UNIVERSITY OF COPENHAGEN
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# Master's Thesis

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# The Unequal Burden of a Safe Haven

**Distributional Effects of the Swiss Franc Shock**

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Submitted on: July 21, 2025

**Abstract**

This thesis examines how heterogeneity in household consumption baskets affects the transmission of exchange rate shocks across the income distribution. Motivated by empirical evidence from Auer et al. (2024), which shows that higher-income households devote a larger share of spending to imported goods, the analysis uses a small open economy Heterogeneous Agent New Keynesian (SOE-HANK) model with nominal wage rigidities, extended to incorporate non-homothetic Stone–Geary preferences. In this framework, poorer households are closer to a minimum consumption threshold for imported goods and thus exhibit higher substitution elasticities in response to changes in relative prices. Richer households, whose import demand exceeds this threshold, adjust less.

The model is used to simulate an expansionary foreign interest rate shock that lowers the relative price of imports. The results show differences in households' expenditure-switching behavior, with poorer households exhibiting a stronger substitution response. The baseline model is then extended to allow for incomplete pass-through of exchange rate changes into import prices, drawing on related evidence from Auer et al. (2021). Under imperfect pass-through, relative price signals are muted, significantly weakening the expenditure-switching response and in addition diluting the non-homothetic effects. As a result, poorer households who are unable to substitute as effectively, bear a larger share of the adjustment burden.

*I thank my supervisor, Nicolai Waldstrøm, for valuable supervision, patient guidance, and for always being available throughout the entire period.

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# Chapter 1

# Introduction

Understanding how external shocks, such as exchange rate fluctuations, affect household consumption has long been a central question in international macroeconomics. A growing body of literature highlights that heterogeneity in household consumption baskets can have important implications for the distributional consequences of such shocks, particularly through differences in expenditure-switching behavior across the income distribution. As emphasized by Jaravel (2021), in the context of external shocks that induce price changes, there are several channels that must be considered to understand the distributional effects of trade or exchange rate shocks, including heterogeneity in import shares, expenditure switching, and variation in import price pass-through. In a recent work, Auer et al. (2024) show that high-income households in Switzerland devote a significantly larger share of their consumption to imported goods. In addition, their study provides evidence of income-based heterogeneity in the price elasticity of import demand, with low-income households being more responsive to changes in relative prices. This heterogeneity in price sensitivity implies that external shocks can generate distributional effects through differences in households' expenditure-switching behaviour. This mechanism is particularly relevant in the context of a major exchange rate shock, such as the Swiss franc appreciation episode in 2015, which led to substantial fluctuations in relative prices.

This thesis takes the empirical findings of Auer et al. (2024) as a starting point and incorporates non-homothetic preferences into a standard New Keynesian open economy (SOE-HANK) model featuring heterogenous agents subject to borrowing constraints and nominal wage rigidities to better capture the unequal expenditure-switching responses observed across income groups. Specifically, Stone–Geary preferences are incorporated to introduce a minimum consumption threshold for imported goods not as a subsistence necessity, but as a luxury benchmark. Reformulating the preferences in this way helps capture their empirical findings such that low-income households who tend to be closer to this threshold exhibit higher substitution elasticities, responding more strongly to relative price changes induced by exchange rate shocks. In contrast, high-income households, whose import consumption is well above the threshold, are less responsive.

The model is calibrated to match the empirical evidence on import shares and substitution elasticities across the income distribution, as presented in their paper. I then use this framework to study the propagation of a foreign interest rate shock that mimics the sharp appreciation of the Swiss franc, referred to by the authors as a "Swiss franc shock". In the model, the channels through which an exchange rate shock affects household consumption can be classified into three: a direct effect through changes in real interest rates, an indirect effect through changes in real labour income, and a price effect, which has both direct and indirect effects. In addition, the presence of non-homotheticity in household consumption baskets implies that additional price effects arise, depending on how close households are to the non-homothetic threshold.

The baseline model is then extended to allow for imperfect import price pass-through, drawing on related evidence by the authors (Auer et al., 2021), who provide evidence that this has implications for households' expenditure-switching behavior and the composition of their consumption baskets. I simulate a foreign interest rate shock and conduct the same exercise. The results show that, compared to a case with full import price pass-through where households engage in expenditure switching at different magnitudes depending on their income level, imperfect pass-through has a disproportionately negative effect on poorer households. The expenditure switching is significantly weakened, diluting the non-homothetic effects that arise under perfect pass-through.

The rest of the thesis is structured as follows. Chapter 2 reviews the literature on heterogeneous agents in open economy macroeconomics. Chapter 3 motivates the modeling approach and introduces the Stone-Geary preference specification. Chapter 4 outlines the structure and calibration of the open economy HANK model and analyzes the effects of a foreign interest rate shock on household consumption, with a focus on the behaviour of expenditure switching across income groups. Chapter 5 extends the model by incorporating imperfect pass-through into import prices and compares the resulting consumption responses to those under the baseline model. Chapter 6 discusses some robustness considerations and the implications of modeling assumptions. Chapter 7 concludes.

# Chapter 2

# Literature Review

In this chapter, I provide an overview of the growing strand of theoretical literature within international macroeconomics that introduces heterogeneous agents and incomplete markets into the analysis of open economy issues.

There is an expanding literature that studies the effects of external shocks in open economies. Guo et al. (2023) studies the distributional effects of monetary policy shocks when households differ in their level of financial integration, and finds that this heterogeneity is an important factor in explaining consumption inequality. Zhou (2022) decomposes the consumption response and identifies the different channels that drive household behavior, following the approach of Auclert (2019), by extending it to an open economy framework. Specifically, he focuses on the revaluation of wealth through household balance sheets denominated in foreign currency,a mechanism he refers to as the foreign currency Fisher channel, which becomes relevant in the context of exchange rate shocks. In addition, he identifies a consumption heterogeneity channel and an earnings heterogeneity channel. The former captures how changes in relative prices can have redistributive implications across households with different marginal propensities to consume (MPC), due to differences in their spending shares on various goods. The latter operates through differences in the sectors where agents are employed. High-MPC households tend to work in tradable sectors and are therefore more exposed to currency fluctuations through their labor income. The consumption heterogeneity channel identified in the literature is also explored in this thesis.

Oskolkov (2023) compares how shocks transmit differently under alternative exchange rate regimes when households differ in their sector of employment, and thus bear the brunt of the adjustment through the interest and labor income channels in the context of sudden stops. The latter mechanism also corresponds to the earnings heterogeneity channel discussed earlier. Druedahl et al. (2022) studies the transmission of foreign demand shocks in HANK and RANK models, and finds that while monetary policy can serve as an important stabilisation tool in the face of such shocks, fiscal policy can be unsuitable in this aspect.

This thesis also relates to the literature that models non-homotheticities in household consumption behaviour and explores how external shocks translate into unequal outcomes across households. Carroll and Hur (2020) build a trade model with non-homothetic preferences and calibrate it to their empirical findings, such that poorer households have a higher expenditure share on tradables. They then use this model to compute the differences in welfare gains, finding that poorer households experience much larger welfare gains, highlighting that these are largely driven by differences in expenditure-switching behaviour. Otten (2021) also draws on these estimates to analyse the implications of demand non-homotheticities under different exchange rate regimes. Pieroni (2023) studies the effects of an energy supply shock in a model where households exhibit non-homothetic demand for energy goods. Along the same lines, Bobasu et al. (2025) examine how monetary policy shapes the aggregate and distributional effects of an energy price shock.

Another strand of the literature that examines the heterogeneous effects of exchange rate shocks has focused on emerging markets, where large devaluation episodes are more frequent. Cravino and Levchenko (2017) examines the unequal inflationary burden that exchange rate devaluations impose on households across the income distribution, through the lens of the 1995 Mexican peso crisis. They show that differences in consumption baskets across income groups imply unequal exposure to exchange rate induced price changes. Cugat et al. (2019) also takes the Mexican crisis as a starting point and builds a two-sector open economy model in a two-agent framework, closely calibrated to the Mexican economy, and investigates the distributional effects of sectoral income shocks. Ferrante and Gornemann (2022) consider the redistributive role of currency mismatch between households' dollar-denominated bank deposits and banks' foreign currency debt in the event of an exchange rate depreciation. De Ferra et al. (2020) focus on the household balance sheet channel and the subsequent revaluation of wealth that occurred during the Hungarian devaluation episode, where the majority of household debt was leveraged in foreign currency.

Finally, this thesis also draws on the literature that studies the relationship between exchange rate movements and prices. Large exchange rate shock episodes have long provided useful starting points for several empirical papers that examine the interaction between prices and exchange rates and their effects on consumer behaviour.[1] The paper by Cravino and Levchenko (2017), mentioned earlier, is also relevant here. They compute income-specific price indices using detailed microdata and find that poor households experienced a larger increase in their price indices compared to richer households. This implies negative welfare effects for low-income groups through a higher cost of living following the devaluation, since poorer households tend to have a larger share of tradables in their consumption baskets and were therefore more exposed to the relative price changes that resulted from the devaluation. In a more recent study, Auer et al. (2024) use scanner data to estimate income-specific substitution elasticities between goods, exploiting the large relative price changes triggered by the 2015 Swiss Franc appreciation. They find higher substitution elasticities for low-income households, implying that these households experience smaller welfare losses from changes in relative prices induced by external shocks. In a related paper, Auer et al. (2021) provide evidence of imperfect exchange rate pass-through by estimating the response of prices at both the border and retail levels. They find that goods invoiced in euros (EUR) were much more responsive to the Swiss Franc appreciation than those invoiced in Swiss francs (CHF). They also find evidence of expenditure switching toward goods based on the currency of invoicing, showing that households' expenditure shares on imported goods increased more for EUR-invoiced products than for those invoiced in CHF. I draw on the findings of these two papers in this thesis, which will be discussed in more detail in the sections that follow.

[1] See Jaravel (2021) for a review.

# Chapter 3

# Background and Theory

This chapter provides background and outlines the theoretical motivation for the thesis. I first go through the events leading up to the Swiss franc appreciation episode and the nature of macroeconomic policy during this period. I then segue into the findings of Auer et al. (2024) whose analysis focuses on this episode and shows that the expenditure share on imported goods is positively correlated with income. These empirical results are later used in the model calibration and analysis in Section 4.2. Next, I provide an overview of the theoretical framework used in the thesis, explaining how the use of Stone-Geary preferences to capture non-homotheticity in consumption allows the model to better match the empirical findings compared to standard CES specification.

