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The BIS Multisector Model: A Multi-Country Environment for Macroeconomic Analysis*

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Abstract

This paper introduces the BIS Multisector Model (BIS-MS), a dynamic stochastic general equilibrium (DSGE) model for analyzing macroeconomic dynamics in a multi-sector production network. The model can be calibrated to match the input-output data of more than 80 economies, enabling a detailed exploration of sectoral interdependencies and cross-industry shock transmission. By incorporating nominal rigidities at the sectoral level, the model can also be used to evaluate alternative monetary policy strategies. The paper demonstrates the model's capabilities by analyzing temporary and permanent energy price shocks under different monetary policy frameworks. In doing so, it illustrates the critical role of the country-specific production networks in shaping macroeconomic outcomes. The accompanying model toolbox equips policymakers and researchers with an easy-to-access platform for flexible scenario analysis.

JEL classification: C54 · E52 · H23 · Q43
Keywords: Multi-sector model · monetary policy · production network · DSGE · climate change

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1 Introduction

This paper describes the BIS Multisector Model (BIS-MS), a dynamic stochastic general equilibrium (DSGE) model for analyzing macroeconomic dynamics in a production network. BIS-MS builds on the foundations of medium-scale DSGE models (Christiano et al., 2005; Smets and Wouters, 2007) and extends them in two key dimensions: (i) a detailed multi-sector structure, and (ii) multi-country availability. These two features differentiate BIS-MS from other models typically used for policy analysis and make it well-suited for studying long-run structural changes (eg the green transition), transitory sectoral shocks (eg short-lived energy price increases), and cross-country differences in the transmission of these developments.[1]

BIS-MS incorporates insights from recent advances in the literature on production networks. Studies such as Baqaee and Farhi (2022) and Kalemli-Özcan et al. (2025) highlight how input-output linkages, sectoral heterogeneity and production complementarities affect the propagation of supply and demand shocks. They show, for example, that negative supply shocks in one sector can ripple through the production network, leading to unemployment in downstream sectors, while network complementarities can mute the transmission of demand shocks. These dynamics underscore the critical role of sectoral interdependencies and highlight how complementarities can alter transmission mechanisms, including the effectiveness of aggregate demand stimulus. We embed the model in a New Keynesian framework by introducing nominal rigidities at the sectoral level, thereby creating scope to assess alternative monetary policy strategies, such as headline or core inflation targeting.

To fit the model to the data, we calibrate BIS-MS to replicate country-specific input-output tables. We set the remaining parameters based on existing estimates from the literature or determine them through a reduced-form moment-matching process. The model features 16–20 sectors, depending on the source, and can be used to assess a wide range of scenarios, including temporary shocks, such as short-term energy price surges, and permanent structural changes. It can also accommodate alternative assumptions about expectation formation, enabling analysis of households' and firms' responses to uncertainty and evolving economic conditions.

To demonstrate the model's capabilities, we use it to study temporary and permanent energy price shifts under alternative monetary policy strategies across a selected group of countries. These exercises highlight the critical role of production networks in the transmission

[1] DSGE models currently used in central banks include Adolfson et al. (2013), Burgess et al. (2013), Campbell et al. (2023), Coenen et al. (2018), Del Negro et al. (2024), Faria-e Castro (2024), Hinterlang et al. (2023), Rees et al. (2016), among many others.

of energy price shocks. By comparing responses across alternative monetary strategies for a broad set of countries, we are able to illustrate factors influencing the inflation-output trade-off under different policy rules. Our findings underscore the critical role of monetary policy design in shaping the macroeconomic and sectoral impacts of energy price fluctuations.[2]

More generally, the BIS-MS model can be applied in various contexts. For example, it can be employed to evaluate the impact of higher tariffs on inflation and output, with a particular emphasis on sectoral dynamics (Burgert et al., 2025a). Specifically, we use the model to map sectoral output and price responses to sectoral supply and demand shocks. This allows us to analyze how sectoral dynamics affect aggregate output and inflation trajectories, as well as to explore alternative monetary policy responses to tariffs.

Purpose and Structure

This document is written as a technical guide for researchers and policy analysts interested in the practical aspects of the BIS-MS model's development and application. We document the model structure and equations and document a use-case featuring the impact of temporary and permanent energy shifts. The model is accompanied by a ready-to-use toolbox implemented in MATLAB and Dynare, which facilitates the simulation of various scenarios, the evaluation of alternative monetary policy strategies, and the exploration of cross-country transmission mechanisms. By leveraging pre-processed input-output data for more than 80 economies, the toolbox simplifies the calibration process and ensures consistency across applications.

The rest of the document is structured as follows: Section 2 provides a technical description of the BIS-MS model. Section 3 discusses the calibration methodology and the use of input-output tables. Section 4 applies the model to temporary and permanent shocks, with a focus on energy price increases. Finally, Section 5 concludes. In addition, we also provide a practical guide to the toolbox, including setup instructions and illustrative examples.

2 Model

BIS-MS is a multi-sector New Keynesian model that augments a medium-scale dynamic stochastic general equilibrium model with a detailed sectoral structure.[3] The model, which

[2] The analysis of energy price fluctuations using the BIS-MS model contributes also to a large model comparison exercise on the macroeconomic effects of carbon-intensive energy price changes, conducted as part of the Network for Greening the Financial System (Burgert et al., 2025c).

[3] The core of the model is based on Rees (2020).

includes 16-20 sectors in its baseline configuration, incorporates a complex intermediate goods structure and imperfect substitutability in demand, labor supply and production across these industries. Sectors differ in their production functions, price stickiness, centrality in the production network and role in final demand. Using the accompanying toolbox, the model can be mapped to the input-output data of more than 80 economies, allowing for a multi-country perspective on policy trade-offs.

In addition to firms, the other key actors in the model are households, the government, and the central bank, with the economy assumed to be closed.[4] Nominal rigidities enter at the sectoral level, allowing for a meaningful analysis of alternative monetary policy strategies such as headline or core inflation targeting. The model features aggregate and sectoral shocks, which can be either temporary or permanent (to capture structural shifts). We outline the model's essential features below, with the full set of equations provided in the Appendix A.

2.1 Firms

The production side of the model features a detailed sectoral structure with inter-industry linkages due to intermediate inputs.[5]

There are $\mathcal{F}$ sectors in the economy (examples include the mining sector or the manufacturing sector). Each sector, denoted with j, consists of a continuum of firms. These firms operate under monopolistic competition and face sector-specific nominal rigidities.

Firms produce output in a multi-stage production process. In the first stage, firms combine labour and capital using a constant elasticity-of-substitution (CES) production function:[6]

$$f_{j,t} = \left[\omega_{f,j}^{\frac{1}{\zeta}} n_{j,t}^{\frac{\zeta-1}{\zeta}} + (1-\omega_{f,j})^{\frac{1}{\zeta}} k_{j,t}^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}} \tag{1}$$

where $f_{j,t}$ is the output produced by combining capital, $k_{j,t}$, and labour, $n_{j,t}$. The parameter ζ governs the elasticity of substitution between capital and labour and the sector-specific parameter $\omega_{f,j}$ determines the weights of the two inputs.

Firms combine the labour-capital aggregate with intermediate inputs (ie goods and services sourced from other sectors) to produce gross output, $y_{j,t}$ using a CES production function.

[4] In some cases, however, it is possible to map open-economy scenarios – such as a change in tariff rates – into a closed economy model (see, eg Werning et al., 2025).

[5] We use the terms "sector" and "industry" interchangeably.

[6] For notational ease, we suppress firm-specific subscripts in this section.

Gross output also depends on the industry-specific total factor productivity $a_{j,t}$:

$$y_{j,t} = a_{j,t} \left[\omega_{y,j}^{\frac{1}{\varphi}} f_{j,t}^{\frac{\varphi-1}{\varphi}} + (1-\omega_{y,j}) x_{j,t}^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}} \tag{2}$$

where $x_{j,t}$ is the amount of intermediate inputs used in industry j, the parameter φ is the elasticity of substitution between intermediate inputs and the aggregate of labour and capital and the sector-specific parameter $\omega_{y,j}$ determines the weights of the two inputs.

The existence of intermediate inputs creates production-side linkages between sectors because the intermediate input consists of goods from all industries, combined using a CES production function:[7]

$$x_{j,t} = \left[\sum_{k=1}^{\mathcal{F}} \omega_{k,j}^{\frac{1}{\psi}} x_{k,j,t}^{\frac{\psi-1}{\psi}} \right]^{\frac{\psi}{\psi-1}} \tag{3}$$

The weight of the inputs from industry k that are used in sector j depends on the parameter $\omega_{k,j}$. The inputs are imperfectly substitutable, with the degree of substitutability depending on the parameter ψ. The use of intermediate inputs creates a distinction between the gross output of a sector and value added output. The latter is calculated by subtracting the value of intermediate inputs from gross output.

Sectoral price setting and nominal rigidities Firms within each sector face price stickiness à la Calvo (1983). This results in a sector-specific New Keynesian Phillips curve.

Each period a fraction of firms, $1-\theta_{pj}$ are able to change their prices in each sector. A firm ι that resets its prices at time t faces the following maximization problem:

$$\max_{p^*_{j,t}(\iota)} E_t \sum_{s=0}^{\infty} (\beta\theta_{pj})^s \left\{ \Lambda_{t+s} \left[\frac{p^*_{j,t}(\iota)\gamma_{j,t+s}\Omega_{j,t,t+s}}{p_{j,t+s}} y_{j,t+s}(\iota) - \frac{1}{1+\phi_{pj}} mc_{j,t+s}\gamma_{j,t+s} y_{j,t+s}(\iota) \right] \right\}$$

where $\gamma_{j,t+s} = p_{j,t+s}/P_{C,t+s}$ is the relative price of goods in industry j, subject to the demand condition given above. Note that $\Omega_{j,t,t+s}$ is the cumulative change in prices between t and m, conditional on not re-optimising, eg $\Omega_{j,t,t+s} = \prod_{m=t}^{t+s-1} (\pi_{j,m})^{\varphi_{j,p}}$.

Firms that do not reset their prices follow a sector-specific indexing rule:

$$p_{j,t}(\iota) = (\pi_{j,t-1})^{\varphi_{j,p}} p_{j,t-1}(\iota)$$

[7] For example, a decrease in output in the manufacturing sector will also lower demand for the output of industries that provide intermediate inputs to that industry. Similarly, lower productivity in the manufacturing sector will raise costs for firms in sectors that use manufacturing as an input into production.

The government also provides a production subsidy to offset the steady-state distortion from imperfect competition. Solving the firms' problem and linearizing around the steady state results then in the sector-specific New Keynesian Phillips curves.

2.2 Households

The model features two types of households.

Ricardian households The first household type, termed 'Ricardian' households, can borrow and save in financial markets. These households consume, supply labor, invest and save in order to maximize their discounted lifetime utility. The utility function of a typical Ricardian household is given by:

$$\sum_{t=0}^{\infty} \beta^t \left[e^{\xi_{c,t}} \log(C_t^r - hC_{t-1}^r) - \frac{A_N}{1+\nu}(N_t^r)^{1+\nu} \right] \tag{4}$$

where the term $e^{\xi_{c,t}}$, which is common to all households, is a preference shock that follows an AR(1) process. C_t^r is the total consumption of the household, where the parameter h governs the degree of habit formation. N_t^r is the total labour supply of the household, which are defined below.

Aggregate consumption consists of bundles of products from individual industries. For the Ricardian households, we have:

$$C_t^r = \left[\sum_{j=1}^{\mathcal{F}} \omega_{cj}^{\frac{1}{\eta}} (c_{j,t}^r)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{5}$$

where $c_{j,t}^r$ is the consumption of the output of industry j at time t for Ricardian consumers.[8] The parameter $\omega_{c,j}$ controls the weight of sector j in the consumption bundle. A shift in consumer preferences from, say, eating food at restaurants (a Recreation service) towards purchasing food for consumption at home (a Retail trade service) would appear in the model as a change in $\omega_{c,j}$.[9] The parameter η controls the degree of substitutability between the output of different industries in consumption. If η is large, different sectors' output are close

[8] The functional form of the consumption bundle for rule-of-thumb consumers is identical to that for Ricardian consumers.

[9] Because the weights in the consumption basket must sum to one, a decrease in $\omega_{c,j}$ for one sector must be offset by an increase in the weight for at least one other sector.

substitutes. If η is small, consumers are less willing to substitute between the output of different sectors.

The aggregate labour supply that appears in the household utility function also consists of a weighted sum of labour supply to individual industries:

$$N_t^r = \left[\sum_{j=1}^{\mathcal{F}} \omega_{nj}^{-\frac{1}{\xi}} n_{j,t}^{\frac{\xi+1}{\xi}} \right]^{\frac{\xi}{\xi+1}} \tag{6}$$

where the term ω_{nj} captures the relative disutility that the household receives from supply labour to sector j and ξ controls the substitutability of work in different sectors. If $\xi = \infty$ workers are indifferent between which sectors they work in. For smaller values of ξ workers are less willing to move between sectors.

The maximisation problem is subject to the budget constraint of the Ricardian household:

$$P_{C,t}C_t^r + P_{I,t}I_t^r + \frac{B_{t+1}^r}{R_t} \leq B_t^r + \sum_{j=1}^{\mathcal{F}} \left(P_{C,t} \frac{r_{j,t}^K}{\mathcal{M}_t} k_{j,t}^r + w_{j,t} n_{j,t}^r \right) + T_t^r \tag{7}$$

where I_t^r is the household's total investment in physical capital, which consists of a bundle similar to the consumption good, but with different weights. B_{t+1}^r is a risk free nominal bond that pays one unit of the consumption good in period $t+1$, R_t is the interest rate attached to that bond and T_t^r are lump sum transfers from the government to Ricardian households.[10] $P_{C,t}$ and $P_{I,t}$ are the prices of the investment and consumption goods. The variables $k_{j,t}^r$ and $n_{j,t}^r$ represent total supply of capital and labour from the household to sector j.[11] The variables $r_{j,t}^k$ and $w_{j,t}$ are the return on capital and nominal wages paid by that sector. The variable $\mathcal{M}_t$ introduces a wedge between the return on capital paid by firms and that received by households, which is returned lump sum to the Ricardian households. The wedge is exogenous and follows an AR(1) process. It is included as a reduced form device to capture the effects of financial frictions and shifts in risk aversion on economic activity.

Hand-to-mouth households The second type of households, termed 'hand-to-mouth' households have a similar utility function to the Ricardian households. However, these households are financially constrained, meaning that each period their consumption is exactly equal

[10] These transfers can be either positive or negative.

[11] The economy features a single investment good, which can be used to produce capital in any sector. However, once installed, capital is sector-specific. This limits the speed with which the economy's production structure can respond to shifts in demand or supply in an individual sector.

to their income, which consists of wage income and transfers from the government. As such, these households also do not invest in either capital or government bonds and do not own claims to the capital stock of firms.

2.3 Monetary authority

The model's central bank adjusts the policy interest rate depending on the level of inflation and the output gap.

In this paper, we compare outcomes for three different rules using alternative inflation measures: headline inflation targeting, core inflation targeting and average inflation targeting.

Headline inflation targeting responds to overall inflation in the economy, and is defined as:

$$\frac{R_t}{\bar{R}} = \left[\frac{R_{t-1}}{\bar{R}}\right]^{\rho^R} \left[(\Pi_t)^{\phi^\pi} (GAP_t)^{\phi^{gap}}\right]^{1-\rho^R} e^{\varepsilon^R_{j,t}} \tag{8}$$

where $GAP_t = Y_t/Y_t^{flex}$ is the output gap, defined as the deviation of real GDP from its flexible price level (defined below). The monetary authority has persistence in their rule, governed by the parameter ρ_r.

Core inflation targeting responds to inflation in the service sectors, which is measured as the price level change in the corresponding service consumption good. The rule reads as follows:

$$\frac{R_t}{\bar{R}} = \left[\frac{R_{t-1}}{\bar{R}}\right]^{\rho^R} \left[(\Pi_{S,t})^{\phi^\pi} (GAP_t)^{\phi^{gap}}\right]^{1-\rho^R} e^{\varepsilon^R_{j,t}} \tag{9}$$

where $\Pi_{S,t} = P_{S,t}/P_{S,t-1}$ is the service sector inflation.

The third rule is average inflation targeting, which we implement as follows:

$$\frac{R_t}{\bar{R}} = \left[\frac{R_{t-1}}{\bar{R}}\right]^{\rho^R} \left[(\bar{\Pi}_t)^{\phi_\pi} (GAP_t)^{\phi^{gap}}\right] e^{\varepsilon^R_{j,t}} \tag{10}$$

where:

$$\bar{\Pi}_t = \frac{1}{N_{AIT}} \sum_{i=0}^{N_{AIT}-1} barPi_{t-i} \tag{11}$$

We set N_{AIT} to 8, implying a two year horizon.

While our focus is on these three rules, the model can easily encompass further rules.

2.4 Government

The government in the model fulfils two functions. First, it purchases goods and services directly from firms. As the model abstracts from international trade, this role of government could stand in for all exogenous demand, including for exports. Government spending consists of bundles of products from the different sectors, that is:

$$G_t = \left[\sum_{j=1}^{\mathcal{F}} \omega_{gj}^{\frac{1}{\eta}} (g_{j,t})^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{12}$$

Aggregate government spending evolves according to the following exogenous process:

$$\frac{G_t}{G} = \left[\frac{G_{t-1}}{G} \right]^{\rho_g} \exp(\varepsilon_t^g) \tag{13}$$

Second, it transfers resources between Ricardian and rule-of-thumb consumers.

2.5 Closing the model

Market clearing for the output of sector j requires that the sector's gross output, $y_{j,t}$ equals the sum of demand for the good as a consumption good ($c_{j,t}$), investment good ($i_{j,t}$) and public demand good ($g_{j,t}$), or as an intermediate input:

$$y_{j,t} = c_{j,t} + i_{j,t} + g_{j,t} + \sum_{k=1}^{\mathcal{F}} x_{k,j,t} \tag{14}$$

where $x_{k,j,t}$ is the quantity of the output of sector j used as an intermediate input in sector k.

2.6 Solution method: Shocks and permanent structural changes

The model can be used to simulate (temporary) shocks as well as permanent structural changes. The former includes our specified shocks, while the latter corresponds to changing structural parameters. The shocks and structural changes can be aggregate (eg monetary policy shock, capital discount rate) as well as sectoral (eg sectoral factor productivity shock, sectoral weights).

The solution method requires us to linearize the model around its non-stochastic steady state. The full system of linearized equations is summarized in Appendix A.3. More generally, this system of equations can be written as:

$$\mathbf{A}x_t = \mathbf{C} + \mathbf{B}x_{t-1} + \mathbf{D}\mathbb{E}_t\{x_{t+1}\} + \mathbf{F}\varepsilon_t \tag{15}$$

where x_t is the vector of model variables and ε_t is a vector of exogenous i.i.d. shocks. The matrices $\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$, $\mathbf{D}$ and $\mathbf{F}$ are the equation coefficients consistent with the initial structure of the economy. Note that by including $\mathbf{C}$, we explicitly account for the steady state of the model in the solution matrices. If it exists and is unique, the standard rational expectations solution to Equation (15) is the VAR:

$$x_t = \mathbf{J} + \mathbf{Q}x_{t-1} + \mathbf{G}\varepsilon_t \tag{16}$$

where the reduced form matrices $\mathbf{J}$, $\mathbf{Q}$ and $\mathbf{G}$ are constant, consistent with the stable economic structure.

Temporary shocks To simulate the impact of shocks, we can directly use (16). This approach will be accurate so long as the perturbations are sufficiently small that the structure of the economy remains unchanged. In the case of standard business cycle fluctuations, this assumption may be justified. However, in case of structural changes, we need to adapt the solution method.

