMFIt} = r_{IBANMFIt} IBA_{NMFIt-1} + r_{IBLGVTt} IBL_{GVTNMFIt-1} \tag{212}$$

$$INTP_{NMFIt} = r_{IBLNMFIt} IBL_{NMFIt-1} \tag{213}$$

$$DIVR_{NMFIt} = DIVP_{NFCt} + DIVP_{PSt} \tag{214}$$

$$DIVP_{NMFIt} = \alpha_{DIVPNMFI}(DIVR_{NMFIt} + INTR_{NMFIt} - INTP_{NMFIt}) \tag{215}$$

Investment income related to pension $PENSR$ and insurance schemes ($INSR$) that is payable to households are defined based on the disposable income of NMFIs and the relative share of pensions and insurance assets (Eqs. (216) & (217)).[37] These equations mean that the return on pension and

[35]So the MFI sector is the counterpart to all residual financial instruments by assumption.

[36]This approach will inevitably lead to overestimating dividend flows to and from NMFIs. However, the net flows are consistent with the data and this approach is a convenient way of dealing with a lack of data on whom-to-whom dividend flow data.

[37]It should be highlighted that these flows, while payable to households, do not actually represent accessible household income. They are the income of pension and insurance schemes which increase the value of these funds held by households. The national accounting convention of recording this as household property income is followed; however, in the model both these flows will directly end up as household pension and insurance transfers leading to growth of these respective assets.

insurance schemes is impacted directly by the economic health of the NMFI sector and if this sector receives lower income, the return on these assets will decrease. Social contributions to the NMFI sector ($SOCC_{NMFI}$) are then equal to the investment income from pensions plus a proportion of household wage income (Eq. (218)). Social benefits paid by NMFIs ($SOCC$) are predominantly pension-related transfers and are therefore modelled as proportional to the overall value of pension schemes (Eq. (219)). The pension adjustment ($PENS_{ADJ}$) is defined as the net social contribution minus social benefit of the NMFI sector (Eq. (220).[38]

$$PENSR_t = \frac{\alpha_{PENSR} YD_{NMFIt-1}(PENS_{t-1}}{(PENS_{t-1} + INS_{t-1}))} \tag{216}$$

$$INSR_t = \frac{\alpha_{INSR} YD_{NMFIt-1}(INS_{t-1}}{(PENS_{t-1} + INS_{t-1}))} \tag{217}$$

$$SOCC_{NMFIt} = PENSR_t + \alpha_{SOCCW} W_t \tag{218}$$

$$SOCB_{NMFIt} = \alpha_{SOCBPENS} PENS_{t-1} \tag{219}$$

$$PENS_{ADJt} = SOCC_{NMFIt} - SOCB_{NMFIt} \tag{220}$$

NMFI model determined net lending ($LEND_{NMFIM}$) is defined as their disposable income and net flows related to pension and insurance schemes (Eq. (221)). The lending discrepancy is driven exogenously as a portion of GDP (Eq. (222)) with the actual NFC net lending position defined as the model determined net lending plus the lending discrepancy (Eq. (223)).

$$LEND_{NMFIMt} = YD_{NMFIt} - INSR_t - PENSR_t + SOCC_{NMFIt} - SOCB_{NMFIt} - PENS_{ADJt} \tag{221}$$

$$DISC_{NMFIt} = \eta_{NMFIT} GDP_t \tag{222}$$

$$LEND_{NMFIt} = LEND_{NMFIMt} + DISC_{NMFIt} \tag{223}$$

Interest bearing asset transfers ($IBATR_{NMFI}$) are set exogenously as equal to a fixed proportion of gross output (GO) (Eq. (224)). Equity liability transfers ($EQLTR_{NMFI}$) are equal to the sum of all other equity asset transfers for domestic sectors and the net equity transfer of the rest of the world (Eq. (225)), this is due to the assumption that the NMFI sector serves as the counterpart to all equity assets in the model. NMFI equity asset transfers ($EQATR_{NMFI}$) are then equal to a fixed proportion of the equity liability transfers (Eq. (226)). Interest-bearing liability transfers ($IBLTR_{NMFI}$) serve as the residual stock transfer and equal the net transfers of all other financial assets (Eq. (227)). The residual financial instrument transaction of the NMFI sector ($RESTR_{NMFI}$) grows exogenously as a fixed proportion of GDP (Eq. (228)).

$$IBATR_{NMFIt} = \alpha_{IBANMFI} GO_t \tag{224}$$

$$EQLTR_{NMFIt} = EQATR_{NFCt} + EQATR_{PSt} + EQATR_{HHt} + EQNTR_{RoWt} \tag{225}$$

$$EQATR_{NMFIt} = \psi_{EQNMFI} EQLTR_{NMFIt} \tag{226}$$

$$\begin{aligned} IBLTR_{NMFIt} = {} & (IBATR_{NMFIt} + EQATR_{NMFIt} + IBLTR_{GVTNMFIt} + RESTR_{NMFIt}) \\ & - (LEND_{NMFIt} + EQLTR_{NMFIt} + PENSTR_t + INSTR_t) \end{aligned} \tag{227}$$

$$RESTR_{NMFIt} = \eta_{NMFIB} GDP_{t-1} \tag{228}$$

Other transfers, which include price revaluations and other changes in asset value, are set mainly as exogenous rates for the NMFI interest-bearing assets, liabilities and the residual financial instrument (Eqs. (229) - (231)). Other transfers related to equity assets ($OT_{EQANMFI}$) are defined based on the other transfers of equity amongst the other sectors in the model (Eq. (232)). Other transfers related to equity liabilities are assumed to be established so that equity prices are positively related to dividend

[38]This is an imputed flow paid to households by NMFIs however it will be used to define the pension transfers of the household sector.

payments by the NMFI sector while being reduced by the current interest rate on interest-bearing liabilities of the government, which serves as an approximation for the so-called 'risk-free interest rate (Eq. (177)). Other transfers relating to pensions (OT_{PENS}) and insurance schemes (OT_{INS}) are based on the other transfers of other net-assets of the NMFI sector, reflecting that the revaluations of these assets are based primarily on the net financial changes within the NMFI sector (Eq. (234) & (235)).

$$OT_{IBANMFIt} = \delta_{IBANMFI} IBA_{NMFIt-1} \tag{229}$$

$$OT_{IBLNMFIt} = \delta_{IBLNMFI} IBL_{NMFIt-1} \tag{230}$$

$$OT_{RESNMFIt} = \delta_{RESNMFI} RES_{NMFIt-1} \tag{231}$$

$$OT_{EQANMFIt} = OT_{EQLNFCt} + OT_{EQLPSt} \tag{232}$$

$$OT_{EQLNMFIt} = \frac{DIVP_{NMFIt}}{r_{IBLGVTt} + \beta_{EQLNMFI}} - EQL_{NMFIt-1} \tag{233}$$

$$\begin{aligned} OT_{PENSt} = (&OT_{IBANMFIt} + \beta_{IBLGVTNMFI}\, OT_{IBLGVTt} + OT_{EQANMFIt} \\ &- OT_{IBLNMFIt} - OT_{EQLNMFIt}) \cdot \frac{PENS_{t-1}}{PENS_{t-1} + INS_{t-1}} \end{aligned} \tag{234}$$

$$\begin{aligned} OT_{INSt} = (&OT_{IBANMFIt} + \beta_{IBLGVTNMFI}\, OT_{IBLGVTt} + OT_{EQANMFIt} \\ &- OT_{IBLNMFIt} - OT_{EQLNMFIt}) \cdot \frac{INS_{t-1}}{PENS_{t-1} + INS_{t-1}} \end{aligned} \tag{235}$$

The financial stocks of the NMFI sector develop according to their respective financial transfers and other transfers (Eqs. (236) - (239)). Total financial assets and liabilities are defined in Eqs. (240) & (241). Financial assets minus liabilities give the NMFI sector model determined financial net worth (FNW_{NMFIM}) (Eq. (242)). The residual financial instrument develops similarly to other financial assets (Eq. (243)) and is then added to the model determined financial net worth to give the overall NMFI financial net-worth FNW_{NMFI} (Eq. (244)).

$$IBA_{NMFIt} = IBA_{NMFIt-1} + IBATR_{NMFIt} + OT_{IBANMFIt} \tag{236}$$

$$EQA_{NMFIt} = EQA_{NMFIt-1} + EQATR_{NMFIt} + OT_{EQANMFIt} \tag{237}$$

$$IBL_{NMFIt} = IBL_{NMFIt-1} + IBLTR_{NMFIt} + OT_{IBLNMFIt} \tag{238}$$

$$EQL_{NMFIt} = EQA_{HHt} + EQA_{NFCt} + EQA_{PSt} + EQN_{RoWt} \tag{239}$$

$$FA_{NMFIt} = IBA_{NMFIt} + IBL_{GVTNMFIt} + EQA_{NMFIt} \tag{240}$$

$$FL_{NMFIt} = IBL_{NMFIt} + EQL_{NMFIt} + PENS_t + INS_t \tag{241}$$

$$FNW_{NMFIMt} = FA_{NMFIt} - FL_{NMFIt} \tag{242}$$

$$RES_{NMFIt} = RES_{NMFIt-1} + RESTR_{NMFIt} + OT_{RESNMFIt} \tag{243}$$

$$FNW_{NMFIt} = FNW_{NMFIMt} + RES_{NMFIt} \tag{244}$$

A.4.4 Government

The government sector is an active part of the economy, reflecting its crucial role in the UK economy. It sets tax levels, including environmental taxes, pays government wages, and decides on levels of government consumption and investment. It is assumed that the government is free to make choices about all these variables without political constraints. In the baseline, government spending is based on OBR estimates and implied rates from past data.

Government disposable income (YD_{GVT}) is equal to the sum of indirect taxation, income taxes, social contribution, and interest received less social benefits paid and interest payments (Eq.(245)). The total indirect tax receipts ($ITAX$) are equal to the indirect taxes on production ($ITAX_P$) and indirect taxes on the power sector ($ITAX_{PS}$). The indirect tax on production is then defined as the indirect tax rate multiplied by gross output plus environmental taxes linked to non-electrical emissions ($ITAX_{NELEC}$) (Eq. (247)). Non-electrical energy taxes are equal to the coverage of the carbon pricing scheme (COV_{ETSP})[39] multiplied by the emission trading scheme (ETS) carbon price (P_{ETS}) all multiplied by the total non-electrical emissions in the economy[40] (Eq. (248). The indirect tax rate on production ($ITAXR_P$) is assumed to tend to a set long-run value based on the adjustment speed (τ_{gvt})[41] (Eq. (249).

$$YD_{GVTt} = (ITAX_t + INTAX_t + SOCC_{GVTt} + INTR_{GVTt}) - (SOCB_{GVTt} + INTP_{GVTt}) \quad (245)$$

$$ITAX_t = ITAX_{Pt} + ITAX_{PSt} \quad (246)$$

$$ITAX_{Pt} = ITAXR_{Pt} GO_{Pt} + ITAX_{NELECt} \quad (247)$$

$$ITAX_{NELECt} = COV_{ETSP} P_{ETSt} EMIS_{NELECt} \quad (248)$$

$$ITAXR_{Pt} = ITAXR_{Pt-1} - \tau_{gvt}(ITAXR_{Pt-1} - ITAXR_{PLR}) \quad (249)$$

The indirect tax on the power sector is defined similarly to that of the production module as the indirect tax rate multiplied by gross output plus environmental taxes linked to electrical emissions (Eq. (250)). The indirect tax rate on the power sector ($ITAXR_P$) is assumed to tend to a set long run value based on the adjustment speed (τ_{gvt}) (Eq. (251)). The baseline carbon price of the emission trading scheme (P_{ETS}) is set to follow a baseline path where it increases marginally over the period (Eq. (252)). This carbon price can be set higher by the government in different scenarios.[42]

$$ITAX_{PSt} = ITAXR_{PSt} GO_{PSt} + COV_{ETSPSt} P_{ETSt} EMIS_{ELECt} \quad (250)$$

$$ITAXR_{PSt} = ITAXR_{PSt-1} - \tau_{gvt}(ITAXR_{PSt-1} - ITAXR_{PSLR}) \quad (251)$$

$$P_{ETSt} = P_{ETSRBt} \quad (252)$$

Income tax receipts ($INTAX$) are defined as the sum of income tax from non-financial corporations ($INTAX_{NFC}$) and households ($INTAX_{HH}$). Both income taxes are modelled as a fixed proportion of the wage bill (Eq. (254) & (255)). With the respective income tax rates assumed to tend to set long-run values based on the adjustment speed (τ_{gvt}) (Eqs. (256) & (257)).

$$INTAX_t = INTAX_{NFCt} + INTAX_{HHt} \quad (253)$$

$$INTAX_{NFCt} = INTAXR_{NFCt} W_t \quad (254)$$

[39] This is assumed to be constant in the baseline scenario

[40] It is assumed that the carbon tax for household non-electric energy use is attributed to the production sector and then passed in through higher prices.

[41] This term is introduced due to the implied initial tax rates being far from historical norms due to the COVID-19 pandemic and other sources of volatility, using an adjustment speed allows these values to gradually return to more normal levels rather than creating a sudden change at the initial condition.

[42] The UK has an emission trading scheme, rather than a direct carbon tax so arguably the government cannot control the price so easily and rather controls the maximum emissions through a cap and trade system. To simplify the modelling, it is assumed that the government effectively sets a cap to achieve an average carbon price over a given period and adjusts the cap if that price is not met.

$$INTAX_{HHt} = INTAXR_{HHt}W_t \tag{255}$$

$$INTAXR_{NFCt} = INTAXR_{NFCt-1} - \tau_{gvt}(INTAXR_{NFCt-1} - INTAXR_{NFCLR}) \tag{256}$$

$$INTAXR_{HHt} = INTAXR_{HHt-1} - \tau_{gvt}(INTAXR_{HHt-1} - INTAXR_{HHLR}) \tag{257}$$

The equations for government interest payments are based on respective rates of return on interest-bearing assets (IBA_{GVT}) and interest bearing liabilities (IBL_{GVT}) (Eqs.(258)&(259)). Social contributions that households pay to the government ($SOCC_{GVT}$) are treated as an additional income tax taken from overall wages (Eq. (260)). With the social contribution rate assumed to tend to set long-run values based on the adjustment speed (τ_{gvt}) (Eqs. (261)). Social benefits paid by the government ($SOCB_{GVT}$), as a share of GDP, are driven by an econometrically calibrated equation, partly driven by a constant exogenous factor (α_{0SOCB}) and also by the rate of unemployment (ru) where higher unemployment rates lead to higher levels of unemployment benefit payments and thus higher government social benefit payments (Eq. (262)).

$$INTR_{GVTt} = r_{IBAGVTt}IBA_{GVTt-1} \tag{258}$$

$$INTP_{GVTt} = r_{IBLGVTt}IBL_{GVTt-1} \tag{259}$$

$$SOCC_{GVTt} = SOCCR_{GVTt}W_t \tag{260}$$

$$SOCCR_{GVTt} = SOCCR_{GVTt-1} - \tau_{gvt}(SOCCR_{GVTt-1} - SOCCR_{GVTLR}) \tag{261}$$

$$\frac{SOCB_{GVTt}}{GDP_t} = \alpha_{0SOCB} + \alpha_{1SOCB}\frac{SOCB_{GVTt-1}}{GDP_{t-1}} + \alpha_{2SOCB}ru_t \tag{262}$$

Consumption of the government sector ($CONS_{GVT}$) is the sum of public wages (W_{PUB})[43] and other government consumption ($OCONS_{GVT}$) (Eq. (263)). Other government consumption ($OCONS_{GVT}$) is assumed to follow an exogenous path based on nominal GDP (Eq. (264)). Government gross capital formation (GCF_{GVT}) is discretionary government spending and is assumed to follow a baseline path based on OBR estimates (Eq. (265)). As with the NFC sector, government gross capital formation is divided between green and conventional capital, with β_{gvt} representing the portion of the gross capital formation allocated to green capital. It is assumed in the baseline that the behavioural effect of energy costs and prices is the same for the government as it is the non-financial corporations, so β_{gvt} is set as equal to β_{nfc} (Eq. (266)). This ratio then defines the level of green and conventional capital investment (Eqs. (271) & (272).

$$CONS_{GVTt} = W_{PUBt} + OCONS_{GVTt} \tag{263}$$

$$OCONS_{GVTt} = \alpha_{OCONSGVT}GDP_{t-1} \tag{264}$$

$$GCF_{GVTt} = GCF_{GVTBASEt} \tag{265}$$

$$\beta_{gvtt} = \beta_{nfct} \tag{266}$$

$$GCF_{GVTGt} = \beta_{gvtt}GCF_{GVTt} \tag{267}$$

$$GCF_{GVTCt} = GCF_{GVTt} - GCF_{GVTGt} \tag{268}$$

The real levels of government consumption and gross capital formation are then defined by dividing the nominal levels by the production price deflator (P_P) (Eqs. (269) - (272)).

$$CONS_{GVTRt} = \frac{CONS_{GVTt}}{P_{Pt}} \tag{269}$$

$$GCF_{GVTRt} = GCF_{GVTGRt} + GCF_{GVTCRt} \tag{270}$$

$$GCF_{GVTGRt} = \frac{GCF_{GVTGt}}{P_{Pt}} \tag{271}$$

$$GCF_{GVTCRt} = \frac{GCF_{GVTCt}}{P_{Pt}} \tag{272}$$

[43] In national accounting public wages are recorded as consumption of the government sector.

The government model determined net lending ($LEND_{GVTM}$) is defined as their disposable income less consumption and gross capital formation spending (Eq. (275)). The lending discrepancy is driven exogenously as a portion of GDP (Eq. (274)) with the actual NFC net lending position defined as the model determined net lending plus the lending discrepancy (Eq. (275)).

$$LEND_{GVTMt} = YD_{GVTt} - (CONS_{GVTt} + GCF_{GVTt}) \tag{273}$$

$$DISC_{GVTt} = \eta_{GVTT} GDP_{t-1} \tag{274}$$

$$LEND_{GVTt} = LEND_{GVTMt} + DISC_{GVTt} \tag{275}$$

Interest bearing asset transfers ($IBATR_{GVT}$) are assumed to equal a fixed proportion of the gross output (GO) (Eq. (276)). Interest bearing liability transfers ($IBLTR_{GVT}$) serve as the residual stock transfer and equal the net transfers of all other financial assets (Eq. (277)). Government bonds, which make up a large portion of government interest-bearing liabilities are held by multiple sectors in the model. The economic accounts data does not provide the whom-to-whom transactions required to establish the transfers of each sector however their are experimental flow-of-funds data for 2020 (ONS 2020) which gives an estimate that can be used. This data suggests that government interest bearing liabilities are equally split between MFIs, NMFIs and RoW. Therefore, the government interest liability transfers are defined to be equal for each of these sectors based on the fixed proportion derived from the flow-of-funds data and assuming these proportions remain constant (Eqs (278)-(280)). The residual financial instrument transaction of the government sector ($RESTR_{GVT}$) grows exogenously as a fixed proportion of GDP (Eq. (281)).

$$IBATR_{GVTt} = \alpha_{IBAGVT} GO_t \tag{276}$$

$$IBLTR_{GVTt} = IBATR_{GVTt} + RESTR_{GVTt} - LEND_{GVTt} \tag{277}$$

$$IBLTR_{GVTMFIt} = \beta_{IBLGVTMFI} IBLTR_{GVTt} \tag{278}$$

$$IBLTR_{GVTNMFIt} = \beta_{IBLGVTNMFI} IBLTR_{GVTt} \tag{279}$$

$$IBLTR_{GVTRoWt} = \beta_{IBLGVTRoW} IBLTR_{GVTt} \tag{280}$$

$$RESTR_{GVTt} = \eta_{GVTB} GDP_{t-1} \tag{281}$$

Other transfers, which include price revaluations and other changes in asset value, are set as exogenous rates for the government sector (Eqs. (282) - (284)).

$$OT_{IBAGVTt} = \delta_{IBAGVT}(IBA_{GVTt-1}) \tag{282}$$

$$OT_{IBLGVTt} = \delta_{IBLGVT}(IBL_{GVTt-1}) \tag{283}$$

$$OT_{RESGVTt} = \delta_{RESGVT}(RES_{GVTt-1}) \tag{284}$$

The financial stocks of the government sector develop according to their respective financial transfers and other transfers (Eqs. (285) - (289)). Total financial assets and liabilities are defined in Eqs. (290) & (291). Financial assets minus liabilities give the government sector model determined financial net worth (FNW_{GVTM}) (Eq. (292)). The residual financial instrument develops similarly to other financial assets (Eq. (293)) and is then added to the model determined financial net worth to give the overall government sector financial net-worth FNW_{GVT} (Eq. (294)).

$$IBA_{GVTt} = IBA_{GVTt-1} + IBATR_{GVTt} + OT_{IBAGVTt} \tag{285}$$

$$IBL_{GVTt} = IBL_{GVTMFIt} + IBL_{GVTNMFIt} + IBL_{GVTRoWt} \tag{286}$$

$$IBL_{GVTMFIt} = IBL_{GVTMFIt-1} + IBLTR_{GVTMFIt} + \beta_{IBLGVTMFI} OT_{IBLGVTt} \tag{287}$$

$$IBL_{GVTNMFIt} = IBL_{GVTNMFIt-1} + IBLTR_{GVTNMFIt} + \beta_{IBLGVTNMFI} OT_{IBLGVTt} \tag{288}$$

$$IBL_{GVTRoWt} = IBL_{GVTRoWt-1} + IBLTR_{GVTRoWt} + \beta_{IBLGVTRoW} OT_{IBLGVTt} \tag{289}$$

$$FA_{GVTt} = IBA_{GVTt} \tag{290}$$

$$FL_{GVTt} = IBL_{GVTt} \tag{291}$$

$$FNW_{GVTMt} = FA_{GVTt} - FL_{GVTt} \tag{292}$$

$$RES_{GVTt} = RES_{GVTt-1} + RESTR_{GVTt} + OT_{RESGVTt} \tag{293}$$

$$FNW_{GVTt} = FNW_{GVTMt} + RES_{GVTt} \tag{294}$$

The capital stock of the government sector is split into conventional and green capital stock. The real value of conventional (K_{GVTCR}) and green (K_{GVTGR}) are increased through real gross capital formation, while a portion of the previous periods real capital stock is lost to depreciation (Eqs. (295) & (296). These stocks are summed to give the overall real capital stock (K_{GVTR}) of government sector (Eq. (297)). The nominal capital stock values are then calculated by multiplying the real capital by the production price deflator (Eqs. (298) - (300)). Government sector net worth is defined as the sum of net financial and real assets (Eq. (301)).

$$K_{GVTCRt} = (1 - \delta_{KPt})K_{GVTCRt-1} + GCF_{GVTCRt} \tag{295}$$

$$K_{GVTGRt} = (1 - \delta_{KPt})K_{GVTGRt-1} + GCF_{GVTGRt} \tag{296}$$

$$K_{GVTRt} = K_{GVTCRt} + K_{GVTGRt} \tag{297}$$

$$K_{GVTt} = K_{GVTCt} + K_{GVTGt} \tag{298}$$

$$K_{GVTCt} = K_{GVTCRt}P_{Pt} \tag{299}$$

$$K_{GVTGt} = K_{GVTGRt}P_{Pt} \tag{300}$$

$$NW_{GVTt} = FNW_{GVTt} + K_{GVTt} \tag{301}$$

A.4.5 Households

Households are the main consumers in the economy and also invest in the building of houses. Households are considered in the aggregate within the model; therefore, inequality effects are not explicitly modelled. Housing stock is included as the main real asset on the household balance sheet while also considering different forms of housing based on their electricity use and energy efficiency. This allows the model to explore the impacts of policies aimed at greening the UK housing stock, which is an important part of achieving climate goals within the UK.