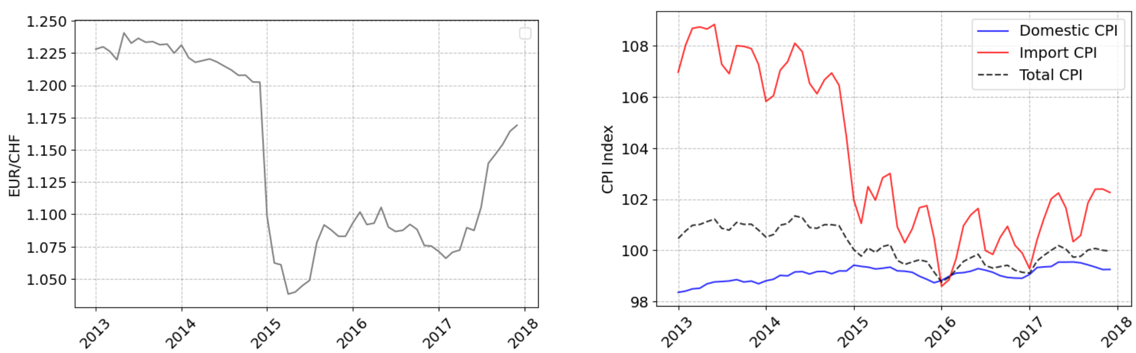
## 3.1 The 2015 Swiss Franc Appreciation

The Swiss franc is widely regarded as a safe haven currency, meaning that it tends to strengthen during periods of global stress. This safe-haven status creates challenges for the Swiss economy, as it leads to appreciation pressures on the franc during crises.[1] This was evident in the exchange rate fluctuations that occurred in the aftermath of the global financial crisis and during the euro area debt crisis, which caused the franc to appreciate sharply, with the EUR/CHF exchange rate falling to nearly 1.0075 in September 2011. With interest rates close to zero and limited room for conventional monetary policy, the Swiss National Bank (SNB) responded by implementing unconventional measures to counter the franc's appreciation through

[1] Grisse and Nitschka (2015) document that the Swiss franc exhibits safe haven characteristics against some currencies, such as the euro, though not consistently against others like the US dollar or the yen.

foreign exchange interventions and the introduction of an exchange rate floor of CHF 1.20 per euro, which was implemented on 6 September 2011 and remained in place until 15 January 2015.

However, in January 2015, the SNB decided to put an end to the peg on the grounds that defending the peg required massive foreign currency purchases and also because it would have to give up its monetary policy independence in the long term.[2] The decision triggered large exchange rate fluctuations and significant price swings across the Swiss economy, causing the CHF to reach a peak intraday appreciation of 41% versus the euro (Cielinska et al. (2017)). Figure 3.1 illustrates the evolution of the exchange rate, import prices, and the domestic consumer price index (CPI) following the removal of the exchange rate floor in January 2015. The left panel shows a sharp appreciation of the Swiss franc against the euro immediately after the announcement. In response, import prices declined significantly, while the overall domestic CPI remained relatively stable.




(a) Exchange rate (EUR/CHF)

(b) CPI components

Figure 3.1: Exchange rate and prices after the 2015 shock.

[2]According to Jordan (2014), "The minimum exchange rate was only ever intended to be an exceptional and temporary measure. It was introduced in September 2011 at a time of extreme uncertainty when the Swiss franc's safe-haven status had caused it to appreciate rapidly and sharply against virtually all currencies."

## 3.2 Household-Level Effects of the Swiss Franc Appreciation: The Role of Unequal Expenditure Switching

Before turning to the full model, I briefly outline the main empirical findings of Auer et al. (2024) in this section, which inform both the calibration and the main analysis conducted in this thesis. The main starting point is the empirical work of Auer et al. (2024), who show that while high-income households have a larger share of imports in their consumption basket, they tend to be less responsive to price changes than low-income households. They find that although the aggregate import share increased across all households, lower-income groups showed a much larger increase following the 2015 Swiss franc appreciation. Table B.1 in Appendix B reports the import share by income group, estimated using Homescan data. Higher-income households have higher aggregate import shares (28%) compared to households in lower income brackets. The authors then estimate the price elasticities across the income distribution. Table B.2 presents the corresponding results from their paper. Their estimates reveal significant heterogeneity in substitution elasticities across income groups, with values rising from 3.0 to 6.6 across the income distribution.

They conclude that these differences in price elasticities across the income distribution contribute significantly to unequal welfare effects. These estimates are used to calibrate a Stone–Geary function to model the non-homotheticity in the consumption basket, which will be detailed below. Building on these insights, my analysis focuses on examining the unequal burden imposed by foreign price shocks induced by exchange rate changes, by accounting for heterogeneity in consumption patterns and the elasticity of substitution, and hence highlights the unequal effects of external shocks through the expenditure channel.

## 3.3 Specification of Preferences

In this section, I describe how using Stone–Geary preferences compared to standard CES preferences helps capture the variation in the elasticity of substitution across households based on their income groups, and hence is a good fit to model the findings of Auer et al. (2024).

### 3.3.1 Homothetic Preferences: Standard CES

The standard Constant Elasticity of Substitution (CES) aggregator has been the most commonly used assumption to model preferences in economic theory. A CES utility function implies that a consumer derives utility from a consumption bundle comprising $n$ different goods, with a constant elasticity of substitution across them. These goods are substitutable at a constant rate $\eta$, where a higher value of $\eta$ indicates greater substitutability. In the limiting case as $\eta \to \infty$, the goods $c_i$ become perfect substitutes.

Consider a CES utility function of the following form:

$$U(c) = \left[ \sum_{i=1}^{n} (\alpha_i c_i)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

where $c_i > 0$ represents consumption of good $i$, $\alpha_i$ denotes the share of good $i$ in the consumption basket, and $\eta$ is the elasticity of substitution. Cobb–Douglas and linear preferences may be viewed as special cases of the CES function, with $\eta = 1$ and $\eta \to \infty$, respectively. In the CES case, the elasticity of substitution between two goods is constant and equal to $\eta$ :[3]

$$\eta = \frac{\partial \left( \frac{C_F}{C_H} \right) / \partial \left( \frac{P_H}{P_F} \right)}{\left( \frac{C_F}{C_H} \right) / \left( \frac{P_H}{P_F} \right)}$$

### 3.3.2 Non-Homothetic Preferences: Stone–Geary

Stone-Geary preferences have been the most common departure from CES preferences in the literature. More often than not, they have been used synonymously with non-homothetic preferences.

$$U(c) = \left[ \sum_{i=1}^{n} \left( \alpha_i^{\frac{1}{\eta}} (c_i - \bar{c}_i)^{\frac{\eta-1}{\eta}} \right) \right]^{\frac{\eta}{\eta-1}}$$

[3]Or more generally, the elasticity of substitution between goods $i$ and $j$ is defined as:

$$\varepsilon \left( \frac{x_i}{x_j}, \frac{p_i}{p_j} \right) = \frac{d \left( \frac{x_i}{x_j} \right)}{d \left( \frac{p_i}{p_j} \right)} \cdot \frac{\frac{p_i}{p_j}}{\frac{x_i}{x_j}}$$

For a detailed discussion, see Matsuyama (2023).

where $\bar{c}_i > 0$ introduces non-homotheticity in the consumption of good $i$ by making demand depend on how far consumption is from this threshold, thereby introducing income-dependent consumption behavior or frictions in spending.

Unlike in the CES case, the elasticity of substitution in this framework is no longer constant. The key driver of this variation across income groups is the non-homotheticity parameter $\bar{c}$ : [4]

$$\frac{\partial\left(\frac{C_F}{C_H}\right)/\partial\left(\frac{P_H}{P_F}\right)}{\left(\frac{C_F}{C_H}\right)/\left(\frac{P_H}{P_F}\right)} = \frac{\eta\frac{\alpha}{1-\alpha}\left(\frac{P_H}{P_F}\right)^{-\eta-1}}{\left(\frac{\alpha}{1-\alpha}\left(\frac{P_H}{P_F}\right)^{-\eta}+\bar{c}\right)/\left(\frac{P_H}{P_F}\right)}$$

Note that $\bar{c}$ is typically interpreted as a subsistence level of consumption, the minimum quantity of good $i$ that must be consumed before utility is derived. However, in the model setup considered in this thesis, which will be introduced in Chaper 4, the Stone–Geary term $\bar{c}$ represents a minimum consumption threshold for a luxury good (i.e., imports). Unlike the standard use of $\bar{c}$ to capture subsistence needs, here it captures the idea that import consumption only starts increasing significantly once the household reaches a certain income level. At higher income levels, this threshold is less binding, since rich households who consume well above this threshold $\bar{c}$, allocate a larger share of spending to imports, and hence respond less elastically to price changes. Poorer households, in contrast, face a tighter constraint and hence show higher elasticity in their spending patterns when relative prices change.

This formulation allows the model to reflect the empirical pattern documented by Auer et al. (2024), in which higher-income households consume a larger share of imports but exhibit lower substitution elasticity, while lower-income households, who consume closer to this threshold, are more responsive to relative price changes.

[4] See Appendix A.1 for derivations of the elasticity expressions under CES and Stone–Geary preferences.

# Chapter 4

# A Small Open Economy HANK Model

In this chapter, I lay out the core structure of the open economy HANK model used in this thesis. I then outline the numerical solution method used to solve the model, followed by a discussion of the calibration strategy. Finally, I present and discuss the main quantitative results.

## 4.1 Model

The model is based on the canonical New Keynesian (NK) small open economy model of Gali and Monacelli (2005), but introduces heterogeneous households subject to borrowing constraints and nominal wage rigidities. The home economy is modelled as a single tradable sector that produces both domestic and foreign goods. To introduce a Stone–Geary specification of preferences over the consumption of foreign and domestic goods, the modelling setup adopted for the household block follows Auclert et al. (2024a).

### 4.1.1 Households

Time is discrete and indexed by $t$. The home economy is populated by a continuum of infinitely lived households indexed by $i$, who are subject to idiosyncratic income risk, which follows a log-normal process with mean $E[z_t] = 1$. When preferences $\nu(c_{F,it}, c_{H,it})$ are non-homothetic, rich and poor households will hold different consumption baskets. A household makes decisions about consumption and asset holdings each period to maximise lifetime utility by solving the consumption–savings problem :

$$v_t(z_{it}, a_{it-1}) = \max_{c_{F,it}, c_{H,it}} \nu(c_{F,it}, c_{H,it}) - \varphi \frac{\ell_{it}^{1+\nu}}{1+\nu} + \beta \mathbb{E}_t \left[ v_{t+1}(z_{it+1}, a_{it}) \right] \tag{4.1}$$

$$\frac{P_{F,t}}{P_{it}} c_{F,it} + \frac{P_{H,t}}{P_{it}} c_{H,it} + a_{it} = (1+r_t) a_{it-1} + (1-\tau_t) w_t L_t z_{it} \tag{4.2}$$

$$\log z_{it+1} = \rho_z \log z_{it} + \psi_{it+1}, \quad \psi_t \sim \mathcal{N}(\mu_\psi, \sigma_\psi), \quad \mathbb{E}[z_{it}] = 1 \tag{4.3}$$

$$a_{it} \geq 0 \tag{4.4}$$

where $P_{it}$ is the ideal price index associated with the consumption basket of individual $i$, $\sigma$ is the coefficient of relative risk aversion, $\nu$ is a constant that governs the disutility of labor supply, and $\varphi$ is the Frisch elasticity. $L_t$ is the labor supplied by the household, and $\tau_t$ is a proportional labor income tax rate imposed by the government. As stated in the model overview, the household problem is modeled following Auclert et al. (2024a) with the value function in Equation 4.1 rewritten as:

$$v_t(z_{it}, a_{it-1}) = \max_{c_{F,it}, c_{H,it}} \nu(\tilde{c_{it}}) - \varphi \frac{\ell_{it}^{1+\nu}}{1+\nu} + \beta \mathbb{E}_t \left[ v_{t+1}(z_{it+1}, a_{it}) \right] \tag{4.5}$$