Permanent structural changes To incorporate structural changes, we follow the approach of Kulish and Pagan (2017). In particular, the structural parameters can change so that the structure of the economy changes, and the system of equation becomes:

$$\mathbf{A}_t x_t = \mathbf{C}_t + \mathbf{B}_t x_{t-1} + \mathbf{D}_t\mathbb{E}_t\{x_{t+1}\} + \mathbf{F}_t\varepsilon_t \tag{17}$$

where $\mathbf{A}_t$, $\mathbf{B}_t$, $\mathbf{C}_t$, $\mathbf{D}_t$ and $\mathbf{F}_t$ are now time-varying in line with changes in the structural parameters. Importantly, the inclusion of a constant in Equation (17) means that we allow the economy's steady state, as well as the dynamic relationship between variables, to change as a result of the permanent change.

The solution to Equation (17) depends upon agents' beliefs about the economic structure that will prevail in the future. Their belief about the economic structure in the next period is

$$\mathbf{A}_{t+1}x_{t+1} = \mathbf{C}_{t+1} + \mathbf{B}_{t+1}x_t + \mathbf{D}_{t+1}\mathbb{E}_{t+1}\{x_{t+2}\} + \mathbf{F}_{t+1}\varepsilon_{t+1} \tag{18}$$

where $\tilde{\mathbf{A}}$, $\tilde{\mathbf{B}}$, $\tilde{\mathbf{C}}$, $\tilde{\mathbf{D}}$ and $\tilde{\mathbf{F}}$ are the equation coefficients consistent with the believed structure of the economy in the next period.

The solution to the model is again time-varying VAR of the form:

$$x_t = \mathbf{J}_t + \mathbf{Q}_t x_{t-1} + \mathbf{G}_t \varepsilon_t \tag{19}$$

where the time-varying reduced form matrices are now given by:

$$\mathbf{J}_t = (\mathbf{A}_t - \mathbf{B}_t \mathbf{Q}_{t+1})^{-1}(\mathbf{C}_t + \mathbf{D}_t \mathbf{J}_{t+1}) \tag{20}$$

$$\mathbf{Q}_t = (\mathbf{A}_t - \mathbf{B}_t \mathbf{Q}_{t+1})^{-1}\mathbf{B}_t \tag{21}$$

$$\mathbf{G}_t = (\mathbf{A}_t - \mathbf{B}_t \mathbf{Q}_{t+1})^{-1}\mathbf{F}_t \tag{22}$$

We know the values of $\mathbf{Q_T}$ and $\mathbf{J_T}$ from (16), as the structural parameters are then constant. For this reason, one can solve this system of equations recursively to derive the sequence of reduced form matrices from the start of the crisis to its resolution.

Expectations and beliefs The solution approach for permanent structural changes highlights that the dynamics depends on the agents' beliefs about the economic structure that will prevail in the future. Such beliefs can be either correct or misspecified. Misspecified beliefs enable us to deviate from rational expectations, and incorporating different assumptions such as staggered expectations or disbelief about structural changes. For more details on the implementation, see also Kulish and Pagan (2017).

2.7 Toolbox

The described New Keynesian multi-sector model is provided in a toolbox that can be downloaded and is freely available.[12] The toolbox features sectoral and aggregate shifts. The shifts can be either temporary shocks or a permanent change. For the permanent change, the toolbox features the option to deviate from correct beliefs. Finally, the toolbox directly sets the sectoral weights for more than 80 economies, as we will explain in more detail in the calibration section.

[12] The toolbox can be accessed at https://github.com/bis-med-it/BIS_Multisector_Model. It is accompanied by a learning guide (Burgert et al., 2025b).

3 Calibration

This section describes the data used to calibrate the BIS-MS model and the tools provided to ensure its applicability across a wide range of economies. The calibration of the production network relies on country-specific input-output (I-O) tables, supplemented by sector-level employment data. To facilitate accessibility and flexibility, our toolbox provides users with the necessary resources to calibrate the model to their selected economy. The remaining parameters that govern the model's dynamics are either sourced from existing estimates in the literature or determined through a reduced-form moment-matching process.

3.1 Production network

The model's production network is calibrated using input-output (I-O) tables, which provide detailed information on the interconnections between sectors. These tables capture the value of inputs that a sector in a given country sources from other sectors (intermediate use) expressed in US dollar terms. They also include data on final demand (ie consumption, investment, and government spending), value added (comprising returns to capital and labour), and gross output, all at a sector level. This rich dataset enables the model to reflect the economic structures and production processes of each economy. To illustrate, Table 1 displays the input-output structure for the United States. This structure provides insights into the centrality of industries within the US economy and their interconnectedness through production networks. For example, the energy sector plays a pivotal role as both a direct input to other industries and a driver of broader economic activity through its extensive linkages.

The BIS-MS model utilises three sources of I-O data: (i) the OECD Inter-Country Input-Output (ICIO) tables (2023 release), [13] (ii) the Asian Development Bank (ADB) Multi-Regional Input-Output (MRIO) tables (2022 release), and (iii) the US Bureau of Economic Analysis (BEA) "Use of Commodities by Industry" summary (retrieved in 2023). The OECD ICIO tables provide data for 76 economies, while the ADB MRIO tables cover 62 economies; both also include data for the "rest of the world". Together, the two datasets allow us to cover a total of 84 economies. A complete list of the economies covered by both sources is provided in Table B.3 in the Appendix B.1.2. The US BEA I-O table includes data for the United States and serves as the primary source for the breakdown of value added into labour

[13] Yamano, N. et al. (2023), "Development of the OECD Inter Country Input-Output Database 2023," OECD Science, Technology and Industry Working Papers, No. 2023/08, OECD Publishing, Paris, https://doi.org/10.1787/5a5d0665-en.

and capital. This breakdown is used as a common benchmark for all other economies, as such information is not provided in the OECD or ADB I-O tables. For the analysis presented in this paper, we focus on six economies: two large advanced economies (the euro area (EA) and the United States (US)), two commodity exporters (Australia (AU) and Brazil (BR)), an emerging market manufacturing exporter (Thailand (TH)) and an emerging market service exporter (the Philippines (PH)). All I-O data used in the paper and provided in the toolbox correspond to the year 2019.

In addition to I-O tables, employment data by sector is incorporated into the calibration process to determine labour supply. The data is sourced from the US Bureau of Labor Statistics for the United States and is used as a common benchmark for all other economies in the model. To ensure compatibility, the employment data is mapped to align with the industries defined in the re-mapped I-O tables. Details of this mapping are provided in Table B.6 in Appendix B.

In the model, we use the I-O tables and employment data to formally define key parameters in the equations. Specifically, the I-O tables determine the weights of capital $(1-\omega_{f,j})$, labor $(\omega_{f,j})$, and industry-specific intermediate inputs $(\omega_{k,j})$ in the production functions of each sector. They also enable us to identify the shares of consumption (ω_{cj}), investment (ω_{ij}), and government spending (ω_{gj}) in domestic demand. Employment data complements this by determining industry-specific labor supply $(\omega_{n,j})$. For an outline, refer to Table B.1 in Appendix B.

The BIS-MS toolbox includes the codes to run the DSGE model, raw I-O and employment data, and the necessary codes to process the raw data into a format compatible with the model for 84 economies.[14] By streamlining the calibration process, the toolbox significantly reduces the computational burden and enables users to seamlessly apply the BIS-MS model to diverse economies and, if desired, to a wide range of contexts.

3.2 Calibrated parameters

Most of the parameters controlling the dynamics of the model, such as the habits and investment adjustment cost parameters, or the aggregate labour supply elasticity, have been estimated in similar models many times before. We set the values for these parameters close

[14]We select these countries to feature a set of different economies, including large advanced economies (US and EA), an advanced economy that is a commodity exporter (AU), an emerging market economy that is a commodity exporter (BR), emerging market economy that is a manufacturer (TH) and an emerging market economy that is a service exporter (PH).

Table 1: Input-Output Structure for the United States[1]

	Mining (I)	Manufact. (II)	Services (III)	Other (IV)	Total (I)+(II) +(III)+(IV)	C (V)	I (VI)	G (VII)	Final Demand (V)+(VI)+(VII)	Gross Output
Mining (A)	0.1	0.3	0.1	0.1	0.5	0.0	0.0	0.1	0.1	0.6
Manufact. (B)	0.1	1.8	1.3	0.6	3.7	2.0	0.0	0.5	2.6	6.3
Services (C)	0.2	1.3	8.8	0.6	10.8	10.3	3.0	3.3	16.6	27.4
Other (D)	0.0	0.3	0.6	0.1	1.1	0.3	0.0	1.4	1.8	2.8
Total Int. (A)+(B) +(C)+(D)	*0.3*	*3.7*	*10.8*	*1.4*	*16.1*					
Wages (E)	0.1	1.3	9.8	0.8	12.0					
Capital Returns (F)	0.2	1.2	6.7	0.6	8.8					
Value Added (E) + (F)	*0.3*	*2.6*	*16.5*	*1.4*	*20.8*					
Total	**0.6**	**6.3**	**27.4**	**2.8**	**36.9**	**13.2**	**3.0**	**5.4**	**20.8**	**36.9**

[1] Based on 2019 OECD ICIO, in trillions of USD. Other (D) includes Agriculture, fishing, electricity, water supply and construction. Direct purchases abroad by residents are excluded. Rows and columns may not sum due to rounding.

Table 2: Common parameter values

Parameter	Description	Value
h	Degree of habits in consumption	0.7
S''	Investment adjustment cost	3
θ_w	Calvo parameter for wages	0.75
θ_p^s	Calvo parameter for sticky prices	0.8
θ_p^f	Calvo parameter for semi-sticky prices	0.65
θ_p^f	Calvo parameter for flexible prices	0.25
ψ	Substitutability of labour and capital in production	0.95
ψ	Substitutability of different intermediate products in production	0.4
φ	Substitutability of primary factors and intermediates in production	0.25
ν	Aggregate labour supply elasticity	2
δ	Capital discount rate	0.02
η	Substitution elasticity in demand functions	0.9
ξ	Substitution elasticity between industries in labour supply	5
ω_r	Share of Ricardian households	0.99
β	Household discount rate	0.995

to the mid-point of estimates from papers such as Smets and Wouters (2007) and Justiniano et al. (2013) for the US and Coenen et al. (2018) and Albonico et al. (2017) for the EA.

We allow the degree of price rigidity to vary across sectors. For sectors such as Agriculture or Mining, whose goods are largely homogeneous and whose prices can vary enormously from quarter to quarter, we impose a Calvo parameter of 0.25, meaning that their prices are very flexible. For the remaining sectors, we rely on information about sectoral differences in the frequency of price adjustment from Bryan and Meyer (2010) and Eusepi et al. (2011). These papers suggest that manufacturing and retail prices are more flexible than those of other sectors, particularly services industries. Consequently, we set the Calvo parameter governing the frequency of price adjustment in the manufacturing and retail industries equal to 0.65, implying an average frequency of price adjustment of two quarters. For all other industries, we set the Calvo parameter equal to 0.8, which is a standard estimate for the value of this parameter in single industry models.

We base the elasticities of substitution in the demand and production functions on available estimates in the literature. For the elasticity of substitution between the output of different industries in final expenditure, we use the value of 0.9 estimated in Herrendorf et al. (2013). For the elasticity of substitution between final goods and intermediate expenditures, we choose a value of 0.25. Estimates of the elasticity of substitution between intermediates suggest that the value of this parameter could be close to zero (Atalay, 2017). However, preliminary investigation revealed that extremely low values of this parameter could result in model instability. Therefore, we set this parameter equal to 0.4. This means that intermediate inputs are less substitutable than other components of the demand and production functions while ensuring that it remains possible to solve the model numerically. For the parameter governing the elasticity of substitution between industries in labour supply, we use a value of 2. Finally, we set the share of Ricardian households in each economy to 0.99, implying a representative agent setup to focus on the role of the production network.[15]

We set the persistence of our shocks to 0.5, which is intentionally a relatively low value.[16] This choice is justified by the model's ability to endogenously generate significant persistence. Our model is primarily designed for scenario analysis, where the focus is on aligning with a predefined target path. We are interested for instance in matching the path of a sectoral price increase. In such cases, it is not necessary to specify the standard deviations of the shocks. However, for certain types of analysis, defining the standard deviations of the shocks can be beneficial. In these instances, we calibrate the shocks by matching the model's implied moments to observed data, such as the standard deviation of aggregate or sectoral inflation or value added output. This moment-matching approach offers a flexible yet data-driven method

[15] We choose this calibration to highlight that the BIS-MS model can account for hand-to-households, where values could be based on estimates of Debortoli and Gali (2017) for the US and Albonico et al. (2017) for the EA.

[16] In future work, we plan to explore approaches to estimate the parameters of the model's shock processes.

for calibrating shocks effectively. Refer to Table B.2 in the Appendix B for details on the data and their sources used in the moment-matching exercise.

4 An application to energy price shocks

This section explores the macroeconomic effects of temporary and permanent increases in carbon-intensive energy prices in BIS-MS. The simulations provide a quantitative lens to analyze the responses of inflation, real economic activity and monetary policy if the increase in energy prices is temporary and if it is permanent.[17] The temporary shock scenario (Section 4.1) focuses on short-term disruptions, highlighting the immediate inflationary pressures and output contractions that propagate through the production network, while also taking a cross-country perspective to assess differences in exposure and transmission across economies. In contrast, the permanent shock scenario (Section 4.2) examines the long-term structural effects of sustained energy price increases, revealing persistent declines in real activity and nuanced inflation dynamics depending on monetary policy frameworks.

4.1 Temporary energy price shock

The temporary shock scenario explores the impact of a temporary 25% increase in carbon-intensive energy prices. We implement this scenario as a combination of productivity and markup shocks in the mining and manufacturing sectors.[18] We assume that the initial price increase persists for four quarters before decaying at a rate of 50% per quarter.

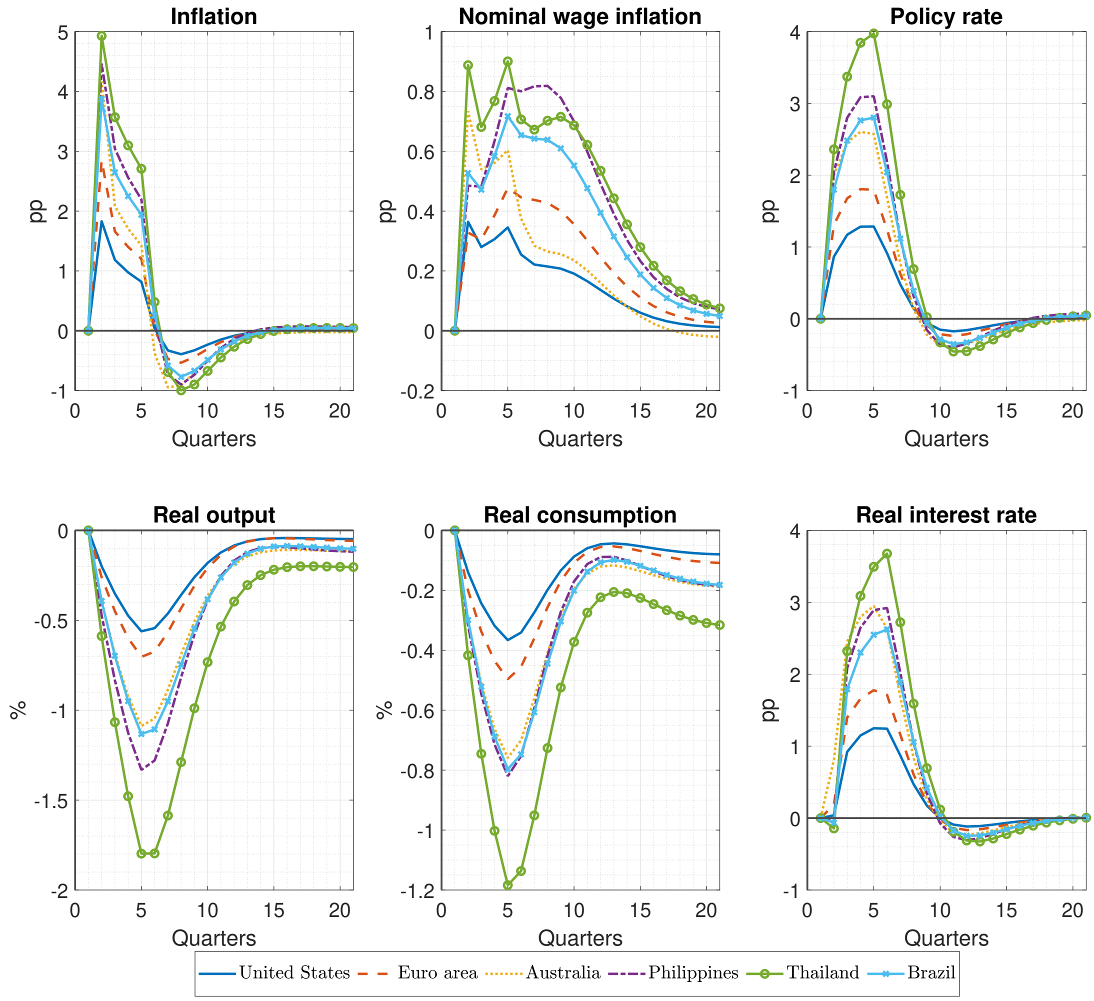
Figure 1 illustrates the macroeconomic dynamics in response to this shock across several key variables: inflation, nominal wage inflation, the policy rate, real output, real consumption and the real interest rate. Across all countries, inflation exhibits a sharp but short-lived spike, driven by the direct pass-through of higher mining and manufacturing costs to consumer prices. Nominal wage inflation increases more gradually and remains elevated for a longer period, reflecting wage catch-up effects in response to higher living costs. Central banks respond to the inflationary pressures by raising policy rates, with adjustments peaking within

[17]New Keynesian DSGE models have played a crucial role in helping central banks assess the effects of the green transition. Examples include studies by Airaudo et al. (2023), Annicchiarico et al. (2023), Del Negro et al. (2023), Nakov and Thomas (2023), Olovsson and Vestin (2023), Sahuc et al. (2024), Kaldorf and Rottner (2025), among many others. We differ from these papers by providing a multi-country view to study the role of monetary policy.

[18]We impose shocks to the manufacturing sector to account for the rapid transmission of energy shocks to the price of gasoline – a manufactured good.

the first few quarters and gradually returning to its initial level as inflation returns to target.

Figure 1: Cross-country comparison for a temporary energy price shock



Output and consumption contract following the shock, as higher production costs reduce profitability and household purchasing power. The real interest rate rises on impact, reflecting the nominal rate increase and the subsequent fall in inflation. These dynamics are consistent across countries, underscoring the BIS-MS model's ability to capture the general transmission mechanisms of energy price shocks.

4.1.1 Cross-country heterogeneity

The size and timing of the macroeconomic responses vary significantly across countries. This reflects differences in input-output structures and the relative size of energy and manufacturing sectors.

Thailand exhibits the strongest responses across all variables, driven by its large manufacturing sector. Inflation rises more sharply in Thailand, prompting a larger policy rate adjustment and a deeper contraction in output and consumption.

The Philippines follows a similar pattern, with strong responses to the shock, also owing to its significant manufacturing sector and limited mining activity. However, its responses are slightly weaker than those of Thailand due to the relatively smaller weight of manufacturing in its economy. In Australia, by contrast, a large mining sector amplifies the transmission of the energy price shock. This results in notable inflationary pressures and economic contractions, though these responses are smaller than for Thailand and the Philippines due to Australia's smaller manufacturing base.

Energy price shocks have a much smaller impact on the euro area and United States. This reflects their smaller manufacturing sectors (relative to Thailand and the Philippines) and, for the euro area, smaller mining sector.