The primary income of the household sector (YP_{HH}), is the sum of wage income (W), interest payments received ($INTR_{HH}$), dividends ($DIVR_{HH}$) less interest payments ($INTP_{HH}$) (Eq. (302)). The equations for interest payments are based on respective rates of return on interest-bearing assets (IBA_{HH}) and interest-bearing liabilities (IBL_{HH}) (Eqs.(303)&(304)). The dividends received by households ($DIVR_{HH}$) are a proportion of the dividends paid by NMFIs multiplied by the share of HH equity assets (Eq. (305)).

$$YP_{HHt} = W_t + (INTR_{HHt} + DIVR_{HHt}) - (INTP_{HHt}) \tag{302}$$

$$INTR_{HHt} = r_{IBAHHt}IBA_{HHt-1} \tag{303}$$

$$INTP_{HHt} = r_{IBLHHt}IBL_{HHt-1} \tag{304}$$

$$DIVR_{HHt} = \beta_{dhh}\frac{EQA_{HHt}}{EQL_{NMFIt}}DIVP_{NMFIt} \tag{305}$$

The disposable income of the household sector (YD_{HH}) is taken as households primary income including net social contributions/benefits and minus income tax payments ($INTAX_{HH}$) (Eq. (306)). The total social contributions and benefits of the households are given by the sum of the respective values of the NMFI and the government sectors (Eqs. (307) & (308)).

$$YD_{HHt} = YP_{HHt} + (SOCB_t) - (SOCC_t + INTAX_{HHt}) \tag{306}$$

$$SOCC_t = SOCC_{NMFIt} + SOCC_{GVTt} \tag{307}$$

$$SOCB_t = SOCB_{NMFIt} + SOCB_{GVTt} \tag{308}$$

Household consumption ($CONS_{HH}$) is given as the sum of household consumption from production ($CONS_{HHP}$) and from the power sector ($CONS_{HHPS}$) (Eq. (309)). The nominal consumption of production is based on post-Keynesian theory, where there is a positive relationship between household disposable (YD_{HH}) income and consumption and also between the financial wealth of the household (FNW_{HH}) and consumption. This aims to capture the distinction between consumption out of wages and consumption out of profits, with the latter generally found to be lower (Lavoie 2014). This equation is estimated econometrically with a significant long-term relationship found between these variables (Eq. (310)). Real household consumption from production is then equal to the nominal consumption divided by the production price deflator (P_P). (Eq. (311)). The nominal consumption of the power sector ($CONS_{HHPS}$) is equal to the real consumption ($CONS_{HHPSR}$) multiplied by the price of electricity (P_{ELEC}) (Eq. (312)). The level of real household consumption is equal to the electrical energy use of households which electricity assumed to make up the majority of household consumption related to this sector (Eq. (313)). The total savings of households(SAV_{HH}) for investment purposes is equal to their disposable income less consumption spending (Eq. (314)).

$$CONS_{HHt} = CONS_{HHPt} + CONS_{HHPSt} \tag{309}$$

$$\Delta\mathbf{L}(CONS_{HHPt}) = \epsilon_{CHHP}\big(\alpha_{0CHHP} + \alpha_{1CHHP}\mathbf{L}(YD_{HHt-1}) + \alpha_{2CHHP}\mathbf{L}(FNW_{HHt-1}) - \mathbf{L}(CONS_{HHPt-1})\big) \tag{310}$$

$$CONS_{HHPRt} = \frac{CONS_{HHPt}}{P_{Pt}} \tag{311}$$

$$CONS_{HHPSt} = CONS_{HHPSRt}P_{ELECt} \tag{312}$$

$$CONS_{HHPSRt} = E_{ELECHt} \tag{313}$$

$$SAV_{HHt} = YD_{HHt} - CONS_{HHt} \tag{314}$$

Households make investments, predominantly related to housing. This gross capital formation is divided into two main categories: House building[44] and home improvements. Total household gross capital formation (GCF_{HH}) is given as the sum of gross capital formation of new build houses (GCF_{HHNB}) and home improvements (GCF_{HHHI}). Household investment in housebuilding (GCF_{HHNB}) is primarily driven by the total value of properties, where higher property values make household investment more attractive, this is expressed in an econometrically estimated co-integration equation (Eq. (317) and it should be noted that while there is a positive relationship between prices and house building, this response is relatively weak.[45] The gross capital formation of households on home improvements (GCF_{HHHI}) follows the overall growth of GDP (Eq. (317)).

$$GCF_{HHt} = GCF_{HHNBt} + GCF_{HHHISt} \tag{315}$$

$$\Delta\mathbf{L}(GCF_{HHNBt}) = \epsilon_{GCFNB}\big(-\alpha_{0GCFNB} + \alpha_{1GCFNB}\mathbf{L}(HVAL_{t-1}) - \mathbf{L}(GCF_{HHNBt-1})\big) - \delta_{1GCFNB}\Delta\big(\mathbf{L}(GCF_{HHNBt-1})\big) \tag{316}$$

$$GCF_{HHHIt} = \alpha_{HHHI}GDP_{t-1} \tag{317}$$

The real levels of gross capital formation are then defined by dividing the nominal levels by the production price deflator (P_P) (Eqs. (318) - (320)).

$$GCF_{HHRt} = \frac{GCF_{HHt}}{P_{Pt}} \tag{318}$$

[44] It is assumed that when a house is built and subsequently purchased by a household this is recorded as gross fixed capital formation of the household sector, this is consistent with national accounting conventions.

[45] This is in line with UK data where there has been a large increase in house prices over the last two decades but a relatively moderate increase in house building, the model cannot assess the impact of other policies that could impact house building, such as planning permission and regulation.

$$GCF_{HHNBRt} = \frac{GCF_{HHNBt}}{P_{Pt}} \tag{319}$$

$$GCF_{HHHIRt} = \frac{GCF_{HHHIt}}{P_{Pt}} \tag{320}$$

The real investment in home improvements is then divided between regular home improvements (GCF_{HIHINR}) and energy-based home improvements (($GCF_{HHHIENR}$) in Eqs.(321 & 322). The division between regular and energy-based home improvements is given by Eq. (323) where there is an exogenous trend towards increasing energy-based home improvements over time and this is further increased based on the difference between non-electric (P_{NELEC}) and electric (P_{ELEC}) energy prices. Energy-based home improvements are then divided further between efficiency improvements and electrification. Efficiency improvements are investments used to turn an energy inefficient house into an efficient one by measures such as wall insulation and window glazing, whereas electrification energy improvements turn efficient houses fully electric by installing electrical heating devices such as heat-pumps. The split between these two types of energy efficiency home improvements is given by Eqs. (324) & (325) with the difference being partly driven by the ratio between inefficient homes (H_I) and efficient non-electric homes (H_{EN}) such that as the number of inefficient homes decreases, there is a shift towards greater electrification as the next step in improving energy efficiency.

$$GCF_{HHHIERt} = \frac{(1}{(1-}sce4r))\beta_{GCFHHt}GCF_{HHHIRt} \tag{321}$$

$$GCF_{HHHINRt} = GCF_{HHHIRt} - GCF_{HHHIERt} \tag{322}$$

$$\beta_{GCFHHt} = \alpha_{0betaHH} + TREND_{betaHH}t + \alpha_{1betaHH}(P_{NELECTt-1} - P_{ELECt-1}) \tag{323}$$

$$GCF_{HHHIENRt} = GCF_{HHHIERt}\frac{\kappa_{hie}H_{It-1}}{\kappa_{hie}H_{It-1} + H_{ENt-1}} \tag{324}$$

$$GCF_{HHHIEERt} = GCF_{HHHIERt} - GCF_{HHHIENRt} \tag{325}$$

Households model determined net lending ($LEND_{HHM}$) is defined as their total savings, less gross capital formation spending plus pension and insurance related flows[46] (Eq. (326)). The lending discrepancy is driven exogenously as a portion of GDP (Eq. (327)) with the actual household net lending position defined as the model determined net lending plus the lending discrepancy (Eq. (328)).

$$LEND_{HHMt} = SAV_{HHt} - GCF_{HHt} + INSR_t + PENSR_t + PENS_{ADJt} \tag{326}$$

$$DISC_{HHt} = \eta_{HHT}GDP_{t-1} \tag{327}$$

$$LEND_{HHt} = LEND_{HHMt} + DISC_{HHt} \tag{328}$$

For household financial stock transfers, it is assumed that interest bearing asset transfers of households ($IBATR_{HH}$) are derived residually (Eq. (329)). Equity asset transfers ($EQATR_{HH}$) are assumed to be a negative fixed proportion of household equity stock, reflecting households withdrawing from their stock of equities as a way to fund financial transactions (Eq. (330)). Pension transfers are ($PENSTR$) are equal to the derived pension adjustment consistent with ONS data (Eq. (331)). Insurance transfers ($INSTR_{HH}$) are equal to the return on insurance funds less net payouts on insurance schemes (Eq. (332)). Interest bearing liability transfers ($IBLTR_{HH}$) which for households are mainly related to mortgage borrowing are set as a fixed proportion of the total value of housing stock (Eq. (333)). The residual financial instrument transaction of the household sector ($RESTR_{HH}$) grows exogenously as a fixed proportion of GDP (Eq. (334)).

$$IBATR_{HHt} = LEND_{HHt} + IBLTR_{HHt} - (EQATR_{HHt} + RESTR_{HHt} + PENSTR_t + INSTR_t) \tag{329}$$

$$EQATR_{HHt} = -\alpha_{EQAHH}EQA_{HHt-1} \tag{330}$$

[46] Recall these flows are an accounting convention and are not accessible income for households.

$$PENSTR_t = PENS_{ADJt} \tag{331}$$

$$INSTR_t = INSR_t - \alpha_{INSTR} INS_{t-1} \tag{332}$$

$$IBLTR_{HHt} = \alpha_{IBLTR} HVAL_t \tag{333}$$

$$RESTR_{HHt} = \eta_{HHB} GDP_{t-1} \tag{334}$$

Other transfers, which include price revaluations and other changes in asset value, are set as exogenous rates for the household sector (Eqs. (335) - (338)).

$$OT_{IBAHHt} = \delta_{IBAHH}(IBA_{HHt-1}) \tag{335}$$

$$OT_{EQAHHt} = \delta_{EQAHH}(EQA_{HHt-1}) \tag{336}$$

$$OT_{IBLHHt} = \delta_{IBLHH}(IBL_{HHt-1}) \tag{337}$$

$$OT_{RESHHt} = \delta_{RESHH}(RES_{HHt-1}) \tag{338}$$

The financial stocks of the household sector develop according to their respective financial transfers and other transfers (Eqs. (339) - (343)). Total financial assets and liabilities are defined in Eqs. (344) & (345). Financial assets minus liabilities give the household sector model determined financial net worth (FNW_{HHM}) (Eq. (346)). The residual financial instrument develops similarly to other financial assets (Eq. (347)) and is then added to the model determined financial net worth to give the overall household sector financial net-worth FNW_{HH} (Eq. (348)).

$$IBA_{HHt} = IBA_{HHt-1} + IBATR_{HHt} + OT_{IBAHHt} \tag{339}$$

$$EQA_{HHt} = EQA_{HHt-1} + EQATR_{HHt} + OT_{EQAHHt} \tag{340}$$

$$PENS_t = PENS_{t-1} + PENSTR_t + OT_{PENSt} \tag{341}$$

$$INS_t = INS_{t-1} + INSTR_t + OT_{INSt} \tag{342}$$

$$IBL_{HHt} = IBL_{HHt-1} + IBLTR_{HHt} + OT_{IBLHHt} \tag{343}$$

$$FA_{HHt} = IBA_{HHt} + EQA_{HHt} + PENS_t + INS_t \tag{344}$$

$$FL_{HHt} = IBL_{HHt} \tag{345}$$

$$FNW_{HHMt} = FA_{HHt} - FL_{HHt} \tag{346}$$

$$RES_{HHt} = RES_{HHt-1} + RESTR_{HHt} + OT_{RESHHt} \tag{347}$$

$$FNW_{HHt} = FNW_{HHMt} + RES_{HHt} \tag{348}$$

The total number of houses (H) is given by the sum of the three types of housing: inefficient houses (H_I) taken as houses with EPC ratings D and below, efficient non-electric houses (H_{EN}) taken as houses with EPC ratings C and above where the primary energy source is non-electric and efficient electric houses (H_{EE})[47] taken as houses with EPC ratings C and above where the primary energy source is electricity based (Eq.(349)).[48] These three housing stocks develop based on house building and efficiency and electrification based home improvements. The number of houses built (HB) is directly proportional to the real household investment in new houses (Eq. (350)). It is assumed that all new build houses are efficient and a portion (β_{HBE}) of them are fully electric.[49] Inefficient houses are transformed into efficient non-electric houses through real energy home improvements (GCF_{HIENR}) which can then be transformed into efficient electric houses through real electric home improvement

[47]Note there is no inefficient electric house category, where properties primary energy source is electricity based while the properties EPC rating is D and below, houses do exist in this category however there are very few in the UK as fully electric houses tend to be efficient, not least because energy efficiency is generally a pre-requisite to using electric heating technologies such as heat-pumps.

[48]The EPC ratings are taken directly from EPC data (UK Department for Levelling UP, Housing & Communities 2025)

[49]This is consistent with what is observed in the UK where the overwhelming majority of new build properties will have at least and EPC rating of C.

(GCF_{HIEER}) with both these transformation rates being determined by the cost of energy and electric home upgrades (Eqs. (351) - (353)). $COST_{HIENR}$ and $COST_{HIEER}$ are the real costs of the upgrades to efficiency and electrification, respectively, and are set to remain constant unless reduced by a policy such as a subsidy (Eqs (354) & (355)).

$$H_t = H_{It} + H_{ENt} + H_{EEt} \tag{349}$$

$$HB_t = \alpha_{HB} GCF_{HHNBRt} \tag{350}$$

$$H_{It} = H_{It-1} - \frac{GCF_{HHHIENRt}}{C_{HIENRt}} \tag{351}$$

$$H_{ENt} = H_{ENt-1} + (1 - \beta_{HBE}) HB_t + \frac{GCF_{HHHIENRt}}{C_{HIENRt}} - \frac{GCF_{HHHIEERt}}{C_{HIEERt}} \tag{352}$$

$$H_{EEt} = H_{EEt-1} + \beta_{HBE} HB_t + \frac{GCF_{HHHIEERt}}{C_{HIEERt}} \tag{353}$$

$$C_{HIENRt} = C_{HIENRB} \tag{354}$$

$$C_{HIEERt} = C_{HIEERB} \tag{355}$$

The total value of housing stock ($HVAL$) is equal to the average house price (P_H) multiplied by the number of houses (H) (Eq. (356)). House prices (P_H) per worker have a long run co-integrating relationship with disposable income per worker and interest bearing liabilities per worker showing that housing demand can be based both on income but can also be financed through increased indebtedness (Eq. (357)). Household sector net worth is defined as the sum of net financial and real assets (Eq. (358)).

$$HVAL_t = H_t P_{Ht} \tag{356}$$

$$\Delta \mathbf{L} \frac{P_{Ht} H_t}{LF_t} = \epsilon_{PH} (\alpha_{0PH} + \alpha_{1PH} \mathbf{L} (\frac{YD_{HHt-1}}{LF_{t-1}}) + \alpha_{2PH} \mathbf{L} (\frac{IBL_{HHt-1}}{LF_{t-1}}) - \mathbf{L} \frac{P_{Ht-1} H_{t-1}}{LF_{t-1}}) \tag{357}$$

$$NW_{HHt} = FNW_{HHt} + HVAL_t \tag{358}$$

A.4.6 Rest of the world

The rest of the world is reasonably passive in the current version of the model where it's main interaction with the model is through imports and exports along with it's holdings of some domestic financial assets and liabilities. The income from production (YP_RoW) of the rest of the world is given as total imports (IMP) minus exports (EXP) (Eq. (359)). Total imports are determined by the real imports (IMP_R) multiplied by the relative price of imports (P_I) (Eq. (360)). Exports are defined based on real export values (EXP_R) multiplied by domestic prices (P_P) (Eq. (361)).

$$YP_{RoWt} = IMP_t - EXP_t \tag{359}$$

$$IMP_t = P_{It} IMP_{Rt} \tag{360}$$

$$EXP_t = P_{Pt} EXP_{Rt} \tag{361}$$

Imports are modelled as input into the production sector and, therefore, the level of real imports (IMP_R) is driven directly by the level of real output (GO_{PR}) and the technical coefficient of imports (α_{IMP}) (Eq. (362)). The technical coefficient of imports is assumed to follow a long-run path (Eq. (363). Real exports (EXP_R) are assumed to follow a long-term path based on exogenous demand from the RoW sector for domestic products (Eq. (364)). Import prices (P_I) relative to domestic prices (P_P) follow an exogenous growth path based on OBR estimates of price changes and future exchange rate fluctuations (Eq. (365)).

$$IMP_{Rt} = \alpha_{IMPt} GO_{PRt} \tag{362}$$

$$\alpha_{IMPt} = \alpha_{IMPLR} \tag{363}$$

$$EXP_{Rt} = EXP_{ROBR} \tag{364}$$

$$P_{It} = P_{IOBR} \tag{365}$$

Unlike other sectors, the model considers property income flows with the rest of the world sector in net, rather than gross terms. This is done for both pragmatic and theoretical reasons. First, the RoW sector is mostly exogenous to the model, and recording gross flows as opposed to net flows is not necessary for any behavioural relationships within the model. Additionally, some of the model assumptions around gross interest and dividend payments are harder to justify for the RoW sector, which includes foreign firms and foreign financial institutions. Generally, net-flows are sufficient to show open economy financial effects, so this is the approach that is taken for the model. Net RoW interest received ($INTN_{RoW}$) is the sum of interest received on the RoWs share of government liabilities (IBL_{GVTRoW}) and their net holding of other interest-bearing assets (IBN_{RoW}) (Eq. (366)). Net RoW dividends received ($DIVN_{RoW}$) is the sum of given as a fixed proportion of RoW net equity holding (EQN_{RoW}) (Eq. (367)). RoW model determined net lending ($LEND_{NFCM}$) is defined as their income from production plus their net interest income received (Eq. (368)). The lending discrepancy is driven exogenously as a portion of GDP (Eq. (369)) with the actual RoW net lending position defined as the model determined net lending plus the lending discrepancy (Eq. (370)).