$\bar{c}_{it}$ is the consumption of any agent $i$, which is a composite of foreign and home goods, $\tilde{c}_{F,it}$ and $c_{H,it}$. To zoom in on how households allocate consumption between goods, the household's consumption bundle is assumed to follow the Stone–Geary consumption function discussed in Section 3.3, and is written as :

$$\tilde{c_{it}} = [\alpha^{1/\eta} (\bar{c}_{Fit})^{\eta-1/\eta} + (1-\alpha)^{1/\eta} c_{Hit}^{\eta-1/\eta}]^{\eta/\eta-1}$$

where $\tilde{c}_{F,it} = c_{F,it} + \underline{c}$, and $\underline{c}$ is the non-homotheticity parameter, which acts as a threshold level of consumption for imports. $\alpha$ is the expenditure share on foreign goods, with $(1-\alpha)$ interpreted as the degree of home bias, and $\eta > 0$ is the elasticity of substitution between home and foreign goods. Non-homothetic preferences help introduce income-dependent frictions in expenditure-switching behaviour. In particular, high-income households are less willing to substitute away from imports in response to relative price changes. Note that the budget constraint in Equation 4.2 was stated in terms of the ideal price index. Reformulating it using $\tilde{c}_{it}$, the budget constraint can now be written as:

$$\frac{P_{F,t}}{P_t} \tilde{c}_{F,it} + \frac{P_{H,t}}{P_t} c_{H,it} + a_{it} = (1+r_t) a_{it-1} + (1-\tau_t) w_t L_t z_{it} + \frac{P_{F,t}}{P_t} \underline{c} \tag{4.6}$$

where $P_t$ is the consumer price index (CPI) . Expressing the budget constraint this way simplifies the household problem, since it now requires using standard CPI instead of computing household-specific price indices. Likewise, the demand functions for foreign and home goods can be written as:[1]

$$c_{F,it} = \alpha \left( \frac{P_{F,t}}{P_t} \right)^{-\eta} \tilde{c}_{it} - \underline{c} \tag{4.7}$$

$$c_{H,it} = (1-\alpha) \left( \frac{P_{H,t}}{P_t} \right)^{-\eta} \tilde{c}_{it} \tag{4.8}$$

### 4.1.2 Firms

A competitive representative firm produces home tradable goods using domestic labor $L_t$ with the production function:

$$Y_t = \Gamma_t L_t \tag{4.9}$$

where $\Gamma_t$ is the exogenous technology level. Profits of domestic firms expressed in CPI units are:

$$\Pi_t = \frac{P_{Ht}}{P_t} Y_t - \frac{W_t}{P_t} L_t \tag{4.10}$$

Profit maximization yields the first-order condition:

$$w_t = \frac{P_{Ht}}{P_t} \tag{4.11}$$

where $w_t = \frac{W_t}{P_t}$ is the real wage.

### 4.1.3 Unions

The standard New Keynesian (NK) model features flexible wages and sticky prices.[2] Auclert et al. (2024b) shows that introducing wage rigidities yields more desirable properties, as it avoids countercyclical profits and better matches empirical evidence, by allowing wages to adjust more sluggishly than prices to external shocks.

[1] See Appendix A.2 for the derivation.

[2] In Section 6.2, the model results are compared to those with sticky prices.

To introduce this feature, it is assumed that each household $i$ belongs to a union $j$, which faces labor demand from firms:

$$L_{j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{-\varepsilon^w} L_t \tag{4.12}$$

Each union sets wages and chooses labor supply by maximizing lifetime utility:

$$\max_{W_{j,t},\, L_{j,t}} \sum_{t=0}^{\infty} \beta^t \left( \int \left[u(c_{i,t}) - \nu(L_{j,t})\right] dD_{i,t} - \frac{\theta^w}{2} \left(\frac{W_{j,t}}{W_{j,t-1}} - 1\right)^2 \right) \tag{4.13}$$

subject to Rotemberg adjustment costs $\frac{\theta^w}{2}\left(\frac{W_{j,t}}{W_{j,t-1}} - 1\right)^2$ when changing wages, which introduces wage stickiness. Solving this maximization problem, subject to the labor demand function, yields the Wage Phillips Curve [3]:

$$\pi_t^w(1+\pi_t^w) = \kappa^w L_t \left(\nu L_t^{1/\varphi} - \frac{w_t}{\mu^w}(1-\tau_t) z_t c_t^{-\sigma}\right) + \beta \pi_{t+1}^w (1+\pi_{t+1}^w) \tag{4.14}$$

where $\pi_t^w = \frac{W_t}{W_{t-1}} - 1$ is the wage inflation rate, $\kappa^w$ is the slope parameter, $\mu^w$ is the wage markup, and $z_t c_t^{-\sigma}$ denotes the productivity-weighted marginal utility of consumption.

### 4.1.4 Central Bank

The central bank is assumed to follow a real rate rule, such that it controls the real interest rate $r_t$ directly :

$$r_t = r_{ss} + (\phi - 1)\pi_t \tag{4.15}$$

where $\pi_t$ is CPI inflation. I discuss the implications for household balance sheets that can arise when the central bank instead sets the nominal interest rate, through valuation changes in their nominal asset holdings, in Section 6.

### 4.1.5 Government

The government finances its past expenses by issuing real debt $B_t$, which pay out the real interest rate $r_t$ after one period. In addition to debt issuance, it imposes taxes on household labor income. The budget constraint for the government is then given by:

[3] See Appendix A.3 for details on the derivation.

$$B_t = (1 + r_t)B_{t-1} - \tau_t w_t L_t \tag{4.16}$$

Labor income taxes are set according to a tax rule that ensures that the government debt remains constant in the long-run steady state:

$$\tau_t = \tau_{ss} + \omega \frac{B_{t-1} - B_{ss}}{Y_{ss}} \tag{4.17}$$

where the subscript $ss$ denotes the variables in steady state. The parameter $\omega$ governs the sensitivity of the tax rate to deviations of public debt from its steady state level.

### 4.1.6 Foreign Economy

Foreign demand for domestic goods is given by a CES demand function:

$$C^*_{H,t} = \alpha \left( \frac{P^*_{H,t}}{P^*_{F,t}} \right)^{-\eta^*} M^*_t \tag{4.18}$$

where $M^*_t$ is overall demand for foreign imports and $\eta^* > 0$ elasticity of foreign demand. The rest of the world is modelled as a continuum of symmetric open economies, each inhabited by a representative agent, which together make up the large foreign economy. Given that the home economy is a small open economy, the foreign variables in the model namely, the price of foreign goods in foreign currency ($P^*_{F,t}$), the foreign real interest rate ($r^*_t$), and foreign demand ($M^*_t$), are taken as exogenous.

The law of one price is assumed to hold for foreign and home goods such that there is perfect pass-through of exchange rate changes into domestic prices, $P_{F,t} = P^*_{F,t}E_t$ and $P_{H,t} = P^*_{H,t}E_t$, where $E_t$ is the nominal exchange rate, and the asterisk denotes that the corresponding variables are expressed in foreign currency. [4]

### 4.1.7 Financial sector

A mutual fund in the home economy collects household savings from the budget constraint in Equation 4.6 and invests them in domestic and foreign real bonds, which yield real interest rates $r_t$ and $r^*_t$, respectively. Total asset holdings of the home economy are denoted by $A_t = B_t + B^*_t$. Under the assumption of free capital

[4] Chapter 5 considers the case of imperfect pass-through of foreign import prices into domestic prices, which essentially makes the model resemble local currency pricing (LCP).

flows, this implies that the uncovered interest parity (UIP) condition holds. The UIP condition can then be written in real terms as:

$$1 + r_t = (1 + r_t^*)\frac{Q_{t+1}}{Q_t} \tag{4.19}$$

$Q_t = \frac{E_t P_{F,t}^*}{P_t}$ is the real exchange rate. In line with the assumption that the home economy is small and therefore takes the foreign interest rate $r_t^*$ as given, foreign agents do not invest in the home economy, thereby ruling out capital inflows. Keeping this in mind, the net foreign asset ($NFA_t$) position can be written as :

$$NFA_t = A_t - B_t \tag{4.20}$$

which implies that $NFA_t = B_t^*$, where foreign holdings of domestic assets are not included in this definition.

### 4.1.8 Trade and Current Account

The value of net exports $NX_t$ in the economy is defined as:

$$NX_t = GDP_t - C_t \tag{4.21}$$

where $GDP_t = \frac{P_{H,t}}{P_t} Y_t$, and $C_t$ denotes aggregate consumption. Then, using Walras' Law, the current account $CA_t$ and the net foreign asset position $NFA_t$ can be shown to be related as:

$$NFA_t - NFA_{t-1} = NX_t + r_t NFA_{t-1} \tag{4.22}$$

where $CA_t = NX_t + r_t NFA_{t-1}$.

### 4.1.9 Equilibrium

Prices and aggregate output are normalised to 1, and inflation rates are set equal to 0 in steady state. As the analysis in this thesis centers on a foreign interest rate shock, which will be presented in Section 4.4, the competitive equilibrium for the model can be defined as follows : Given the sequence $\{r_t^*\}$ of foreign interest rate shocks and an initial distribution over assets and earnings, $D_0(a, z)$, a competitive equilibrium in the model is defined as a path of household policies $\{c_t(a, z), a_t(a_{t-1}, z)\}$, distributions $D_t(a, z)$, prices:

$$\left\{E_t, Q_t, P_{H,t}, P_{F,t}, P_{F,t}^*, P_{H,t}^*, w_t, W_t, P_t, r_t, r_t^*\right\},$$

and quantities:

$$\left\{B_t, C_t, Y_t, C_{H,t}, C_{F,t}, C^*_{H,t}, A_t, L_t, NFA_t, \tau_t, Z_t\right\},$$

such that households maximise expected utility, firms maximise profits, the mutual fund balance sheet is satisfied, and the goods market clears :

$$Y_t = C_{H,t} + C^*_{H,t} \tag{4.23}$$

## 4.2 Numerical Methods

This section introduces the numerical methods used to solve the model. In particular, the model is solved using the Endogenous Grid Method (EGM) to efficiently handle the household's dynamic optimization problem, and the Sequential Space Jacobian (SSJ) method to solve for the general equilibrium. These two methods are briefly summarised in the subsections that follow.

### 4.2.1 Solving the Model Using EGM

Solving the household's consumption-saving problem involves applying numerical dynamic programming techniques to evaluate the value function for a continuum of agents facing idiosyncratic income shocks. The Endogenous Grid Point Method (EGM), proposed by Carroll (2006) offers a faster and more efficient alternative to traditional value function or time iteration methods. By avoiding root-finding steps and instead constructing endogenous grids over the household's state variables namely,asset and income levels, EGM significantly reduces the computational burden.

In the standard EGM procedure, the solution typically involves inverting the Euler equation to compute optimal consumption, followed by constructing the associated level of cash-on-hand. In an open economy setting, with the household consumption basket comprising both foreign and domestic goods, this now requires solving two Euler equations, one for each consumption good, which can increase computational complexity. Following the approach in Auclert et al. (2024a) and introducing a composite consumption variable $\tilde{c}$, which captures total expenditure with the non-homothetic component included, helps circumvent this issue by reducing the problem to a single Euler equation expressed in terms of $\tilde{c}$. Once $\tilde{c}$ is determined, the individual consumption levels of home and foreign goods can be recovered through their demand functions. The steps involved in solving the household problem using this approach are outlined below.