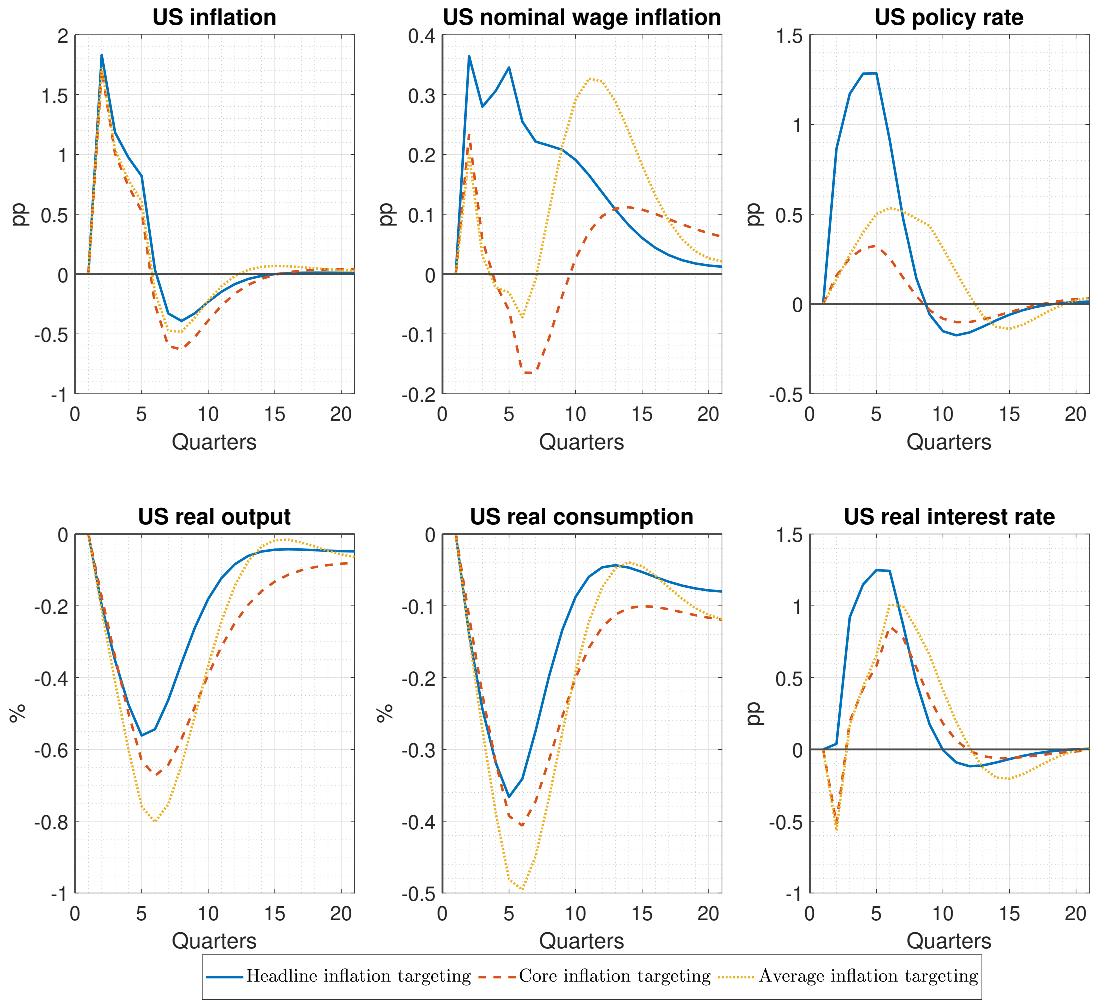
These results highlight the critical role of cross-country heterogeneity in shaping the macroeconomic impact of energy price shocks. Countries with large manufacturing sectors, such as Thailand and the Philippines, or mining sectors, such as Australia, experience stronger inflationary pressures, larger monetary policy adjustments, and deeper contractions in real activity. In comparison, economies like the euro area and the United States, with more diversified production structures and less reliance on mining, exhibit smaller responses. These findings underscore the importance of sectoral composition in determining the economic consequences of such shocks.

Monetary policy tradeoff are more pronounced in countries with larger mining or manufacturing sectors. The strong inflationary pressures in these economies necessitate more aggressive interest rate adjustments, which in turn exacerbate the contraction in real activity. This tradeoff between stabilizing inflation and mitigating output losses is particularly acute for economies like Thailand and the Philippines, where sectoral exposure amplifies the shock's transmission.

4.1.2 Monetary policy regimes

The temporary shock scenario also provides insights into the role of different monetary policy rules in affecting macroeconomic outcomes. This subsection focuses on the United States and compares the outcomes under three distinct monetary policy frameworks: (i) headline inflation targeting, (ii) core inflation targeting, and (iii) average inflation targeting (AIT) over an eight-quarter horizon.[19] Note that previous simulations in this section were based on headline inflation targeting. Figure 2 illustrates the transmission of a temporary energy price shock under these alternative rules.

Figure 2: Transmission of a temporary energy price shock under alternative monetary policy rules



All three rules yield broadly similar inflation paths in response to the temporary energy price shock. However, the mechanisms through which inflation is managed and the associated real economic outcomes differ significantly across the rules. Under headline inflation targeting, an aggressive monetary policy response is required on impact to control inflation. This strong initial tightening allows monetary policy to return close to its steady state after eight quarters and is associated with a less severe and less persistent decline in real output compared to AIT.

[19] Appendix C presents results for the other economies.

In contrast, AIT achieves the same inflation path by engineering a smaller but more persistent rise in the policy rate. While AIT smooths the interest rate adjustment over time, this comes at the cost of a much stronger and more prolonged decline in real output. This occurs because, under AIT, the central bank commits to maintaining higher interest rates for an extended period to offset temporary inflation overshooting with future undershooting. By ensuring that inflation overshooting is counterbalanced to maintain average inflation at the target, the AIT framework enforces a tighter overall monetary stance, which dampens private consumption and output. The persistent tightening under AIT underscores the trade-off between inflation stabilization and real economic activity.

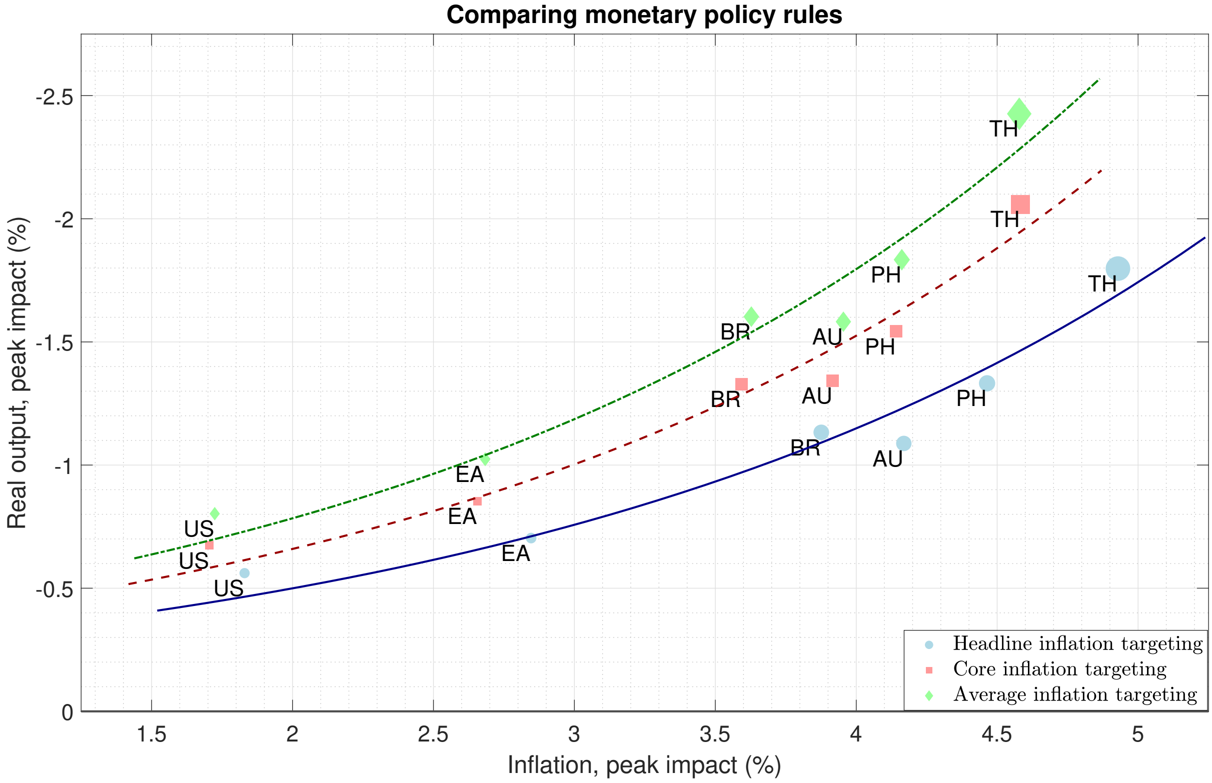
Core inflation targeting lies somewhat in the middle. While the policy rate under core inflation targeting rises by less than under headline inflation targeting over the first two years, the monetary policy stance is more restrictive over the subsequent two years. This is also reflected in a persistently higher real interest rate under core inflation targeting in year 3 and year 4. As a consequence, output and consumption fall by more under core inflation targeting than under headline inflation targeting.

The choice of the monetary policy rule ultimately boils down to the trade-offs policymakers are willing to accept. Headline inflation targeting is effective at containing inflation in the short term and is associated with smaller and less persistent output losses. AIT, on the other hand, prioritizes smoother interest rate adjustments but at the cost of much larger declines in real output. Core inflation targeting balances these trade-offs, offering a compromise between inflation control and output stabilization.

4.1.3 Summary

Figure 3 illustrates the inflation-output trade-off arising from a 25% increase in carbon-intensive energy prices, with results shown for three monetary policy rules: headline inflation targeting (solid line), core inflation targeting (dashed line), and average inflation targeting (dash-dotted line). Each regression line represents the relationship between inflation and output losses under a specific policy rule, with country-specific exposure to manufacturing and mining sectors indicated by the size of the bubbles. Along each line, the trade-off becomes increasingly severe as one moves northeast, reflecting the aggravation of inflation and output losses with rising exposure to energy-intensive sectors. Countries with larger bubbles, such as Thailand and Australia, face the most pronounced trade-offs due to their higher reliance on manufacturing and mining, while economies like the United States, with smaller bubbles, experience more limited effects.

Figure 3: Cross-country comparison for a temporary energy price shock



The chart also highlights differences across monetary policy rules. AIT exhibits the strongest inflation-output trade-off, followed by core inflation targeting, with headline inflation targeting showing the weakest trade-off. This is reflected in the regression slopes, where the line for AIT has the steepest slope, followed by core inflation targeting, and then headline inflation targeting. This pattern is driven by differences in the peak output loss across the rules. AIT results in the largest output contraction, followed by core inflation targeting, while headline inflation targeting minimizes the output loss. Importantly, the peak inflation effects are relatively similar across the individual countries, regardless of the policy rule. This suggests that the choice of monetary policy rule primarily affects the magnitude of output losses, with AIT amplifying the trade-off and headline inflation targeting mitigating it. These findings underscore the critical role of monetary policy design in shaping the macroeconomic consequences of energy price shocks.

4.2 Energy transition (permanent increase in energy price)

The permanent shock scenario examines the macroeconomic impact of a sustained 25% increase in carbon-intensive energy prices, gradually implemented over a 10-year horizon. This approach allows for the analysis of long-term structural adjustments as the economy transitions to a new steady state characterized by permanently higher energy costs and lower potential output.

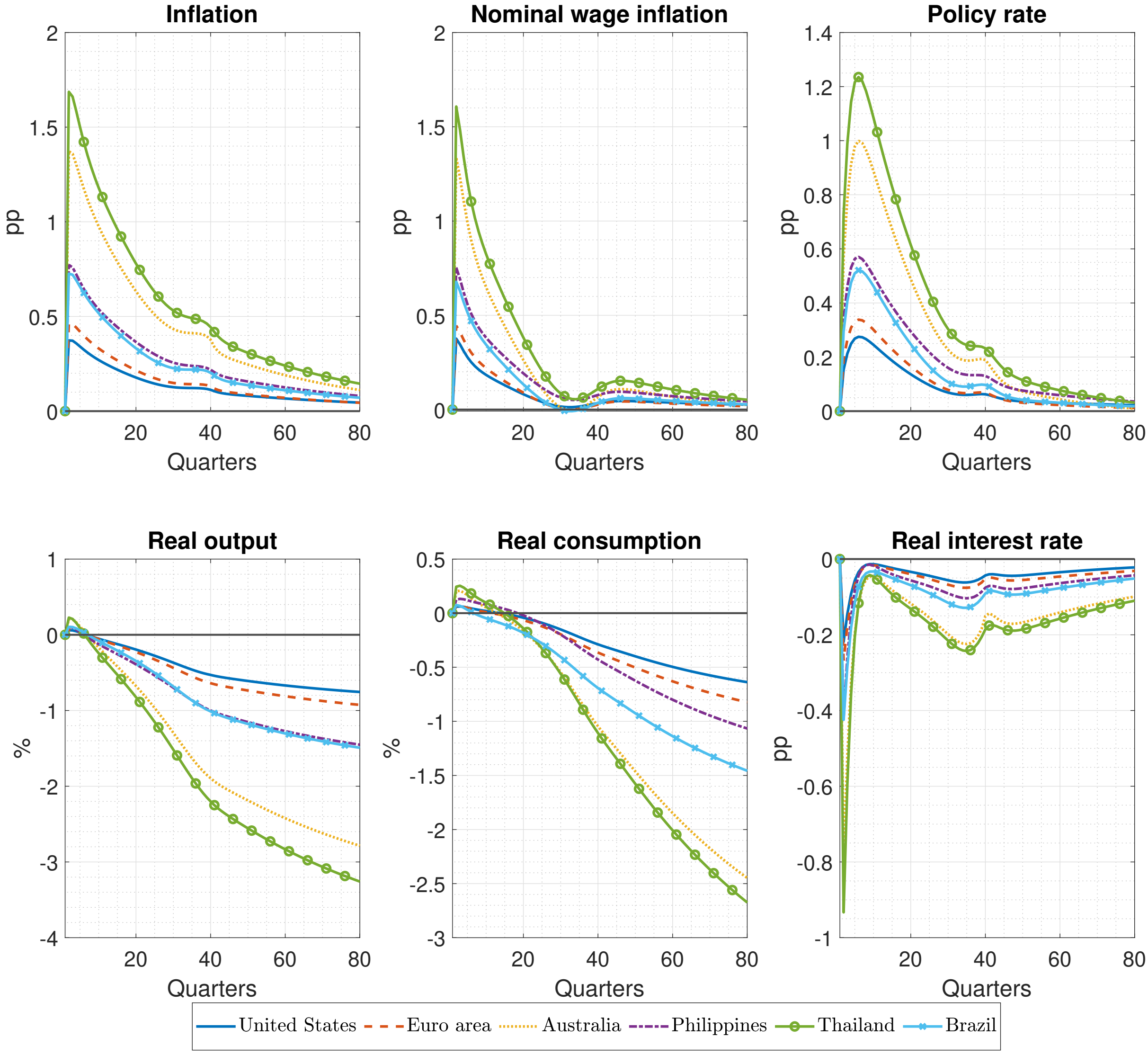
An important challenge for central banks in such a scenario is to determine the level of potential output in real time.[20] To illustrate this, we consider two alternative assumptions about the central bank's assessment of the level of potential output. In the first, the central bank correctly estimates the initial level of potential output and its final level, and assumes that potential output follows a linear trend in the transition between the two steady states. In the second, the central bank can correctly identify the level of potential output at each point in time. As potential output declines more quickly than the linear trend implies, the first assumption causes the central bank to systematically believe that the output gap is more negative than it actually is.

In the first scenario (Figure 4), where the central bank's estimate of potential output is based on a linear trend, the central bank provides persistent monetary accommodation to offset the perceived negative output gap, resulting in inflationary pressures during the transition. Inflation increases on impact and remains elevated throughout the transition. Similarly, the policy rate increases on impact and then remains elevated for a prolonged period, reflecting the central bank's efforts to balance inflation stabilization with output support. Output and consumption decline steadily over the transition, with the cumulative contraction reflecting the economy's adjustment to higher energy costs.

In the second scenario (Figure 5), the central correctly identifies the fall in potential output in real time. This approach results in a more restrained monetary response, as the central bank avoids overstimulating demand relative to the new lower supply potential. Inflation initially declines, driven by the negative demand effects of reduced real income and profitability, before stabilizing near target in the long run. The policy rate decreases in the short term to support the economy but remains relatively stable over the transition. Output and consumption decline more sharply at the onset compared to the first scenario and then stabilize as the economy adjusts to the new steady state.

[20] See eg Orphanides and van Norden (2002)

Figure 4: Permanent shock with trend estimate of potential output

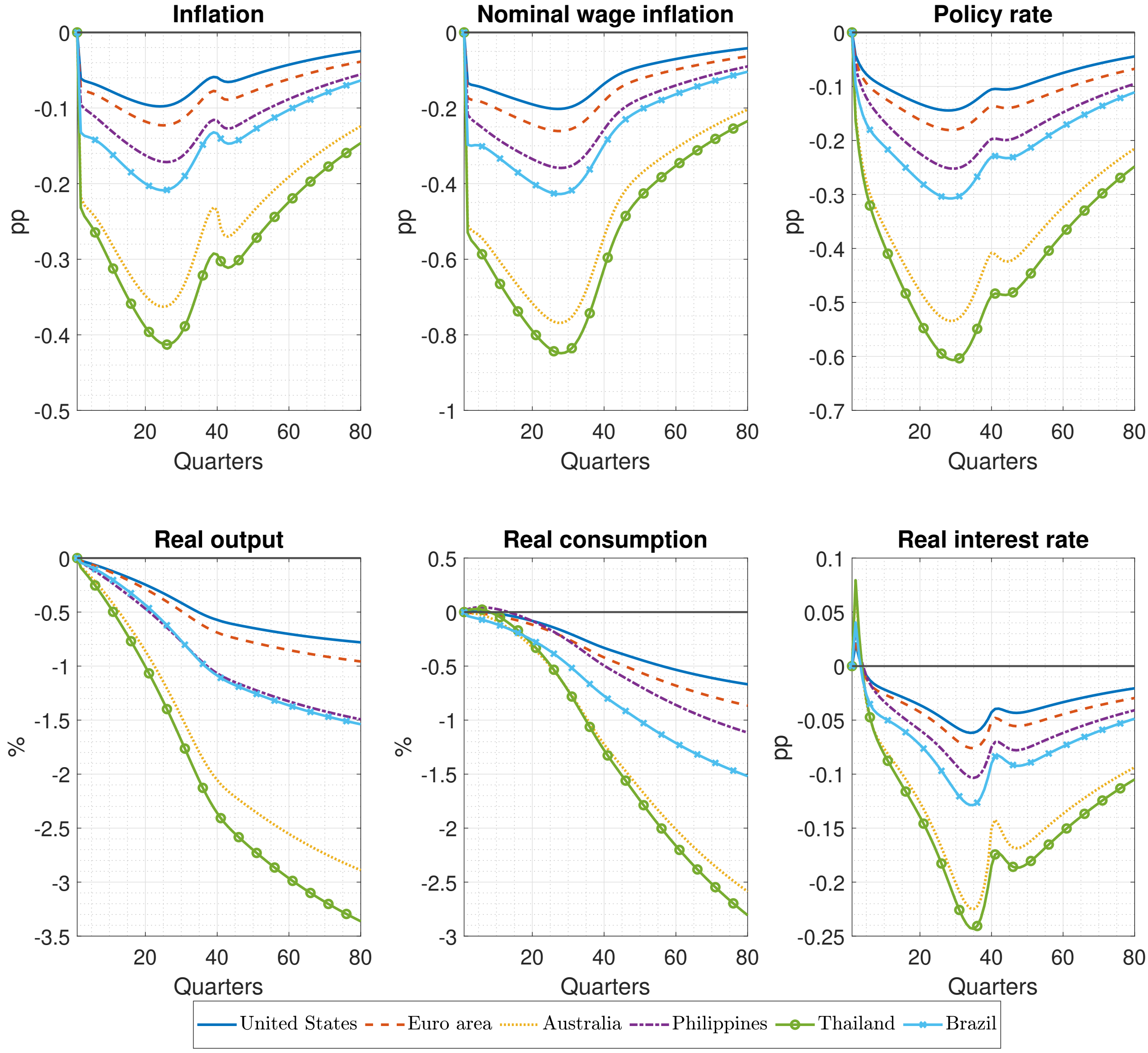


4.2.1 Cross-country heterogeneity

The macroeconomic effects of the permanent shock vary significantly across countries, reflecting differences in the size of their mining and manufacturing sectors and their reliance on carbon-intensive energy inputs. As in the temporary scenario, Thailand experiences the strongest effects, with inflationary (Figure 4) as well as deflationary (Figure 5) pressures and output contractions being the most pronounced. The large weight of its mining and manufacturing sectors amplifies the transmission of the shock, leading to significant policy rate adjustments and deeper declines in real activity.