$$INTN_{RoWt} = r_{IBLGVTt} IBL_{GVTRoWt-1} + r_{IBNRoWt} IBN_{RoWt-1} \tag{366}$$

$$DIVN_{RoWt} = \alpha_{DIVNRoW} EQN_{RoWt-1} \tag{367}$$

$$LEND_{RoWMt} = YP_{RoWt} + INTN_{RoWt} + DIVN_{RoWt} \tag{368}$$

$$DISC_{RoWt} = \eta_{RoWT} GDP_{t-1} \tag{369}$$

$$LEND_{RoWt} = LEND_{RoWMt} + DISC_{RoWt} \tag{370}$$

Net RoW interest-bearing asset transfers ($IBNTR_{RoW}$) are set as the residual of all other financial transactions (Eq. (371). Net-equity asset transfers ($EQNTR_{RoW}$) are set as proportional to RoW income from production (Eq. (378)). The residual financial instrument transaction of the RoW sector ($RESTR_{RoW}$) grows exogenously as a fixed proportion of GDP (Eq. (373)).

$$IBNTR_{RoWt} = LEND_{RoWt} - (IBLTR_{GVTRoWt} + EQNTR_{RoWt} + RESTR_{RoWt}) \tag{371}$$

$$EQNTR_{RoWt} = \alpha_{EQNTRRoW} YP_{RoWt} \tag{372}$$

$$RESTR_{RoWt} = \eta_{RoWB} GDP_{t-1} \tag{373}$$

$$OT_{IBARoWt} = \delta_{IBARoW}(IBN_{RoWt-1}) \tag{374}$$

$$OT_{EQNRoWt} = \delta_{EQNRoW}(EQN_{RoWt-1}) \tag{375}$$

$$OT_{RESRoWt} = \delta_{RESRoW}(RES_{RoWt-1}) \tag{376}$$

The net-financial stocks of the NFC sector develop according to their respective financial transfers and other transfers (Eqs. (377) & (378)). Teh sum of net-Financial assets give the RoW sector model determined financial net worth (FNW_{RoWM}) (Eq. (379)). The residual financial instrument develops similarly to other financial assets (Eq. (380)) and is then added to the model determined financial net worth to give the overall RoW sector financial net-worth FNW_{RoW} (Eq. (381)).

$$IBN_{RoWt} = IBN_{RoWt-1} + IBNTR_{RoWt} + OT_{IBARoWt} \tag{377}$$

$$EQN_{RoWt} = EQN_{RoWt-1} + EQNTR_{RoWt} + OT_{EQNRoWt} \tag{378}$$

$$FNW_{RoWMt} = IBN_{RoWt} + EQN_{RoWt} + IBL_{GVTRoWt} \tag{379}$$

$$RES_{RoWt} = RES_{RoWt-1} + RESTR_{RoWt} + OT_{RESRoWt} \tag{380}$$

$$FNW_{RoWt} = FNW_{RoWMt} + RES_{RoWt} \tag{381}$$

A.4.7 Rates of return

The base rate is set based on a simple Taylor rule, where the long-run Bank of England base rate (r_{BOE}) is based on the current level of inflation (Eq. (382)). This equation uses logged values which ensures the base rate cannot fall below the zero lower bound.

$$\Delta \mathbf{L} r_{BOEt} = \epsilon_{rboe}(\alpha_{rboe}\mathbf{L}INF_{t-1} - \mathbf{L}r_{BOEt-1}) \tag{382}$$

Interest rates on interest-bearing assets for model sector j (r_{IBAjt}) tends towards a long run interest rate with adjustment speed (τ_{raj}) (Eq. (383)). With the long run asset interest rates being set as the maximum of a mark down on the base rate and a minimum value ($minr_j$) which is used to respect the zero lower bound for interest rates in the model (Eq. (384).

$$r_{IBAjt} = r_{IBAjt-1} + \tau_{raj}(r_{IBAjLRt} - r_{IBAjt-1}) \tag{383}$$

$$r_{IBAjLRt} = max(minr_j, r_{BOEQt} - spr_{ja}) \tag{384}$$

Interest rates on interest-bearing liabilities for model sector j (r_{IBLjt}) tends towards a long run interest rate with adjustment speed (τ_{rlj}) while also being directly impacted by short run adjustments in the base rate, accounting for the observed phenomena of interest bearing liability rates reacting more quickly to changes in the base rate (Eq. (385)). With the long run liability interest rates being set as a mark up over the interest bearing asset interest rate for the sector and an additional risk premia, which is calculated based on the depreciation rate of the sectors liabilities (δ_j) and the financial health of the MFI sector, proxied as the ratio between its financial liabilities and assets (Eq. (386)).

$$r_{IBLjt} = r_{IBLjt-1} + \tau_{rlj}(r_{IBLjLRt} - r_{IBLjt-1}) + \delta_{rlj}\Delta r_{BOEQt} \tag{385}$$

$$r_{IBLjLRt} = r_{IBAjLRt} + (spr_{jl} + \delta_{jt})(1 + \sigma_j r_{BOEQt})\frac{FL_{MFIt-1}}{FA_{MFIt-1}} \tag{386}$$

B Model parameters and initial values

Table 6: Parameter Values

Symbol	Description	Parameter category	Initial value	Source/remarks
CF_{FF}	Capacity factor of fossil fuel energy generation	Free	1.132	Calculated based on past values and assumed to be constant over time
CF_{max}	Maximum non-fossil fuel electricity capacity factor	Free	2	Selected as a reasonable maximum value based on UK data
CF_{min}	Minimum non-fossil fuel electricity capacity factor	Free	0.5	Selected as a reasonable minimum value based on UK data and reasonably greater than 0
CO_{NFF}	Crowding out parameter for government gross capital formation	Free	0.5	Set as a reasonable estimate
FNW_{MFIT}	Target MFI FNW ratio	Free	0.008084	Calculated based on recent data
g_{LFB}	Labor force base growth rate	Free	0.001747	Based on OBR estimates
$INTAXR_{HHLR}$	Long run income tax rate on the HH sector set by the government	Free	0.2005	Based on past data and OBR fiscal forecasts
$INTAXR_{NFCLR}$	Long run income tax rate on the NFC sector set by the government	Free	0.03826	Based on past data and OBR fiscal forecasts
$ITAXR_{PLR}$	Long run indirect tax rate on production set by the government	Free	0.07041	Based on past data and OBR fiscal forecasts
$ITAXR_{PSLR}$	Long run indirect tax rate on the power sector set by the government	Free	0.01341	Based on past data and OBR fiscal forecasts
$minr_{gvt}$	Minimum lower bound GVT deposit interest rate	Free	0.006119	Calculated based on the 2010s zero lower bound interest rate period
$minr_{hh}$	Minimum lower bound household deposit interest rate	Free	0.002509	Calculated based on the 2010s zero lower bound interest rate period
$minr_{nfc}$	Minimum lower bound NFC deposit interest rate	Free	0.003204	Calculated based on the 2010s zero lower bound interest rate period

Continued on next page

Table 6 – continued from previous page

Symbol	Description	Parameter category	Initial value	Source/remarks
$minr_{nmfi}$	Minimum lower bound NMFI deposit interest rate	Free	0.004289	Calculated based on the 2010s zero lower bound interest rate period
$minr_{row}$	Minimum lower bound RoW deposit interest rate	Free	-0.01033	Calculated based on the 2010s zero lower bound interest rate period
PT_{ETS}	Pass through of carbon pricing to electricity prices	Free	1	Reasonable estimate based on research of carbon prices
$SOCCR_{GVTLR}$	Long run social contribution rate on the HH sector set by the government	Free	0.1393	Based on past data and OBR fiscal forecasts
spr_{gvta}	Mark down on government deposit interest rates	Free	-0.002054	Based on average of the pre 2010s zero lower bound period
spr_{gvtl}	Interest rate spread on GVT liabilities interest rates	Free	0.001794	Based on recent values
spr_{hha}	Mark down on household deposit interest rates	Free	0.003593	Based on average of the pre 2010s zero lower bound period
spr_{hhl}	Interest rate spread on HH liabilities interest rates	Free	0.00577	Based on recent values
spr_{nfca}	Mark down on NFC deposit interest rates	Free	0.005769	Based on average of the pre 2010s zero lower bound period
spr_{nfcl}	Interest rate spread on NFC liabilities interest rates	Free	-0.0008321	Based on recent values
spr_{nmfia}	Mark down on NMFI deposit interest rates	Free	0.002524	Based on average of the pre 2010s zero lower bound period
spr_{nmfil}	Interest rate spread on NMFI liabilities interest rates	Free	0.001641	Based on recent values
spr_{psl}	Interest rate spread on PS liabilities interest rates	Free	-0.0008321	Based on recent values
spr_{rowa}	Mark down on RoW deposit interest rates	Free	-0.008781	Based on average of the pre 2010s zero lower bound period
$\alpha_{0\beta HH}$	Parameter in the equation for green home improvements	Free	0.2	Estimate based on green housing investment data
$\alpha_{0\beta NFC}$	Parameter in the equation governing the proportion of gross green NFC gross capital formation	Free	-0.02402	Calibrated to generate the baseline scenario
α_{0CHHP}	Constant parameter in the household consumption equation	Free	0.2507	Calculated from Eq. (340)
α_{0CRNFC}	Parameter in the credit rationing equation for the NFC sector	Free	-0.02062	Econometrically estimated
α_{0CRPS}	Parameter in the credit rationing equation for the power sector	Free	-0.02854	Econometrically estimated and adjusted to power sector initial conditions
$\alpha_{0DEFNFC}$	Parameter in the power sector default equation	Free	-0.03222	Based on econometric estimates
α_{0DEFPS}	Parameter in the power sector default equation	Free	-0.02935	Based on econometric estimates, adjusted for the power sector initial conditions
α_{0GCFNB}	Parameter in the HH gross capital formation for new builds equation	Free	7.679	Econometrically estimated
$\alpha_{0GCFNFC}$	Parameter in the NFC gross capital formation equation	Free	-0.0135	Calibrated based on OBR projections
α_{0IMP}	Constant parameter in the Import equation	Free	-0.0539	Set such that the ratio of imports to final expenditure follows a path consistent with OBR 2024 estimates
α_{0PH}	Parameter in the house price equation	Free	1	Econometrically estimated
α_{0SOCB}	Parameter in the GVT social benefit equation	Free	0.0601	Econometrically estimated
α_{0WR}	Constant parameter in the wage rate share equation	Free	-0.6516	Econometrically estimated
$\alpha_{1\beta HH}$	Parameter in the equation for green home improvements	Free	0.3038	Estimate based on green housing investment data
$\alpha_{1\beta NFC}$	Parameter in the equation governing the proportion of gross green NFC gross capital formation	Free	0.1	Calibrated to generate the baseline scenario
α_{1CHHP}	Long run propensity to consume out of disposable income	Free	0.7337	Econometrically estimated and adjusted
α_{1CRNFC}	Parameter in the credit rationing equation for the NFC sector	Free	0.9316	Econometrically estimated
α_{1CRPS}	Parameter in the credit rationing equation for the power sector	Free	0.9195	Econometrically estimated
$\alpha_{1DEFNFC}$	Parameter in the power sector default equation	Free	0.1534	Based on econometric estimates

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Table 6 – continued from previous page

Symbol	Description	Parameter category	Initial value	Source/remarks
α_{1DEFPS}	Parameter in the power sector default equation	Free	0.1534	Based on econometric estimates
α_{1GCFNB}	Parameter in the HH gross capital formation for new builds equation	Free	1.224	Econometrically estimated
$\alpha_{1GCFNFC}$	Parameter in the NFC gross capital formation equation	Free	0.04342	Econometrically estimated
$\alpha_{1GCFPSFF}$	Parameter in the power sector fossil fuel gross capital formation equation	Free	0.025	Selected based on past UK data to generate the baseline projection
$\alpha_{1GCFPSNFF}$	Parameter in the power sector non-fossil fuel gross capital formation equation	Free	0.03	Selected based on past UK data to generate the baseline projection
$\alpha_{1lambda}$	Parameter in the productivity equation relating real GDP growth to productivity growth	Free	0.725	Reasonable estimate based on past values, UK studies and calibrated to generate the baseline projections
α_{1PH}	Parameter in the house price equation	Free	1.04	Econometrically estimated
α_{1SOCB}	Parameter in the GVT social benefit equation	Free	0.5317	Econometrically estimated
α_{1WR}	Long run relationship between unemployment rate and wage share per worker	Free	-0.8412	Econometrically estimated
$\alpha_{2\beta NFC}$	Parameter in the equation governing the proportion of gross green NFC gross capital formation	Free	0.4	Calibrated to generate the baseline scenario
α_{2CHHP}	Long run propensity to consume out of financial net worth	Free	0.1645	Econometrically estimated and adjusted
α_{2CRNFC}	Parameter in the credit rationing equation for the NFC sector	Free	0.003712	Econometrically estimated
α_{2CRPS}	Parameter in the credit rationing equation for the power sector	Free	0.001823	Econometrically estimated
$\alpha_{2DEFNFC}$	Parameter in the power sector default equation	Free	0.03139	Based on econometric estimates
α_{2DEFPS}	Parameter in the power sector default equation	Free	0.03139	Based on econometric estimates
$\alpha_{2GCFNFC}$	Parameter in the NFC gross capital formation equation	Free	0.3172	Econometrically estimated
$\alpha_{2GCFPSFF}$	Parameter in the power sector fossil fuel gross capital formation equation	Free	0.005	Selected based on past UK data to generate the baseline projection
$\alpha_{2GCFPSNFF}$	Parameter in the power sector non-fossil fuel gross capital formation equation	Free	0.02	Selected based on past UK data to generate the baseline projection
$\alpha_{2lambda}$	Parameter in the productivity equation relating real GCF growth to productivity growth	Free	0.025	Reasonable estimate based on past values and UK studies
α_{2PH}	Parameter in the house price equation	Free	0.539	Econometrically estimated
α_{2SOCB}	Parameter in the NFC gross capital formation equation	Free	0.1392	Econometrically estimated
α_{3CRNFC}	Parameter in the credit rationing equation for the NFC sector	Free	0.05689	Econometrically estimated
α_{3CRPS}	Parameter in the credit rationing equation for the power sector	Free	0.0651	Econometrically estimated
α_{DEF}	Parameter relating default rates to illiquidity ratios	Free	0.03078	Based on implied value from past data
$\alpha_{DIVPNFC}$	Rate of NFC sector dividend payments relative to disposable income	Free	0.4048	Set as the mean of past implied values
$\alpha_{DIVPNMFI}$	Proportion of primary NMFI net income distributed as dividends	Free	0.7965	Set as the mean over past values
α_{DIVPPS}	Rate of power sector dividend payments relative to output	Free	0.05453	Set as the mean of past implied values
α_{EQAHH}	Relationship between HH EQA transfers and household equity stock	Model-constrained	0.005407	Calculated from Eq. (362)
α_{EQANFC}	Relationship between NFC EQA transfers and total output from production	Model-constrained	0.01113	Calculated from Eq. (189)
α_{EQAPS}	Relationship between PS EQA transfers and total output from production	Model-constrained	0.01298	Calculated from Eq. (114)

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Table 6 – continued from previous page

Symbol	Description	Parameter category	Initial value	Source/remarks
α_{EQNRoW}	Relationship between RoW EQA transfers and total output	Model-constrained	0.01588	Calculated from Eq. (405)
$\alpha_{EQNTRRoW}$	Relationship between net RoW equity transfers and RoW income	Model-constrained	1.635	Calculated from Eq. (405)
$\alpha_{FUELPSLR}$	Long run technical coefficient of fuel input to the power sector	Free	0.3233	Assumes fossil fuel electricity is output is proportional to fuel input and that at the initial condition fuel price is normalised to equal 1
α_{HB}	Conversion between real investment in new houses and the building of new houses	Model-constrained	0.00239	Calculated from Eq. (382)
α_{HHHI}	Parameter relating household home improvement investment to overall GDP levels	Free	0.008546	Estimated based on past values
α_{IBAGVT}	Relationship between GVT IBA transfers and total output from production	Model-constrained	0.004541	Calculated from Eq. (306)
α_{IBANFC}	Relationship between NFC IBA transfers and total output from production	Model-constrained	0.01086	Calculated from Eq. (188)
$\alpha_{IBANMFI}$	Relationship between NMFI IBA transfers and total output from production	Model-constrained	0.02611	Calculated from Eq. (248)
α_{IBAPS}	Relationship between PS IBA transfers and total output from power sector	Model-constrained	0.0121	Calculated from Eq. (113)
α_{IBLHH}	Relationship between HH IBL transfers and total output from production	Model-constrained	0.01579	Calculated from Eq. (365)
α_{IBLTR}	Parameter relating total housing value to household interest bearing liability transfers	Free	0.00175	Calculated based on ONS stock data
α_{IMPLR}	Long run technical coefficient of imports	Free	0.1957	Taken as the average implied technical coefficient over past data
α_{INS}	Relationship between HH insurance transfers and total output	Model-constrained	0.0008341	Calculated from Eq. (374)
α_{INSR}	Parameter relating NMFI disposable income to investment income on insurance schemes	Free	1.372	Calculated based on past implied values
α_{INSTR}	Insurance transfer payout rate	Free	0.003204	Calculated from past data
α_{MU}	Linear relationship between production price mark-up and unit costs	Free	0.2064	Approximated base on past data
α_{NELEC}	Pass through from gas and oil prices to overall non-electric energy costs	Free	2.557	Calculated using the mean over past data
$\alpha_{OCONSGVT}$	Parameter relating GDP output to total government other consumption	Free	0.081	Set based on OBR projections of government spending and past
α_{OPPSLR}	Long run technical coefficient of other inputs to the power sector	Free	0.05029	Taken as the average implied technical coefficient over past data
α_{PENS}	Relationship between HH insurance transfers and total output	Model-constrained	0.06666	Calculated from Eq. (374)
α_{PENSR}	Parameter relating NMFI disposable income to investment income on pension schemes	Free	1.213	Calculated based on past implied values
α_{PFUEL}	Relationship between wholesale gas prices and the price of a fuel input to the power sector	Free	10.98	Based on initial data
α_{PPLR}	Long run technical coefficients of internal production intermediate consumption	Free	0.2742	Taken as the average implied technical coefficient over past data
α_{PSPSLR}	Long run technical coefficient of internal power sector intermediate consumption	Free	0.3836	Taken as the average implied technical coefficient over past data
α_{rboe}	Parameter relating to inflation in the BoE Taylor rule	Free	0.9092	Set to generate observed early period baseline behavior
$\alpha_{SOCBPENS}$	Rate of social benefit payments relative to total value of pension schemes	Model-constrained	0.008159	Calculated from Eq. (243)

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Table 6 – continued from previous page