#### 4.2.1.1 Solution Algorithm

The algorithm proceeds as follows:

1. Compute $\tilde{c}_t$ over end-of-period asset states from the inverted Euler equation.[5]

$$\tilde{c}_t = \left(\beta R \mathbb{E}_t \left[\tilde{c}_{t+1}(\tilde{m}_{t+1})^{-\rho}\right]\right)^{-\frac{1}{\rho}}$$

2. Construct the endogenous grid: $\tilde{m}_t = \tilde{c}_t + a_t$. Since labour is exogenous, labour income enters directly into $m_t$ and therefore does not need to be deducted from cash-on-hand.

3. Compute total cash-on-hand:

$$m_t = (1 + r_t)a_{t-1} + (1 - \tau)w_{it}n_{it}z_{it} + \frac{P_{F,t}}{P_t}\underline{c}$$

4. Use linear interpolation to construct the consumption policy function $\tilde{c}_t^*$ and savings policy function $a_t^*$ over the cash-on-hand grid $m_t$.

Assuming exogenous labour supply simplifies the household problem by restricting choices to consumption, since labour is no longer a decision variable. This follows from the assumption of sticky wages, discussed in Section 4.1 when introducing the model framework.

### 4.2.2 Sequence-Space Jacobian Method

In this section, I discuss how to solve for general equilibrium in models with aggregate uncertainty, where shocks are assumed to follow stochastic processes. The solution method builds on the idea of Boppart et al. (2018), who solve non-linearly for impulse responses to a single, small, unexpected shock that hits the economy at its steady state, or an "MIT shock". In a model where it is assumed to have perfect foresight with respect to aggregate variables, the non-linear transition path for an arbitrary sequence of exogenous shocks $Z_t$ using the sequence-space solution method can therefore be used to find the non-linear transition given a sequence of exogenous shocks. Solving this involves identifying the shocks and unknowns from the different blocks and writing the model as an equation system. The equilibrium can then be

[5] See Appendix A.4 for details on solving the household problem modified to accommodate non-homothetic preferences.

condensed to a sequence of unknowns and shocks, which can be used to solve the entire model:

$$\mathbf{H}(\mathbf{U}, \mathbf{Z}) = \mathbf{0} \tag{4.24}$$

Where $\mathbf{Z}$ are exogenous shocks, $\mathbf{U}$ are unknowns in the equation system, and $\mathbf{X} = \mathbf{M}(\mathbf{U}, \mathbf{Z})$ are the aggregate variables summarising the equation system. The solution to this equation system is then found using a non-linear equation solver, Broyden's method, by computing the Jacobian of these residuals in the equation system with respect to the unknowns from the model blocks. The easiest way to do this would be to use a DAG structure of the model and then compute the necessary Jacobians using the chain rule. The full Jacobians can be written as :

$$H_X = \begin{bmatrix} \frac{\partial H_0}{\partial X_0} & \frac{\partial H_0}{\partial X_1} & \cdots \\ \frac{\partial H_1}{\partial X_0} & \ddots & \\ \vdots & & \ddots \end{bmatrix} \tag{4.25}$$

The Jacobian matrix captures how aggregate household dynamics respond to changes in model inputs. Albeit computing the individual Jacobians is relatively straightforward, computing the household Jacobians involves additional complexity. This is done efficiently, using the "fake news algorithm" from Auclert et al. (2021).

Solving models with aggregate uncertainty typically requires assuming that shocks follow stochastic processes. However, the solution method used above assumes perfect foresight with respect to aggregate variables, which implies that aggregate shocks are not truly stochastic, but rather treated as MIT shocks. It can be shown that the impulse responses generated under perfect foresight are equivalent, to first order, to the linearized impulse responses of a model with aggregate risk. The "fake news algorithm" proposed by Auclert et al. (2021) allows for efficient computation of the linearized responses of aggregate consumption, savings, and other macro variables with respect to aggregate shocks. Alternatively, the model can be solved to first order by totally differentiating Equation (4.24):

$$H_U\, dU + H_Z\, dZ = 0 \quad \Leftrightarrow \quad dU = -H_U^{-1} H_Z\, dZ \equiv G_U \tag{4.26}$$

where $G_U$ is referred to as the general equilibrium solution matrix for individual variables. By also differentiating the aggregate variables in $\mathbf{X}$ , the remaining linearized impulse responses can be computed as:

$$dX = M_{XU}\, dU + M_{XZ}\, dZ = \left(-M_{XU} H_U^{-1} H_Z + M_{XZ}\right) dZ \tag{4.27}$$

where $G \equiv -M_{XU} H_U^{-1} H_Z + M_{XZ}$ is the full general equilibrium matrix.

## 4.3 Calibration

In this section, I detail the calibration of the model. The main focus is on calibrating the parameters in the household block to match the consumption behaviour of Swiss households, drawing on the findings of Auer et al. (2024). The parameters in the remaining blocks are set externally to their standard values in the literature. The model is calibrated at a quarterly frequency. Table 4.2 summarises the calibration.

**Household** The parameters related to household consumption baskets are set to match the estimates in Auer et al. (2024). These estimates are also provided in Appendix B. The share of imports in the consumption basket, $\alpha$, and the non-homothetic parameter, $\bar{c}$, are chosen to match an aggregate import share of 26% and a top-quintile import share of 28% , respectively. This yields $\alpha = 0.30$ and $\bar{c} = 0.040$ in the model. To account for the heterogeneous elasticity of substitution between home and foreign goods implied by non-homothetic preferences as discussed in Section 3.3, the average of the quintile specific elasticities in the model is calibrated to match the average of the corresponding elasticities reported in Auer et al. (2024) (see Table B.2 in Appendix B.). In order to better isolate the role of non-homothetic preferences in shaping the household consumption behavior, I also compare the baseline model to its homothetic counterpart, performing essentially the same calibration exercise as in the baseline model, the only difference being that the non-homothetic parameter, $\bar{c}$, is set to zero. The calibrated parameters for the two models are reported in Table 4.2.

The intertemporal elasticity of substitution (IES) is set to 0.5 (see Cugat et al. (2019); Druedahl et al. (2022)). The Frisch elasticity of labor supply, $\varphi$, is set to a standard value of 0.5. The persistence, $\rho_i$, and volatility, $\sigma_i$, of the income process are set equal to the estimates in Floden and Lindé (2001).

**Phillips curve parameters** The slope of the wage Phillips curve, $\kappa_w$, is set to 0.01 following Bobasu et al. (2025). The markup is set to $\mu = 1.2$, such that firms impose a markup of 20% on final goods, as in Smets and Wouters (2007).

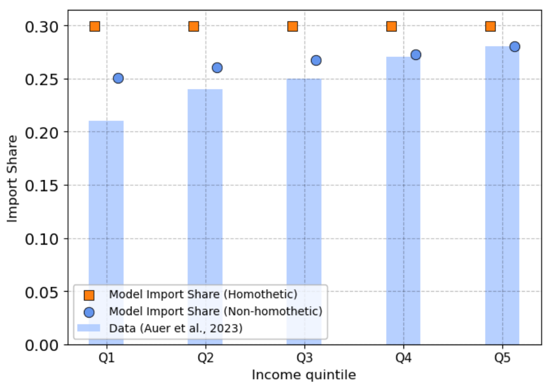
**Monetary and Fiscal policy** The Taylor rule coefficient on inflation, $\phi_\pi$, is set to the standard value of 1.5 to indicate an inflation-responsive central bank, with persistence $\rho_r = 0.90$. The tax sensitivity parameter $\omega$ is set to 0.10. All assets are perfect substitutes and are set to yield the same real return, such that $r_t = r_t^* = r_{ss} = 0.5\%$, where $r_{ss}$ denotes the steady-state quarterly interest rate.

**Foreign economy** The foreign interest rate is set to a quarterly value of 0.5%. The Armington elasticity of foreign demand, $\eta^*$, is set to 2, following Boehm et al. (2023).

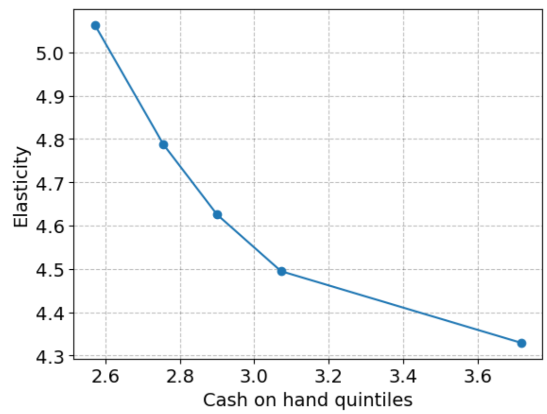
| | Description | Value | | Target/Source |
|---|---|---|---|---|
| | | **Households** | | |
| $1/\sigma$ | IES | 0.5 | | Cugat et al. (2019) |
| $\varphi$ | Frisch elasticity | 0.5 | | Chetty et al. (2011) |
| $\rho_i$ | Persistence of income process | 0.96 | | Floden and Lindé (2001) |
| $\sigma_i$ | Std. dev. of income process | 0.13 | | Floden and Lindé (2001) |
| | | **Unions** | | |
| $\mu$ | Markup | 1.2 | | Smets and Wouters (2007) |
| $\kappa^w$ | Slope of Phillips curve | 0.05 | | Bobasu et al. (2025) |
| | | **Government and Monetary Policy** | | |
| $\phi_\pi$ | Taylor rule coefficient | 1.5 | | Standard value |
| $\rho_r$ | Persistence | 0.90 | | Standard value |
| $\omega$ | Tax sensitivity parameter | 0.10 | | – |
| | | **Non-homothetic** | **Homothetic** | |
| $\beta$ | Discount factor | 0.952 | 0.937 | Asset market clearing |
| $\alpha$ | Share of imports in home basket | 0.300 | 0.26 | Auer et al. (2024) |
| $\underline{c}$ | Non-homotheticity | 0.040 | 0 | Auer et al. (2024) |
| $\eta$ | Subs. elasticity between home and foreign goods | 3.924 | 3.924 | Auer et al. (2024) |

Table 4.2: Calibration Values, and Sources.

I validate the model below and show that it does quite well in matching the targeted consumption behaviour. Figure 4.1 presents the two results : Panel (a) compares the model-implied import share across income quintiles in the baseline model and in a version without non-homothetic preferences, plotted against household expenditure shares on imports as reported in Auer et al. (2024). The baseline model matches these import share estimates well, showing an increasing pattern with income. Panel (b) plots the model-implied substitution elasticities against households' cash-on-hand, which exhibit a declining pattern with income.




(a) Import share across income quintiles




(b) Substitution elasticity against cash-on-hand quintiles

Figure 4.1: Model validation outcomes: import shares and substitution elasticities by income.

As described in Section 3.3, deviating from the standard CES specification implies that the elasticity of substitution becomes non-constant. Under Stone–Geary preferences, the elasticity of substitution becomes income-dependent as it is linked to the non-homothetic component. In the baseline model, the average of the quintile-based substitution elasticities is calibrated to match the corresponding estimates reported in Auer et al. (2024). Table 4.3 below compares the elasticity estimates from Auer et al. (2024) to the model-implied elasticity estimates in partial equilibrium.