Australia follows, with its mining-intensive economy experiencing strong inflationary pres-

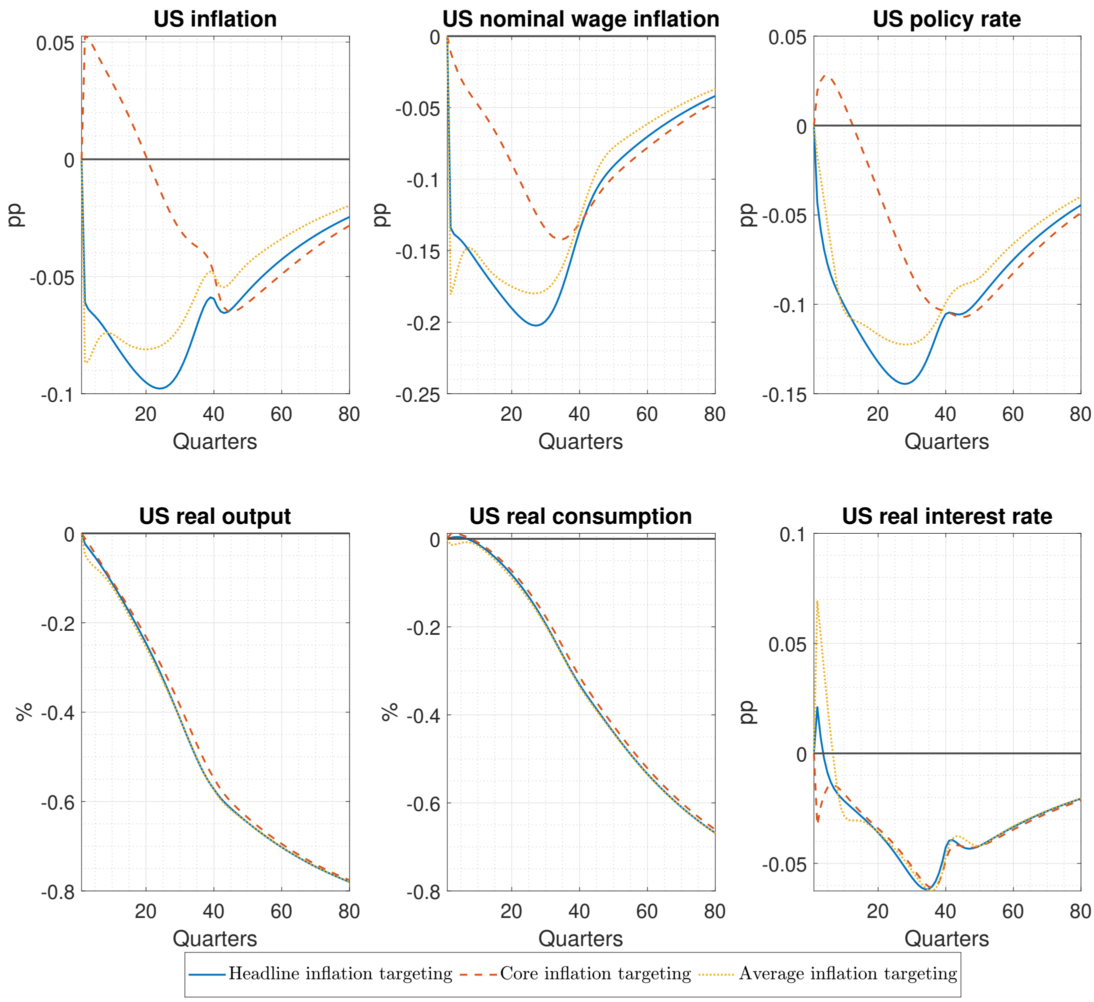
Figure 5: Permanent shock with real-time estimate of potential output



sures and output losses, though slightly less severely than Thailand. The Philippines also exhibits notable responses, with its manufacturing sector contributing to significant inflationary pressures and output declines. In the euro area, the effects are more moderate, as its diversified production structure and smaller reliance on energy-intensive sectors dampen the transmission of the shock. However, the euro area's relatively larger manufacturing sector amplifies the effects compared to the United States. Among the countries analyzed, the United States exhibits the smallest responses, owing to its more balanced production structure and smaller energy-intensive sectoral weights.

These cross-country differences highlight the critical role of sectoral composition in de-

Figure 6: Permanent energy transition under alternative monetary policy rules



termining the macroeconomic consequences of permanent energy price shocks. Economies with larger mining or manufacturing sectors face stronger effects on inflation and more severe output contractions, complicating the monetary policy trade-off between inflation stabilization and output support.

4.2.2 Monetary policy regimes

The second scenario, where the central bank targets long-run output, is used to study the effects of alternative monetary policy regimes. The analysis is based on simulations for the United States, and three policy rules are considered: targeting headline inflation, targeting core inflation, and average inflation targeting (AIT) over an eight-quarter horizon. Figure 6 illustrates the results under these alternative monetary policy frameworks.

The results show little difference between headline inflation targeting and AIT, both producing similar outcomes with modest deflationary pressures on prices and wages, a declining policy rate in the early quarters, and gradual declines in output and consumption.

Core inflation targeting, however, produces distinct outcomes compared to the other two rules. Under core inflation targeting, inflation rises moderately over the first five years, in contrast to the deflation observed throughout the transition under headline inflation targeting and AIT. It is important to note, however, that the inflationary effects under core inflation targeting remain relatively small. This inflationary response leads to a less pronounced nominal wage deflation compared to headline inflation targeting and AIT.

The inflationary pressures under core inflation targeting also result in a small increase in the policy rate during the first five years, whereas the policy rate declines under headline inflation targeting and AIT during the same period. However, the changes in the policy rate across all regimes remain very modest.

5 Conclusion

This paper has presented the main features of BIS-MS and demonstrated its capacity to simulate temporary and permanent shocks, across a large number of economies, under a range of assumptions about the behaviour of monetary policy. While the specific applications in this paper focussed on energy price shocks, BIS-MS is capable of modelling a range of economic phenomena. Applications by the authors of this paper include assessing the effects of AI-adoption on output and inflation, and quantifying the cross-country effects of trade tariffs.[21] We hope that the accompanying toolbox will make it easy for interested readers to experiment with the model and test potential use cases.

[21] See Aldasoro et al. (2024) and Burgert et al. (2025a).

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A Model Equations

The economy is made up of $\mathcal{F}$ industries. We use the letter j to describe individual industries and the letter ι to describe individual firms within each industry. With some abuse of notation, we also use ι to denote household-level variables.

A.1 Nonlinear model

A.1.1 Households

The economy features two types of households: Ricardian households, who have access to financial markets and non-Ricardian households, who don't. The share of the two household types is ω_r and $1-\omega_r$.

Ricardian Households

There is a continuum of identical households indexed by ι (which we suppress when not important). The household's problem is to choose aggregate and industry-level consumption, investment and capital, household-by-industry level wages and aggregate bond holdings to maximise utility [ν **is the inverse Frisch elasticity**]:

$$\sum_{t=0}^{\infty} \beta^t \left[e^{\xi_{c,t}} \log(C_t^r - hC_{t-1}^r) - \frac{A_N}{1+\nu} N_t^r(\iota)^{1+\nu} \right] \tag{A.1}$$

subject to the budget constraint:

$$P_{C,t}C_t^r + P_{I,t}I_t^r + \frac{B_{t+1}}{R_t} \leq B_t + \sum_{j=1}^{\mathcal{F}} \left(P_{C,t} \frac{r_{j,t}^K k_{j,t} u_{j,t}}{\mathcal{M}} + w_{j,t}(\iota) n_{j,t}^r(\iota) - a(u_{j,t}) k_{j,t} \right) + T_t^r \tag{A.2}$$

and capital accumulation constraints for each industry:

$$k_{j,t+1} = (1-\delta)k_{j,t} + \left(1 - \mathcal{S}\left(\frac{z_{j,t}}{z_{j,t-1}}\right)\right) z_{j,t} \tag{A.3}$$

where C_t is aggregate consumption, $\xi_{c,t}$ is a consumption preference shifter, I_t is aggregate investment, $k_{j,t}$ is the capital stock of industry j, $u_{j,t}$ is the utilisation of capital in industry j and $z_{j,t}$ is gross investment in industry j. $w_{j,t}$ is the wage in industry j, which is distinct from the wage paid to household ι in industry j, $w_{j,t}(\iota)$. Similarly $n_{j,t}(\iota)$ is hours worked by household ι in industry j, while $n_{j,t}$ is total hours worked in industry j. The household takes industry-level wages and hours worked as given in making its decisions. T_t are lump sum transfers to the government. $\mathcal{M}$ is a wedge between the return on capital paid by firms and the amount received by households. It can be viewed as a reduced form for firm defaults or other factors that cause investors to demand a risk premium on lending to corporates.

Aggregate consumption and investment consist of bundles of consumption and investment goods sourced from each industry:

$$C_t^r = \left[\sum_{j=1}^{\mathcal{F}} \omega_{cj}^{\frac{1}{\eta}} c_{j,t}^{r\,\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{A.4}$$

$$I_t^r = \left[\sum_{j=1}^{\mathcal{F}} \omega_{ij}^{\frac{1}{\eta}} i_{j,t}^{r\,\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{A.5}$$

The price indices accompanying the consumption and investment aggregates are:

$$P_{C,t} = \left[\sum_{j=1}^{\mathcal{F}} \omega_{c,j} p_{j,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{A.6}$$

$$P_{I,t} = \left[\sum_{j=1}^{\mathcal{F}} \omega_{i,j} p_{j,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{A.7}$$

where $p_{j,t}$ is the price of the good produced by industry j.

It follows that the demand functions for the output of individual industries are:

$$c_{j,t} = \omega_{cj}\left(\frac{p_{j,t}}{P_{C,t}}\right)^{-\eta} C_t \tag{A.8}$$

$$i_{j,t} = \omega_{ij}\left(\frac{p_{j,t}}{P_{I,t}}\right)^{-\eta} I_t \tag{A.9}$$

Similarly, total labour supply, $N_t(\iota)$ is a bundle of labour supplied to each sector:

$$N_t^r(\iota) = \left[\sum_{j=1}^{\mathcal{F}} \omega_{nj}^{-\frac{1}{\xi}} n_{j,t}^r(\iota)^{\frac{\xi+1}{\xi}}\right]^{\frac{\xi}{\xi+1}} \tag{A.10}$$

A labour packer aggregates the labour supply of individual households in each industry according to:

$$n_{j,t} = \left(\int_0^1 n_{j,t}(\iota)^{\frac{\epsilon_w - 1}{\epsilon_w}} du \right)^{\frac{\epsilon_w}{\epsilon_w - 1}} \tag{A.11}$$

Consequently, demand for different types of labour is given by:

$$n_{j,t}(\iota) = \left(\frac{w_{j,t}(\iota)}{w_{j,t}} \right)^{-\epsilon_w} n_{j,t} \tag{A.12}$$

where $w_{j,t}$ is the aggregate wage index in industry j. The household takes this labour demand function into account when making its wage decisions.

Price inflation is given by:

$$\Pi_t = \frac{P_{C,t}}{P_{C,t-1}} \tag{A.13}$$

$$\tag{A.14}$$

Market clearing for investment goods requires the aggregate volume of investment goods demanded by households to equal the sum of investment in all of the industries, that is:

$$I_t^r = \sum_{j=1}^{\mathcal{F}} z_{j,t}^r \tag{A.15}$$

Letting the Lagrange multipliers for the constraints on the budget constraint and the capital accumulation condition be $\Lambda_t / P_{C,t}$ and $\Lambda_t q_{j,t}$, the first order conditions for the household's problem are:

$$\frac{e^{\xi_{c,t}}}{C_t^r - hC_{t-1}^r} = \Lambda_t^r + \beta E_t \left\{ \frac{he^{\xi_{c,t+1}}}{C_{t+1}^r - hC_t^r} \right\} \tag{A.16}$$

$$\Lambda_t^r = \beta R_t E_t \left\{ \frac{\Lambda_{t+1}^r}{\Pi_{C,t+1}} \right\} \tag{A.17}$$

$$\Lambda_t^r q_{j,t} = \beta E_t \left\{ (1-\delta_j)\Lambda_{t+1}^r q_{j,t+1} + \Lambda_{t+1}^r \frac{r_{j,t+1}^K u_{j,t+1}}{\mathcal{M}} \right\} \tag{A.18}$$

$$\Lambda_t^r = \Lambda_t^r q_{j,t} \left[1 - \mathcal{S}\left(\frac{z_{j,t}}{z_{j,t-1}}\right) - \mathcal{S}'\left(\frac{z_{j,t}}{z_{j,t-1}}\right)\frac{z_{j,t}}{z_{j,t-1}} \right] + \beta E_t \left\{ \Lambda_{t+1}^r q_{j,t+1} \mathcal{S}'\left(\frac{z_{j,t+1}}{z_{j,t}}\right) \frac{z_{j,t+1}^2}{z_{j,t}^2} \right\} \tag{A.19}$$

$$r_{j,t}^k = a(u_{j,t}) \tag{A.20}$$

Non-Ricardian households

Non-Ricardian households maximise the utility function:

$$\sum_{t=0}^{\infty} \beta^t \left[e^{\xi_{c,t}} \log(C_t^{nr} - hC_{t-1}^{nr}) - \frac{A_N}{1+\nu} N_t^{nr}(\iota)^{1+\nu} \right] \tag{A.21}$$

subject to the budget constraint:

$$P_{C,t} C_t^{nr} \leq \sum_{j=1}^{\mathcal{F}} w_{j,t} n_{j,t}^{nr} + T_t^{nr} \tag{A.22}$$

The first order conditions for their problem are:

$$\frac{e^{\xi_{c,t}}}{C_t^{nr} - hC_t^{nr}} = P_{C,t}\Lambda_t^{nr} + \beta E_t \left\{ \frac{e^{\xi_{c,t+1}} h}{C_{t+1}^{nr} - hC_t^{nr}} \right\} \tag{A.23}$$

which defines the marginal utility of consumption for non-Ricardian households

A.1.2 Aggregate consumption and marginal utility of consumption

The 'aggregate' marginal utility of consumption, Λ_t is a weighted average of the marginal utilities of the Ricardian and non-Ricardian households:

$$\Lambda_t = \omega_r \Lambda_t^r + (1-\omega_r)\Lambda_t^{nr} \tag{A.24}$$

Similarly, aggregate consumption is a weighted average of Ricardian and non-Ricardian consumption:

$$C_t = \omega_r C_t^r + (1-\omega_r) C_t^{nr} \tag{A.25}$$

A.1.3 Labour market:

In each industry, a continuum of perfectly competitive labour hiring firms combine the specialised labour types according to:

$$n_{j,t} = \left(\int_0^1 n_{j,t}(s)^{\frac{\epsilon_w - 1}{\epsilon_w}} ds \right)^{\frac{\epsilon_w}{\epsilon_w - 1}} \tag{A.26}$$

The hiring firm's demand for each labour type j is given by:

$$n_{j,t}(s) = \left(\frac{w_{j,t}(s)}{w_{j,t}} \right)^{-\epsilon_w} n_{j,t} \tag{A.27}$$

where $w_{j,t}$ is the industry wage index given by:

$$w_{j,t} = \left(\int_0^1 w_{j,t}(s)^{1-\epsilon_w} ds \right)^{\frac{1}{1-\epsilon_w}} \tag{A.28}$$

Workers of type s unionise in order to take advantage of their monopoly power. These unions set nominal wages subject to the labour demand constraint and a Calvo friction that means that a random proportion, $\theta_{w,j}$ of households cannot re-optimise their wage each period.

Unions that do not re-optimise their wages re-scale them according to the indexation rule that depends on industry-specific lagged wage inflation ($\pi_{t-1}^{w,j}$) :

$$w_{j,t}(s) = (\pi_{j,t-1}^w)^{\chi_{w,j}} w_{j,t-1}(s)$$

Define:

$$\Omega_{j,t,t+s} = \prod_{m=t}^{t+s-1} (\pi_{j,m}^w)^{\chi_{w,j}}$$

to be the total indexation in period s of a union that last updated its wage in period t.

Unions choose $w_{j,t}(s)$ to maximise:

$$\mathcal{L} = \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_{w,j})^s \Bigg[\Upsilon_j^w \frac{\Lambda_{t+s}}{P_{C,t+s}} w_{j,t}(s)\Omega_{j,t,t+s} \left(\frac{w_{j,t}(s)\Omega_{j,t,t+s}}{w_{j,t+s}}\right)^{-\epsilon_w} n_{j,t+s} - \frac{A_N}{1+\nu} \left[\sum_{j=1}^{\mathcal{F}} \left(\int_0^1 \left(\frac{w_{j,t}(k)\Omega_{j,t,t+s}}{w_{j,t+s}}\right)^{-\epsilon_w} n_{j,t+s} dk \right)^{\frac{1+\xi}{\xi}} \right]^{\frac{\xi(1+\nu)}{1+\xi}} \Bigg] \tag{A.29}$$

where Υ^w is a wage subsidy calibrated to offset the effect of imperfect labour market competition on employment.