Symbol	Description	Parameter category	Initial value	Source/remarks
α_{SOCCW}	Rate of wage contribution to household social contribution for pension schemes (Defined contribution)	Model-constrained	0.05693	Calculated from Eq. (242)
β_{dhh}	Relationship between household equity holding and dividend distribution	Model-constrained	1.333	Calculated from Eq. (335)
β_{dps}	Relationship between power sector holding and dividend distribution	Model-constrained	0.773	Calculated from Eq. (99)
β_{ELECH}	Proportion of electric energy use in total energy use for non-electric houses	Free	0.205	Calculated from UK EPC data
β_{EQLNFC}	Parameter determining NFC equity liability price revaluation rate	Model-constrained	-0.001676	Calculated from Eq. (195)
$\beta_{EQLNMFI}$	Parameter determining NMFI equity liability price revaluation rate	Model-constrained	0.008593	Calculated from Eq. (256)
β_{HBE}	Proportion of new build properties which are fully electric	Free	0.08422	Based on implied UK data and assumed constant
$\beta_{IBLGVTMFI}$	Proportion of government borrowing held by the MFI sector	Free	0.3333	Based on ON experimental flow of funds data 2020 and assumed constant in simulations
$\beta_{IBLGVTNMFI}$	Proportion of government borrowing held by the NMFI sector	Free	0.3333	Based on ON experimental flow of funds data 2020 and assumed constant in simulations
$\beta_{IBLGVTRoW}$	Proportion of government borrowing held by the RoW sector	Free	0.3333	Based on ON experimental flow of funds data 2020 and assumed constant in simulations
$\beta_{NELECGAS}$	Proportion of non-electric energy provided by gas	Free	0.55	Taken from 2023 data and assumed constant
$\beta_{NELECOIL}$	Proportion of non-electric energy provided by oil	Free	0.45	Taken from 2023 data and assumed constant
β_{WRPRI}	Parameter linking private sector wage rate to overall economy wage rate	Model-constrained	1.01	Calculated from Eq. (59)
β_{WRPUB}	Parameter linking public sector wage rate to overall economy wage rate	Model-constrained	0.9731	Calculated from Eq. (60)
δ_{1CHHP}	Short run change in consumption based on disposable income	Free	0	Set to 0 for initial projections
δ_{1GCFNB}	Parameter in the HH gross capital formation for new builds equation	Free	0.1647	Econometrically estimated
δ_{1WR}	Differenced parameter in the wage rate share equation	Free	0.2018	Econometrically estimated
δ_{2WR}	Differenced parameter in that wage rate share equation related to the unemployment rate	Free	0.4744	Econometrically estimated
δ_{EQAHH}	Revaluation rate of HH EQAs	Model-constrained	0.005407	Calculated from EQ. (368)
δ_{EQANFC}	Revaluation rate of NFC EQAs	Model-constrained	0.001397	Calculated from EQ. (194)
δ_{EQAPS}	Revaluation rate of PS EQAs	Model-constrained	0.001397	Calculated from EQ. (119)
δ_{EQLNFC}	Revaluation rate of NFC EQLs	Model-constrained	0.008192	Calculated from EQ. (195)
δ_{EQLPS}	Revaluation rate of PS EQLs	Model-constrained	0.008192	Calculated from EQ. (120)
δ_{EQNRoW}	Revaluation rate of RoW EQAs	Model-constrained	0.005344	Calculated from EQ. (408)
δ_{IBAGVT}	Revaluation rate of GVT IBAs	Model-constrained	0.0007799	Calculated from EQ. (312)
δ_{IBAHH}	Revaluation rate of HH IBAs	Model-constrained	0.0007537	Calculated from EQ. (367)
δ_{IBANFC}	Revaluation rate of NFC IBAs	Model-constrained	0.001064	Calculated from EQ. (193)
$\delta_{IBANMFI}$	Revaluation rate of NMFI IBAs	Model-constrained	-0.0001727	Calculated from EQ. (253)
δ_{IBAPS}	Revaluation rate of PS IBAs	Model-constrained	0.001064	Calculated from EQ. (118)
δ_{IBARoW}	Revaluation rate of RoW IBAs	Model-constrained	0.0006782	Calculated from EQ. (407)
δ_{IBLGVT}	Revaluation rate of GVT IBLs	Model-constrained	-0.0008064	Calculated from 1. (313)

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Table 6 – continued from previous page

Symbol	Description	Parameter category	Initial value	Source/remarks
δ_{IBLHH}	Revaluation rate of NFC IBLs	Model-constrained	-1.208e-06	Calculated from EQ. (196)
δ_{IBLNFC}	Revaluation rate of NFC IBLs	Model-constrained	-0.004033	Calculated from EQ. (196)
$\delta_{IBLNMFI}$	Revaluation rate of NMFI IBLs	Model-constrained	0.0009828	Calculated from EQ. (254)
δ_{IBLPS}	Revaluation rate of PS IBLs	Model-constrained	-0.004033	Calculated from EQ. (121)
δ_{INS}	Revaluation rate of Insurance	Model-constrained	-0.01428	Calculated from EQ. (374)
δ_{kpc}	Constant depreciation rate of productive capital	Free	0.02375	Calculated from implied rates based on capital stock data
$\delta_{OTEQLNMFI}$	Revaluation rate of NMFI residual financial instrument	Model-constrained	0.1996	Calculated from EQ. (256)
δ_{RESGVT}	Revaluation rate of GVT residual financial instrument	Model-constrained	0.009843	Calculated from EQ. (314)
δ_{RESHH}	Revaluation rate of HH residual financial instrument	Model-constrained	-0.6181	Calculated from EQ. (370)
δ_{RESNFC}	Revaluation rate of NFC residual financial instrument	Model-constrained	-0.009193	Calculated from EQ. (198)
$\delta_{RESNMFI}$	Revaluation rate of NMFI residual financial instrument	Model-constrained	-0.1662	Calculated from EQ. (259)
δ_{RESPS}	Revaluation rate of PS residual financial instrument	Model-constrained	-0.09408	Calculated from EQ. (123)
δ_{RESRoW}	Revaluation rate of RoW residual financial instrument	Model-constrained	-0.01354	Calculated from EQ. (409)
δ_{rlgvt}	Short run adjustment speed of GVT interest rates to long run rate	Free	0.8	Reasonable number selected from a range of values
δ_{rlnfc}	Short run adjustment speed of NFC interest rates to long run rate	Free	0.5	Reasonable number selected from a range of values
δ_{rlnmfi}	Short run adjustment speed of NMFI interest rates to long run rate	Free	0.5	Reasonable number selected from a range of values
δ_{rlps}	Short run adjustment speed of PS interest rates to long run rate	Free	0.5	Reasonable number selected from a range of values
ϵ_{CHHP}	Error correction parameter for the household production consumption equation	Free	0.1212	Econometrically estimated
ϵ_{GCFNB}	Parameter in the HH gross capital formation for new builds equation	Free	0.5646	Econometrically estimated
ϵ_{GDP}	Adjustment factor to GDP in order to compare model GDP with data based GDP	Free	1.152	Calculated from initial data
ϵ_{max}	Maximum energy intensity of production	Free	0.002	Selected as a reasonable maximum value based on UK past data
ϵ_{min}	Minimum energy intensity of production	Free	0.00025	Selected such that it is reasonably higher than 0
ϵ_{PH}	Parameter in the house price equation	Free	0.06219	Econometrically estimated
ϵ_{rboe}	Adjustment parameter in the BoE Taylor rule	Free	0.125	Set to generate observed early period baseline behavior
ϵ_{WR}	Error correction parameter for wage share equation	Free	0.3237	Econometrically estimated
η_{GVTB}	Long run residual transaction discrepancy of GVT sector relative to GDP	Free	-0.002836	Taken as the mean of past data
η_{GVTT}	Long run lending discrepancy of government sector relative to GDP	Free	-0.01756	Taken as the mean of past data
η_{HHB}	Long run lending discrepancy of H sector relative to GDP	Free	-0.004357	Taken as the mean of past data
η_{HHT}	Long run lending discrepancy of H sector relative to GDP	Free	0.06507	Taken as the mean of past data
η_{MFIT}	Long run lending discrepancy of MFI sector relative to GDP	Free	-0.01394	Taken as the mean of past data
η_{NFCB}	Long run residual transaction discrepancy of NFC sector relative to GDP	Free	-0.002931	Taken as the mean of past data
η_{NFCT}	Long run lending discrepancy of NFC sector relative to GDP	Free	-0.05163	Taken as the mean of past data
η_{NMFIB}	Long run residual transaction discrepancy of NMFI sector relative to GDP	Free	0.005626	Taken as the mean of past data

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Table 6 – continued from previous page

Symbol	Description	Parameter category	Initial value	Source/remarks
η_{NMFIT}	Long run lending discrepancy of NMFI sector relative to GDP	Free	0.01951	Taken as the mean of past data
η_{PSB}	Long run residual transaction discrepancy of PS sector relative to GDP	Free	-0.05267	Taken as the mean of past data
η_{RoWB}	Long run residual transaction discrepancy of RoW sector relative to GDP	Free	0.0006594	Taken as the mean of past data
η_{RoWT}	Long run lending discrepancy of RoW sector relative to GDP	Free	-0.001445	Taken as the mean of past data
κ_1	Parameter linking green to conventional non-electric capital ratio with the energy intensity of production	Free	15	Calibrated such that the model generates the baseline scenario
κ_2	Parameter linking non-fossil fuel to fossil fuel electricity generation ratio with the capacity factor of non-fossil fuel electricity generation	Free	0.4	Calibrated such that the model generates the baseline scenario
κ_3	Parameter linking green to conventional non-electric capital ratio with the ratio between electric and non-electric energy use in production	Free	10	Calibrated such that the model generates the baseline scenario
κ_4	Parameter linking green to conventional non-electric capital ratio with the emission intensity of non-electric energy	Free	5	Calibrated such that the model generates the baseline scenario
κ_5	Parameter linking green to conventional non-electric capital ratio with the emission intensity of fossil fuel electricity production	Free	0.25	Calibrated such that the model generates the baseline scenario
κ_{hie}	Adjusting constant for the balance between energy efficiency and electrification home improvements (£ billion)	Model-constrained	2.765	Calculated from Eq. (355)
MU_{ELEC}	Mark up of electricity prices above the marginal cost of electricity production	Free	1.228	Calculated based on past data
μ_{MCELEC}	Parameter relating the marginal cost of fossil fuel electricty to the overall marginal cost of electricity	Free	0.325	Set as a reasonable estimate to generate the baseline scenario
ω_{emax}	Maximum emission intensity of electric fossil fuel based energy production	Free	0.8	Selected as a reasonable maximum value based on UK data
ω_{emin}	Minimum emission intensity of electric fossil fuel based energy production	Free	0.3	Selected such that it is reasonably higher than 0
ω_{nemax}	Maximum emission intensity of non-electric energy production	Free	1	Selected as a reasonable maximum value based on UK data
ω_{nemin}	Minimum emission intensity of non-electric energy production	Free	0.225	Selected such that it is reasonably higher than 0
π_1	Parameter linking green to conventional non-electric capital ratio with the energy intensity of production	Model-constrained	0.003995	Calculated from Eq. (18)
π_2	Parameter linking non-fossil fuel to fossil fuel electricity generation ratio with the capacity factor of non-fossil fuel electricity generation	Model-constrained	4.468	Calculated from Eq. (19)
π_3	Parameter linking green to conventional non-electric capital ratio with the ratio between electric and non-electric energy use in production	Model-constrained	8.87	Calculated from Eq. (20)
π_4	Parameter linking green to conventional non-electric capital ratio with the emission intensity of non-electric energy	Model-constrained	9.072	Calculated from Eq. (omega)
π_5	Parameter linking green to conventional non-electric capital ratio with the emission intensity of fossil fuel electricity production	Model-constrained	1.838	Calculated from Eq. (omega)

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Table 6 – continued from previous page

Symbol	Description	Parameter category	Initial value	Source/remarks
ψ_{EQNMFI}	Ratio determining NMFI EQA transfers based on their liability transfers from other sectors	Model-constrained	0.3921	Calculated from Eq. (250)
σ_{ELEC}	Maximum proportion of non-fossil fuel electricity in the electricity generation mix	Free	0.975	Reasonable estimate slightly below 1 to account for the requirement for fossil fuel electricity as a back-stop
σ_{gvt}	Parameter driving the size of the interest rate spread on GVT liabilities	Free	-22.92	Based on recent values
σ_{hh}	Parameter driving the size of the interest rate spread on HH liabilities	Free	24.3	Based on recent values
σ_{nfc}	Parameter driving the size of the interest rate spread on NFC liabilities	Free	34.85	Based on recent values
σ_{nmfi}	Parameter driving the size of the interest rate spread on NMFI liabilities	Free	21.63	Based on recent values
σ_{ps}	Parameter driving the size of the interest rate spread on PS liabilities	Free	34.85	Based on recent values
τ	Adjustment parameter for variables with long run constant values	Free	0.125	Taken such that the adjustment speed is reasonable
τ_{gvt}	Adjustment speed to long run government income and spending rates	Free	0.25	Set based on reasonable estimate and to generate the baseline scenario
τ_{ragvt}	Adjustment speed of GVT interest rates to long run rate	Free	0.75	Reasonable number selected to be faster than general rates based on observed past interest rate behavior
τ_{rahh}	Adjustment speed of HH interest rates to long run rate	Free	0.2	Reasonable number selected to be slower than general rates based on observed past interest rate behavior
τ_{ranfc}	Adjustment speed of NFC interest rates to long run rate	Free	0.5	Reasonable number selected from a range of values
τ_{ranmfi}	Adjustment speed of NMFI interest rates to long run rate	Free	0.5	Reasonable number selected from a range of values
τ_{raps}	Adjustment speed of PS interest rates to long run rate	Free	0.5	Reasonable number selected from a range of values
τ_{rlgvt}	Adjustment speed of GVT interest rates to long run rate	Free	0.75	Reasonable number selected to be faster than general rates based on observed past interest rate behavior
τ_{rlhh}	Adjustment speed of HH interest rates to long run rate	Free	0.1391	Reasonable number selected to be slower than general rates based on observed past interest rate behavior
τ_{rlnfc}	Adjustment speed of NFC interest rates to long run rate	Free	0.5271	Reasonable number selected from a range of values
τ_{rlnmfi}	Adjustment speed of NMFI interest rates to long run rate	Free	0.5271	Reasonable number selected from a range of values
τ_{rlps}	Adjustment speed of PS interest rates to long run rate	Free	0.5271	Reasonable number selected from a range of values
τ_{rnrow}	Adjustment speed of RoW interest rates to long run rate	Free	0.5	Reasonable number selected from a range of values
θ_{divp}	Proportion of NMFI dividends distributed to other sectors	Model-constrained	1.125	Calculated from Eq. (238)
θ_{HEE}	Energy intensity of efficient electric housing stock	Model-constrained	0.9783	Calculated from Eq. (11)
θ_{HEN}	Energy intensity of efficient non-electric housing stock	Model-constrained	2.242	Calculated from Eq. (14)
θ_{HI}	Energy intensity of inefficient housing stock	Free	5.607	Calculated from UK EPC data
θ_{psb}	Share of power sector financial assets in overall assets	Free	0.02744	Taken from ratio of power sector to firm loans from Bank of Endland data
θ_{socb}	Payment rate on NMFI insurance stock	Model-constrained	0.02552	Calculated from Eq. (243)
$TREND_{\beta HH}$	Parameter in the equation for green home improvements	Free	0.0005668	Estimate based on green housing investment data

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Table 7: Initial Variable Values

Symbol	Description	Variable category	Initial value	Source/remarks
AC_{FF}	Average cost of power sector fossil fuel electricity production (£ billion)	Model-constrained	0.6176	Calculated from Eq. (88)
AC_{NFF}	Average cost of power sector non-fossil fuel electricity production (£ billion)	Model-constrained	0.2039	Calculated from Eq. (87)
C_{HIEER}	Cost of upgrading an energy efficient home to an electric home 2022 prices (million homes/ £ billion)	Free	10	10 (£ thousands) estimated cost of energy efficiency installations 2022 prices
C_{HIENR}	Cost of upgrading an energy inefficient home to an efficient non-electric home 2022 prices (million homes/ £ billion)	Free	7.529	7.5 (£ thousands) estimated cost of energy efficiency installations 2022 price
CF_{NFF}	Capacity factor of non-fossil fuel electricity production	Model-constrained	0.7215	Calculated from Eq. (7)
$CONS$	Consumption (£ billion)	Model-constrained	459.5	Calculated from Eq. (25)
$CONS_{GVT}$	Government consumption (£ billion)	Model-constrained	119.1	Calculated from Eq. (291)
$CONS_{GVTR}$	Government consumption 2022 prices (£ billion)	Model-constrained	115	Calculated from Eq. ($CONS_{GVTPR}$)
$CONS_{HH}$	Household consumption (£ billion)	Free	340.4	Taken from the ONS UK economic accounts 2024 adjusting for rents and FISIM
$CONS_{HHP}$	Household consumption (£ billion)	Model-constrained	333.1	Calculated from Eq. (339)
$CONS_{HHPR}$	Household consumption from production 2022 prices (£ billion)	Model-constrained	321.9	Calculated from Eq. (343)
$CONS_{HHPS}$	Household consumption from the power sector (£ billion)	Free	7.314	Taken from the ONS supply and use tables 2024
$CONS_{HHPSR}$	Household consumption from the power sector 2022 prices (£ billion)	Model-constrained	22.87	Calculated from Eq. (344)
$CONS_{HHR}$	Household consumption 2022 prices (£ billion)	Model-constrained	328.9	Calculated from Eq. (342)
$CONS_{R}$	Real Consumption 2022 prices (£ billion)	Model-constrained	444	Calculated from Eq. (29) and consumption deflators
$COST_{ER}$	Total economy energy costs from electric and non-electric sources including taxes (£ billion)	Model-constrained	47.68	Calculated from Eq. ($COST_{ET}$)
$COST_{NELEC}$	Cost of non-electric energy (£ billion)	Free	27.86	Taken from DUKES table 1.1.6 non-electric energy cost
$COST_{P}$	Total "cost" in production module (£ billion)	Model-constrained	992.5	Calculated from Eq. (51)
$COST_{PS}$	Total "cost" in power sector (£ billion)	Model-constrained	43.18	Calculated from Eq. (82)
$COST_{PSFF}$	Total cost of power sector fossil fuel electricity production (£ billion)	Model-constrained	30.07	Calculated from Eq. (86)
$COST_{PSNFF}$	Total cost of power sector non-fossil fuel electricity production (£ billion)	Model-constrained	14.75	Calculated from Eq. (85)
COV_{ETSP}	Proportion of production emissions subject to ETS	Free	0.1882	Taken as a rate consistent with UK ETS revenue in 2022
COV_{ETSPS}	Proportion of power sector emissions subject to ETS	Free	0.5	Taken as an estimate based on OBR emission and tax forecasts
CR_{NFC}	Credit rationing rate for NFCs	Free	0.1188	Constructed from credit conditions index while assuming maximum rationing rate of 40%
CR_{PS}	Credit rationing rate for power sector	Free	0.1188	Constructed from credit conditions index while assuming maximum rationing rate of 40%
$DEBT_{GDP}$	Debt to GDP ratio (%)	Free	81.66	Calculated from initial Government debt and 23 levels
DEF_{NFC}	NFC default rates assumed to be proportional to NFC Revaluations	Model-constrained	0.02982	Calculated from EQ. (196)
DEF_{PS}	PS default rates assumed to be proportional to PS Revaluations	Model-constrained	-0.02111	Calculated from EQ. (121)
det_{IA}	Determinant of I - A matrix for calculating Leiontief matrix coefficients	Model-constrained	0.3869	Calculated from Eq. (165)

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
$DISC_{GVT}$	Lending discrepancy for the government sector (£ billion)	Model-constrained	-8.678	Calculated from Eq. (305)
$DISC_{HH}$	Lending discrepancy for the HH sector (£ billion)	Model-constrained	10.58	Calculated from Eq. (360)
$DISC_{MFI}$	Lending discrepancy for the MFI sector (£ billion)	Model-constrained	-21.13	Calculated from Eq. (222)
$DISC_{NFC}$	Lending discrepency for the NFC sector (£ billion)	Model-constrained	-35.52	Calculated from Eq. (187)
$DISC_{NMFI}$	Lending discrepancy for the NMFI sector (£ billion)	Model-constrained	81.8	Calculated from Eq. (247)
$DISC_{RoW}$	Lending discrepancy for the RoW sector (£ billion)	Model-constrained	-27.05	Calculated from Eq. (403)
$DIVN_{RoW}$	Net-Dividends received by the RoW sector (£ billion)	Free	-5.44	Taken from the ONS UK economic accounts 2024
$DIVP_{NFC}$	Dividends paid by the NFC sector (£ billion)	Free	44.34	Taken from the ONS UK economic accounts 2024
$DIVP_{NMFI}$	Dividends paid by the NMFI sector (£ billion)	Model-constrained	57.44	Calculated from Eq. (238)
$DIVP_{PS}$	Dividends paid by the power sector (£ billion)	Free	1.251	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
$DIVR_{HH}$	Dividends received by the Household sector (£ billion)	Free	32.47	Taken from the ONS UK economic accounts 2024
$DIVR_{NFC}$	Dividends received by the NFC sector (£ billion)	Free	24.28	Taken from the ONS UK economic accounts 2024
$DIVR_{NMFI}$	Dividends recieved by the NMFI sector (£ billion)	Model-constrained	51.04	Calculated from Eq. (238)
$DIVR_{PS}$	Dividends received by the power sector (£ billion)	Free	0.685	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
E	Total final energy use (TwH)	Free	365.2	Taken from ONS DUKES table 1.1.5
E_{ELEC}	Total final electricity use (TwH)	Free	66.88	Taken from ONS DUKES table 1.1.5
E_{ELECFF}	Total final electricity use from fossil fuel sources (TwH)	Model-constrained	26.91	Calculated from Eq. (8)
E_{ELECH}	Total domestic final electricity use (TwH)	Free	22.87	Taken from ONS DUKES table 1.1.5
$E_{ELECMAX}$	Maximum electrical energy production (TwH)	Model-constrained	127.3	Calculated from Eq. (6)
$E_{ELECNFF}$	Total final electricity use from non-fossil fuel sources (TwH)	Free	39.97	Calculated from non-fossil fuel energy supply proportions from UK energy trends table 5.1
E_{ELECP}	Electric energy use in production (TwH)	Model-constrained	44.01	Calculated from Eq. (5)
E_H	Total final domestic energy use (TwH)	Free	107.9	Taken from ONS DUKES table 1.1.5
E_{NELEC}	Total final non-electric energy use (TwH)	Model-constrained	298.4	Calculated from Eq. (12)
E_{NELECH}	Non-electric energy use in housing (TwH)	Model-constrained	85.03	Calculated from Eq. (3)
E_{NELECP}	Total final production non-electric energy use (TwH)	Model-constrained	213.3	Calculated using Eq. (13)
E_P	Total final energy use from production (TwH)	Model-constrained	257.3	Calculated from Eq. (1)
$EMIS$	Total greenhouse gas emissions (MtCO2e)	Free	101.5	Taken from DESNZ final greenhouse gas emissions table 1.2
$EMIS_{ELEC}$	Total greenhouse gas emissions from electricty (MtCO2e)	Free	13.72	Taken from DESNZ final greenhouse gas emissions table 1.2
$EMIS_{NELEC}$	Total greenhouse gas emissions from non-electric energy (MtCO2e)	Model-constrained	87.83	Calculated from Eq. (15)
EMP	Total employed people (millions)	Free	32.81	Taken from the ONS labour market survey 2023
EMP_{PRI}	Total employed people in the private sector (millions)	Model-constrained	27.01	Calculated from Eq. (36)
EMP_{PUB}	Total employed people in the public sector (millions)	Free	5.802	Taken from the ONS labour market survey 2023
EQA_{HH}	Equity assets of the HH sector (£ billion)	Free	1070	Taken from the ONS UK economic accounts 2024