The non-homothetic model yields variation in the elasticity of substitution across income groups, as shown for income quintiles in the table. The model is able to reproduce the declining pattern observed in the data, with lower-income households exhibiting higher elasticities of substitution, consistent with the empirical findings.

| **Income Quintile** | **Model** | **Data (Auer et al. (2024))** |
|---|---|---|
| Quintile 1 | 5.06 | 6.6 |
| Quintile 2 | 4.78 | 4.4 |
| Quintile 3 | 4.62 | 3.0 |

Table 4.3: Elasticity of Substitution Estimates Across Income Quintiles

## 4.4 Results

### 4.4.1 Foreign Interest Rate Shock

In this section, I use the calibrated model to assess the consequences of an exchange rate shock resulting from foreign monetary easing. I consider an interest rate shock of 10 basis points to align with the size of the monetary policy easing implemented by the ECB during this period. Note that even though the Swiss franc appreciated around the time of the peg removal due to safe haven flows, I consider a foreign interest rate shock as the source of appreciation as the franc was already facing appreciation pressures even prior to the removal of the peg.[6] The effective exchange rates used are noted in direct quotation, such that an increase in the exchange rate in this notation implies an depreciation of the domestic currency.

The impulse response functions (IRFs) shown in Figures 4.2 and 4.3 present the responses in the model with and without non-homothetic preferences. The homothetic model is obtained by setting the threshold component $\bar{c} = 0$. I first focus on the IRFs under non-homothetic preferences. Through the real UIP condition, a foreign monetary easing leads to an appreciation of the real exchange rate. Intuitively, the fall in foreign interest rates makes the foreign currency less attractive to investors, as it yields lower returns. This triggers capital inflows into the small open economy, as investors become more interested in domestic bonds, which now offer higher returns and appear more attractive than foreign ones. The increased demand for domestic assets puts pressure on the domestic currency, while the foreign currency loses value. The fall in relative import prices from the appreciation causes both foreign and domestic consumers to substitute away from relatively more expensive domestic goods

[6]This pressure was partly driven by deflationary trends in the euro area, which led the ECB to impose negative interest rates. At the same time, there was a growing divergence in the monetary policy stance between the US and the euro area around this period, with the US starting to shift toward future tightening, while the euro area pursued even more accommodative policies with negative interest rates and asset purchase programs (Swiss National Bank, 2015).

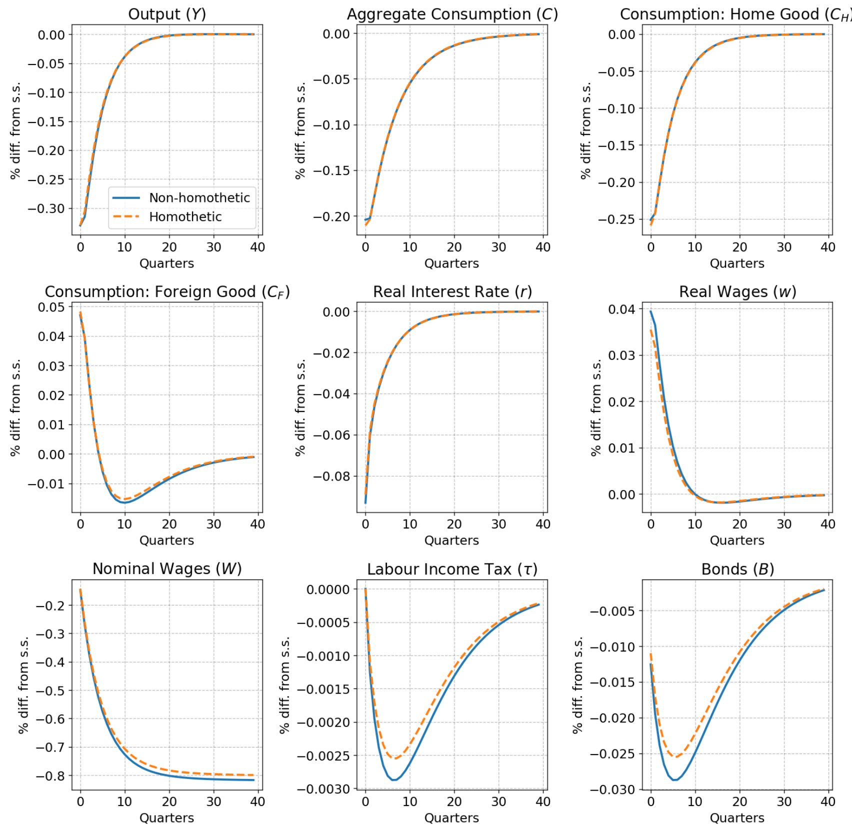



Figure 4.2: Impulse responses comparing homothetic and non-homothetic models.

toward cheaper foreign goods, thus implying a fall in domestic demand as a result of expenditure switching. CPI inflation falls, largely driven by the fall in import prices. The home country's competitiveness deteriorates as net exports fall. The central bank responds to the deflationary pressures by lowering the real interest rate. The lower demand for domestic goods at home and abroad induces firms to lower their labour demand, thereby causing unions to cut nominal wages by $\kappa_w$. Given nominal wage frictions, real wages rise slightly. The government reduces labour income taxes in response to the decline in output and income, and issues less debt as the fall in the real interest rate reduces the cost of debt service. Despite lower prices raising real wages, households' after-tax labour income falls due to lower output. Comparing the IRFs to the one under homothetic prefernces (i.e, with the the threshold on imports $\bar{c} = 0$), there appears to be little difference in the overall shape and dynamics of the responses. Since both models are calibrated to the same elasticity of substitu-

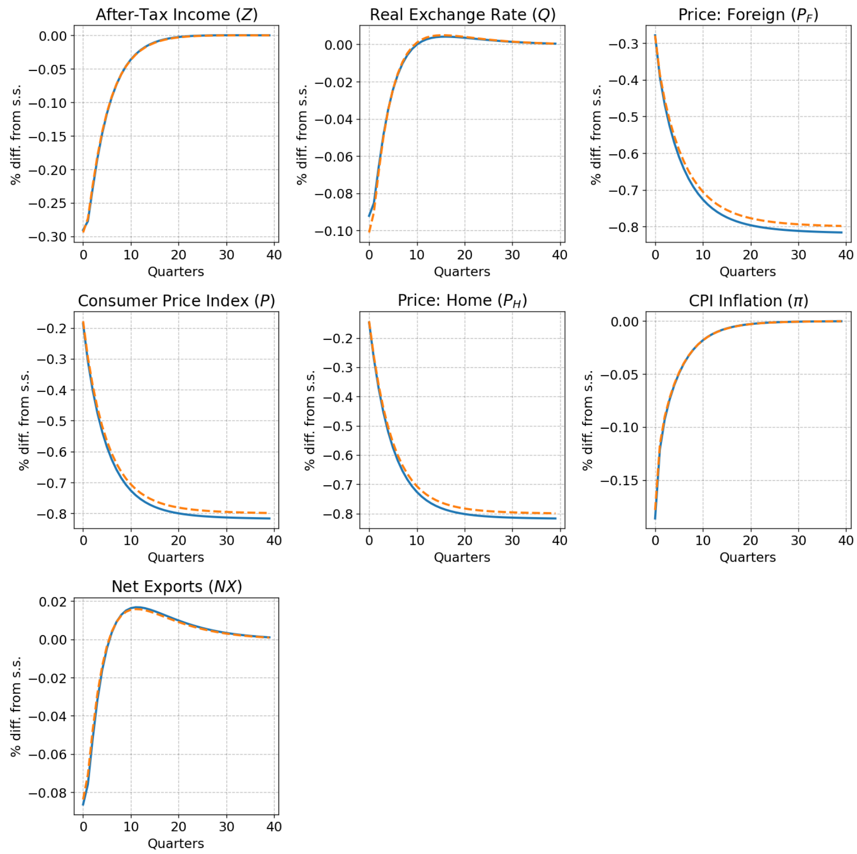



Figure 4.3: Impulse responses comparing homothetic and non-homothetic models (continued from Figure 4.2).

tion, the IRFs are qualitatively very similar across both models, though quantitative differences emerge in the magnitude of responses for certain variables.

### 4.4.2 Decomposition of Output Response

To understand how exchange rate shocks propagate through the economy, it is useful to examine the underlying channels driving the responses of output and consumption. Following Auclert et al. (2024a), I use the sequence-space representation of the model, which involves writing the model variable $X_t$ as a stacked vector containing deviations from steady state, where $d\mathbf{X}_t = \mathbf{X}_t - \mathbf{X}_{ss}$. The following two sections explore these mechanisms in more detail.

In response to a foreign monetary policy shock that causes an exchange rate appreciation at home, the impulse response of output can be described by the Intertemporal Keynesian Cross (IKC), which is the intertemporal form of the standard static Keynesian cross (see Auclert et al. (2024b)).[7]

$$dY = \underbrace{(1-\alpha)\mathbf{M}^r d\mathbf{r}}_{\text{Interest rate}} + \underbrace{(1-\alpha)\mathbf{M}d\mathbf{Y}}_{\text{Multiplier}} - \underbrace{\alpha\mathbf{M}d\mathbf{Q}}_{\text{Real income}} + \underbrace{\frac{\alpha}{1-\alpha}\chi d\mathbf{Q}}_{\text{Expenditure switching}} \tag{4.28}$$

Where $\chi$ is defined as:

$$\chi \equiv \eta(1-\alpha) + \eta^* \tag{4.29}$$

is the trade elasticity which captures the sensitivity of trade to changes in the exchange rate.$\mathbf{M}^r$ and $\mathbf{M}$ are the Jacobians of aggregate consumption with respect to the real interest rate, real labour income written in sequence space, which are essentially matrices containing derivatives of consumption with respect to the corresponding variables in the budget constraint:

$$\boldsymbol{M} = \mathcal{J}^{c^{hh},x} = \begin{bmatrix} \frac{\partial c_0^{hh}}{\partial x_0} & \frac{\partial c_0^{hh}}{\partial x_1} & \cdots \\ \frac{\partial c_1^{hh}}{\partial x_0} & \ddots & \ddots \\ \vdots & \ddots & \ddots \end{bmatrix}$$

The columns correspond to the dynamic response of consumption to a change in the variable of interest at time $t$, and can also be interpreted as the announcement effects of the shock. The rows represent the response of consumption in period 0 to shocks occurring at different future dates. These are the household Jacobians discussed in Section 4.2.2. Building on the expression for the intertemporal Keynesian cross (IKC) in Equation (4.28), I now look into each component to illustrate the underlying transmission mechanisms.

The first term captures the interest rate channel. This is the direct effect described in Kaplan et al. (2018) and is driven solely by the central bank response to external shocks. Capital inflow pressures at home induce the central bank to lower the interest rate which raises aggregate consumption and translates into dY$>$ 0. The second term in Equation 4.28 is the standard multiplier effect, which captures the feedback loop between falling consumption and output.

Auclert et al. (2024a) identify two key channels through which the exchange rate operates: expenditure switching and real income channels. Changes in the relative price of goods caused by exchange rate shocks lead households to engage

[7]See Appendix A.6 for details on the derivation.

in expenditure switching, shifting their consumption baskets toward the relatively cheaper good. From Equation 4.28, an exchange rate appreciation reduces output by $\frac{\alpha}{1-\alpha}\chi$ as it raises the relative price of home goods compared to the domestic CPI, $\frac{P_{H,t}}{P_t}$. This is because an exchange rate appreciation (i.e, a fall in Q) raises the relative price of home goods $\frac{P_{H,t}}{P_t}$. This makes home goods more expensive relative to imports, reducing domestic consumption of home goods. At the same time, the appreciation reduces the competitiveness of home goods abroad, as foreign households cut back on demand for home produced goods, further weighing down output in the domestic economy.