The first order condition for this problem is:

$$0 = \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\theta_{w,j})^s \Bigg[-(1-\epsilon_w)\Upsilon_j^w \frac{\Lambda_{t+s}}{P_{C,t+s}} \Omega_{j,t,t+s} \left(\frac{w_{j,t}(s)\Omega_{j,t,t+s}}{w_{j,t+s}}\right)^{-\epsilon_w} n_{j,t+s} + \epsilon_w A_N N_{t+s}^{\nu-\frac{1}{\xi}} n_{j,t+s}^{\frac{1+\xi}{\xi}} \left(\frac{\Omega_{j,t+s}}{w_{j,t+s}}\right)^{-\epsilon_w \frac{1+\xi}{\xi}} w_{j,t}(k)^{-\epsilon_w \frac{1+\xi}{\xi}-1} \Bigg] \tag{A.30}$$

which we can re-arrange to:

$$\left[\frac{w_{j,t}(k)}{w_{j,t}}\right]^{\frac{\xi+\epsilon_w}{\xi}} = \frac{H_{w1,t}}{H_{w2,t}} \tag{A.31}$$

where:

$$H_{w1,t} = \sum_{s=0}^{\infty} (\beta\theta_{w,j})^s A_N N_{t+s}^{\nu-\frac{1}{\xi}} n_{j,t+s}^{\frac{1+\xi}{\xi}} \left(\frac{\Omega_{j,t+s}}{\pi_{w,j,t,t+s}}\right)^{-\epsilon_w \frac{1+\xi}{\xi}} \tag{A.32}$$

$$H_{w2,t} = \sum_{s=0}^{\infty} (\beta\theta_{w,j})^s \Lambda_{t+s} \frac{w_{j,t+s}}{P_{C,t+s}} n_{j,t+s} \left(\frac{\Omega_{j,t+s}}{\pi_{w,j,t,t+s}}\right)^{1-\epsilon_w} \tag{A.33}$$

We can-re-write $H_{w1,t}$ and $H_{w2,t}$ as:

$$H_{w1,t} = A_N N_t^{\nu-\frac{1}{\xi}} n_{j,t}^{\frac{1}{\xi}+1} + \beta\theta_{w,j}\mathbb{E}_t \left\{ \left(\frac{\pi_{j,t}^{w\chi_w}}{\pi_{j,t+1}^w}\right)^{-\epsilon_w \frac{1+\xi}{\xi}} H_{w1,t+1} \right\} \tag{A.34}$$

$$H_{w2,t} = \Lambda_t \frac{w_{j,t}}{P_{C,t}} n_{j,t} + \beta\theta_{w,j}\mathbb{E}_t \left\{ \left(\frac{\pi_{j,t}^{w\chi_w}}{\pi_{j,t+1}^w}\right)^{1-\epsilon_w} H_{w2,t+1} \right\} \tag{A.35}$$

From the definition of the wage index, we also know that:

$$1 = (1-\theta_{w,j}) \left(\frac{w_{j,t}(k)}{w_{j,t}} \right)^{1-\epsilon_w} + \theta_{w,j} \left(\frac{\pi_{j,t-1}^{w\chi_w}}{\pi_{j,t}^{w}} \right)^{1-\epsilon_w} \tag{A.36}$$

A.1.4 Firms:

Firms in industry j produce output using capital, labour and intermediate goods according to the multi-layered production function:

$$y_{j,t}^{va}(\iota) = \left[\omega_{n,j}^{\frac{1}{\zeta}} n_{j,t}(\iota)^{\frac{\zeta-1}{\zeta}} + (1-\omega_{n,j})^{\frac{1}{\zeta}} k_{j,t}^{s}(\iota)^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}} \tag{A.37}$$

$$x_{j,t}(\iota) = \left[\sum_{k=1}^{\mathcal{F}} \omega_{k,j}^{\frac{1}{\psi}} x_{k,j,t}(\iota)^{\frac{\psi-1}{\psi}} \right]^{\frac{\psi}{\psi-1}} \tag{A.38}$$

$$y_{j,t}(\iota) = a_j \left[\omega_{y,j}^{\frac{1}{\varphi}} y_{j,t}^{va}(\iota)^{\frac{\varphi-1}{\varphi}} + (1-\omega_{y,j})^{\frac{1}{\varphi}} x_{j,t}(\iota)^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}} \tag{A.39}$$

where $y_{j,t}^{va}(\iota)$ is the value added of firm ι in industry j, $k_{j,t}^{s}(\iota)$ is the amount of capital hired by the firm, $x_{j,t}(\iota)$ is the amount of intermediate goods used by the firm and $y_{j,t}(\iota)$ is gross output of the firm. The total capital hired by industry j and total capital available to be hired is related by:

$$k_{j,t}^{s} = u_{j,t} k_{j,t} \tag{A.40}$$

Marginal costs (deflated by industry-specific final prices) and the resulting demand functions are:

$$mc_{j,t}(\iota) = \frac{1}{a_j} \left[\omega_{y,j} (p_{j,t}^{yva}(\iota)/p_{j,t})^{1-\varphi} + (1-\omega_{y,j})(p_{j,t}^{x}(\iota)/p_{j,t})^{1-\varphi} \right]^{\frac{1}{1-\varphi}} \tag{A.41}$$

$$(p_{j,t}^{yva}(\iota))^{\varphi} y_{j,t}^{va}(\iota) = \frac{\omega_{y,j}}{1-\omega_{y,j}} (p_{j,t}^{x}(\iota))^{\varphi} x_{j,t}(\iota) \tag{A.42}$$

where the price indices for value-added and intermediate goods in each industry are given by:

$$p_t^{yva} = \left[\omega_n w_{j,t}^{1-\zeta} + (1-\omega_{n,j}) r_{j,t}^{k1-\zeta}\right]^{\frac{1}{1-\zeta}} \tag{A.43}$$

$$p_{j,t}^{x} = \left[\sum_{k=1}^{\mathcal{F}} \omega_{k,j} p_{k,t}^{1-\psi}\right]^{\frac{1}{1-\psi}} \tag{A.44}$$

These imply the demand functions:

$$n_{j,t} = \omega_{n,j} \left(\frac{w_{j,t}}{p_{j,t}^{yva}}\right)^{-\zeta} y_{j,t}^{va} \tag{A.45}$$

$$k_{j,t} = (1-\omega_{n,j}) \left(\frac{r_{j,t}^{k}}{p_{j,t}^{yva}}\right)^{-\zeta} y_{j,t}^{va} \tag{A.46}$$

$$x_{kj,t} = \omega_{k,j} \left(\frac{p_{k,t}}{p_{j,t}^{x}}\right)^{-\psi} x_{j,t} \tag{A.47}$$

In each industry, individual firms face price stickiness a la Calvo. Each period a fraction of firms, $1-\theta_{pj}$ are able to change their prices. The remainder follow an indexing rule:

$$p_{j,t}(\iota) = (\pi_{j,t-1})^{\varphi_{j,p}}\, p_{j,t-1}(\iota)$$

Define:

$$\Omega_{j,t,t+s} = \prod_{m=t}^{t+s-1} (\pi_{j,m})^{\varphi_{j,p}}$$

as the cumulative change in prices between t and m, conditional on not re-optimising.

The problem for a firm that is able to reset its prices at time t is:

$$\max_{p_{j,t}^{*}(\iota)} E_t \sum_{s=0}^{\infty} (\beta\theta_{pj})^s \left\{\Lambda_{t+s}\left[\frac{p_{j,t}^{*}(\iota)\gamma_{j,t+s}\Omega_{j,t,t+s}}{p_{j,t+s}} y_{j,t+s}(\iota) - \frac{1}{1+\phi_{pj}} mc_{j,t+s}\gamma_{j,t+s} y_{j,t+s}(\iota)\right]\right\}$$

where $\gamma_{j,t+s} = p_{j,t+s}/P_{C,t+s}$ is the relative price of goods in industry j, subject to the demand condition given above. The parameter ϕ_j is a production subsidy to offset the steady-state distortion from imperfect competition. The first order condition for this problem is:

$$E_t \sum_{s=0}^{\infty} (\beta\theta_{pj})^s \left\{ \Lambda_{t+s} \left[\frac{1-\epsilon_{jp}\gamma_{j,t+s}}{p_{j,t}(\iota)} \left(\frac{p_{jt}(\iota)\Omega_{j,t,t+s}}{p_{j,t+s}} \right)^{1-\epsilon_{jp}} y_{j,t+s} \right.\right.$$
$$\left.\left. + \frac{\epsilon_{jp}}{1+\phi_{jp}} \frac{mc_{j,t+s}}{p_{j,t}(\iota)} \left(\frac{p_{j,t}(\iota)\Omega_{j,t,t+s}}{p_{j,t+s}} \right)^{-\epsilon_{jp}} \gamma_{j,t+s} y_{j,t+s} \right] \right\} = 0 \qquad \text{(A.48)}$$

Re-arranging gives:

$$\frac{p_{j,t}(\iota)}{p_{j,t}} = \frac{\epsilon_{j,p}}{(1+\phi_{jp})(\epsilon_{jp}-1)} \frac{h_{j,p1,t}}{h_{j,p2,t}}$$

where

$$h_{j,p1,t} = E_t \sum_{s=0}^{\infty} (\beta\theta_{pj})^s \Lambda_{t+s} \left(\frac{\Omega_{j,t,t+s}}{\pi_{j,t,t+s}} \right)^{-\epsilon_{jp}} mc_{j,t+s}\gamma_{j,t+s}y_{j,t+s} \qquad \text{(A.49)}$$

$$h_{j,p2,t} = E_t \sum_{s=0}^{\infty} (\beta\theta_{pj})^s \Lambda_{t+s} \left(\frac{\Omega_{j,t,t+s}}{\pi_{j,t,t+s}} \right)^{1-\epsilon_{jp}} \gamma_{j,t+s}y_{j,t+s} \qquad \text{(A.50)}$$

Note that:

$$h_{j,p1,t} = \Lambda_t mc_{j,t}\gamma_{j,t}y_{j,t} + \beta\theta_{pj} E_t \left(\frac{\Omega_{j,t,t+1}}{\pi_{j,t,t+1}} \right)^{-\epsilon_{jp}} h_{j,p1,t+1} \qquad \text{(A.51)}$$

$$h_{j,p2,t} = \Lambda_t \gamma_{j,t}y_{j,t} + \beta\theta_{pj} \left(\frac{\Omega_{j,t,t+1}}{\pi_{j,t+1}} \right)^{1-\epsilon_{jp}} h_{j,p2,t+1} \qquad \text{(A.52)}$$

Note also that the domestic price index can be expressed as:

$$1 = (1-\theta_{jp}) \left(\frac{p_{j,t}(\iota)}{p_{j,t}} \right)^{1-\epsilon_p} + \theta_{jp} \left(\frac{(\pi_{j,t-1})^{\varphi_{jp}}}{\pi_{j,t}} \right)^{1-\epsilon_{jp}} \qquad \text{(A.53)}$$

A.1.5 Market clearing and aggregate price indices:

Goods market clearing requires that:

$$y_{j,t} = c_{j,t} + i_{j,t} + g_{j,t} + \sum_{k=1}^{\mathcal{F}} x_{j,k} \qquad \text{(A.54)}$$

A.1.6 Monetary policy:

The monetary policy authority follows either headline inflation targeting, core inflation targeting or average inflation targeting. For headline inflation targeting, the monetary policy authority follows the policy rule:

$$\frac{R_t}{\bar{R}} = \left[\frac{R_{t-1}}{\bar{R}}\right]^{\rho^R} \left[(\Pi_t)^{\phi^\pi} (GAP_t)^{\phi^{gap}}\right]^{1-\rho^R} e^{\varepsilon^R_{j,t}} \tag{A.55}$$

where $GAP_t = Y_t/Y_t^{flex}$ is the output gap, defined as the deviation of real GDP from its flexible price level (defined below).

For core inflation targeting, the monetary policy authority responds to inflation in the service sectors:

$$\frac{R_t}{\bar{R}} = \left[\frac{R_{t-1}}{\bar{R}}\right]^{\rho^R} \left[(\Pi_{S,t})^{\phi^\pi} (GAP_t)^{\phi^{gap}}\right]^{1-\rho^R} e^{\varepsilon^R_{j,t}} \tag{A.56}$$

where $\Pi_{S,t} = P_{S,t}/P_{S,t-1}$ is the service sector inflation. The corresponding consumption good, e.g. for the Ricardian consumers, is given as:

$$C^r_{S,t} = \left[\sum_{j\in\tilde{\mathcal{F}}} \omega_{csj}^{\frac{1}{\eta}} (c^r_{j,t})^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{A.57}$$

where $\tilde{F}$ is the set of industries that are part of the service sector. Note that the weight of the corresponding industry ω_{csj} is reweighted accordingly.

The third rule is average inflation targeting, where the central bank targets average inflation over n^{AIT} quarters:

$$\frac{R_t}{\bar{R}} = \left[\frac{R_{t-1}}{\bar{R}}\right]^{\rho^R} \left[(\bar{\Pi}_t)^{\phi^\pi} (GAP_t)^{\phi^{gap}}\right]^{1-\rho^R} e^{\varepsilon^R_{j,t}} \tag{A.58}$$

The average level of inflation is given as:

$$\bar{\Pi}_t = \frac{1}{n^{AIT}} \sum_{i=0}^{n^{AIT}-1} \Pi_{t-i} \tag{A.59}$$

A.1.7 Fiscal policy:

The government budget constraint is:

$$\frac{B_{t+1}}{R_t} = B_t + P_{G,t}G_t - T_t \tag{A.60}$$

We assume that in steady state, government bonds are in zero net supply, so that $B_t = 0 \forall t$. Fiscal policy purchases goods and services, G_t, according to the aggregate:

$$G_t = \left[\sum_{j=1}^{\mathcal{F}} \omega_{g,j}^{\frac{1}{\eta}} g_{j,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{A.61}$$

Implying the price index:

$$P_t^g = \left[\sum_{j=1}^{\mathcal{F}} \omega_{g,j} p_{j,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{A.62}$$

and final output demands:

$$g_{j,t} = \omega_{g,j} \left(\frac{p_{j,t}}{P_t^g} \right)^{-\eta} G_t \tag{A.63}$$

Aggregate government spending evolves according to:

$$\frac{G_t}{G} = \left[\frac{G_{t-1}}{G} \right]^{\rho_g} \exp(\varepsilon_t^g) \tag{A.64}$$

Transfers consist of transfers to Ricardian and non-Ricardian households:

$$T_t = T_t^r + T_t^{nr} \tag{A.65}$$

A.1.8 Flexible price allocation

Flexible price variables are defined by the superscript $flex$. All equations are the same, except that in the flexible price system marginal costs are always at their steady state level and the marginal efficiency of labour equals its marginal product in all industries. This implies that:

$$MC = 0 \tag{A.66}$$

and

$$A_N N_{t+1}^{flex,\nu-\frac{1}{\zeta}} n_{j,t+s}^{flex,\frac{1+\zeta}{\zeta}} = \Lambda_{t+1}^{flex} \frac{w_{j,t+s}^{flex}}{P_{C,t+s}^{flex}} n_{j,t+s}^{flex} \tag{A.67}$$

A.2 Steady state

The steady state of the system is given by:

From the first order condition for bond holdings:

$$R = 1/\beta \tag{A.68}$$

From the first order condition for investment

$$q_j = 1 \tag{A.69}$$

From the first order condition for capital:

$$r_j^k = \mathcal{M}\left(\frac{1}{\beta} - 1 + \delta\right) \tag{A.70}$$

From the consumption choice for Ricardian households:

$$\frac{1-\beta h}{C^r(1-h)} = \frac{\Lambda^r}{e^{\xi_c}} \tag{A.71}$$

From the budget constraint for for non-Ricardian households:

$$C_t^{nr} = W_t N_t^{nr} + T_t^{nr} \tag{A.72}$$

From the consumption choice of non-Ricardian households

$$\frac{1-\beta h}{C^{nr}(1-h)} = \frac{\Lambda^{nr}}{e^{\xi_c}} \tag{A.73}$$

we set the level of transfers so that the marginal utility of consumption for Ricardian and non-Ricardian households are equal, i.e. $\Lambda^r = \Lambda^{nr} = \Lambda$.

From the definition of aggregate marginal utility:

$$\Lambda = \omega_r \Lambda^r + (1-\omega_r)\Lambda^{nr} \tag{A.74}$$

From the definition of aggregate consumption:

$$C = \omega_r C^r + (1 - \omega_r) C^{nr} \tag{A.75}$$

From the wage choice:

$$\omega_{wj}^{\frac{1}{\xi}} A_N N^{\nu + \frac{1}{\xi}} n_j^{-\frac{1}{\xi}} = \Lambda w_j \tag{A.76}$$

From the definition of aggregate labour supply:

$$N = \left[\sum_{j=1}^{\mathcal{F}} \omega_{nj}^{-\frac{1}{\xi}} n_j^{\frac{\xi+1}{\xi}} \right]^{\frac{\xi}{\xi+1}} \tag{A.77}$$

From the capital accumulation condition:

$$z_j = \delta k_j \tag{A.78}$$

From the market clearing condition for investment:

$$I = \sum_{j=1}^{\mathcal{F}} z_j \tag{A.79}$$

From the demand function for consumption:

$$c_j = \omega_{cj} \gamma_j^{-\eta} C \tag{A.80}$$

From the demand function for investment:

$$i_j = \omega_{ij} \left(\frac{\gamma_j}{\gamma_I} \right)^{-\eta} I \tag{A.81}$$

From the demand function for government expenditure:

$$g_j = \omega_{g,j} \left(\frac{\gamma_j}{\gamma_G} \right)^{-\eta} G \tag{A.82}$$

From the price index for consumption:

$$1 = \left[\sum^{\mathcal{N}} \omega_{c,j} \gamma_j^{1-\eta} \right] \tag{A.83}$$

From the price index for investment:

$$\gamma_I = \left[\sum^{\mathcal{N}} \omega_{i,j} \gamma_j^{1-\eta} \right] \tag{A.84}$$

From the price index for government expenditure:

$$\gamma_G = \left[\sum_{j=1}^{\mathcal{F}} \omega_{g,j} \gamma_j^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{A.85}$$

From the definition of aggregate wages:

$$W = \left[\sum^{\mathcal{N}} \omega_{l,j} w_j^{1+\xi} \right]^{\frac{1}{1+\xi}} \tag{A.86}$$

From the production function:

$$y_j = a_j \left[\omega_{y,j}^{\frac{1}{\varphi}} y_j^{va\,\frac{\varphi-1}{\varphi}} + (1-\omega_{y,j})^{\frac{1}{\varphi}} x_j^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}} \tag{A.87}$$

From the demand functions for intermediate goods:

$$x_{kj} = \omega_{kj} \left(\frac{\gamma_k}{\gamma_j} \right)^{-\psi} x_j \tag{A.88}$$

From the demand function for capital:

$$k_j = (1-\omega_n) \left(\frac{r_j^k}{\gamma_j^{yva}} \right)^{-\zeta} y_j^{va} \tag{A.89}$$

From the demand function for labour:

$$n_j = \omega_{nj}\left(\frac{w_j}{\gamma_j^{yva}}\right)^{-\zeta} y_j^{va} \tag{A.90}$$

From the definition of the price index of intermediate goods:

$$\gamma_j^x = \left[\sum_{j=1}^{\mathcal{F}} \omega_{kj}\gamma_k^{1-\psi}\right]^{\frac{1}{1-\psi}} \tag{A.91}$$

From the definition of the price of value added:

$$\gamma_j^{yva} = \left[\omega_{nj} w_j^{1-\zeta} + (1-\omega_n j) r_j^{k1-\zeta}\right]^{\frac{1}{1-\zeta}} \tag{A.92}$$

From the relative demand for inputs:

$$(\gamma_j^{yva})^{\varphi} y_j^{va} = \frac{\omega_{y,j}}{1-\omega_{y,j}}(\gamma_j^x)^{\varphi} x_j \tag{A.93}$$

From goods market clearing:

$$y_j = c_j + i_j + g_j + \sum_{k=1}^{\mathcal{F}} x_{j,k} \tag{A.94}$$

From the definition of $h_{j,p2}$:

$$h_{j,p2} = \frac{\Lambda \gamma_j y_j}{1-\beta\theta_{pj}} \tag{A.95}$$

From the price index for good j:

$$h_{j,p2} = h_{j,p1} \tag{A.96}$$

From the definition of $h_{j,p1}$:

$$mc_j = 1 \tag{A.97}$$

From the definition of marginal costs:

$$a_j = \left[\omega_{y,j}(\gamma_j^{yva})^{1-\varphi} + (1-\omega_{y,j}(\gamma_j^x)^{1-\varphi}\right]^{\frac{1}{1-\varphi}} \tag{A.98}$$

A.3 Linearised equations

Capital accumulation:

$$\hat{k}_{j,t+1} - \delta \hat{z}_{j,t} = (1-\delta)\hat{k}_{j,t} \tag{A.99}$$

Consumption price index:

$$0 = \sum_{j=1}^{\mathcal{F}} \omega_{c,j} \gamma_j^{1-\eta} \hat{\gamma}_{j,t} \tag{A.100}$$

Investment price index:

$$\gamma_I^{1-\eta} - \sum_{j=1}^{\mathcal{F}} \omega_{i,j} \gamma_j^{1-\eta} \hat{\gamma}_{j,t} = 0 \tag{A.101}$$

Government price index:

$$\gamma_G^{1-\eta} - \sum_{j=1}^{\mathcal{F}} \omega_{g,j} \gamma_j^{1-\eta} \hat{\gamma}_{j,t} = 0 \tag{A.102}$$

Consumption variety choice:

$$\hat{c}_{j,t} = \hat{C}_t - \eta \hat{\gamma}_{j,t} \tag{A.103}$$

Investment variety choice:

$$\hat{i}_{j,t} = \hat{I}_t - \eta(\hat{\gamma}_{j,t} - \hat{\gamma}_{I,t}) \tag{A.104}$$

Government expenditure variety choice:

$$\hat{g}_{j,t} = \hat{G}_t - \eta(\hat{\gamma}_{j,t} - \hat{\gamma}_{G,t}) \tag{A.105}$$

Aggregate labour supply:

$$N^{\frac{\xi+1}{\xi}} \hat{n}_t - \sum_{j=1}^{\mathcal{F}} \omega_{nj}^{-\frac{1}{\xi}} n_j^{\frac{\xi+1}{\xi}} \hat{n}_{j,t} = 0 \tag{A.106}$$

Investment price inflation:

$$\hat{\pi}_{I,t} - \hat{\pi}_t - \hat{\gamma}_{I,t} = -\hat{\gamma}_{I,t-1} \tag{A.107}$$

Wage inflation:

$$\hat{\pi}_{W,t} - \hat{\pi}_t - \hat{w}_t = -\hat{w}_{t-1} \tag{A.108}$$

Aggregate wage index:

$$W^{1+\xi}\hat{w}_t = \sum_{j=1}^{\mathcal{F}} \omega_{nj} w_j^{1+\xi} \hat{w}_{j,t} \tag{A.109}$$

Investment market clearing:

$$I\hat{i}_t - \sum_{j=1}^{\mathcal{F}} z_j \hat{z}_{j,t} = 0 \tag{A.110}$$

Consumption choice for Ricardian consumers:

$$h\hat{c}^r_{t-1} + \beta h E_t\{\hat{c}^r_{t+1}\} = (1+\beta h^2)\hat{c}^r_t + (1-h)(1-\beta h)\hat{\lambda}^r_t - (1-h)(\hat{\xi}_{c,t} - \beta\hat{\xi}_{c,t+1}) \tag{A.111}$$

Euler equation for Ricardian consumers:

$$\hat{\lambda}^r_t = \hat{r}_t + E_t\{\hat{\lambda}^r_{t+1}\} - E_t\{\hat{\pi}_{t+1}\} \tag{A.112}$$

Capital stock choice for Ricardian consumers:

$$\hat{\lambda}^r_t + \hat{q}_{j,t} = E_t\{\hat{\lambda}^r_{t+1}\} + \beta(1-\delta)E_t\{\hat{q}_{j,t+1}\} + \frac{\beta r^K_j}{\mathcal{M}} E_t\{\hat{r}^k_{j,t+1}\} \tag{A.113}$$

Relationship between capital supplied to firms and total capital stock:

$$\hat{k}^s_{j,t} = u_{j,t} + \hat{k}_{j,t} \tag{A.114}$$

Capital utilisation in industry j:

$$\mathcal{A}\hat{r}^k_{j,t} = \hat{u}_{j,t} \tag{A.115}$$

where $\mathcal{A}$ controls the degree of capital utilisation costs.