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
EQA_{NFC}	Equity assets of the NFC sector (£ billion)	Free	1379	Taken from the ONS UK economic accounts 2024
EQA_{NMFI}	Equity assets of the NMFI sector (£ billion)	Model-constrained	3857	Calculated as the sum of other sector equity liabilities
EQA_{PS}	Equity assets of the power sector (£ billion)	Free	38.92	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
$EQATR_{HH}$	Equity asset net-transfers of the HH sector (£ billion)	Free	-19.04	Taken from the ONS UK economic accounts 2024
$EQATR_{NFC}$	Equity asset net-transfers of the NFC sector (£ billion)	Free	13.59	Taken from the ONS UK economic accounts 2024
$EQATR_{NMFI}$	Equity assets transfers of the NMFI sector (£ billion)	Model-constrained	-15.75	Calculated from Eq. (250)
$EQATR_{PS}$	Equity asset net-transfers of the power sector (£ billion)	Free	0.3836	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
EQL_{NFC}	Equity liabilities of the NFC sector (£ billion)	Free	3751	Taken from the ONS UK economic accounts 2024
EQL_{NMFI}	Equity liabilities of the NMFI sector (£ billion)	Model-constrained	2522	Calculated as the sum of other sector equity assets
EQL_{PS}	Equity liabilities of the power sector (£ billion)	Free	105.8	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
$EQLTR_{NFC}$	Equity liabilities net-transfers of the NFC sector (£ billion)	Free	-15.31	Taken from the ONS UK economic accounts 2024
$EQLTR_{NMFI}$	Equity liability transfers of the NMFI sector (£ billion)	Model-constrained	-83.46	Calculated from Eq. (249)
$EQLTR_{PS}$	Equity liabilities net-transfers of the power sector (£ billion)	Free	-0.4321	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
EQN_{RoW}	Equity assets of the RoW sector (£ billion)	Free	34.07	Taken from the ONS UK economic accounts 2024
$EQNTR_{RoW}$	Equity asset net-transfers of the RoW sector (£ billion)	Free	-78.4	Taken from the ONS UK economic accounts 2024
ER	Exchange Rate between domestic productive prices and import prices	Free	1	Based on initial disparity between price indices
EXP	Total Exports (£ billion)	Free	235	Taken from the ONS UK economic accounts 2024
EXP_R	Total exports 2022 prices (£ billion)	Model-constrained	226.6	Calculated from Eq. (396)
F_P	Final demand for production sector products	Model-constrained	786.6	Calculated from EQ. (47)
F_{PR}	Final demand of the production sector £ billion) (IMP_R)	Model-constrained	760	Calculated from Eq. (48)
F_{PS}	Final demand of the power sector (£ billion)	Model-constrained	7.314	Calculated from Eq. (78)
F_{PSR}	Final demand of the power sector £ billion)	Model-constrained	22.87	Calculated from Eq. (79)
FA_{GVT}	Financial assets of the GVT sector (£ billion)	Model-constrained	465	Calculated from Eq. (320)
FA_{HH}	Financial assets of the HH sector (£ billion)	Model-constrained	6785	Calculated from Eq. (376)
FA_{MFI}	Financial assets of the MFI sector (£ billion)	Model-constrained	7701	Calculated from Eq. (224)
FA_{NFC}	Financial assets of the NFC sector (£ billion)	Model-constrained	2654	Calculated from Eq. (203)
FA_{NMFI}	Financial assets of the NMFI sector (£ billion)	Model-constrained	9090	Calculated from Eq. (264)
FA_{PS}	Financial assets of the power sector (£ billion)	Model-constrained	74.88	Calculated from Eq. (128)
FL_{GVT}	Financial liabilities of the GVT sector (£ billion)	Model-constrained	2517	Calculated from Eq. (321)
FL_{HH}	Financial liabilities of the HH sector (£ billion)	Model-constrained	2083	Calculated from Eq. (377)
FL_{MFI}	Financial liabilities of the MFI sector (£ billion)	Model-constrained	7591	Calculated from Eq. (228)
FL_{NFC}	Financial liabilities of the NFC sector (£ billion)	Model-constrained	5380	Calculated from Eq. (204)

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
FL_{NMFI}	Financial liabilities of the NMFI sector (£ billion)	Model-constrained	9191	Calculated from Eq. (265)
FL_{PS}	Financial liabilities of the power sector (£ billion)	Model-constrained	151.8	Calculated from Eq. (129)
FNW	Overall financial net worth - should equal 0 by definition	Model-constrained	3.411e-13	Calculated from Eq. (445)
FNW_{GVT}	Financial net-worth of the GVT sector (£ billion)	Free	-1854	Taken from the ONS UK economic accounts 2024 adjusted to account for Maastricht debt
FNW_{GVTM}	Model determined financial net-worth of the GVT sector (£ billion)	Model-constrained	-2052	Calculated from Eq. (322)
FNW_{HH}	Financial net-worth of the HH sector (£ billion)	Free	4382	Taken from the ONS UK economic accounts 2024
FNW_{HHM}	Model determined financial net-worth of the HH sector (£ billion)	Model-constrained	4701	Calculated from Eq. (378)
FNW_M	Overall model determined financial net worth - should equal 0 by definition	Model-constrained	5.684e-13	Calculated from Eq. (444)
FNW_{MFI}	Financial net-worth of the MFI sector (£ billion)	Model-constrained	40.74	Calculated from Eq. (231)
FNW_{MFIM}	Model determined financial net-worth of the MFI sector (£ billion)	Model-constrained	110.3	Calculated from Eq. (229)
FNW_{NFC}	Financial net-worth of the NFC sector (£ billion)	Free	-2991	Taken from the ONS UK economic accounts 2024
FNW_{NFCM}	Model determined financial net-worth of the NFC sector (£ billion)	Model-constrained	-2726	Calculated from Eq. (205)
FNW_{NMFI}	Financial net-worth of the NMFI sector (£ billion)	Free	161.8	Taken from the ONS UK economic accounts 2024
FNW_{NMFIM}	Model determined financial net-worth of the NMFI sector (£ billion)	Model-constrained	-100.9	Calculated from Eq. (266)
FNW_{PS}	Financial net-worth of the power sector (£ billion)	Free	-84.4	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
FNW_{PSM}	Model determined financial net-worth of the power sector (£ billion)	Model-constrained	-76.91	Calculated from Eq. (130)
FNW_{RoW}	Financial net-worth of the RoW sector (£ billion)	Free	344.7	Taken from the ONS UK economic accounts 2024
FNW_{RoWM}	Model determined financial net-worth of the NFC sector (£ billion)	Model-constrained	143.8	Calculated from Eq. (205)
g	Nominal GDP growth rate	Model-constrained	1.009	Calculated from Eq. (32)
GCF	Gross fixed capital formation (£ billion)	Model-constrained	99.49	Calculated from Eq. (26)
GCF_{GVT}	Gross capital formation of the government sector (£ billion)	Free	20.76	Taken from the ONS UK economic accounts 2024
GCF_{GVTC}	Conventional gross capital formation of the GVT sector (£ billion)	Model-constrained	19.61	Calculated from Eq. (297)
GCF_{GVTCR}	Conventional gross capital formation of the GVT sector 2022 prices (£ billion)	Model-constrained	19.02	Calculated from Eq. (301)
GCF_{GVTG}	Gross capital formation of the GVT sector (£ billion)	Free	1.153	Taken by assuming government has the same initial proportion of green investment as the NFC sector
GCF_{GVTGR}	Green gross capital formation of the GVT sector 2022 prices (£ billion)	Model-constrained	1.119	Calculated from Eq. (300)
GCF_{GVTR}	Gross capital formation of the GVT sector 2022 prices (£ billion)	Model-constrained	20.14	Calculated from Eq. (299)
GCF_{HH}	Gross capital formation of the household sector (£ billion)	Free	29.33	Taken from the ONS UK economic accounts 2024
GCF_{HHHI}	Household Gross capital formation in home improvement 2022 prices (£ billion)	Model-constrained	1.559	Calculated from Eq. (346)
$GCF_{HHHIEER}$	Gross fixed capital formation in electrification home improvements 2022 prices (£ billion)	Model-constrained	0.06804	Calculated from Eq. (356)
$GCF_{HHHIENR}$	Gross fixed capital formation in energy efficiency home improvements 2022 prices (£ billion)	Free	0.1437	Calculated such that initial value is reasonable

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
GCF_{HHHIER}	Gross fixed capital formation in energy efficient home improvements 2022 prices (£ billion)	Model-constrained	0.2117	Calculated from Eq. (353)
GCF_{HHHINR}	Gross fixed capital formation in non-energy home improvements 2022 prices (£ billion)	Model-constrained	1.3	Calculated from Eq. (354)
GCF_{HHHIR}	Gross fixed capital formation in home improvements 2022 prices (£ billion)	Model-constrained	1.512	Calculated from Eq. (350)
GCF_{HHNB}	Gross fixed capital formation in new houses 2022 prices (£ billion)	Model-constrained	27.77	Calculated from Eq. (350)
GCF_{HHNBR}	Gross fixed capital formation in new houses 2022 prices (£ billion)	Free	26.94	Taken from the ONS UK economic accounts 2024
GCF_{HHR}	Gross fixed capital formation in new houses (£ billion)	Model-constrained	28.45	Calculated from Eq. (350)
GCF_{NFC}	Gross capital formation of the NFC sector (£ billion)	Free	47.24	Taken from the ONS UK economic accounts 2024
GCF_{NFCC}	Conventional gross capital formation of the NFC sector (£ billion)	Model-constrained	44.62	Calculated from Eq. (181)
GCF_{NFCCR}	Conventional gross capital formation of the NFC sector 2022 prices (£ billion)	Model-constrained	43.28	Calculated from Eq. (184)
GCF_{NFCD}	Desired NFC gross capital formation	Model-constrained	53.61	Calculated from Eq. (178)
GCF_{NFCG}	Green gross capital formation of the NFC sector (£ billion)	Free	2.625	Based on UK Government Green Financing: Allocation Report 2024
GCF_{NFCGR}	Green gross capital formation of the NFC sector 2022 prices (£ billion)	Model-constrained	2.546	Calculated from Eq. (183)
GCF_{NFCR}	Gross capital formation of the NFC sector 2022 prices (£ billion)	Model-constrained	45.82	Calculated from Eq. (182)
GCF_{PSFF}	Gross capital formation of fossil fuel power capital (£ billion)	Model-constrained	0.6638	Calculated from Eq. (104)
GCF_{PSFFD}	Desired PS fossil fuel gross capital formation	Model-constrained	0.7533	Calculated from Eq. (104)
GCF_{PSFFR}	Gross capital formation of fossil fuel power capital 2022 prices (£ billion)	Model-constrained	0.6438	Calculated from Eq. (134)
GCF_{PSNFF}	Gross capital formation of non-fossil fuel power capital (£ billion)	Model-constrained	1.489	Calculated from Eq. (105)
GCF_{PSNFFD}	Desired PS non-fossil gross capital formation	Model-constrained	1.69	Calculated from Eq. (105)
GCF_{PSNFFR}	Gross capital formation of non-fossil fuel power capital 2022 prices (£ billion)	Model-constrained	1.444	Calculated from Eq. (140)
GCF_{PSR}	Gross capital formation of the power sector 2022 prices (£ billion)	Model-constrained	2.088	Calculated from Eq. (109)
GCF_{R}	Real gross fixed capital formation 2022 prices (£ billion)	Model-constrained	96.5	Calculated from Eq. (30) and GFCF deflators
GDP	Gross domestic product (£ billion)	Model-constrained	567.5	Calculated from Eq. (23)
GDP_{R}	Real gross domestic product 2022 prices (£ billion)	Model-constrained	546.2	Calculated from Eq. (28)
GDP_{RFE}	Labour-determined potential GDP (£ billion)	Model-constrained	567.3	Calculated using Eq. (44)
GDP_{RFK}	Capital-determined potential GDP (£ billion)	Model-constrained	670.1	Calculated using Eq. (46)
GDP_{RMAX}	Maximum real supply constrained GDP (£ billion)	Model-constrained	567.3	Calculated using Eq. (41)
GO	Total output (£ billion)	Model-constrained	1174	Calculated from Eq. (27)
GO_{P}	Gross output from production (£ billion)	Model-constrained	1135	Calculated from Eq. (50)
GO_{PR}	Production sector gross output 2022 prices (£ billion)	Model-constrained	1096	Calculated from Eq. (49)
GO_{PS}	Gross output from the power sector (£ billion)	Model-constrained	38.71	Calculated from Eq. (50)
GO_{PSR}	Power sector gross output 2022 prices (£ billion)	Model-constrained	121	Calculated from (80)
GO_{R}	Total output (£ billion 2022 prices)	Model-constrained	1134	Calculated from Eq. (31)
GOS_{P}	Gross operating surplus from production (£ billion)	Model-constrained	142.4	Calculated from Eq. (52)

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
GOS_{PS}	Gross operating surplus of the power sector (£ billion)	Model-constrained	-4.474	Calculated Eq. (83)
H	Total number of UK properties (millions)	Free	30.06	From UK census data
H_{EE}	Total number of UK energy efficient electric properties (EPC rating C and above with electric primary fuel) (millions)	Free	0.9634	From UK EPC data
H_{EN}	Total number of UK energy efficient non-electric properties (EPC rating C and above with non-electric primary fuel) (millions)	Free	16.69	From UK EPC data
H_I	Total number of UK non-energy efficient non-electric properties (EPC rating D and below) (millions)	Free	12.4	From UK EPC data
HB	Number of houses built in the UK (millions)	Model-constrained	0.021	Calculated as the change in house numbers based on housing data
$HVAL$	Total value of housing stock (£ billion)	Model-constrained	8727	Calculated from Eq. (388)
IBA_{GVT}	Interest bearing assets of the government sector (£ billion)	Free	465	Taken from the ONS UK economic accounts 2024
IBA_{HH}	Interest bearing assets of the HH sector (£ billion)	Free	2151	Taken from the ONS UK economic accounts 2024
IBA_{NFC}	Interest bearing assets of the NFC sector (£ billion)	Free	1274	Taken from the ONS UK economic accounts 2024
IBA_{NMFI}	Interest bearing assets of the NMFI sector (£ billion) excluding government borrowing	Free	4394	Taken from the ONS UK economic accounts 2024
IBA_{PS}	Interest bearing assets of the power sector (£ billion)	Free	35.96	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
$IBATR_{GVT}$	Interest bearing asset net-transfers of the GVT sector (£ billion)	Free	-9.236	Taken from the ONS UK economic accounts 2024
$IBATR_{HH}$	Interest bearing asset net-transfers of the HH sector (£ billion)	Free	15.41	Taken from the ONS UK economic accounts 2024
$IBATR_{MFI}$	Interest bearing asset transfers of the MFI sector (£ billion)	Model-constrained	-155.3	Calculated from Eq. (225)
$IBATR_{NFC}$	Interest bearing asset net-transfers of the NFC sector (£ billion)	Free	-37.73	Taken from the ONS UK economic accounts 2024
$IBATR_{NMFI}$	Interest bearing asset net-transfers of the NMFI sector (£ billion)	Free	-141.5	Taken from the ONS UK economic accounts 2024
$IBATR_{PS}$	Interest bearing asset net-transfers of the power sector (£ billion)	Free	-1.065	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
IBL_{GVT}	Interest bearing liabilities of the government sector (£ billion)	Free	2517	Taken from UK government Maastricht debt data
IBL_{GVTMFI}	Interest bearing liabilities of the government sector held by MFIs (£ billion)	Free	838.9	Taken as a proportion of total government IBLs based on flow of funds data
$IBL_{GVTNMFI}$	Interest bearing liabilities of the government sector held by NMFIs (£ billion)	Free	838.9	Taken as a proportion of total government IBLs based on flow of funds data
IBL_{GVTRoW}	Interest bearing liabilities of the government sector held by RoW (£ billion)	Free	838.9	Taken as a proportion of total government IBLs based on flow of funds data
IBL_{HH}	Interest bearing liabilities of the HH sector (£ billion)	Free	2083	Taken from the ONS UK economic accounts 2024
IBL_{NFC}	Interest bearing liabilities of the NFC sector (£ billion)	Free	1628	Taken from the ONS UK economic accounts 2024
IBL_{NMFI}	Interest bearing liabilities of the NMFI sector (£ billion)	Free	3105	Taken from the ONS UK economic accounts 2024
IBL_{PS}	Interest bearing liabilities of the power sector (£ billion)	Free	45.94	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
$IBLTR_{GVT}$	Interest bearing liabilities net-transfers of the GVT sector (£ billion)	Free	65.64	Taken from the ONS UK economic accounts 2024

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
$IBLTR_{GVTMFI}$	Interest bearing liabilities transfers of the government sector held by MFIs (£ billion)	Free	21.88	Taken as a proportion of total government IBLs based on flow of funds data
$IBLTR_{GVTNMFI}$	Interest bearing liabilities transfers of the government sector held by NMFIs (£ billion)	Free	21.88	Taken as a proportion of total government IBLs based on flow of funds data
$IBLTR_{GVTRoW}$	Interest bearing liabilities transfers of the government sector held by RoW (£ billion)	Free	21.88	Taken as a proportion of total government IBLs based on flow of funds data
$IBLTR_{HH}$	Interest bearing liabilities net-transfers of the HH sector (£ billion)	Free	15.36	Taken from the ONS UK economic accounts 2024
$IBLTR_{MFI}$	Interest bearing liability transfers of the MFI sector (£ billion)	Model-constrained	-146.3	Calculated from Eq. (226)
$IBLTR_{NFC}$	Interest bearing liabilities net-transfers of the NFC sector (£ billion)	Free	-51.33	Taken from the ONS UK economic accounts 2024
$IBLTR_{NMFI}$	Interest bearing liability net-transfers of the NMFI sector (£ billion)	Free	-139.8	Taken from the ONS UK economic accounts 2024
$IBLTR_{PS}$	Interest bearing liabilities net-transfers of the power sector (£ billion)	Free	-1.448	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
IBN_{RoW}	Interest bearing assets of the RoW sector (£ billion)	Free	-729.2	Taken from the ONS UK economic accounts 2024
$IBNTR_{RoW}$	Interest bearing asset net-transfers of the RoW sector (£ billion)	Free	27.85	Taken from the ONS UK economic accounts 2024
IC_{FUELPS}	Intermediate consumption of the power sector for fuel products	Free	15.75	Taken from the ONS supply and use tables 2024
$IC_{FUELPSR}$	Intermediate consumption of the power sector for fuel products (£ bn 2022 prices)	Model-constrained	15.75	Calculated from Eq. (163)
IC_{OPPS}	Intermediate consumption of the power sector for other production products (£ billion)	Model-constrained	8.833	Calculated from Eq. (162)
IC_{OPPSR}	Intermediate consumption of the power sector for other products (£ bn 2022 prices)	Model-constrained	8.534	Calculated from Eq. (164)
IC_{PP}	Internal intermediate consumption of the production sector	Free	323.6	Taken from the ONS supply and use tables 2024
IC_{PPS}	Intermediate consumption of the power sector for production products	Free	24.58	Taken from the ONS supply and use tables 2024
IC_{PSP}	Intermediate consumption of the production sector for power sector products	Free	14.07	Taken from the ONS supply and use tables 2024
IC_{PSPR}	Real intermediate consumption of the production sector for power sector products (£bn 2022 prices)	Model-constrained	44.01	Calculated from Eq. (156)
IC_{PSPS}	Internal intermediate consumption of the power sector	Free	17.32	Taken from the ONS supply and use tables 2024
$ILLIQ_{PS}$	Illiquidity ratio of the power sector	Model-constrained	1.1	Calculated from Eq. (147)
IMP	Total Imports (£ billion)	Free	226.4	Taken from the ONS UK economic accounts 2024
IMP_R	Total imports 2022 prices (£ billion)	Model-constrained	220.9	Calculated from Eq. (395)
INF_A	UK annual CPI inflation rate	Free	0.107	From ONS CPI data
INS	Total Insurance stock - asset of households and a liability of the NMFI sector (£ billion)	Free	970.5	Taken from the ONS UK economic accounts 2024
$INSR$	Income payable on insurance entitlements	Free	3.14	Taken from the ONS UK economic accounts 2024
$INSTR$	Total Insurance stock net transfers - asset of households and a liability of the NMFI sector (£ billion)	Free	-2.347	Taken from the ONS UK economic accounts 2024
$INTAX$	Total income tax received by the government (£ billion)	Model-constrained	99.07	Calculated from Eq. (281)
$INTAX_{HH}$	Income tax paid by the household sector (£ billion)	Free	79.91	Taken from the ONS UK economic accounts 2024
$INTAX_{NFC}$	Income tax paid by the NFC sector (£ billion)	Free	19.16	Taken from the ONS UK economic accounts 2024