In addition, the fall in import prices resulting from an appreciation indirectly affects real labour income. This can be seen through the firm's first-order condition, $Z_t = Y_t\frac{P_{H,t}}{P_t}$, where the decline in import prices lowers the overall consumer price index (CPI), thereby raising real labour income. This is the real income channel, through which households experience a rise in purchasing power. Which of the two channels dominates depends on the values of trade elasticity parameters defined in 4.29 . Auclert et al. (2024a) show that with plausibly lower short-term elasticities, the real income channel dominates and exchange rate appreciations can be expansionary. This implies that for low enough values of $\chi$, the gains from higher real labour income can outweigh the fall in employment resulting from the shift in demand towards relatively cheaper imports.

Figure 4.4 below shows the output and consumption responses under different values of the trade elasticity. Following the calibration described in Section 4.2, the trade openness parameter is set to 0.3. Note that given this value of $\alpha$, choosing $\eta = \eta^* = 0.5$ implies a trade elasticity of $\chi = 0.85$ while setting $\eta = \eta^* = 3.0$ yields a value of $\chi = 5.1$ . For lower values of trade elasticity, the contractionary effect on output is of a much lesser degree and aggregate consumption rises.

### 4.4.3 Decomposition of Consumption Response

Similar to output, the transmission channels of an exchange rate shock can also be understood by decomposing the response of aggregate consumption into distinct channels. The consumption response can be attributed to direct effects (or partial equilibrium effects) and indirect effects (or general equilibrium effects). As discussed by Kaplan et al. (2018), direct effects arise independently of any changes in disposable income. The most commonly identified direct effect being the intertemporal substitution effect that operates through the Euler equation, where a lower interest rate raises current consumption by encouraging households to shift consumption from the future to the present. In addition to this, relative prices also induce substi-

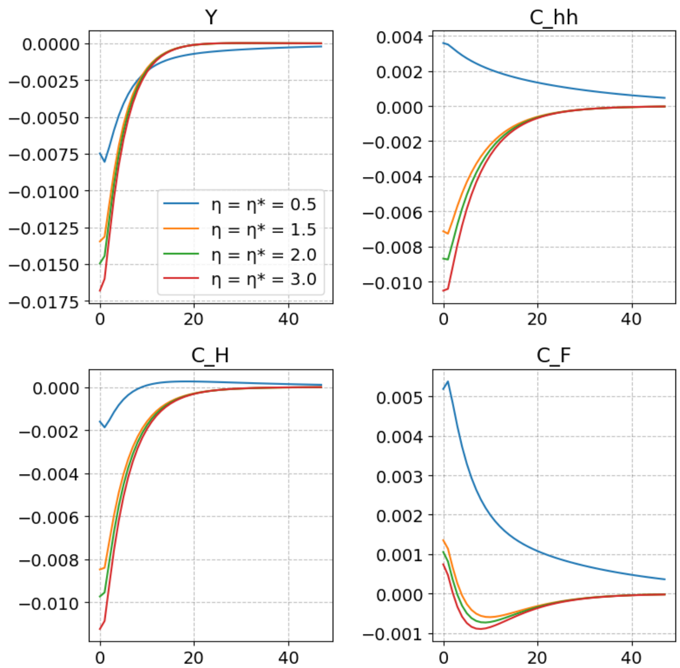



Figure 4.4: Output and consumption responses under varying trade elasticity values.

tution effects (synonymously, expenditure switching). But the exchange rate shock can also have general equilibrium implications by affecting household income. In the case of an exchange rate appreciation, the changes in relative prices will positively impact consumption by raising household real income.

From the budget constraint in equation 4.6, the aggregate consumption function can be written as a function of the real interest rate, real labour income and relative prices in sequence space. This way the consumption function depends on the entire time path of these variables. Linearising the consumption function around steady state, the impulse response of consumption can then be written as :

$$C^{hh}\left(\{\mathbf{r}_s, \mathbf{Z}_s, \mathbf{PF}_s/\mathbf{P}_s\}_{s=0}^{\infty}\right): \quad d\mathbf{C}^{hh} = \mathbf{M}^r\, d\mathbf{r} + \mathbf{M}\, d\mathbf{Z} + \mathbf{M}^p\, d\frac{\mathbf{PF}}{\mathbf{P}} \tag{4.30}$$

where $d\mathbf{X}_t$ for $\mathbf{X} \in \{\mathbf{C}, \mathbf{r}, \mathbf{Z}, \mathbf{PF}/\mathbf{P}\}$ denotes the relevant variables written in stacked matrix form to reflect the entire dynamic path of responses, and $\mathbf{M}^r = \frac{\partial \mathbf{C}_t}{\partial \mathbf{r}_t}$, $\mathbf{M} = \frac{\partial \mathbf{C}_t}{\partial \mathbf{Z}_t}$, and $\mathbf{M}^p = \frac{\partial \mathbf{C}_t}{\partial \frac{\mathbf{P_F}}{\mathbf{P_t}}}$ denote the Jacobian of consumption with respect to $\mathbf{r}_t$, $\mathbf{Z}_t$, and $\frac{\mathbf{P_F}}{\mathbf{P_t}}$, respectively. Figure 4.5 plots the contribution of each of these channels. The different channels that drive the aggregate consumption response can be classified into three: a direct effect from real interest rate changes, an indirect effect from real labour income changes, and a price effect, which has both direct and indirect effects on aggregate consumption. The direct effects play out as follows. The direct effect corresponds to the intertemporal substitution effect, arises from the decline in real interest rates, which encourages households to dissave, thereby having a positive impact on aggregate consumption. Changes in the relative prices also induce substitution effects, where the decline in relative import prices induces a rise in consumption, while on the other hand, rising relative home domestic prices have a negative impact on aggregate consumption. In addition, prices also have indirect effects through their impact on household labour income, by changing the price of the overall consumption basket. This follows from the definition of real income, which was also shown in the previous section: $Z_t = w_t N_t = \frac{P_{H,t}}{P_t} Y_t$ where the fall in import prices lowers the overall CPI. For a given level of output $Y_t$, this implies that the relative price of home goods $\frac{P_{H,t}}{P_t}$ increases, which raises the purchasing power of households through higher real labour income. This is the real income channel discussed in Auclert et al. (2024a).

While the two above-mentioned price effects are relevant even in a model with homothetic preferences, the presence of non-homothetic preferences introduces additional price effects. This non-homothetic price effect stems from the relative import price term that appears in the consumption function in Equation 4.30. In the model, imports are modeled as luxury goods with a Stone–Geary threshold ($\bar{c} > 0$). This means that when import prices fall, poorer households, whose consumption of imports lies near the threshold, show a disproportionately large increase in import consumption, since small changes in prices affect how close they are to affording the luxury good. As a result, they reallocate spending away from home goods in response to the relative import price drop. In contrast, richer households, whose import consumption is already well above the threshold, do not switch as much. This means that, the relative price changes trigger a stronger substitution response by households at the lower end of the income distribution, essentially generating income-based differences in the expenditure switching of households, a mechanism that would not arise under homothetic preferences.

Focusing on the strength of these transmission channels, while both relative import price changes and interest rate changes have a positive effect on consumption in the figure, the increase in consumption is driven largely by the fall in relative import prices. Real labour income exerts a much stronger negative effect on consumption, resulting in a decline in aggregate consumption of more than $-0.2\%$ initially, before gradually returning to its steady-state level. [8]

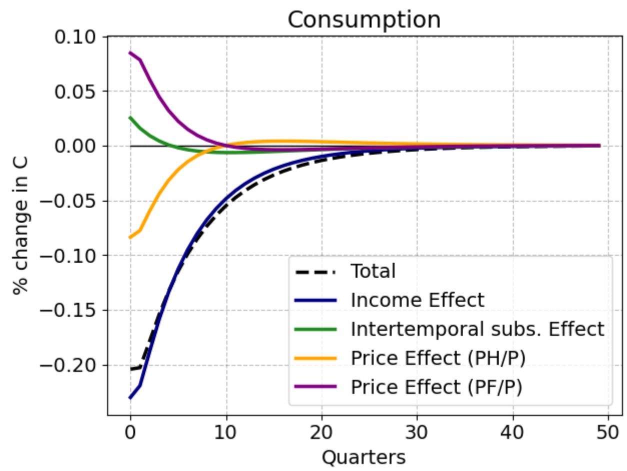



Figure 4.5: Decomposition of the consumption response to an exchange rate shock.

### 4.4.4 Consumption Response Across the Income Distribution

Figure 4.6 shows how the consumption response varies for households across the income distribution. The non-homothetic structure of the model amplifies differences in consumption responses across income groups.

While import consumption increases for all income groups, households in the lower income quintiles exhibit a stronger decline in home goods consumption, reflecting a greater degree of switching towards relatively cheaper imports. This is because, given the Stone-Geary setup assumed in the model, where imports are treated as luxury goods, poor households who are near this luxury threshold are more responsive to price changes. When import prices fall significantly, they can finally afford to consume more imports, crossing the threshold. Rich households, by contrast, already consume well above this threshold. As a result, there is a smaller decline in their domestic goods consumption, suggesting that they do not change the composition of their consumption basket as much, and therefore continue to hold a larger share of import goods. This also highlights the non-homothetic effect, where low-income households react more strongly to drops in import prices by shifting

[8] The consumption decomposition results from the homothetic model are also provided in Appendix B.1.

their consumption basket more substantially towards luxury goods. In Section 5.0.3, I compare these results to those obtained under an extended version of the model that incorporates imperfect pass-through to import prices, which yields different results from those shown here.

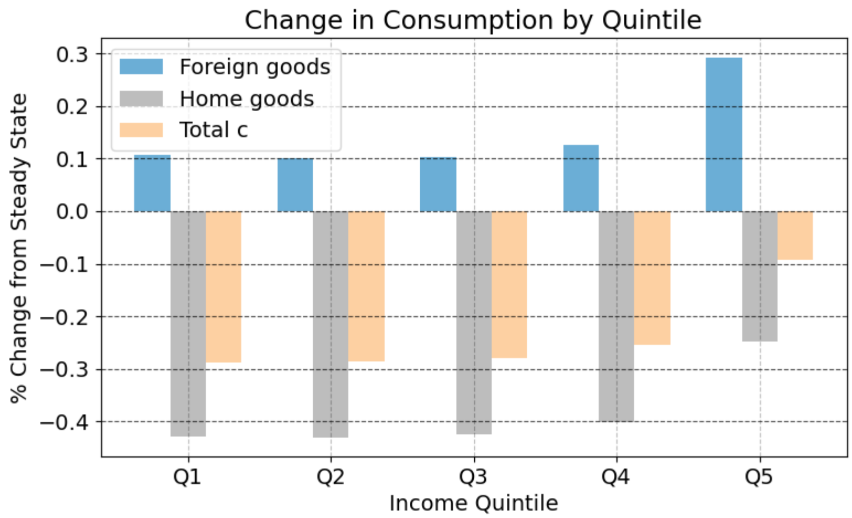



Figure 4.6: Response across income quintiles.

# Chapter 5

# Exchange Rate Pass-Through into Prices

In this chapter, I extend the baseline model to allow for imperfect pass-through of exchange rate changes into import prices. To do this, I conduct the same exercise as in Chapter 4, where I simulate a foreign interest rate shock and compare the outcomes under non-homothetic preferences with those under homothetic preferences. I then examine the resulting distributional effects.