Investment choice:

$$(1+\beta)\hat{z}_{j,t} = \frac{\hat{q}_{j,t}}{S''} + \beta E_t\{\hat{z}_{j,t+1}\} + \hat{z}_{j,t-1} \tag{A.116}$$

Consumption choice for non-Ricardian consumers

$$C^{nr}\hat{c}^{nr}_t - WN(\hat{w}_t + \hat{n}_t) - TRANS\hat{trans}_t = 0 \tag{A.117}$$

Marginal utility of consumption for non-Ricardian consumers

$$h\hat{c}^{nr}_{t-1} + \beta h E_t\{\hat{c}^{nr}_{t+1}\} = (1+\beta h^2)\hat{c}^{nr}_t + (1-h)(1-\beta h)\hat{\lambda}^{nr}_t - (1-h)(\hat{\xi}_{c,t} - \beta\hat{\xi}_{c,t+1}) \quad \text{(A.118)}$$

Aggregate consumption:

$$\hat{c}_t - \omega_r \frac{C^r}{C}\hat{c}^r_t - (1-\omega_r)\frac{C^{nr}}{C}\hat{c}^{nr}_t = 0 \quad \text{(A.119)}$$

Aggregate marginal utility:

$$\hat{\lambda}_t - \omega_r \frac{\lambda^r}{\Lambda}\hat{\Lambda}^r_t - (1-\omega_r)\frac{\Lambda^{nr}}{\Lambda}\hat{\lambda}^{nr}_t = 0 \quad \text{(A.120)}$$

Wages choice:

$$\hat{\pi}^w_{j,t} - \frac{\beta}{1+\beta\chi_w}E_t\{\hat{\pi}^w_{j,t+1}\} - \frac{\kappa_{w,j}}{(1+\beta\chi_w)}\left[-\hat{\lambda}_t + (\nu - \frac{1}{\xi})\hat{n}_t + \frac{1}{\xi}\hat{n}_{j,t} - \hat{w}_{j,t}\right] = \frac{\chi_w}{1+\beta\chi_w}\hat{\pi}^w_{j,t-1} \quad \text{(A.121)}$$

where $\kappa_{w,j} = \frac{\xi}{\xi+\epsilon_w}(1-\beta\theta_{w,j})(1-\theta_{w,j})/\theta_{w,j}$

Gross output in sector j:

$$y_j^{\frac{\varphi-1}{\varphi}}\hat{y}_{j,t} - a_j^{\frac{\varphi-1}{\varphi}}\hat{a}_{j,t} - \omega_{y,j}^{\frac{1}{\varphi}}(y_j^{va})^{\frac{\varphi-1}{\varphi}}\hat{y}^{va}_{j,t} - (1-\omega_{y,j})^{\frac{1}{\varphi}}x_j^{\frac{\varphi-1}{\varphi}}\hat{x}_{j,t} = 0 \quad \text{(A.122)}$$

Marginal costs in sector j:

$$\begin{aligned}\hat{m}c_{j,t} + \hat{a}_{j,t} - \omega_{y,j}(\gamma^{va}_j/a_j\gamma_j)^{1-\varphi}\hat{\gamma}^{va}_{j,t} \\ - (1-\omega_{y,j})(\gamma^x_j/a_j\gamma_j)^{1-\varphi}\hat{\gamma}^x_{j,t} + \hat{\gamma}_{j,t} = 0\end{aligned} \quad \text{(A.123)}$$

Factor demand in sector j:

$$\varphi\hat{\gamma}^{va}_{j,t} + \hat{y}^{va}_{j,t} - \varphi\hat{\gamma}^x_{j,t} - \hat{x}_{j,t} = 0 \quad \text{(A.124)}$$

Value added price index in sector j:

$$\left(\gamma^{va}_j\right)^{1-\zeta}\hat{\gamma}^{va}_{j,t} - \omega_{nj}w_j^{1-\zeta}\hat{w}_{j,t} - (1-\omega_{nj})(r^k_j)^{1-\zeta}\hat{r}^k_{j,t} = 0 \quad \text{(A.125)}$$

Intermediate good price index in sector j:

$$(\gamma_j^x)^{1-\psi}\hat{\gamma}_{j,t}^x - \sum_{k=1}^{\mathcal{F}} \omega_{k,j}(\gamma_k)^{1-\psi}\hat{\gamma}_{k,t} = 0 \tag{A.126}$$

Labour demand in sector j:

$$\hat{y}_{j,t}^{va} - \zeta\hat{w}_{j,t} + \zeta\hat{\gamma}_{j,t}^{va} - \hat{n}_{j,t} = 0 \tag{A.127}$$

Capital demand in sector j:

$$\hat{y}_{j,t}^{va} - \zeta\hat{r}_{j,t}^k + \zeta\hat{\gamma}_{j,t}^{va} = \hat{k}_{j,t} \tag{A.128}$$

Intermediate good k demand in sector j:

$$\hat{x}_{j,t} - \hat{x}_{kj,t} - \psi\hat{\gamma}_{k,t} + \psi\hat{\gamma}_{j,t}^x = 0 \tag{A.129}$$

Definition of relative price in sector j:

$$\hat{\gamma}_{j,t} - \hat{\pi}_{j,t} + \hat{\pi}_t = \hat{\gamma}_{j,t-1} \tag{A.130}$$

Phillips curve in sector j:

$$\hat{\pi}_{j,t} - \frac{\beta}{1+\beta\chi_p}E_t\{\hat{\pi}_{j,t+1}\} - \frac{(1-\theta)(1-\beta\theta)}{\theta(1+\beta\chi_p)}\hat{mc}_{j,t} = \frac{\chi_p}{1+\beta\chi_p}\hat{\pi}_{j,t-1} \tag{A.131}$$

Link between wage inflation and real wages in sector j:

$$\pi_{j,t}^w - w_{j,t} - \pi_t = -w_{j,t-1} \tag{A.132}$$

Market clearing in sector j:

$$y_j\hat{y}_{j,t} - \epsilon_{j,t}^\kappa - c_j\hat{c}_{j,t} - i_j\hat{i}_{j,t} - g_j\hat{g}_{j,t} - \sum_{k=1}^{\mathcal{F}} x_{jk}\hat{x}_{jk,t} = 0 \tag{A.133}$$

Monetary policy rule for headline inflation targeting:

$$\hat{r}_t - (1-\rho_r)(\phi_\pi\hat{\pi}_t + \phi_{gap}\hat{gap}_t) + \varepsilon_{r,t} = \rho_r\hat{r}_{t-1} \tag{A.134}$$

Monetary policy rule for core inflation targeting:

$$\hat{r}_t - (1-\rho_r)(\phi_\pi \hat{\pi}_{s,t} + \phi_{gap} g\hat{a}p_t) + \varepsilon_{r,t} = \rho_r \hat{r}_{t-1} \tag{A.135}$$

Monetary policy rule for average inflation targeting:

$$\hat{r}_t - (1-\rho_r)(\phi_\pi \hat{0}\bar{\pi}_{s,t} + \phi_{gap} g\hat{a}p_t) + \varepsilon_{r,t} = \rho_r \hat{r}_{t-1} \tag{A.136}$$

The average inflation target is measured as

$$\bar{\hat{\pi}}_t = \frac{1}{n^{AIT}} \sum_{i=0}^{n^{AIT}-1} \hat{\pi}_{t-i} \tag{A.137}$$

Output gap:

$$g\hat{a}p_t = \hat{y}_t - \hat{y}_t^{flex} \tag{A.138}$$

Additional aggregate variables:

Year-ended inflation:

$$\hat{\pi}_t^{ye} = \hat{\pi}_t + \hat{\pi}_{t-1} + \hat{pi}_{t-2} + \hat{\pi}_{t-3} \tag{A.139}$$

Aggregate value added:

$$y_t^{va} - \sum_{j=1}^{\mathcal{F}} nva_j \hat{y}^v a_{j,t} = 0 \tag{A.140}$$

where nva_j is the steady-state share of sector j in nominal GDP.

Shock processes:

Productivity in sector j:

$$\hat{a}_{j,t} = \rho_{aj} \hat{a}_{j,t-1} + \varepsilon_{aj,t} \tag{A.141}$$

Aggregate government expenditure:

$$\hat{g}_t = \rho_g \hat{g}_{t_1} + \varepsilon_{gt} \tag{A.142}$$

Transfers:

$$trans_t = \rho_{trans} trans_{t-1} + \varepsilon_{trans,t} \tag{A.143}$$

B Calibration

B.1 Production network

B.1.1 Data sources

Table B.1: Data sources

Variable		Data	Source	Detail	Period
Share of industry-specific intermediate inputs	$\omega_{k,j}$	I-O tables by economy	ADB	Multi-Regional Input-Output tables (MRIO) at current prices	2019
Share of industry-specific consumption	ω_{cj}		OECD	Inter-Country Input-Output tables (ICIO)	2019
Share of industry-specific investment	ω_{ij}				
Share of industry-specific government spending	ω_{gj}		US BEA	The Use of Commodities by Industries – Summary	2019
Weight of capital by industry	$(1-\omega_{f,j})$	I-O table for the US	US BEA	The Use of Commodities by Industries – Summary	2019
Weight of labour by industry	$\omega_{f,j}$				
Share of industry-specific labour supply	$\omega_{n,j}$	Employment for the US	US BLS	Employment Projections - Employment and output by industry	2019

Table B.2: Data used in moment matching exercise

Variable	Source
GDP	National data
Inflation	National data
Core inflation	OECD; LSEG Datastream; national data
Interest rate	Federal Reserve Bank of St.Louis, FRED; national data
Real value added (for manufacturing and mining industries)	OECD; LSEG Datastream
Gross output deflator (for manufacturing and mining industries)	OECD; LSEG Datastream
Oil price in local currency	LSEG Datastream; national data

B.1.2 List of economies

Table B.3: List of economies by source

ADB MRIO		OECD ICIO	
-	KG: Kyrgyz Republic	AR: Argentina	-
AT: Austria	KH: Cambodia	AT: Austria	KH: Cambodia
AU: Australia	KR: Korea	AU: Australia	KR: Korea
BD: Bangladesh	KZ: Kazakhstan	BD: Bangladesh	KZ: Kazakhstan
BE: Belgium	LA: Laos	BE: Belgium	LA: Laos
BG: Bulgaria	LK: Sri Lanka	BG: Bulgaria	-
BN: Brunei	LT: Lithuania	BN: Brunei	LT: Lithuania
BR: Brazil	LU: Luxembourg	BR: Brazil	LU: Luxembourg
BT: Bhutan	LV: Latvia	-	LV: Latvia
-	-	BY: Belarus	MA: Morocco
CA: Canada	-	CA: Canada	MM: Myanmar
CH: Switzerland	MN: Mongolia	CH: Switzerland	-
-	MT: Malta	CI: Côte d'Ivoire	MT: Malta
-	MV: Maldives	CL: Chile	-
-	MX: Mexico	CM: Cameroon	MX: Mexico
CN: China	MY: Malaysia	CN: China	MY: Malaysia
-	-	CO: Colombia	NG: Nigeria
-	NL: Netherlands	CR: Costa Rica	NL: Netherlands
CY: Cyprus	NO: Norway	CY: Cyprus	NO: Norway
CZ: Czechia	NP: Nepal	CZ: Czechia	-
DE: Germany	-	DE: Germany	NZ: New Zealand
DK: Denmark	-	DK: Denmark	PE: Peru
EA: Euro area	PH: Philippines	EA: Euro area	PH: Philippines
EE: Estonia	PK: Pakistan	EE: Estonia	PK: Pakistan
-	PL: Poland	EG: Egypt	PL: Poland
ES: Spain	PT: Portugal	ES: Spain	PT: Portugal
FI: Finland	RO: Romania	FI: Finland	RO: Romania
FJ: Fiji	RU: Russia	-	RU: Russia
FR: France	-	FR: France	SA: Saudi Arabia
GB: United Kingdom	SE: Sweden	GB: United Kingdom	SE: Sweden
GR: Greece	SG: Singapore	GR: Greece	SG: Singapore
HK: Hong Kong	SI: Slovenia	HK: Hong Kong	SI: Slovenia
HR: Croatia	SK: Slovakia	HR: Croatia	SK: Slovakia
HU: Hungary	-	HU: Hungary	SN: Senegal
ID: Indonesia	TH: Thailand	ID: Indonesia	TH: Thailand
IE: Ireland	-	IE: Ireland	TN: Tunisia
-	TR: Türkiye	IL: Israel	TR: Türkiye
IN: India	TW: Chinese Taipei	IN: India	TW: Chinese Taipei
-	-	IS: Iceland	UA: Ukraine
IT: Italy	US: United States	IT: Italy	US: United States
-	VN: Vietnam	JO: Jordan	VN: Vietnam
JP: Japan	-	JP: Japan	ZA: South Africa

B.1.3 List of industries

Table B.4: List of industries - OECD ICIO

Industry group (18)	**Components**
Agriculture	Agriculture, hunting, forestry Fishing and aquaculture
Mining	Mining and quarrying, energy producing products Mining and quarrying, non-energy producing products Mining support service activities
Manufacturing	Food products, beverages and tobacco Textiles, textile products, leather and footwear Wood and products of wood and cork Paper products and printing Coke and refined petroleum products Chemical and chemical products Pharmaceuticals, medicinal chemical and botanical products Rubber and plastics products Other non-metallic mineral products Basic metals Fabricated metal products Computer, electronic and optical equipment Electrical equipment Machinery and equipment, nec Motor vehicles, trailers and semi-trailers Other transport equipment Manufacturing not elsewhere classified (nec); repair and installation of machinery and equipment
Utilities	Electricity, gas, steam and air conditioning supply Water supply; sewerage, waste management and remediation activities
Construction	Construction
Wholesale and retail	Wholesale and retail trade; repair of motor vehicles
Transport	Land transport and transport via pipelines Water transport Air transport Warehousing and support activities for transportation Postal and courier activities
Recreation	Accommodation and food service activities
Information	Publishing, audiovisual and broadcasting activities Telecommunications IT and other information services
Finance	Financial and insurance activities
Real Estate	Real estate activities
Professional	Professional, scientific and technical activities
Administration	Administrative and support services
Government	Public administration and defense, compulsory social security
Education	Education
Health	Human health and social work activities
Arts	Arts, entertainment and recreation
Other	Other service activities Activities of households as employers, undifferentiated goods- and services-producing activities of households for own use

Table B.5: List of industries - ADB MRIO

Industry group (16)	**Components**
Agriculture	Agriculture, hunting, forestry, and fishing
Mining	Mining and quarrying
Manufacturing	Food, beverages, and tobacco Textiles and textile products Leather, leather products, and footwear Wood and products of wood and cork Pulp, paper, paper products, printing, and publishing Coke, refined petroleum, and nuclear fuel Chemicals and chemical products Rubber and plastics Other nonmetallic minerals Basic metals and fabricated metal Machinery, nec Electrical and optical equipment Transport equipment Manufacturing, nec; recycling
Utilities	Electricity, gas, and water supply
Construction	Construction
Retail	Sale, maintenance, and repair of motor vehicles and motorcycles; retail sale of fuel Retail trade, except of motor vehicles and motorcycles; repair of household goods
Wholesale	Wholesale trade and commission trade, except of motor vehicles and motorcycles
Recreation	Hotels and restaurants
Transport	Inland transport Water transport Air transport Other supporting and auxiliary transport activities; activities of travel agencies
Information	Post and telecommunications
Finance	Financial intermediation
Real Estate	Real estate activities Renting of machinery and equipment and other business activities
Government	Public administration and defense; compulsory social security
Education	Education
Health	Health and social work
Other	Other community, social, and personal services Private households with employed persons

Table B.6: List of industries - US BLS employment

Industry group (18)	**Components**
Agriculture	Crop production Animal production and aquaculture Forestry Logging Fishing, hunting and trapping Support activities for agriculture and forestry
Mining	Oil and gas extraction Coal mining Metal ore mining Nonmetallic mineral mining and quarrying Support activities for mining
Utilities	Electric power generation, transmission and distribution Natural gas distribution Water, sewage and other systems
Construction	Construction
Manufacturing	Animal food manufacturing Grain and oilseed milling Sugar and confectionery product manufacturing Fruit and vegetable preserving and specialty food manufacturing Dairy product manufacturing Animal slaughtering and processing Seafood product preparation and packaging Bakeries and tortilla manufacturing Other food manufacturing Beverage and tobacco manufacturing Textile mills and textile product mills Apparel, leather and allied product manufacturing Sawmills and wood preservation Veneer, plywood, and engineered wood product manufacturing Other wood product manufacturing Pulp, paper, and paperboard mills Converted paper product manufacturing Printing and related support activities Petroleum and coal products manufacturing Basic chemical manufacturing Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing Pesticide, fertilizer, and other agricultural chemical manufacturing Pharmaceutical and medicine manufacturing Paint, coating, and adhesive manufacturing Soap, cleaning compound, and toilet preparation manufacturing Other chemical product and preparation manufacturing Plastics product manufacturing Rubber product manufacturing Clay product and refractory manufacturing Glass and glass product manufacturing Cement and concrete product manufacturing

(Continued in the next page)

Table B.6: List of industries - US BLS employment *(Continued from the previous page)*