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
$INTAXR_{HH}$	Income tax rate of Households	Model-constrained	0.2193	Calculated from Eq. (284)
$INTAXR_{NFC}$	Income tax rate of NFCs	Model-constrained	0.05261	Calculated from Eq. (282)
$INTN_{RoW}$	Net-Interest received by the RoW sector (£ billion)	Free	19.52	Taken from the ONS UK economic accounts 2024
$INTP_{GVT}$	Interest received by the GVT sector (£ billion)	Free	32.87	Taken from the ONS UK economic accounts 2024
$INTP_{HH}$	Interest received by the HH sector (£ billion)	Free	15.46	Taken from the ONS UK economic accounts 2024
$INTP_{MFI}$	Interest paid by the MFI sector (£ billion)	Model-constrained	66.65	Calculated from Eq. (221)
$INTP_{NFC}$	Interest paid by the NFC sector (£ billion)	Free	10.28	Taken from the ONS UK economic accounts 2024
$INTP_{NMFI}$	Interest paid by the NMFI sector (£ billion)	Free	18.85	Taken from the ONS UK blue book 2023, annual data converted to quarterly using cubic spline interpolation
$INTP_{PS}$	Interest paid by the power sector (£ billion)	Free	0.2902	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
$INTR_{GVT}$	Interest received by the GVT sector (£ billion)	Free	3.089	Taken from the ONS UK economic accounts 2024
$INTR_{HH}$	Interest received by the HH sector (£ billion)	Free	5.36	Taken from the ONS UK economic accounts 2024
$INTR_{MFI}$	Interest received by the MFI sector (£ billion)	Model-constrained	77.75	Calculated from Eq. (220)
$INTR_{NFC}$	Interest received by the NFC sector (£ billion)	Free	4.206	Taken from the ONS UK economic accounts 2024
$INTR_{NMFI}$	Interest received by the NMFI sector (£ billion)	Free	34.35	Taken from the ONS UK blue book 2023, annual data converted to quarterly using cubic spline interpolation
$INTR_{PS}$	Interest received by the power sector (£ billion)	Free	0.1187	Taken from the ONS UK economic accounts 2024 with the power sector accounting for a fixed proportion of NFC financial variables
$ITAX$	Total indirect tax received by the government (£ billion)	Model-constrained	65.35	Calculated from Eq. (270)
$ITAX_{NELEC}$	ETS tax on non-electric energy production	Model-constrained	0.1102	Calculated from Eq. (272)
$ITAX_{P}$	Total indirect taxes - subsidies on production (£ billion)	Free	64.07	Taken from the ONS UK economic accounts 2024
$ITAX_{PS}$	Total indirect taxes - subsidies on the power sector (£ billion)	Free	1.284	Taken from the ONS supply and use tables 2024
$ITAX_{PSFF}$	Indirect tax of the power sector on fossil fuel electricity production (£ billion)	Model-constrained	0.5441	Calculated from Eq. (277)
$ITAX_{PSNFF}$	Indirect tax of the power sector on non-fossil fuel electricity production (£ billion)	Model-constrained	0.7403	Calculated from Eq. (278)
$ITAXR_{P}$	Indirect tax rate (excluding ETS) of the production sector	Model-constrained	0.05636	Calculated from Eq. (273)
$ITAXR_{PS}$	Indirect tax rate (excluding ETS) of power sector	Model-constrained	0.032	Calculated from Eq. (276)
K_{GVT}	GVT capital(£ billion)	Model-constrained	886.7	Calculated from Eq. (328)
K_{GVTC}	Conventional GVT capital(£ billion)	Model-constrained	851.2	Calculated from Eq. (329)
K_{GVTCR}	Conventional GVT capital stock 2022 prices (£ billion)	Model-constrained	825.6	Calculated from Eq. (325)
K_{GVTG}	Green GVT capital(£ billion)	Model-constrained	35.47	Calculated from Eq. (330)
K_{GVTR}	Capital stock of the GVT sector 2022 prices (£ billion)	Free	860	Taken from the ONS capital stock tables 2023
K_{NFC}	NFC capital(£ billion)	Model-constrained	2501	Calculated from Eq. (211)
K_{NFCC}	Conventional NFC capital(£ billion)	Model-constrained	2401	Calculated from Eq. (212)
K_{NFCCR}	Conventional NFC capital stock 2022 prices (£ billion)	Model-constrained	2329	Calculated from Eq. (208)

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
K_{NFCG}	Green NFC capital(£ billion)	Model-constrained	100	Calculated from Eq. (213)
K_{NFCR}	Capital stock of the NFC sector 2022 prices (£ billion)	Free	2426	Taken from the ONS capital stock tables 2023
K_{P}	Total production capital (£ billion)	Model-constrained	3388	Calculated from Eq. (71)
K_{PC}	Total conventional production capital (£ billion)	Model-constrained	3252	Calculated from Eq. (73)
K_{PCR}	Real total conventional production capital 2022 prices (£ billion)	Model-constrained	3155	Calculated from Eq. (76)
K_{PG}	Total green production capital (£ billion)	Model-constrained	135.5	Calculated from Eq. (72)
K_{PGR}	Real total green production capital 2022 prices (£ billion)	Model-constrained	131.4	Calculated from Eq. (75)
K_{PR}	Real total production capital 2022 prices (£ billion)	Model-constrained	3286	Calculated from Eq. (74)
K_{PS}	Capital stock of the power sector(£ billion)	Free	132.5	Taken from the ONS capital stock tables 2023 assuming D351 capital is proportion to the sectors GVA in the supply and use tables 2023
K_{PSFF}	Power sector fossil fuel capital (£ billion)	Model-constrained	79.51	Calculated from Eq. (143)
K_{PSFFR}	Power sector fossil fuel capital 2022 prices (£ billion)	Model-constrained	77.12	Calculated from Eq. (133)
K_{PSNFF}	Power sector non-fossil fuel capital (£ billion)	Model-constrained	57.11	Calculated from Eq. (143)
K_{PSNFFR}	Non-fossil fuel capital stock of the power sector (£ billion)	Free	55.4	Calculated using DUKES table 5.7
K_{PSR}	Capital stock of the power sector 2022 prices (£ billion)	Free	132.5	Taken from the ONS capital stock tables 2023 assuming D351 capital is proportion to the sectors GVA in the supply and use tables 2023
L_{PP}	Leiontief coefficient for internal intermediate consumption of the production sector	Model-constrained	1.428	Calculated from Eq. (166)
L_{PPS}	Leiontief coefficient for the powersector intermediate consumption of the production products	Model-constrained	0.5184	Calculated from Eq. (167)
L_{PSP}	Leiontief coefficient for the production sector intermediate consumption of the power products	Model-constrained	0.1037	Calculated from Eq. (168)
L_{PSPS}	Leiontief coefficient for internal intermediate consumption of the power sector	Model-constrained	1.847	Calculated from Eq. (169)
$LEND$	Overall net lending - should equal 0 by definition	Model-constrained	0	Calculated from Eq. (443)
$LEND_{GVT}$	Net-lending position of the GVT sector (£ billion)	Free	-41.27	Taken from the ONS UK economic accounts 2024
$LEND_{GVTM}$	Model determined net-lending position of the government sector (£ billion)	Model-constrained	-32.59	Calculated from Eq. (303)
$LEND_{HH}$	Net-lending position of the HH sector (£ billion)	Free	-0.471	Taken from the ONS UK economic accounts 2024
$LEND_{HHM}$	Model determined net-lending position of the HH sector (£ billion)	Model-constrained	-11.05	Calculated from Eq. (358)
$LEND_{M}$	Overall model determined net lending - should equal 0 by definition	Model-constrained	5.44	Calculated from Eq. (442)
$LEND_{MFI}$	Net-lending position of the MFI sector (£ billion)	Free	-15.47	Taken from the ONS UK economic accounts 2024
$LEND_{MFIM}$	Model determined net lending of the MFI sector (£ billion)	Model-constrained	11.1	Calculated from Eq. (219)
$LEND_{NFC}$	Net-lending position of the NFC sector (£ billion)	Free	14.28	Taken from the ONS UK economic accounts 2024
$LEND_{NFCM}$	Model determined net-lending position of the NFC sector (£ billion)	Model-constrained	49.81	Calculated from Eq. (185)
$LEND_{NMFI}$	Net-lending position of the NMFI sector (£ billion)	Free	66.38	Taken from the ONS UK economic accounts 2024
$LEND_{NMFIM}$	Model determined net-lending position of the NMFI sector (£ billion)	Model-constrained	-15.42	Calculated from Eq. (245)
$LEND_{PS}$	Net-lending position of the power sector (£ billion)	Model-constrained	-7.365	Calculated from Eq. (112)

Continued on next page

Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
$LEND_{RoW}$	Net-lending position of the RoW sector (£ billion)	Free	-16.09	Taken from the ONS UK economic accounts 2024
$LEND_{RoWM}$	Disposable income of the rest of the world (£ billion)	Model-constrained	10.96	Calculated from Eq. (399)
LEV_{NFC}	Leverage ratio of the NFC sector	Model-constrained	0.651	Calculated from Eq. (215)
LEV_{PS}	Leverage ratio of the power sector	Model-constrained	0.3467	Calculated from Eq. (146)
LF	Labour force (millions)	Free	34.08	Taken from the ONS labour market survey 2023
$MAAS_{ADJ}$	Maastricht debt adjustment to interest bearing liability stock of the government sector	Free	-94.69	Calculated from past data
MC_{ELEC}	Marginal cost of overall electricity generation (£ bn/ TwH)	Model-constrained	0.4365	Calculated from Eq. (91)
MC_{FF}	Marginal cost of fossil fuel electricity generation (£ bn/ TwH)	Model-constrained	0.5868	Calculated from Eq. (90)
NW_{GVT}	GVT net worth (£ billion)	Model-constrained	-967.2	Calculated from Eq. (331)
NW_{HH}	HH net worth (£ billion)	Model-constrained	13110	Calculated from Eq. (390)
NW_{NFC}	NFC net worth (£ billion)	Model-constrained	-489.9	Calculated from Eq. (214)
NW_{PS}	Net worth of the power sector (£ billion)	Model-constrained	48.12	Calculated from Eq. (145)
$OCONS_{GVT}$	Other consumption of the Government sector (£ billion)	Free	57.57	Taken from the ONS UK economic accounts 2024 by deducting government wages and gross operating surplus from total government consumption
OT_{EQAHH}	Revaluations of equity assets of the NFC sector (£ billion)	Model-constrained	57.13	Calculated from Eq. (200)
OT_{EQANFC}	Revaluations of equity assets of the NFC sector (£ billion)	Model-constrained	-42.8	Calculated from Eq. (194)
$OT_{EQANMFI}$	Revaluations of equity assets of the NMFI sector (£ billion)	Model-constrained	180.3	Calculated from Eq. (255)
OT_{EQAPS}	Revaluations of equity assets of the power sector (£ billion)	Model-constrained	-1.208	Calculated from Eq. (119)
OT_{EQLNFC}	Revaluations of equity liabilities of the NFC sector (£ billion)	Model-constrained	175.3	Calculated from Eq. (195)
$OT_{EQLNMFI}$	Revaluations of equity liabilities of the NMFI sector (£ billion)	Model-constrained	127.1	Calculated from Eq. (256)
OT_{EQLPS}	Revaluations of equity liabilities of the power sector (£ billion)	Model-constrained	4.948	Calculated from Eq. (120)
OT_{EQNRoW}	Revaluations of equity assets of the RoW sector (£ billion)	Model-constrained	114	Calculated from Eq. (408)
OT_{IBAGVT}	Revaluations of interest bearing assets of the GVT sector (£ billion)	Model-constrained	-3.454	Calculated from Eq. (312)
OT_{IBAHH}	Revaluations of interest bearing assets of the HH sector (£ billion)	Model-constrained	-1.288	Calculated from Eq. (371)
OT_{IBANFC}	Revaluations of interest bearing assets of the NFC sector (£ billion)	Model-constrained	-0.5874	Calculated from Eq. (193)
$OT_{IBANMFI}$	Revaluations of interest bearing assets of the NMFI sector (£ billion)	Model-constrained	-149.3	Calculated from Eq. (253)
OT_{IBAPS}	Revaluations of interest bearing assets of the power sector (£ billion)	Model-constrained	-0.01658	Calculated from Eq. (118)
OT_{IBARoW}	Revaluations of interest bearing assets of the RoW sector (£ billion)	Model-constrained	71.83	Calculated from Eq. (407)
OT_{IBLGVT}	Revaluations of interest bearing liabilities of the GVT sector (£ billion)	Model-constrained	7.012	Calculated from Eq. (313)
OT_{IBLHH}	Revaluations of interest bearing liabilities of the HH sector (£ billion)	Model-constrained	-0.567	Calculated from Eq. (375)
OT_{IBLNFC}	Revaluations of interest bearing liabilities of the NFC sector (£ billion)	Model-constrained	34.72	Calculated from Eq. (196)
$OT_{IBLNMFI}$	Revaluations of interest bearing liabilities of the NMFI sector (£ billion)	Model-constrained	-63.68	Calculated from Eq. (254)
OT_{IBLPS}	Revaluations of interest bearing liabilities of the power sector (£ billion)	Model-constrained	0.9797	Calculated from Eq. (121)

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
OT_{INS}	Revaluations of insurance assets of the HH sector (£ billion)	Model-constrained	244.8	Calculated from Eq. (374)
OT_{PENS}	Revaluations of pension assets of the HH sector (£ billion)	Model-constrained	37.02	Calculated from Eq. (373)
OT_{RESGVT}	Revaluations of residual financial instrument of the HH sector (£ billion)	Model-constrained	-34.38	Calculated from Eq. (379)
OT_{RESHH}	Revaluations of residual financial instrument of the HH sector (£ billion)	Model-constrained	-286.8	Calculated from Eq. (379)
OT_{RESNFC}	Revaluations of residual financial instrument of the NFC sector (£ billion)	Model-constrained	-38.3	Calculated from Eq. (206)
$OT_{RESNMFI}$	Revaluations of residual financial instrument of the NMFI sector (£ billion)	Model-constrained	371.4	Calculated from Eq. (267)
OT_{RESPS}	Revaluations of residual financial instrument of the power sector (£ billion)	Model-constrained	6.687	Calculated from Eq. (131)
OT_{RESRoW}	Revaluations of residual financial instrument of the RoW sector (£ billion)	Model-constrained	-0.8433	Calculated from Eq. (413)
P	GDP price deflator indexed at Q4 2022	Model-constrained	1.039	Calculated from Eq. (33)
P_{ELEC}	Price of electricity (£billion/TwH)	Model-constrained	0.3198	Calculated by dividing implied prices to households and production and taking the average
P_{ELECLR}	Long run electricity price (£bn / TwH)	Model-constrained	0.3198	Set equal to initial electricity price
P_{ETS}	ETS Price £ bn/MtCO2e adjusted for 2024 pricing	Free	0.006664	Based on initial government income from the ETS scheme in 2022
P_{FUEL}	Price of fuel inputs to the power sector	Model-constrained	1	Calculated from Eq. (154)
P_{GAS}	Wholesale gas price in the UK	Free	0.06182	From OBR estimates 2024
P_H	House prices (£ billion per million houses)	Free	290.3	Taken as the average house price from the UK house price index
P_I	Import prices	Free	1.035	Taken from the ONS UK economic accounts 2024 and normalised around the initial condition
P_{NELEC}	Price of non-electricity energy (£billion/TwH)	Free	0.09337	Calculated by dividing total non-electric costs from DUKES table 1.1.6 by non-electric energy use
P_{NELECT}	Non-electric energy price including energy taxes (£ billion)	Model-constrained	0.09374	Calculated from Eq. (68)
P_{OIL}	Wholesale oil price in the UK	Free	0.05405	From OBR estimates 2024
P_P	Production sector price level	Model-constrained	1.035	Calculated
$PENS$	Total pension scheme stock - asset of households and a liability of the NMFI sector (£ billion)	Free	2594	Taken from the ONS UK blue book accounts 2023 - converted to quarterly data using cubic spline interpolation
$PENS_{ADJ}$	Adjustment to pension entitlements as defined within the SNA (£ bn)	Model-constrained	21.44	Calculated from Eq. (244)
$PENSR$	Income payable on pension entitlements	Free	21.39	Taken from the ONS UK economic accounts 2024
$PENSTR$	Total pension scheme stock net transfers - asset of households and a liability of the NMFI sector (£ billion)	Free	21.44	Taken from the ONS UK blue book accounts 2023 - converted to quarterly data using cubic spline interpolation
POP	Total 16+ population (millions)	Free	54.55	Taken from OBR data
r_{BOE}	Bank of England annual base rate	Free	0.0225	From Bank of England data
r_{BOEQ}	Quarterly Bank of England interest rate	Model-constrained	0.005578	Calculated from Eq. (416)
r_{IBAGVT}	rate of return on GVT interest bearing assets	Model-constrained	0.006466	Calculated from Eq. (286)
$r_{IBAGVTLR}$	Long run interest bearing asset interest rates for the GVT sector	Model-constrained	0.007632	Calculated from Eq. (424)
r_{IBAHH}	rate of return on HH interest bearing assets	Model-constrained	0.002509	Calculated from Eq. (333)