Auer et al. (2021) documents that following the Swiss franc appreciation in 2015, the prices of euro-invoiced goods declined more than those of CHF- invoiced goods, providing evidence on differences in exchange rate pass through into consumer prices. In addition, they also show how this translates into household consumption decisions, with households shifting their expenditure more strongly towards imports invoiced in euros compared to CHF-invoiced goods. This means that any changes in the nominal exchange rate caused by external shocks do not fully translate into the prices of imported goods that consumers see. For instance, when the CHF appreciates against the euro, a product invoiced in euros becomes cheaper following the exchange rate shock, compared to the same good invoiced in CHF. This is because CHF invoiced goods adjust less to exchange rate changes, depending on the degree of pass-through. This quite evidently leads to deviations from the law of one price, since consumers now pay different prices for the same good depending on the currency of invoicing. As a result, the usual price channel through which exchange rate changes affect the consumption basket is narrowed.[1]

[1] Although empirical studies suggest that there is little evidence that trade occurs exclusively under LCP or PCP. The majority of international markets instead follow Dominant Currency Pricing (DCP) typically using the US dollar. See Gopinath and Itskhoki (2022) who develop a

To model imperfect pass through into import prices I describe the import process from foreign exporters. I add to the standard small open economy New Keynesian model considered in Chapter 4 an additional layer of importing firms that mediate between foreign exporters in the large foreign economy and households in the domestic economy. These importing firms have sticky prices which dampens the pass through of foreign prices denoted as $PF_s$ into local currency prices, hence implying the law of one price no longer holds for imported goods. Households consume domestic goods produced by perfectly competitive manufacturers at home, as before.The foreign composite is now produced by imperfectly competitive foreign importers who now faces pricing frictions and set prices according to the calvo parameter $\theta_F$. Figure 5.1 below illustrates this process.

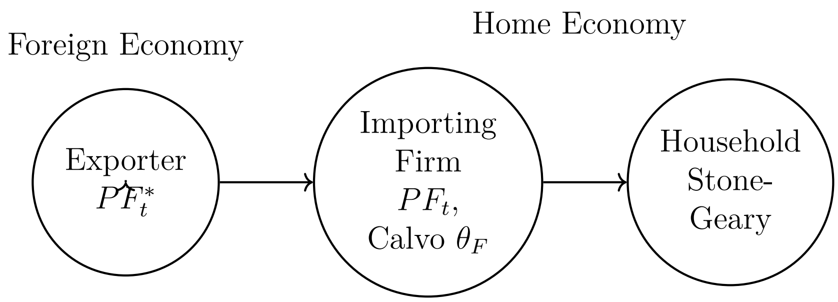



Figure 5.1: Overview of Import Process from Foreign exporter

**Pricing friction** This extension builds on a variant considered in Auclert et al. (2023). Households consume a Stone-Geary aggregate of the domestic good ($C_H$) and the foreign good ($C_F$). Domestic manufacturers produce the domestic good using labor while there is a continuum of monopolistically competitive import producers that import the foreign good. Each foreign importer buy differentiated goods at the real cost $\frac{E_t P_{Ft}^*}{P_t}$ and sell them at price $P_{Ft}$. A representative final goods firm buy import goods from these importers assemble them using CES technology with substitution elasticity $\epsilon^F$.The Phillips curve defining inflation $\pi_{Ft}$ for imported goods can then be written as:

$$\pi_{Ft}(1+\pi_{Ft}) = \kappa^F \left( \frac{E_t P_{Ft}^*}{P_{Ft}} - 1 \right) + \beta \pi_{Ft+1}(1+\pi_{Ft+1})$$

where $\kappa^F = \frac{\epsilon^F}{\theta^F}$. The foreign imports are assumed to be highly substitutable such that markups are set equal to 1 in steady state. Dividends to foreign firms are given

model based on this framework.

by :

$$\Pi_{Ft} = \frac{P_{Ft} - E_t P^*_{Ft}}{P^*_t} C_{Ft}$$

### 5.0.1 Foreign Interest Rate Shock

This section examines the implications of imperfect pass-through into import prices by simulating a foreign interest rate shock, similar to the one considered in Section 4.4. Figure 5.2 below plots the impulse responses. I compare how the response varies under different degrees of price rigidity by varying the slope of the import price Phillips curve. A monetary expansion in the foreign economy leads to a fall in the price of exported goods in the home currency, thereby inducing expenditure switching by home consumers.The presence of nominal rigidities in the price adjustment of imported consumer goods now will have implications for the strength of the expenditure switching mechanism. Under producer currency pricing, which is the standard assumption in New Keynesian models, there is perfect pass through of the import firm's marginal cost which is denoted by $E_t P^*_{Ft}$ to import prices. In other words, the law of one price holds, and import prices fluctuate fully with exchange rate movements.

With higher levels of price rigidity, implied by a lower slope of the import price Phillips curve, there is lower pass through of exchange rate changes into the importer firm's prices, and exchange rate movements now have a smaller impact on prices at home. As a result, fluctuations in the exchange rate no longer fully translate into domestic import prices. So if prices are sticky at home (i.e, under local currency pricing), a nominal appreciation raises the price of imports relative to exports, improving competitiveness. In this case a currency appreciation may not necessarily result in the expected switching of domestic demand away from domestic goods toward imports. This is also visible in the figure, where there is a larger rise in demand for foreign goods, accompanied by a decline in consumption of home goods under more flexible pricing. Hence, the extent to which exchange rates can induce expenditure switching by altering prices depends on how responsive prices are to exchange rate movements. The expenditure switching channel becomes weaker when there is imperfect pass through.

### 5.0.2 Comparison with Homothetic Model

I also examine the interaction between non-homothetic preferences and price pass-through by comparing the IRFs to those generated under homothetic preferences in

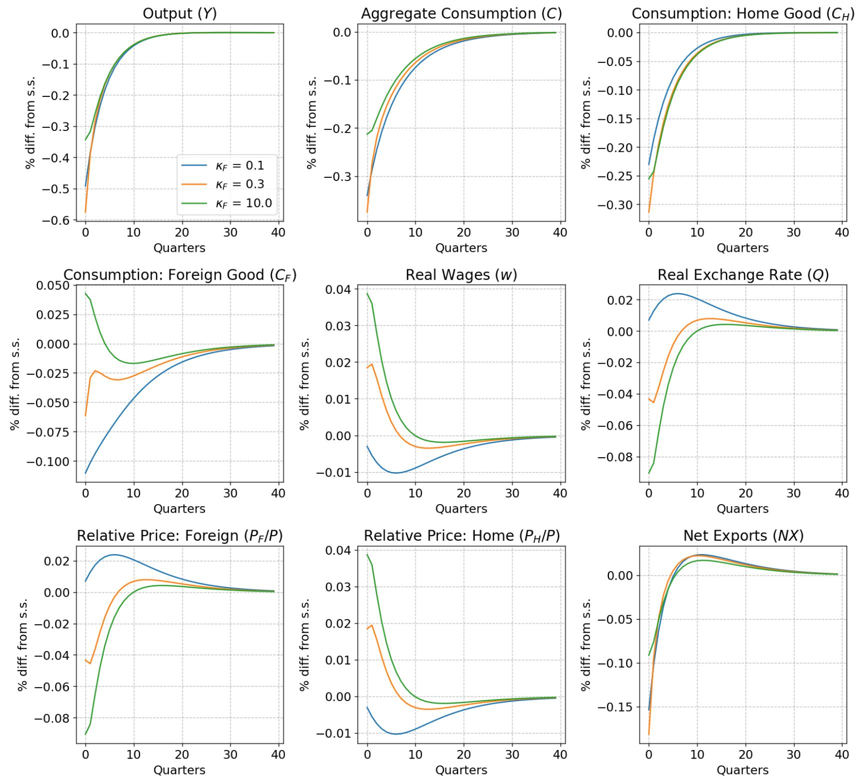



Figure 5.2: Responses when there is imperfect pass-through into import prices

Figure 5.3 below. I set the slope of the import Phillips curve, $\kappa_F = 0.1$, implying high import price stickiness. While the overall consumption response is similar in magnitude across the two models, the responses of imported consumption and home consumption differs.

The stronger depreciation in the non-homothetic case implies a larger contraction in foreign goods consumption than in the homothetic model. With imperfect pass-through, import prices do not fall as much, which weakens the relative price signal that typically encourages substitution toward imported goods. While this dampens expenditure switching across all households, it hits poorer households more, since it reduces the benefits of an effective drop in relative prices, such that poorer households no longer shift their consumption baskets toward luxury goods, this will be clear from the household response that will be presented in the next section. As a result, the decline in imported consumption is larger in the non-homothetic model compared to the homothetic one.

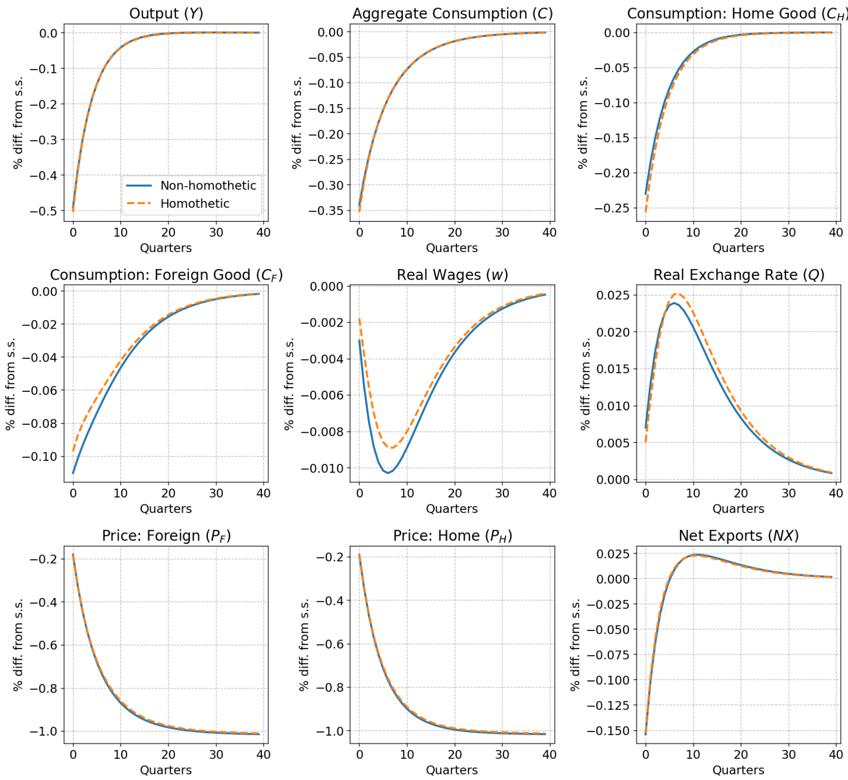



Figure 5.3: Impulse responses comparing homothetic and non-homothetic models under imperfect pass-through into import prices.

### 5.0.3 Consumption Response Across Income Distribution

Plotting household-level consumption responses across income quintiles in Figure 5.4 reveals that the stronger import demand response in the non-homothetic case is primarily driven by a decline in foreign demand from lower-income households. This implies that imperfect pass-through has a disproportionately larger impact on poorer households. In Figure 4.6, which showed the consumption responses under complete pass-through, import prices fall significantly following an exchange rate appreciation. This allows poorer households who consume near the minimum consumption threshold on imported goods ($\bar{c}$) to reallocate spending toward relatively cheaper imports.