Industry group (18)	**Components**
	Lime, gypsum and other nonmetallic mineral product manufacturing
	Iron and steel mills and ferroalloy manufacturing
	Steel product manufacturing from purchased steel
	Alumina and aluminum production and processing
	Nonferrous metal (except aluminum) production and processing
	Foundries
	Forging and stamping
	Cutlery and handtool manufacturing
	Architectural and structural metals manufacturing
	Boiler, tank, and shipping container manufacturing
	Hardware manufacturing
	Spring and wire product manufacturing
	Machine shops; turned product; and screw, nut, and bolt manufacturing
	Coating, engraving, heat treating, and allied activities
	Other fabricated metal product manufacturing
	Agriculture, construction, and mining machinery manufacturing
	Industrial machinery manufacturing
	Commercial and service industry machinery manufacturing
	Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing
	Metalworking machinery manufacturing
	Engine, turbine, and power transmission equipment manufacturing
	Other general purpose machinery manufacturing
	Computer and peripheral equipment manufacturing, excluding digital camera manufacturing
	Communications equipment manufacturing
	Audio and video equipment manufacturing
	Semiconductor and other electronic component manufacturing
	Navigational, measuring, electromedical, and control instruments manufacturing
	Manufacturing and reproducing magnetic and optical media
	Electric lighting equipment manufacturing
	Household appliance manufacturing
	Electrical equipment manufacturing
	Other electrical equipment and component manufacturing
	Motor vehicle manufacturing
	Motor vehicle body and trailer manufacturing
	Motor vehicle parts manufacturing
	Aerospace product and parts manufacturing
	Railroad rolling stock manufacturing
	Ship and boat building
	Other transportation equipment manufacturing
	Household and institutional furniture and kitchen cabinet manufacturing
	Office furniture (including fixtures) manufacturing
	Other furniture related product manufacturing
	Medical equipment and supplies manufacturing
	Other miscellaneous manufacturing
Wholesale and retail	Wholesale trade
	Motor vehicle and parts dealers
	Food and beverage retailers
	General Merchandise retailers

(Continued in the next page)

Table B.6: List of industries - US BLS employment *(Continued from the previous page)*

Industry group (18)	**Components**
	All other retail
Transport	Air transportation
	Rail transportation
	Water transportation
	Truck transportation
	Transit and ground passenger transportation
	Pipeline transportation
	Scenic and sightseeing transportation and support activities for transportation
	Couriers and messengers
	Warehousing and storage
Information	Newspaper, periodical, book, and directory publishers
	Software publishers
	Motion picture and sound recording industries
	Radio and television broadcasting, media streaming distribution services, social networks, and other media networks and content providers
	Wired telecommunications carriers
	Wireless telecommunications carriers (except satellite)
	Satellite, telecommunications resellers, and all other telecommunications
	Computing infrastructure providers, data processing, web hosting, and related service
	Web search portals, libraries, archives, and other information services
Finance	Monetary authorities - central bank, credit intermediation, and related activities
	Securities, commodity contracts, investments, and funds and trusts
	Insurance carriers
	Agencies, brokerages, and other insurance related activities
Real estate	Real estate
	Automotive equipment rental and leasing
	Consumer goods rental and general rental centers
	Commercial and industrial machinery and equipment rental and leasing
	Lessors of non-financial intangible assets (except copyrighted works)
Professional	Legal services
	Accounting, tax preparation, bookkeeping, and payroll services
	Architectural, engineering, and related services
	Specialized design services
	Computer systems design and related services
	Management, scientific, and technical consulting services
	Scientific research and development services
	Advertising, public relations, and related services
	Other professional, scientific, and technical services
	Management of companies and enterprises
Administration	Office administrative services
	Facilities support services
	Employment services
	Business support services
	Travel arrangement and reservation services
	Investigation and security services
	Services to buildings and dwellings

(Continued in the next page)

Table B.6: List of industries - US BLS employment *(Continued from the previous page)*

Industry group (18)	**Components**
	Other support services Waste management and remediation services
Education	Elementary and secondary schools; private Junior colleges, colleges, universities, and professional schools; private Other educational services; private
Health	Offices of physicians Offices of dentists Offices of other health practitioners Outpatient care centers Medical and diagnostic laboratories Home health care services Other ambulatory health care services Hospitals Nursing and residential care facilities Individual and family services Community food and housing, emergency and other relief services, and vocational rehabilitation services Child day care services
Arts	Performing arts companies Spectator sports Arts and sports promoters and agents and managers for public figures Independent artists, writers, and performers Museums, historical sites, and similar institutions Amusement parks and arcades Gambling industries (except casino hotels) Other amusement and recreation industries
Recreation	Accommodation Food services and drinking places
Other	Automotive repair and maintenance Electronic and precision equipment repair and maintenance Commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance Personal and household goods repair and maintenance Personal care services Death care services Drycleaning and laundry services Other personal services Religious organizations Grantmaking and giving services and social advocacy organizations Civic, social, professional, and similar organizations Private households
Government	Federal general government defense Federal general government nondefense Postal Service Federal electric utilities Other federal government enterprises

(Continued in the next page)

Table B.6: List of industries - US BLS employment *(Continued from the previous page)*

Industry group (18)	Components
	State and local government educational services
	State and local government hospitals and health services
	State and local government other services
	State and local government passenger transit
	State and local government electric utilities
	Other state and local government enterprises

C Additional charts

C.1 Temporary energy price shock: country-specific results

Figure C.1: Temporary energy price shock: Euro area

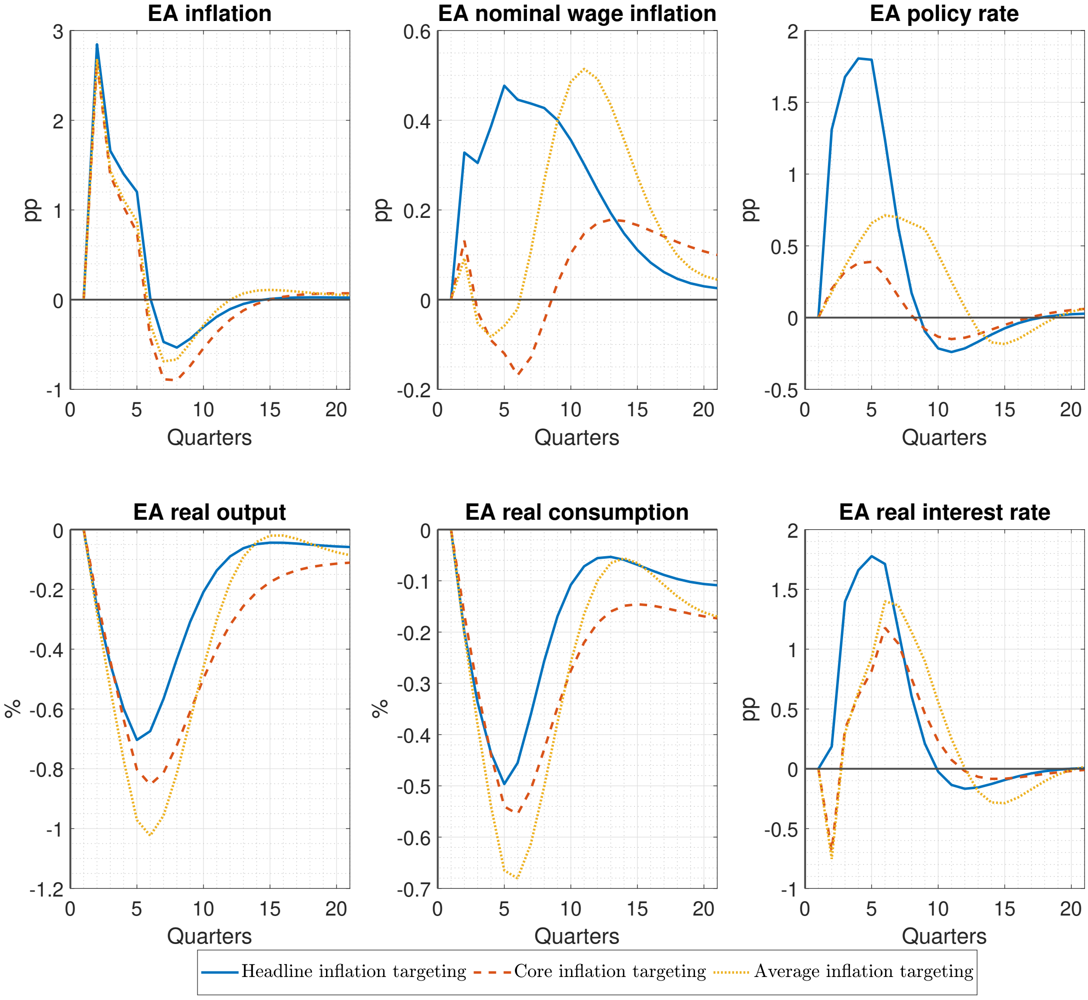


Figure C.2: Temporary energy price shock: Australia

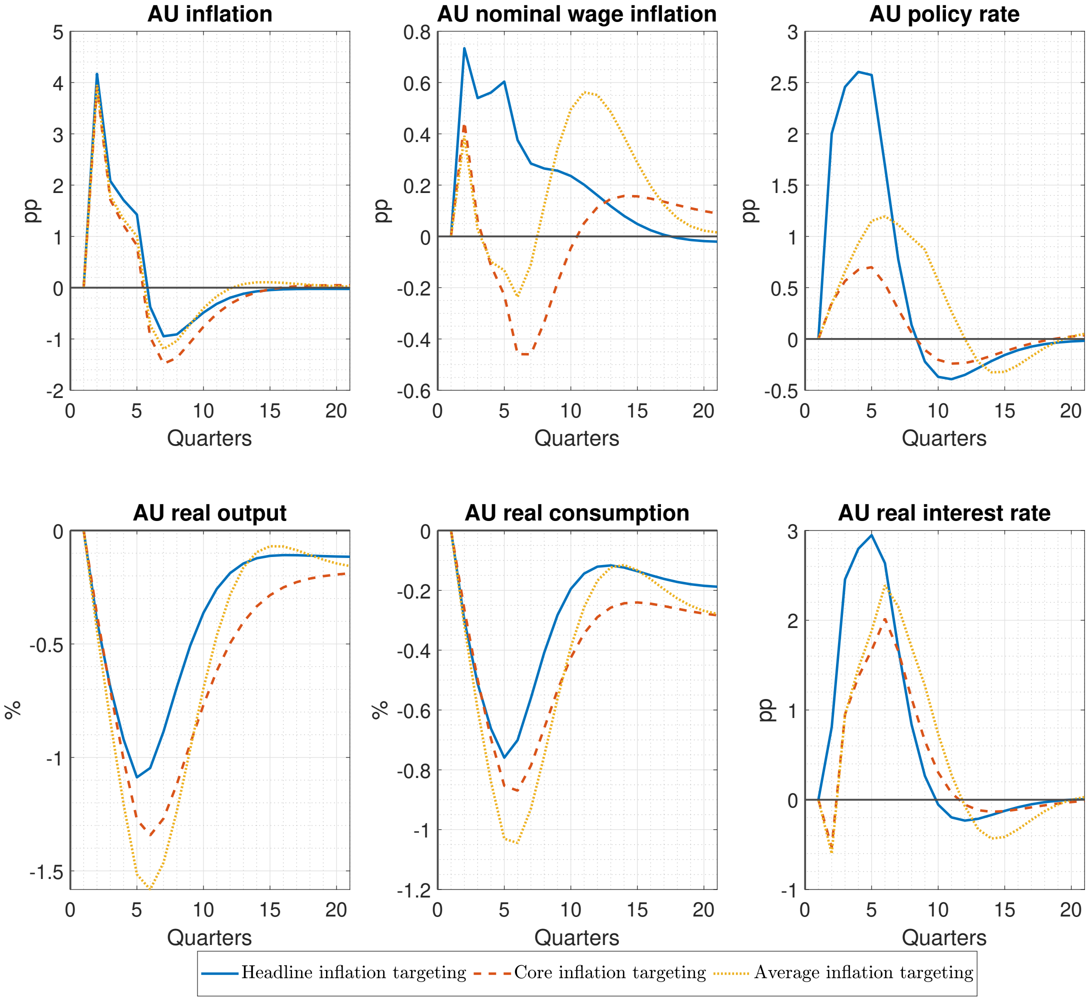


Figure C.3: Temporary energy price shock: Philippines

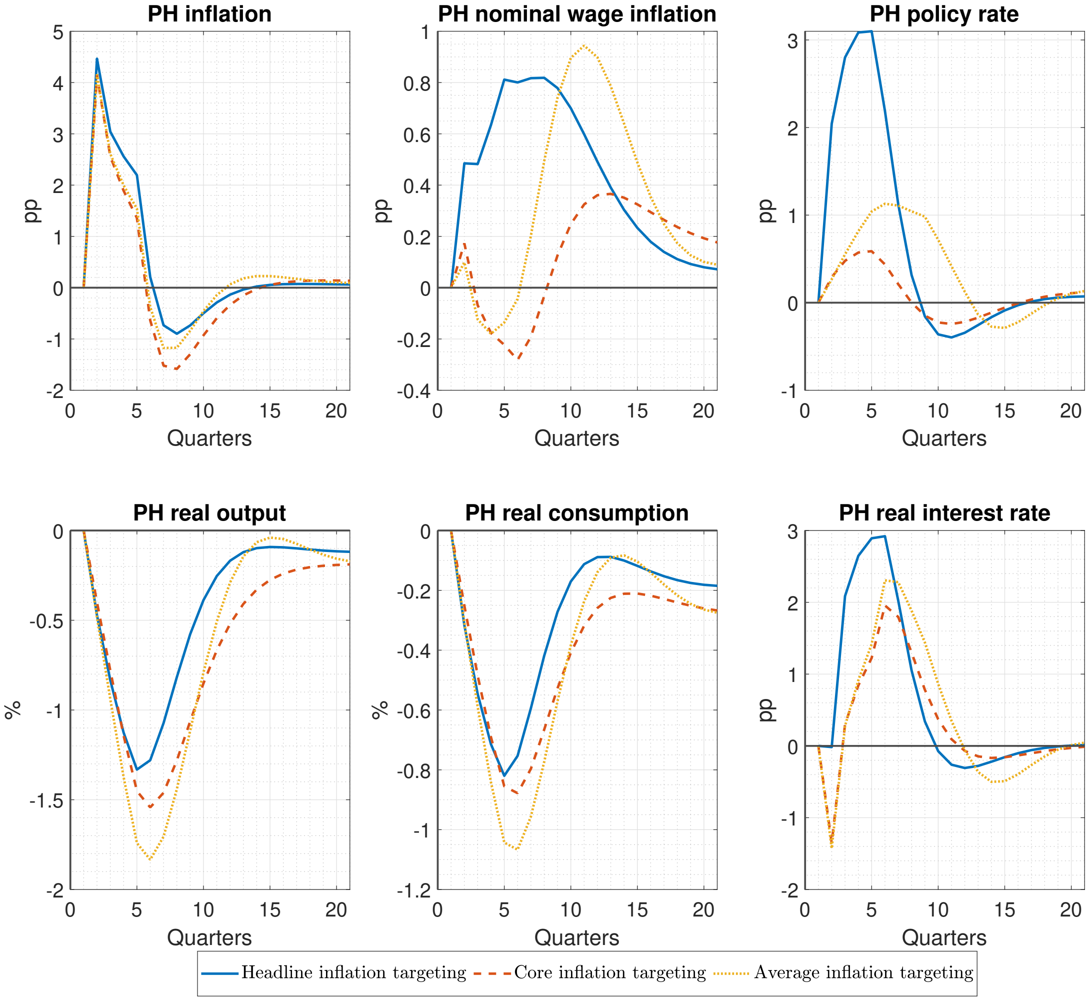


Figure C.4: Temporary energy price shock: Thailand

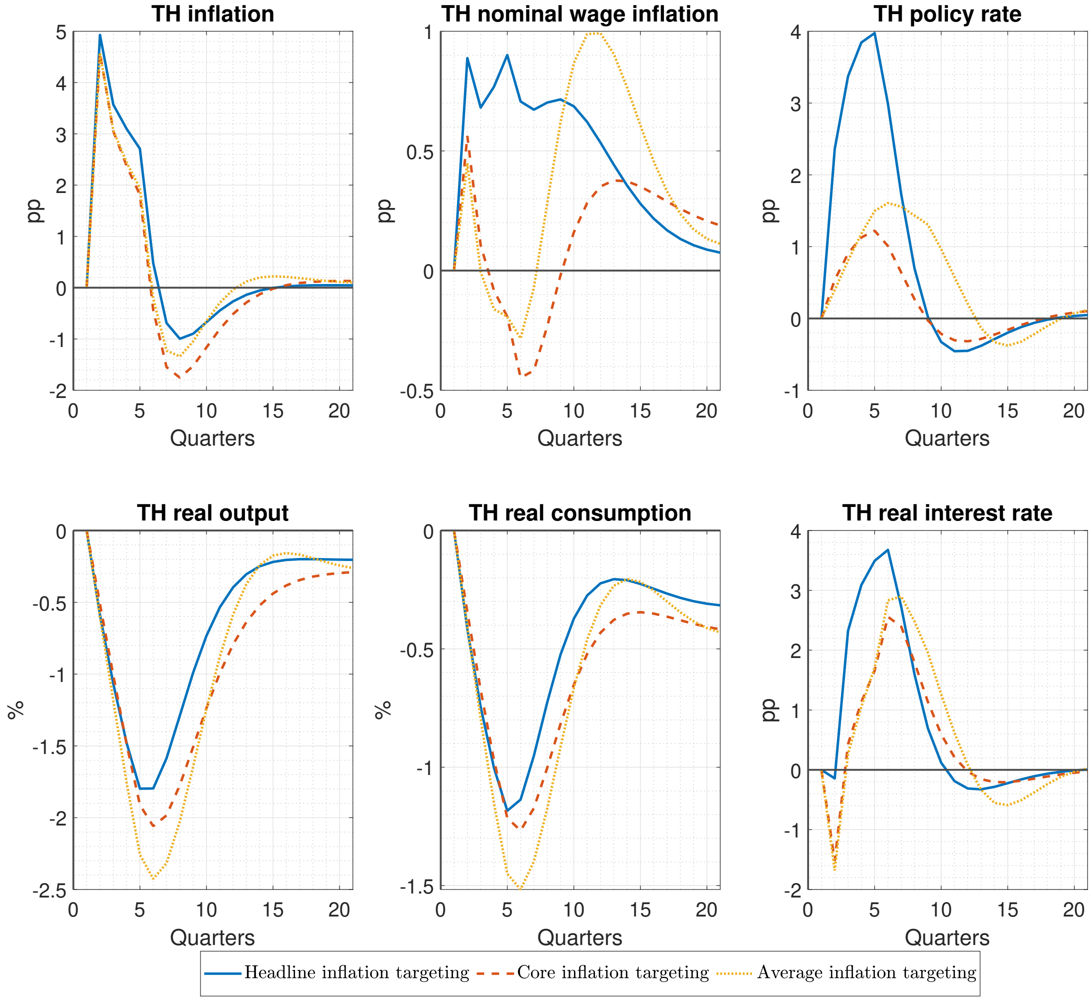
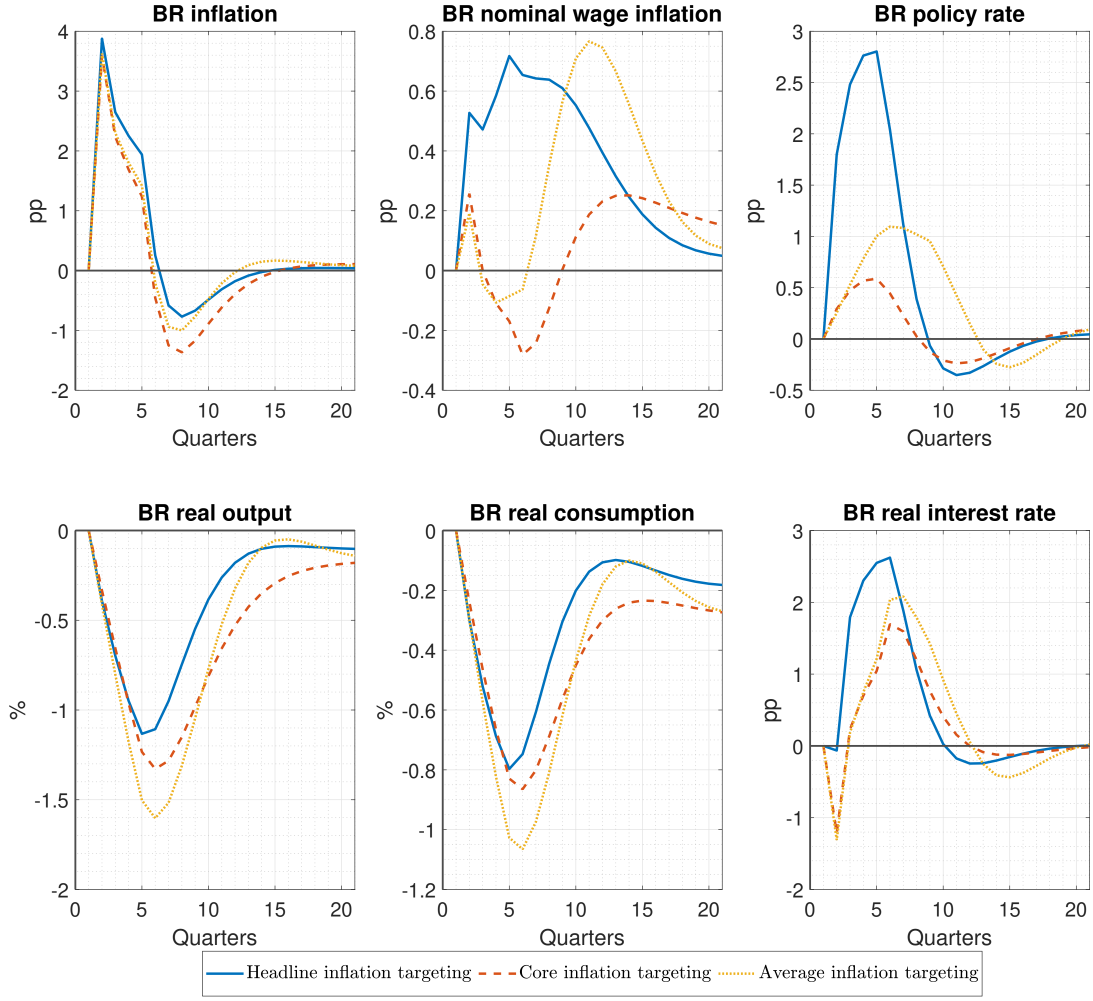