Continued on next page

Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
$r_{IBAHHLR}$	Long run interest bearing asset interest rates for the household sector	Model-constrained	0.002509	Calculated from Eq. (426)
r_{IBANFC}	rate of return on NFC interest bearing assets	Model-constrained	0.003204	Calculated from Eq. (171)
$r_{IBANFCLR}$	Long run interest bearing asset interest rates for the NFC sector	Model-constrained	0.003204	Calculated from Eq. (418)
$r_{IBANMFI}$	rate of return on NFC interest bearing assets	Model-constrained	0.004994	Calculated from Eq. (236)
$r_{IBANMFILR}$	Long run interest bearing asset interest rates for the NMFI sector	Model-constrained	0.004289	Calculated from Eq. (422)
r_{IBAPS}	rate of return on PS interest bearing assets	Model-constrained	0.003204	Calculated from Eq. (96)
$r_{IBAPSLR}$	Long run interest bearing asset interest rates for the Power sector	Model-constrained	0.003204	Calculated from Eq. (420)
r_{IBLGVT}	rate of return on GVT interest bearing liabilities	Model-constrained	0.01345	Calculated from Eq. (287)
r_{IBLHH}	rate of return on HH interest bearing liabilities	Model-constrained	0.007475	Calculated from Eq. (334)
r_{IBLNFC}	rate of return on NFC interest bearing liabilities	Model-constrained	0.006253	Calculated from Eq. (172)
$r_{IBLNMFI}$	rate of return on NMFI interest bearing liabilities	Model-constrained	0.005697	Calculated from Eq. (237)
r_{IBLPS}	rate of return on PS interest bearing liabilities	Model-constrained	0.006253	Calculated from Eq. (97)
r_{IBNRoW}	rate of return on RoW interest bearing assets	Model-constrained	-0.01033	Calculated from Eq. ($INTR_{RoW}$)
$r_{IBNRoWLR}$	Long run net interest bearing asset interest rates for the RoW sector	Model-constrained	0.01436	Calculated from Eq. ($r_{IBARoWLR}$)
re	Rate of employment	Free	0.9627	Taken from the ONS labour market survey 2023
RES_{GVT}	Residual finalcial instrument of the GVT sector (£ billion)	Model-constrained	197.9	Calculated from Eq. (324)
RES_{HH}	Residual financial instrument of the H sector (£ billion)	Model-constrained	-319.2	Calculated from Eq. (380)
RES_{MFI}	Residual financial instrument of the MFI sector (£ billion)	Model-constrained	-69.54	Calculated from Eq. (231)
RES_{NFC}	Residual finalcial instrument of the NFC sector (£ billion)	Model-constrained	-265.3	Calculated from Eq. (207)
RES_{NMFI}	Residual financial instrument of the NMFI sector (£ billion)	Model-constrained	262.7	Calculated from Eq. (268)
RES_{PS}	Residual finalcial instrument of the power sector (£ billion)	Model-constrained	-7.486	Calculated from Eq. (132)
RES_{RoW}	Residual financial instrument of the NFC sector (£ billion)	Model-constrained	200.9	Calculated from Eq. (207)
$RESTR_{GVT}$	Residual financial instrument transfer of the GVT sector (£ billion)	Model-constrained	33.6	Calculated from Eq. (307)
$RESTR_{HH}$	Residual financial instrument transfer of the HH sector (£ billion)	Model-constrained	-0.5674	Calculated from Eq. (361)
$RESTR_{MFI}$	residual financial instrument transfers of the MFI sector (£ billion)	Model-constrained	-6.416	Calculated from Eq. (227)
$RESTR_{NFC}$	Residual financial instrument transfer of the NFC sector (£ billion)	Model-constrained	-28.23	Calculated from Eq. (191)
$RESTR_{NMFI}$	Residual financial instrument transfer of the NMFI sector (£ billion)	Model-constrained	-2.405	Calculated from Eq. (251)
$RESTR_{PS}$	Residual financial instrument transfer of the PS sector (£ billion)	Model-constrained	-8.565	Calculated from Eq. (116)
$RESTR_{RoW}$	Residual financial instrument transfer of the RoW sector (£ billion)	Model-constrained	12.58	Calculated from Eq. ($IBATR_{RoW}$)
RP_{NFC}	Retained profits of the NFC sector (£ billion)	Model-constrained	97.05	Calculated from Eq. (101)
RP_{PS}	Retained profits of the power sector (£ billion)	Model-constrained	-5.212	Calculated from Eq. (101)
ru	Rate of unemployment	Model-constrained	0.03726	Calculated from Eq. (45)
SAV_{HH}	Household savings (£ billion)	Model-constrained	-27.69	Calculated from Eq. (345)

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Symbol	Description	Variable category	Initial value	Source/remarks
$SOCB$	Total social benefits received by the Household sector (£ billion)	Model-constrained	103.5	Calculated from Eq. (338)
$SOCB_{GVT}$	Social benefits paid by the Government sector (£ billion)	Free	82.8	Taken from the ONS UK economic accounts 2024
$SOCB_{NMFI}$	Social benefits paid by the NMFI sector (£ billion)	Free	20.68	Taken from the ONS UK economic accounts 2024
$SOCC$	Total social contributions paid by the Household sector (£ billion)	Model-constrained	97.5	Calculated from Eq. (337)
$SOCC_{GVT}$	Social contributions received by the Government sector (£ billion)	Free	55.38	Taken from the ONS UK economic accounts 2024
$SOCC_{NMFI}$	Social contributions received by the NMFI sector (£ billion)	Free	42.13	Taken from the ONS UK economic accounts 2024
$SOCCR_{GVT}$	Social contribution rate on government social contributions	Model-constrained	0.152	Calculated from Eq. (288)
u	Rate of capital capacity utilisation	Free	0.815	Based on data from the directorate General for Economic and Financial Affairs - 2021 and 2022 extrapolated
UC	Unit costs of the production module	Model-constrained	0.9052	Calculated from Eq. (54)
W	Total wages including mixed income (£ billion)	Free	364.3	Taken from the ONS UK economic accounts 2024
W_{PRI}	Total private wages (£ billion)	Model-constrained	302.8	Calculated from Eq. (63)
W_{PUB}	Total public wages (£ billion)	Free	61.49	Taken from the ONS UK blue book accounts 2023 - converted to quarterly data using cubic spline interpolation
W_S	Wage share of GDP	Model-constrained	0.6419	Calculated from Eq. (57)
WR	Overall wage rate (£ thousands)	Model-constrained	11.1	Calculated from Eq. (58)
WR_{PRI}	Private sector wage rate (£ thousands)	Model-constrained	11.21	Calculated from Eq. (61)
WR_{PUB}	Public sector wage rate (£ thousands)	Model-constrained	10.6	Calculated from Eq. (62)
YD_{GVT}	Government disposable income (£ billion)	Model-constrained	107.2	Calculated from Eq. (269)
YD_{HH}	Household disposable income (£ billion)	Model-constrained	312.7	Calculated from Eq. (336)
YD_{NFC}	NFC disposable income (£ billion)	Model-constrained	117.1	Calculated from Eq. (173)
YD_{NMFI}	NMFI disposable income (£ billion)	Model-constrained	9.106	Calculated from Eq. (235)
YD_{PS}	Disposable income of the power sector (£ billion)	Model-constrained	-4.646	Calculated from Eq. (98)
YP_{HH}	Household income from production (£ billion)	Model-constrained	386.7	Calculated from Eq. (332)
YP_{NFC}	NFC income from production (£ billion)	Model-constrained	136.3	Calculated from Eq. (170)
YP_{RoW}	RoW income from production (£ billion)	Model-constrained	-8.561	Calculated from Eq. (391)
α_{FUELPS}	Technical coefficient for the power sector intermediate consumption of fuel products	Model-constrained	0.1301	Calculated from Eq. (163)
α_{IMP}	Technical coefficient for the production sector intermediate consumption of imports	Model-constrained	0.2015	Calculated from Eq. (163)
α_{OPPS}	Technical coefficient for the power sector intermediate consumption of other production products	Model-constrained	0.07051	Calculated from Eq. (164)
α_{PP}	Technical coefficient for internal intermediate consumption of the production sector	Model-constrained	0.2852	Calculated from Eq. (159)
α_{PPS}	Technical coefficient for the power sector intermediate consumption of production products	Model-constrained	0.2006	Calculated from Eq. (155)
α_{PSP}	Technical coefficient for the production sector intermediate consumption of the power products	Model-constrained	0.04014	Calculated from Eq. (151)
α_{PSPS}	Technical coefficient for internal intermediate consumption of the power sector	Model-constrained	0.4474	Calculated from Eq. (161)

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Table 7 – continued from previous page

Symbol	Description	Variable category	Initial value	Source/remarks
β_{GCFHH}	Estimate of initial proportion of home improvement spending on energy efficiency	Free	0.14	Estimate based on ONS data and to generate the baseline scenario
β_{gvt}	Proportion of government green investment	Model-constrained	0.05556	Calculated from Eq. (296)
β_{nfc}	Proportion of NFC green investment	Model-constrained	0.05556	Calculated from Eq. (180)
β_{NFF}	Share of non-fossil fuel electrical energy in total electrical energy production	Model-constrained	0.5976	Calculated from Eq. (84)
δ_{KP}	Depreciation rate of Production sector capital	Free	0.02149	Calculated from the ONS capital stock tables 2023
δ_{KPSFF}	Depreciation rate of power sector fossil capital	Free	0.01227	Calculated from the ONS capital stock tables 2023
δ_{KPSNFF}	Depreciation rate of power sector non-fossil capital	Free	0.01227	Calculated from the ONS capital stock tables 2023
ϵ	Energy intensity of production (TwH)	Model-constrained	0.2347	Calculated from Eq. (2)
λ	Labour productivity rate - GDP per employee	Model-constrained	16.64	Calculated using Eq. (39)
μ	Mark up over unit costs for the domestic production module	Model-constrained	0.16	Calculated from Eq. (53)
ν	Capital productivity rate	Model-constrained	0.2039	Calculated from Eq. (40)
ω_{ELEC}	Emission intensity of fossil fuel electric energy production (MtCO2e/TwH)	Model-constrained	0.5098	Calculated from Eq. (17)
ω_{NELEC}	Emission intensity of non-electric energy production (MtCO2e/TwH)	Model-constrained	0.2944	Calculated from Eq. (16)
θ_P	Share of electric energy for production in total energy for production (TwH)	Model-constrained	0.171	Calculated from Eq. (10)

C Econometric Results

Econometric results estimated through the process outlined in Philips (2018) are presented here. we only present estimates that ultimately were used in the model as in some cases econometric estimates were not meaningful from an economic standpoint and alternative calibration techniques were employed. The basis for all estimates are provided in Table 6 and additional information on estimates is available on request.

D Sensitivity Analysis

D.1 Reducing Carbon Price Pass Through

In the results presented so far, the pass through from increasing carbon prices to general prices is quite strong. Carbon price increases are included within indirect taxation within the production cost equation (Eq. (48)) that is then passed through to higher prices in the price equation (Eq. (49)). As discussed in Section 4, the degree to which carbon prices would pass through to overall prices is debatable. Given the level of uncertainty around this channel, we choose to assess the impacts of reducing the pass through of carbon prices to general prices by 50%. Some results comparing the original "Carbon Price Increase" to the lower pass through "Carbon Price Increase - Low PT" are shown in Figure 11.

The lower pass through dampens the initial spike in inflationary pressure from the policy and lowers inflationary pressures throughout the period, as shown in Figure 11a. This is then reflected in a reduced base rate throughout the period in Figure 11b. Lower inflation and interest rates slightly reduce the negative impact on GDP, shown in Figure 11c. Although the second-order negative impacts of inflation on output are reduced, sectors still face the same higher costs from the carbon price rise, and this is still reflected in a lowering of demand and overall GDP. Emissions, on the other hand, are not strongly impacted, being slightly lower in the original Carbon Price scenario with full pass through, shown in Figure 11d. This is due to the greater green investment in gross terms for

Table 8: Household Consumption Equation Econometric Results

Dependent variable: Δ LogCONSHH
Sample: 1989Q4 - 2022Q4
Observations: 133
Bounds F-statistic: 16.5385 (Cointegration, Lower bound = 3.79, Upper bound = 4.85)
Model type: ECM

Variable	Estimate	Std. Error	t-statistic	p-value
(Intercept)	0.0442	0.03	1.64	0.10
L(LogCONSHH, 1)	-0.1568***	0.02	-7.01	0.00
LogYDHH	0.122***	0.02	5.65	0.00
LogFNWHH	0.0219.	0.01	1.91	0.06
Δ(L(LogCONSHH, 1))	-0.3399***	0.04	-8.19	0.00
Δ(L(LogCONSHH, 2))	-0.0945*	0.04	-2.22	0.03
Δ(L(LogCONSHH, 3))	0.2024***	0.04	5.17	0.00
dummy2009	-0.0103	0.01	-0.70	0.49
dummycovid	-0.3297***	0.01	-22.26	0.00

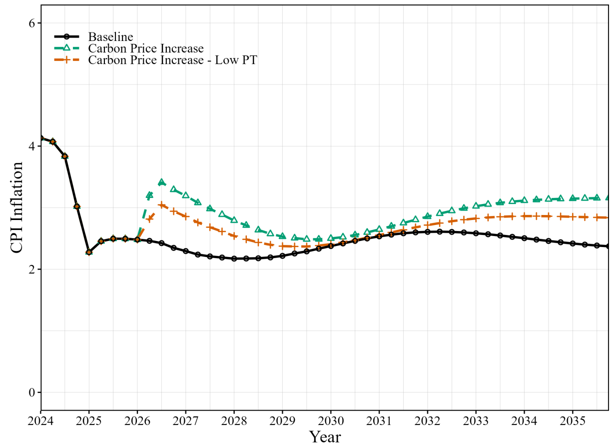
R-squared: 0.8454
Adjusted R-squared: 0.8354
F-statistic: 84.7641 (df=8,124)
p-value: 1.428e-46
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

the low pass through scenario being outweighed by higher energy demand due to increased economic activity when the pass through level is reduced. NFC credit rationing falls in the lower pass-through scenario, as shown in Figure 11e as slightly lower firm income is outweighed by higher demand and lower costs of borrowing such that firms are able to get access to more credit compared to the full pass-through scenario (although there is still a significant increase in rationing compared to the baseline). In terms of the public debt to GDP ratio, shown in Figure 11f, the outcome here is changed compared to the full pass through scenario. The less severe impact on economic activity, while still maintaining the same increase in government income from the carbon price rise, leads to a long term fall in the debt to GDP ratio compared to the baseline.
These results suggest that the degree to which carbon price increases will negatively impact economic activity is driven in part by the degree to which they pass through general prices. However, regardless of the degree of pass through, this policy is always in general contractionary. Understanding to what degree price increases are likely to be passed through to end users will be crucial to understanding the impacts of increasing carbon prices. This also determines whether the policy ultimately improves or worsens the governments overall financial position. This latter point is of significant interest when looking at designing policy mixes, as carbon prices or carbon taxes may be used to fund other green government spending with the aim of creating a fiscally neutral policy package. This, however, will only be possible if the carbon price does improve the governments finances, which for the UK model is found to only be the case when the pass through of the policy to overall prices is reduced.

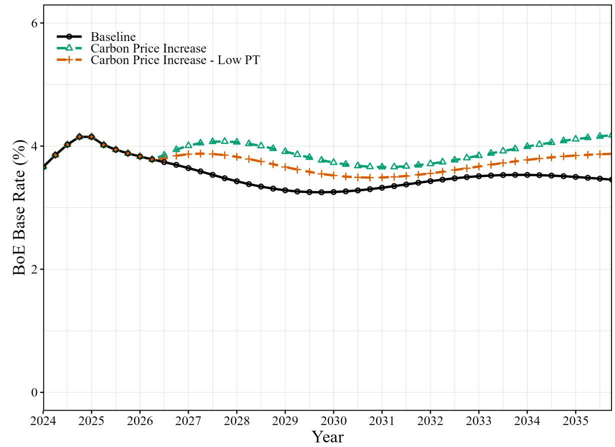
D.2 Housing responsiveness to the housing subsidy

Within the results of the main scenarios, the response of households to the subsidy is relatively neutral. Households are assumed to pay the same gross amount in green home improvements when the subsidy is active, which, as the subsidy reduces the cost of green home improvements, means the total amount of green home improvements taking place increases. For the main scenario, this translates into an increase of 67% in green home improvement investment. However, households' response to a home improvement subsidy is unclear and will depend on factors outside the model, such as changing perceptions and how well the subsidy is publicised. The response to the subsidy

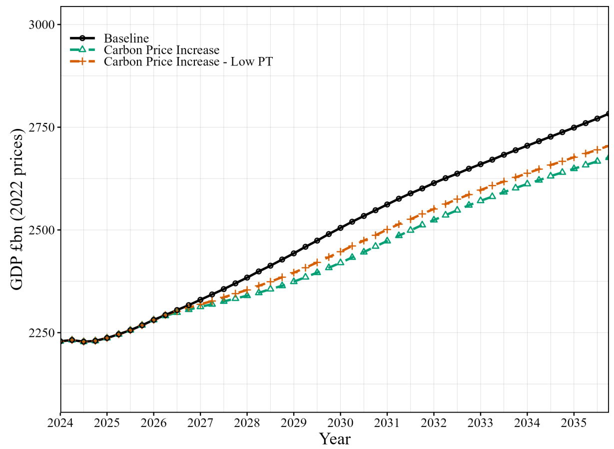
Figure 11: Comparison between normal high pass through and low pass through carbon pricing scenarios



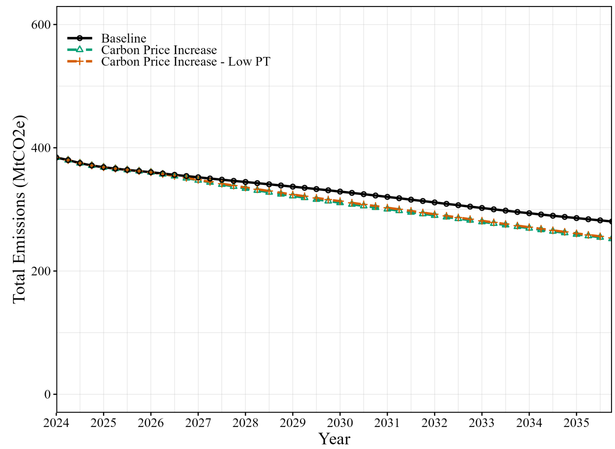
(a) Price Inflation



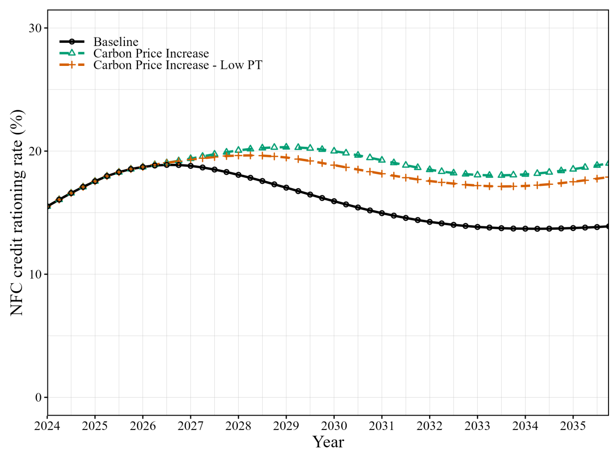
(b) Bank of England Base Rate



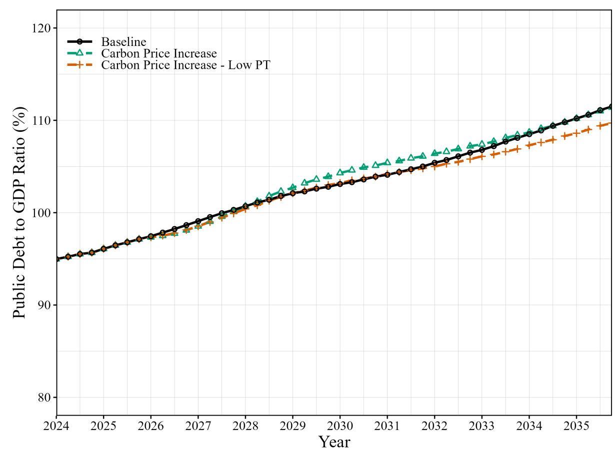
(c) GDP



(d) Total Emissions



(e) NFC Credit Rationing



(f) Gross Public Debt-GDP Ratio

Table 9: Firm Investment Equation Econometric Results

Dependent variable: GCFNFC
Sample: 1995Q4 - 2022Q4
Observations: 109
Model type: ARDL in levels

Variable	Estimate	Std. Error	t-statistic	p-value
(Intercept)	-0.0117	0.01	-1.45	0.15
L(GCFNFC, 1)	0.3181**	0.09	3.36	0.00
Util	0.0435***	0.01	4.23	0.00
dummycovid	0.0061	0.00	1.49	0.14

R-squared: 0.2828
Adjusted R-squared: 0.2623
F-statistic: 13.8029 (df=3,105)
p-value: 1.179e-07
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 10: Household New Build Investment Equation Econometric Results

Dependent variable: Δ LogGCFHH
Sample: 2009Q2 - 2022Q4
Observations: 55
Bounds F-statistic: 52.9042 (Cointegration, Lower bound = 4.94, Upper bound = 5.73)
Model type: ECM

Variable	Estimate	Std. Error	t-statistic	p-value
(Intercept)	-4.3355***	0.42	-10.21	0.00
L(LogGCFHH, 1)	-0.5646***	0.06	-9.31	0.00
LogHVAL	0.6911***	0.07	10.24	0.00
Δ(L(LogGCFHH, 1))	-0.1647**	0.05	-3.19	0.00
dummycovid	-0.5501***	0.03	-15.87	0.00

R-squared: 0.9028
Adjusted R-squared: 0.895
F-statistic: 116.1321 (df=4,50)
p-value: 1.152e-24
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

may be an acceleration in household home improvement investment where many households who previously would not have been in a position to undertake home improvements now, with the help of the subsidy, are able to. However, if the subsidy amount is insufficient or poorly publicised, then take-up may be muted and mainly be used by households who would have already undertaken this investment without the subsidy. The following scenarios present a high-sensitivity scenario (Green Housing Subsidy - HS), where the subsidy leads to a significant increase in home improvement investments of 178% and a low-sensitivity scenario (Green Housing Subsidy - LS) where the increase is only 29%. The results are shown in Figure 12.