Figure C.5: Temporary energy price shock: Brazil



C.2 Permanent energy transition: country-specific results

Figure C.6: Permanent energy transition: Euro area

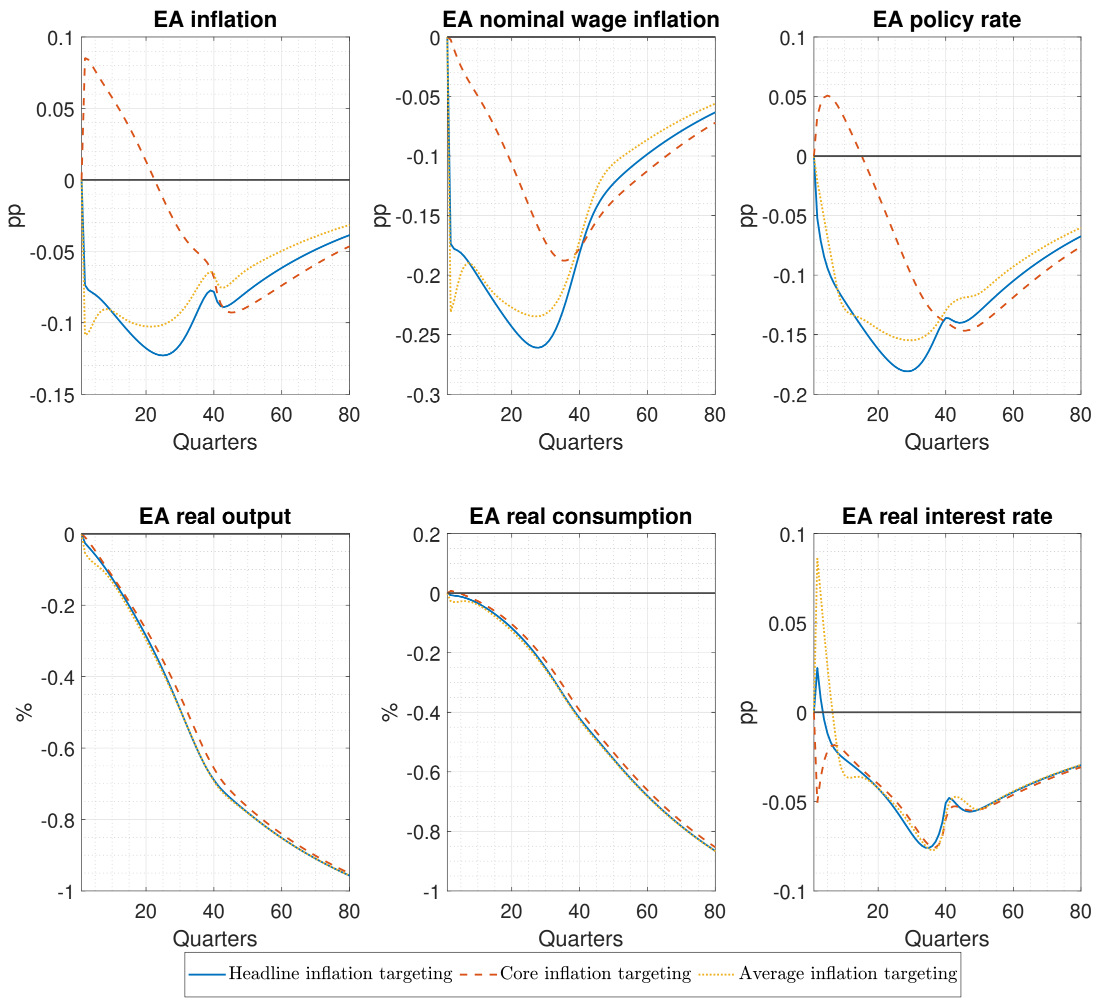


Figure C.7: Permanent energy transition: Australia

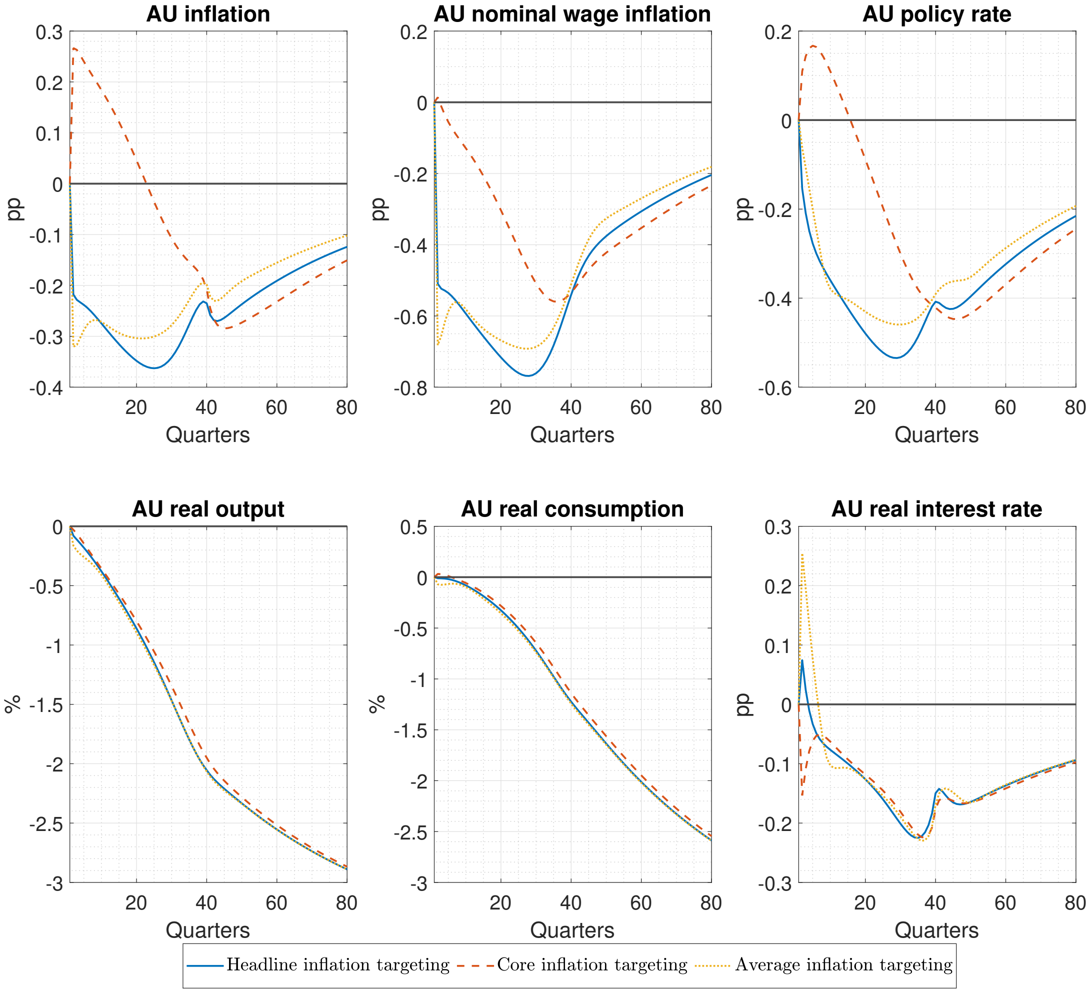


Figure C.8: Permanent energy transition: Philippines

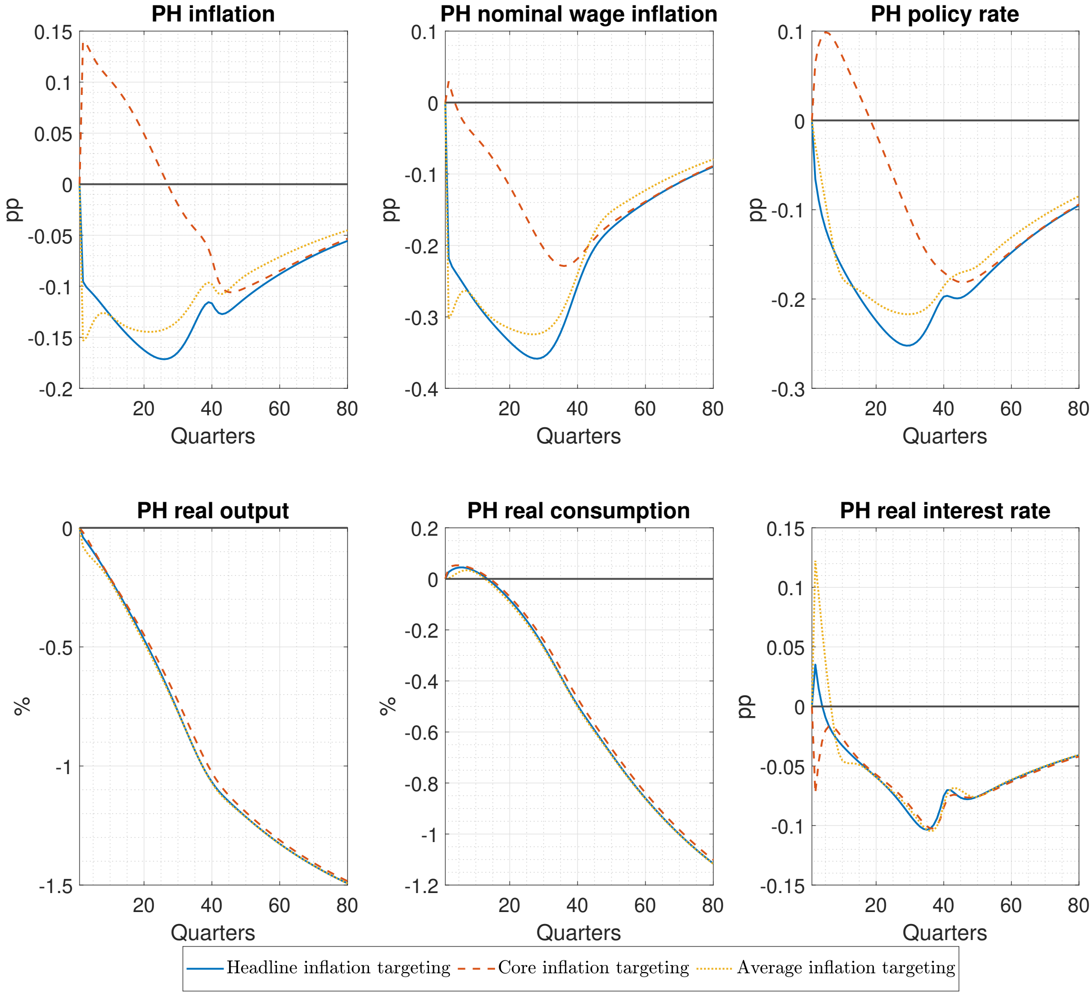


Figure C.9: Permanent energy transition: Thailand

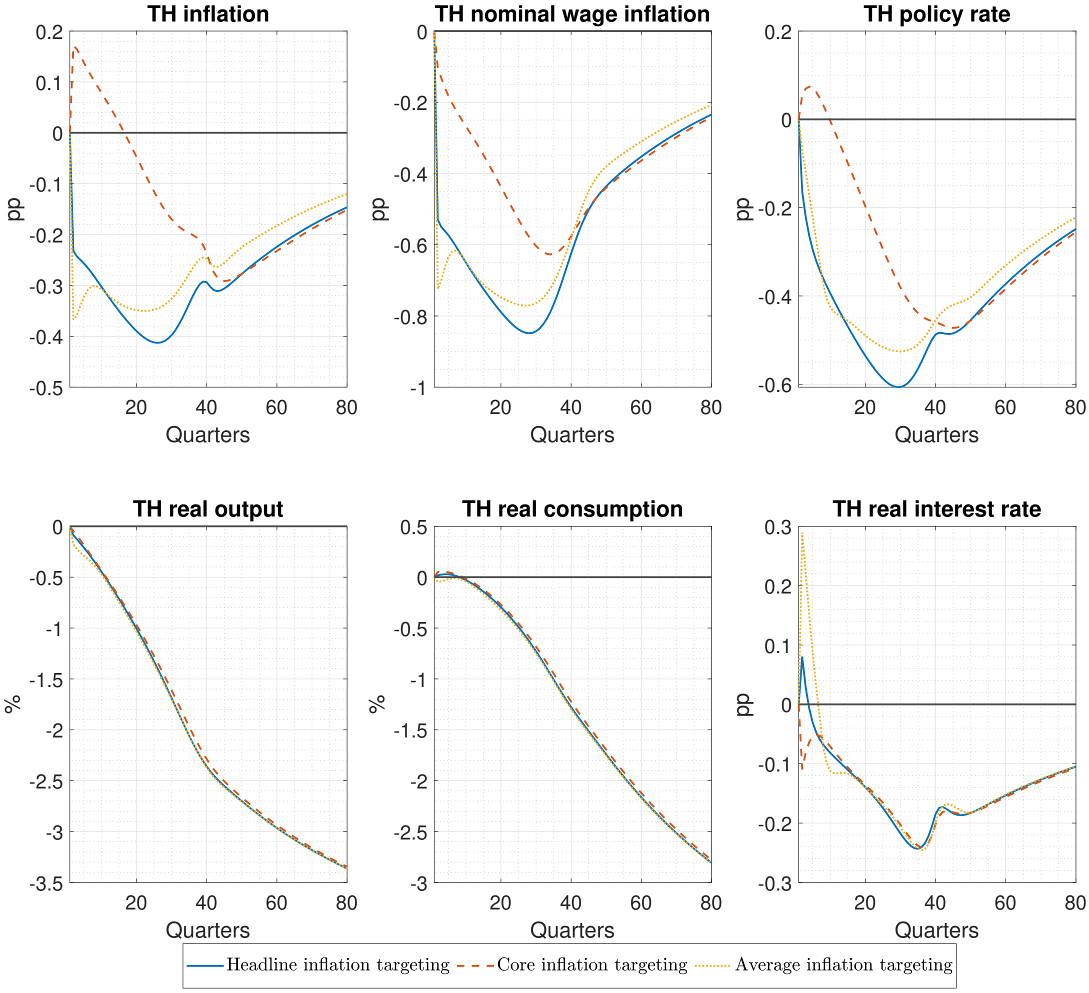
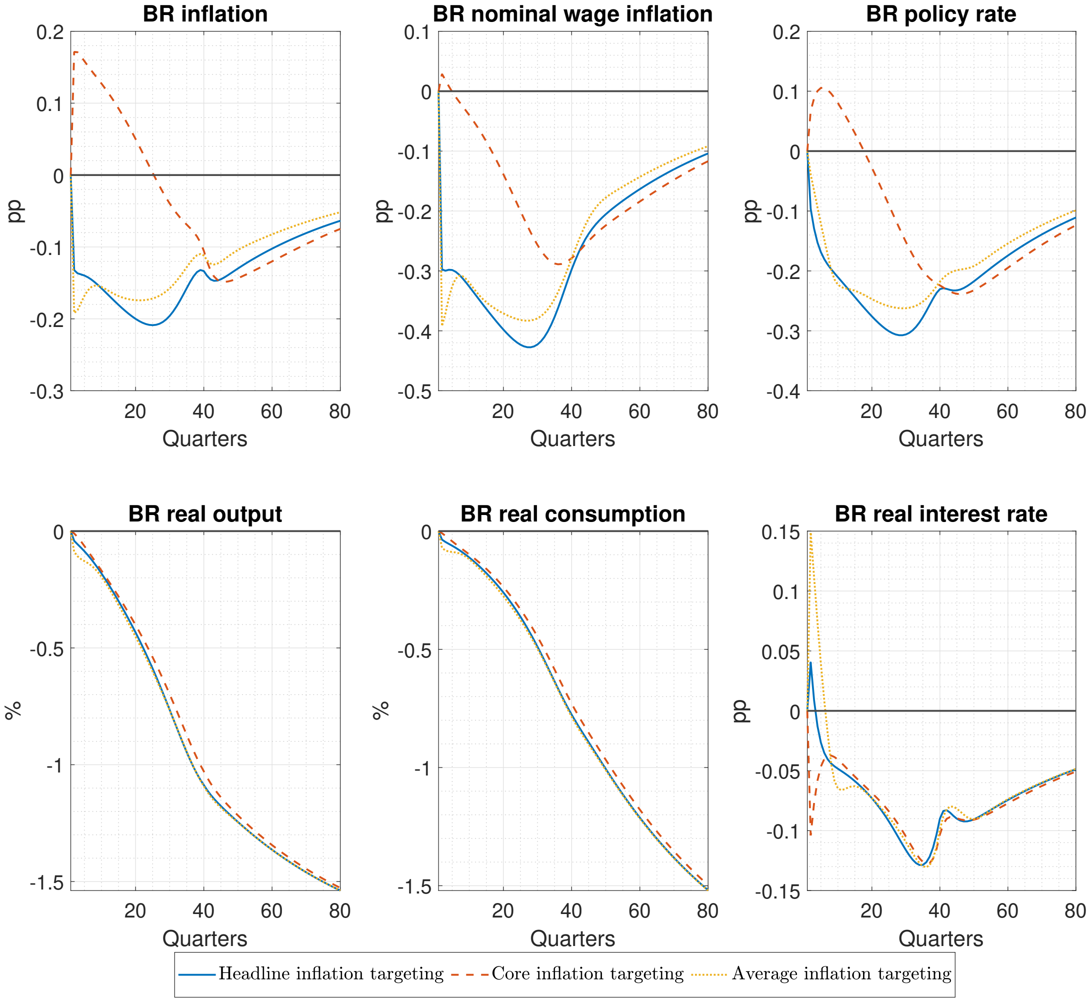


Figure C.10: Permanent energy transition: Brazil



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