Different sensitivities lead to significant differences in the overall investment in green home improvement in Figure 12a. However, green home improvements are still a relatively small part of overall economic activity, and without significant spillover effects of the policy, the impact on GDP is still minor in Figure 12b, with higher sensitivities leading only to a marginal increase in the overall GDP level. There is similarly a marginal increase in the inflationary pressure of the policy, and this is greater for the high-sensitivity scenario, as shown in Figure 12c. Some minor spillovers can be observed in the case of the proportion of green power investment in Figure 12d, where this rises marginally when more home improvements occur due to the increased demand for electricity that incentivises the power sector to invest. Despite modest macroeconomic impacts, the impact on

Table 11: Wage Share Econometric Results

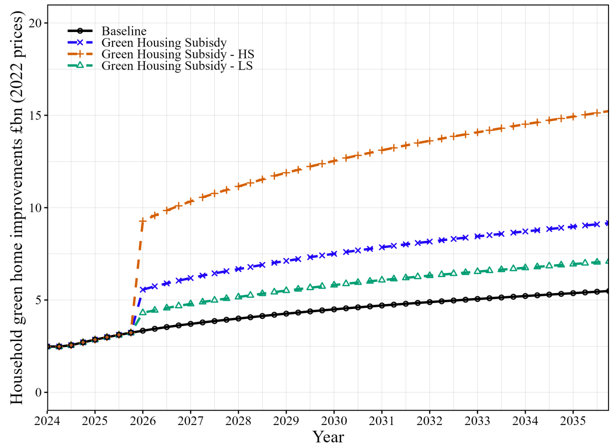
Dependent variable: Δ WAGESHARE				
Sample: 2012Q2 - 2022Q4				
Observations: 43				
Bounds F-statistic: 12.8426 (Cointegration, Lower bound = 4.94, Upper bound = 5.73)				
Model type: ECM				
Variable	**Estimate**	**Std. Error**	**t-statistic**	**p-value**
(Intercept)	0.2109***	0.04	5.03	0.00
L(WAGESHARE, 1)	-0.3237***	0.06	-5.02	0.00
L(Unemprate, 1)	-0.2723**	0.09	-2.92	0.01
Δ(L(WAGESHARE, 1))	-0.2018*	0.08	-2.65	0.01
Δ(Unemprate)	-1.4219*	0.65	-2.17	0.04
Δ(L(Unemprate, 1))	1.8963**	0.66	2.88	0.01
dummycovid	0.0895***	0.01	11.60	0.00
R-squared: 0.8745				
Adjusted R-squared: 0.8536				
F-statistic: 41.8215 (df=6,36)				
p-value: 8.757e-15				
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1				

emissions increases significantly when households are more sensitive to the subsidy, as shown in Figure 12e. This highlights the targetted nature of the housing subsidy and reflects that household emissions make up a considerable portion of total emissions in the UK. The impact on public finances, shown through the DEBT-GDP ratio, is shown in Figure 12f. The greater sensitivity households have to the policy, the more they make use of the subsidy and the greater the subsidy related expenses for the government; with marginal rises in GDP this puts greater pressure on the government finances and increases the debt-GDP ratio.
These sensitivity results highlight some interesting properties of the green housing subsidy. Firstly, the effectiveness of the policy, in terms of emission reduction, is greatly impacted by the degree to which it influences the behaviour of households. Therefore, understanding this will be essential to designing effective household subsidy approaches. As the policy is highly targeted, it has limited wider macroeconomic impacts, which could be seen as a negative if pursuing a more "green growth" policy agenda, however it could also be seen as a positive in that this reduces the risk of environmental rebound effects. The uncertainty in the impact on government finances poses a challenge for this kind of policy, as governments might wish for a more predictable impact on government finances. This uncertainty could be mitigated by capping the total available subsidy funding as has been the case for similar policies implemented in the UK since 2010.

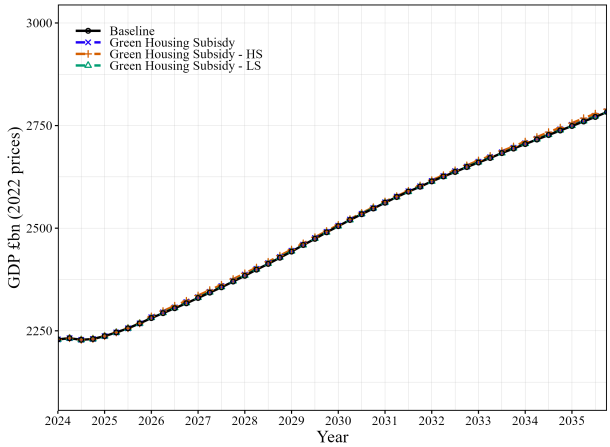
D.3 Electricity Price Floor

In the scenario results, there was a significant behavioural impact when policies led to a fall in electricity prices. Due to marginal-cost pricing of electricity, it is possible for prices to fall significantly, particularly when an energy transition is achieved in the power sector. Lower electricity prices incentivise green investment while simultaneously eroding the income of the power sector and leading to financial instability within this sector. In reality, electricity prices may not fall as significantly as a marginal price system might suggest. This could be due to energy regulation setting a price floor, some level of oligopolistic power in the power sector, or the ability to sell electricity overseas. Any of these situations might lead to a higher long-term electricity price than the projections would suggest. To consider the impacts of adjusting the price system within the model, we will look at the case of setting a price floor for electricity which is related to the average costs of the power sector, such that when the marginal cost-based price falls sufficiently, this price floor kicks in and stops any further price reductions. This system still allows for a non-fossil fuel

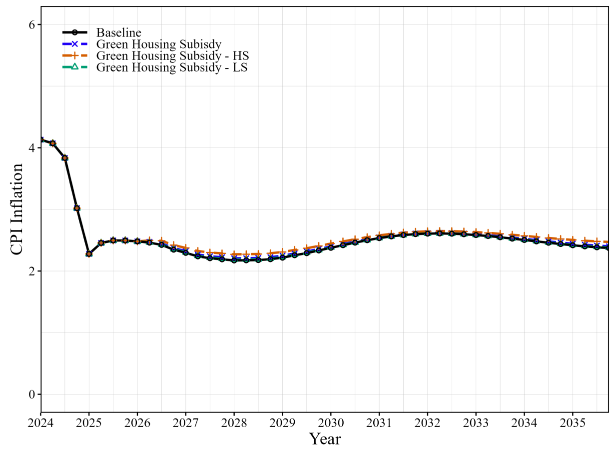
Figure 12: Comparison between normal high pass through and low pass through carbon pricing scenarios



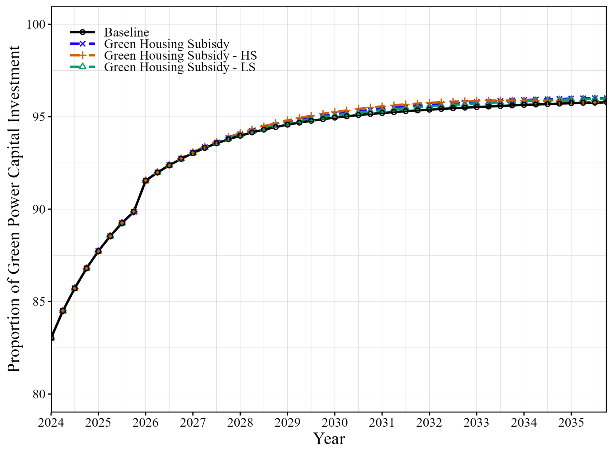
(a) Green Home Improvement Investment



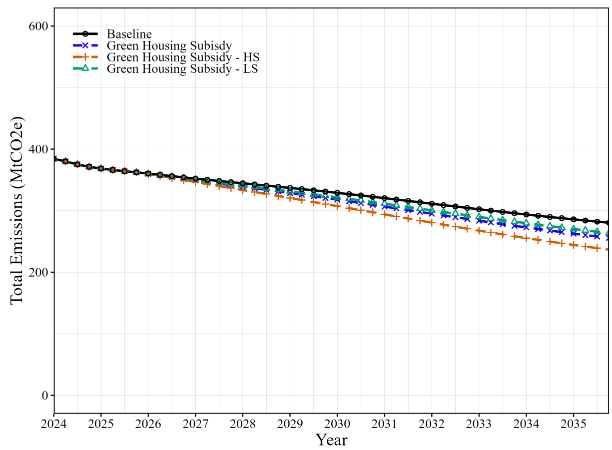
(b) GDP



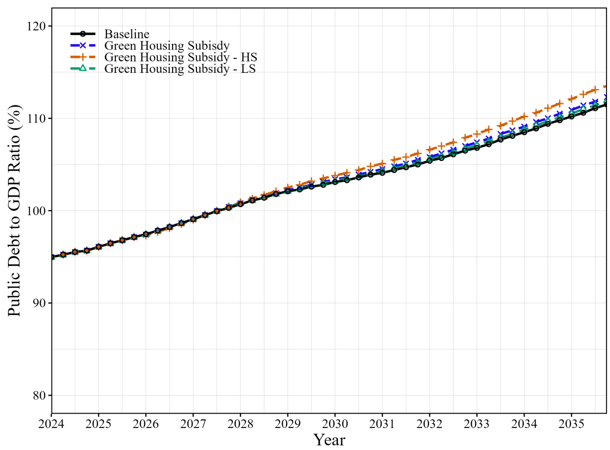
(c) Price Inflation



(d) Proportion of Green Power Investment



(e) Total Emissions



(f) Gross Public Debt-GDP Ratio

Table 12: Firm Loan Default Rate

Dependent variable: Δ DEF$_NFC$
Sample: 1997Q4 - 2022Q4
Observations: 101
Bounds F-statistic: 37.1791 (Cointegration, Lower bound = 4.94, Upper bound = 5.73)
Model type: ECM

Variable	**Estimate**	**Std. Error**	**t-statistic**	**p-value**
(Intercept)	-0.0328.	0.02	-1.76	0.08
L(DEF_NFC, 1)	-0.8337***	0.10	-8.49	0.00
ILLIQ_NFC	0.0322.	0.02	1.91	0.06
dummycovid	-0.0293	0.02	-1.55	0.12

R-squared: 0.4356
Adjusted R-squared: 0.4182
F-statistic: 24.9589 (df=3,97)
p-value: 4.723e-12
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 13: Firm Credit Rationing Rate

Dependent variable: ΔCR_NFC
Sample: 2008Q2 - 2022Q4
Observations: 59
Bounds F-statistic: 2.7202 (No cointegration, Lower bound = 3.79, Upper bound = 4.85)
Model type: ARDL in differences

Variable	**Estimate**	**Std. Error**	**t-statistic**	**p-value**
(Intercept)	-0.0206	0.04	-0.58	0.57
CR_NFC_L1	-0.0684**	0.02	-3.48	0.00
DSR_NFC	-0.0037***	0.00	-5.63	0.00
FLMFIFAMFI	0.0569.	0.03	1.72	0.09

R-squared: 0.3751
Adjusted R-squared: 0.341
F-statistic: 11.0025 (df=3,55)
p-value: 9.181e-06
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

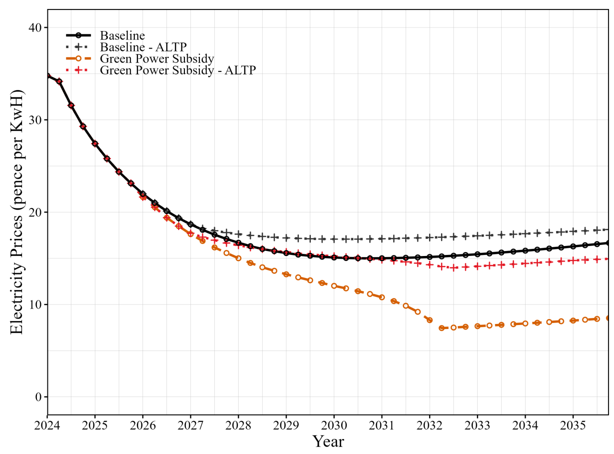
transition to continue to reduce electricity prices, as the average cost of non-fossil fuel electricity generation is still lower than that of fossil fuels, however, it mitigates against the severe fall in power sector income seen within the main results. Changing the price system impacts both the baseline and the scenarios, the most impacted scenario being the power sector subsidy. Therefore, results will be presented for both the baseline and green power subsidy with the alternate price system (ALTP in the figure). The results are shown in Figure 13.
The impact on electricity prices, shown in Figure 13a, is higher long-term electricity prices in both the baseline and the Green power subsidy scenarios. In particular, the reduction in price when compared to the baseline is also much more modest for the green power subsidy due to the impact of a transition to fully non-fossil fuel energy having less of an impact on the electricity price. This leads to elevated overall inflation levels for the alternative pricing scenarios in 13b and no long-term inflation reduction that was seen for the green power subsidy in the main results. The more modest impact on electricity prices leads to a lower behavioural impact on general green non-power investment in Figure 13 c, with the alternative price system leader having much less of a positive spillover effect than in the case where electricity prices are allowed to fall significantly. The total emission reductions, shown in Figure 13d, are significantly lower with the alternate price system, suggesting that a large proportion of the positive spillover effects of the green power subsidy are

Table 14: Government social benefit payment equation

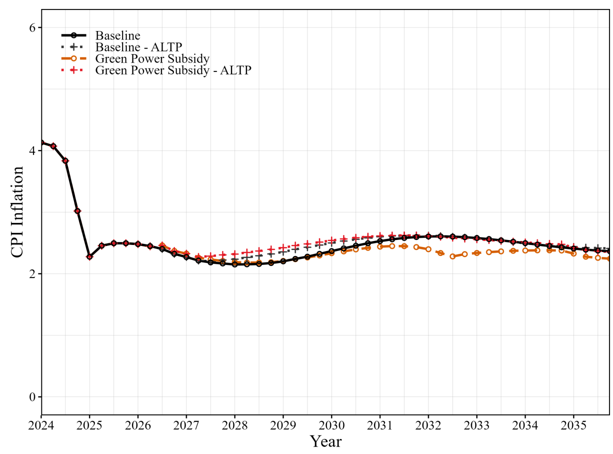
Dependent variable: Δ SOCBGVT/GDP				
Sample: 2007Q1 - 2022Q4				
Observations: 64				
Bounds F-statistic: 15.5971 (Cointegration, Lower bound = 4.94, Upper bound = 5.73)				
Model type: ECM				
Variable	**Estimate**	**Std. Error**	**t-statistic**	**p-value**
(Intercept)	0.0609***	0.01	5.25	0.00
L(SOCBGVT_GDP, 1)	-0.4739***	0.09	-5.55	0.00
UnempRate	0.1402**	0.05	2.92	0.00
dummycovid	0.0344***	0.01	6.21	0.00
R-squared: 0.5533				
Adjusted R-squared: 0.531				
F-statistic: 24.7737 (df=3,60)				
p-value: 1.491e-10				
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1				

related to the impact this policy has on electricity prices. The negative financial impact on the power sector is now reduced, as shown in figure 13 e, and credit is more available in both the baseline and policy scenarios. There is still a sharp increase in credit rationing for the green power subsidy scenario once the subsidy stops being provided due to a non-fossil fuel electricity transition being achieved. This suggests even with the price floor the long term financial stability of the power sector is threatened and further government-based or other interventions could be required. Finally, the public-Debt-GDP ratio, shown in 13f, is increased within the alternative pricing system, mainly due to the reduced positive spillover effects on economic activity from lower electricity prices.
These results highlight an interesting trade-off around the reduction in electricity prices and power sector investment. On the one hand, lower electricity prices are expansionary and have a behavioural impact on green investments throughout the model. However, lower electricity prices could be unsustainable for the power sector itself. Intervening by setting a price floor reduces some of the positive environmental impacts of the green power subsidy, while supporting the power sector financially. It is likely that some intervention would be required if the marginal price system leads to the severity of a cannibalisation effect seen within the main results. This could be in the form of a price cap as seen here, there could also be an effort to allow electricity to be exported, although the effectiveness of this relies on European counties not carrying out their own non-fossil fuel power transition. Other options could involve continued financial support to the power sector while allowing electricity prices to fall, which would maintain some of the environmental benefits of the non-fossil power transition but would put even greater pressure on government finances. Further interventions could include a more active role for the government in the power sector through partial or complete nationalisation.

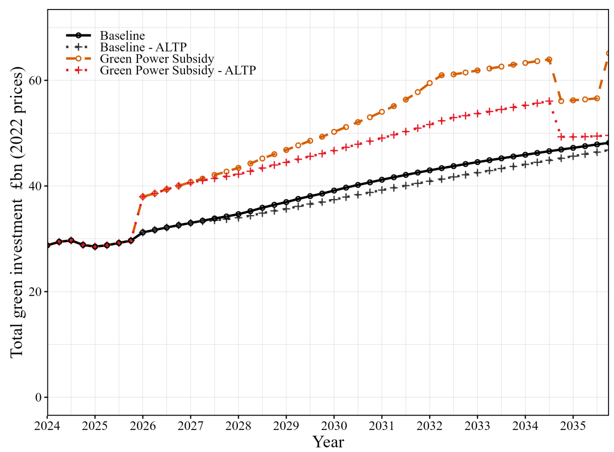
Figure 13: Comparison between normal high pass through and low pass through carbon pricing scenarios



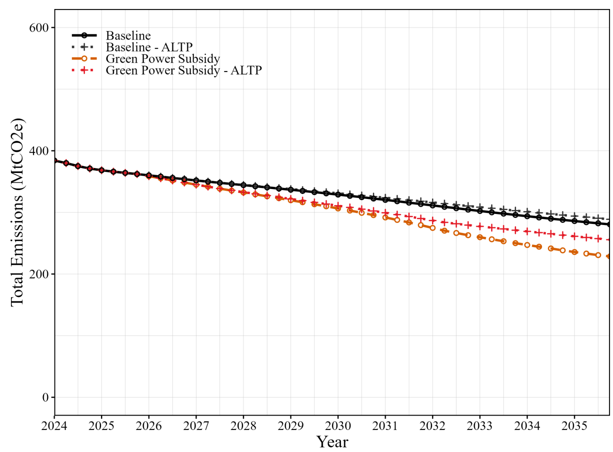
(a) Electricity Price



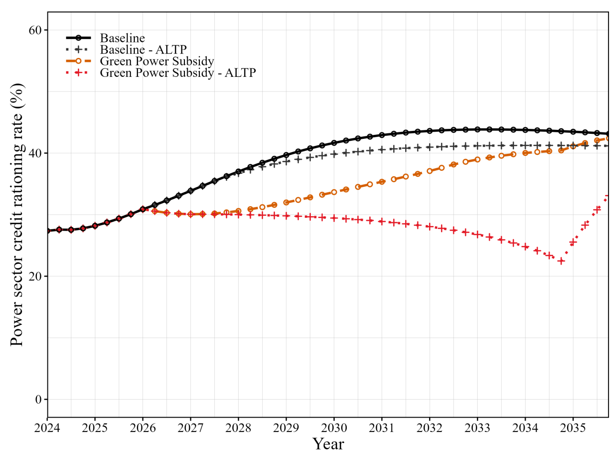
(b) Price Inflation



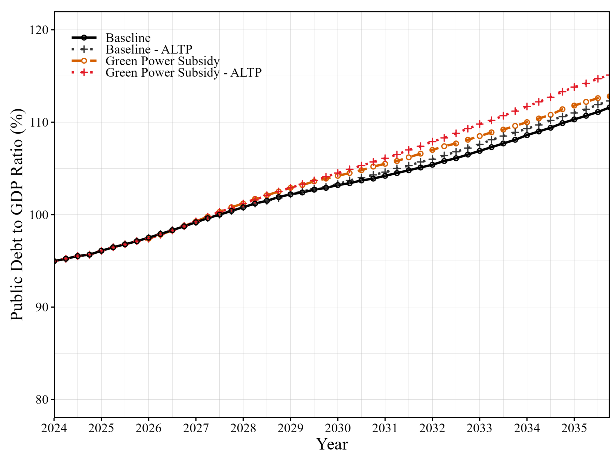
(c) Green Non-Power Capital Investment



(d) Total Emissions



(e) PS Credit Rationing



(f) Gross Public Debt-GDP Ratio

Table 15: House Price Equation

Dependent variable: Δ Log(PriceHouse/POP)
Sample: 2009Q3 - 2022Q4
Observations: 54
Bounds F-statistic: 7.5321 (Cointegration, Lower bound = 4.94, Upper bound = 5.73)
Model type: ECM

Variable	**Estimate**	**Std. Error**	**t-statistic**	**p-value**
(Intercept)	0.1688*	0.08	2.23	0.03
L(Log(PriceHouse/POP), 1)	-0.0706*	0.03	-2.67	0.01
L(LogYDHH_POP, 1)	0.1159**	0.03	3.37	0.00
Δ(L(Log(PriceHouse/POP), 1))	0.8273***	0.11	7.27	0.00
Δ(L(Log(PriceHouse/POP), 2))	-0.5317***	0.11	-4.67	0.00
Δ(Log(YDHH/POP))	0.0427	0.07	0.59	0.56
Δ(L(Log(YDHH/POP), 1))	-0.3396***	0.07	-4.68	0.00
Δ(L(Log(YDHH/POP), 2))	-0.268***	0.06	-4.13	0.00
dummycovid	-0.0239*	0.01	-2.63	0.01

R-squared: 0.7329
Adjusted R-squared: 0.6854
F-statistic: 15.4315 (df=8,45)
p-value: 1.275e-10
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1