As a result, the relative price changes trigger a strong non-homothetic price effect, discussed earlier in Section 4.4.3, with households at the bottom of the income distribution, who have higher substitution elasticities, cutting down the consumption

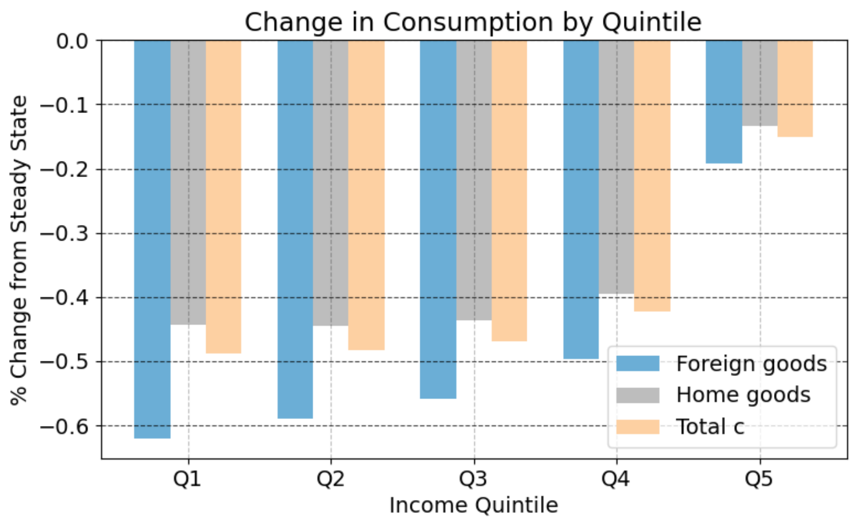



Figure 5.4: Consumption responses across income quintiles under imperfect pass-through.

of home goods more sharply in order to reallocate their spending toward luxury imports.

However, as pass-through to import prices declines and import prices fall only modestly, poorer households no longer adjust their consumption baskets in the same way. This means that the non-homothetic price effect is subdued. This occurs because imperfect pass-through dampens not only the aggregate expenditure-switching response, but also the income-dependent substitution effect (i.e., the non-homothetic price effect) that arises under non-homothetic preferences. As a result, the difference between the non-homothetic and homothetic models becomes smaller, since the non-homothetic price effect that generates this difference is muted or even eliminated, forcing poorer households to effectively cut back on their consumption of imports. [2]

[2]Figure B.2 in the Appendix shows the decomposition of consumption under imperfect pass-through.

# Chapter 6

# Discussion

## 6.1 Sensitivity to Calibration

The choice of parameters in the calibration has important implications for the model's results. In the baseline specification, the elasticity of substitution between goods is calibrated to match the estimates from Auer et al. (2024). The literature provides a wide range of estimates for trade elasticities (see Boehm et al. (2023)). As discussed in Section 4.4.2, the value of this parameter can largely determine whether exchange rate appreciations are expansionary or contractionary, by influencing the relative strength of the real income and expenditure switching channels.

## 6.2 Model Assumptions and Limitations

### 6.2.1 Sticky Prices

The baseline model presented in Chapter 4 assumes fully flexible prices while wages are determined in a union setup. This was primarily for tractability and as will become clear from the analysis in this section, restricting the baseline model to sticky wages allows for a clearer illustration of the expenditure switching channel. In this section, I compare the results in the presence of additional pricing frictions. To that end, I briefly outline the supply side of the model from Section 4.1 modified to allow for price rigidities in domestic goods.

**Final goods firm** The specification of price stickiness features a representative final good domestic firms who takes prices as given under perfect competition and aggregates the output of a continuum of monopolistically competitive firms using CES production function

$$Y_t = \left( \int_0^1 y_{jt}^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{\epsilon}{\epsilon-1}}$$

the demand for $y_{jt}$ is given by :

$$y_{jt} = \left( \frac{p_{H,jt}}{P_t} \right)^{-\epsilon} Y_t$$

**Intermediary goods firms** The representative competitive producer purchases goods from a continuum of intermediate firms indexed by j who produce differentiated goods using labor and face Rotemberg price adjustment costs $\theta^P$ when resetting prices. The implied production technology of these firms is described by a linear production where output $y_{jt}$ :

$$y_{jt} = \Gamma_t l_{jt}$$

All the firms face the same nominal marginal costs $MC_t = \frac{W_t}{\Gamma_t}$.Profits of intermediate goods firms written in terms of CPI is then:

$$\Pi_t = \frac{P_{Ht}}{P_t} Y_t - \frac{W_t}{P_t} L_t - \frac{\theta^p}{2} \pi_{Ht}^2 Y_t$$

These firm profits now enter the household budget constraint in - as dividends. The Phillips curve describing inflation for domestic goods can then be described as[1]:

$$\pi_t^H (1 + \pi_t^H) = \kappa^P \left( \frac{w_t}{\Gamma_t} - \frac{1}{\mu} \right) + \mathbb{E}_t \left[ \pi_{t+1}^H (1 + \pi_{t+1}^H) \frac{Y_{t+1}}{Y_t} \frac{1}{1 + r_{t+1}} \right]$$

where $w_t$ is the real wage rate, $\kappa^P = \frac{\epsilon^P}{\theta^P}$ denotes the slope of the Phillips curve and $\mu = \frac{\epsilon^P}{\epsilon^P - 1}$ is the markup charged by the intermediate firms.

#### 6.2.1.1 Effects on Output and Prices

Figure 6.1 compares the results under varying degrees of price rigidity. I first focus on the impulse response functions when $\kappa_P$ is set to 0.1, a standard value in the literature. The slope of the wage Phillips curve presented in Equation 4.14 is assumed to be 0.01, such that wages are more rigid than prices. Compared to the results presented in Section 4.2, introducing sticky prices into the baseline model amplifies

[1]See Appendix A.5 for the derivation.

the negative effects on output, due to the fall in real wages caused by the sluggish adjustment of prices in response to the exchange rate shock. As a result, output falls by a significantly larger amount. Households experience a decline in real income from the slow adjustment of real wages, which in turn dampens their consumption.

For lower levels of pass-through from marginal costs into prices, as implied by a lower slope of the price Phillips curve (e.g., $\kappa_P = 0.01$)—and for a given degree of wage rigidity ($\kappa_w = 0.01$), the fall in real wages is even more pronounced. Hence, a higher degree of price rigidity amplifies the adverse output response to an exchange rate shock as sluggish price adjustment exacerbates the decline in real wages, while the contractionary effect on output is much less pronounced under the assumption of flexible prices,since the presence of nominal wage rigidities imply a rise in real wages. One issue often flagged in the literature is the inability of standard New Keynesian models with sticky prices and flexible wages to replicate the procyclical nature of firm profits. As seen in the figure, firm profits increase under higher levels of price rigidity. Hence, introducing a union setup implies that wages fall less than prices in response to a deflationary shock, thereby helping to circumvent this issue and generate a fall in profits. As a result, firm dividends decline by a smaller amount when prices are more rigid.

### 6.2.2 Fisher Effects

The baseline model assumes real bonds for simplicity. However, including nominal bonds into the picture means that large price shocks entail winners and losers. As a result, there can now be revaluation effects on households from differences in real returns, this is the Fisher channel discussed in Auclert (2019).

Assuming the central bank now sets the nominal interest rate such that the real return on nominal bonds $r_t^b$ equal the return on real bonds $r_t$ :

$$(1 + r_t^b) = (1 + r_t) = \frac{1 + i_{t-1}}{1 + \pi_t}$$

When a deflationary shock hits in period 0, it generates a positive effect for households holding nominal bonds. A bond purchased in the period prior to the shock undergoes a revaluation effect, as the real return on bonds is higher than expected. This results in a change in household capital in period 0:

$$\frac{1 + i_{-1}}{1 + \pi_0} B_{-1}$$

This implies that the budget constraint for period 0 needs to be rewritten to account for the initial capital gain, while it remains the same for the period after:

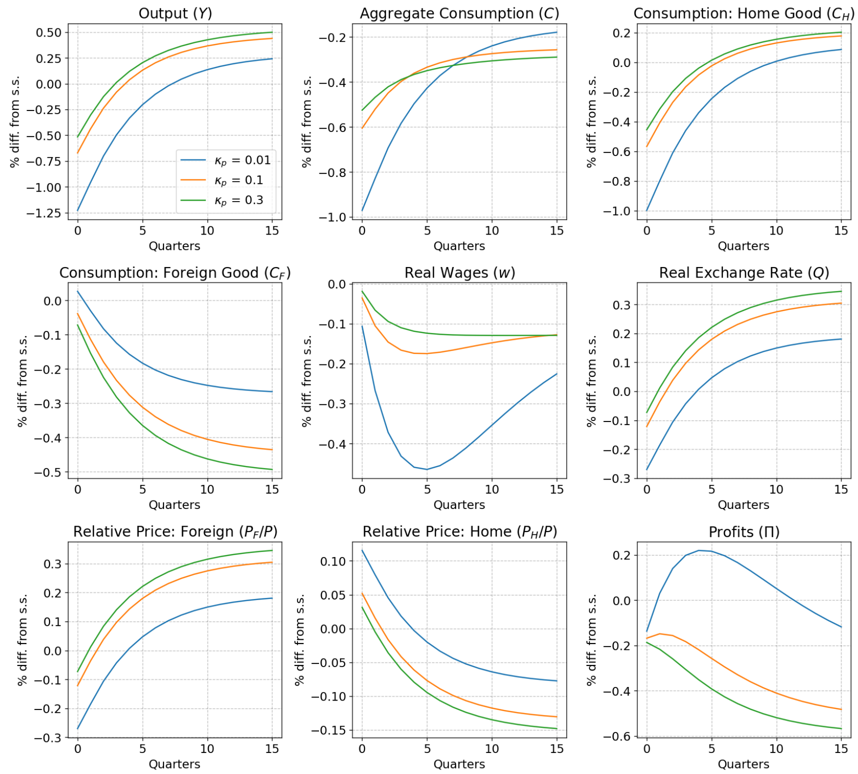



Figure 6.1: Responses under varying degrees of price rigidity.

$$a_t + c_t = (1 - \tau_t) Y_t z_t + \begin{cases} (1 + r_{t-1}) a_{t-1} & \text{if } t > 0 \\ (1 + \text{cap}_0) a_{t-1} & \text{if } t = 0 \end{cases}$$

where

$$\text{cap}_0 = \frac{(1 + r_{-1})(1 + \pi_{-1})}{1 + \pi_0}$$

The consumption function in equation - is also a function of the capital gain effect in period 0, $\mathbf{C}^{hh} = C^{hh}(\mathbf{r}_t, \mathbf{Z}_t, (\mathbf{P}_F/\mathbf{P}_t), \mathbf{cap}_0)$ which can be written in sequence space form as

$$d\mathbf{C}^{hh} = \mathbf{M}^r \, d\mathbf{r} + \mathbf{M} \, d\mathbf{Z} + \mathbf{M}^p \, d\mathbf{P} + \mathbf{m}^{\text{cap}} \, \mathbf{cap}_0$$

where

$$\mathbf{m}_t^{\text{cap}} = \left[ \frac{\partial C_t^{hh}}{\partial \text{r}_0} \right]$$

is the Jacobian of consumption with respect to the real return in period 0. Auclert et al. (2024b) documents that the marginal propensity to consume (MPC) out of capital gains are small (approximately 1–4% per year) indicating that the entries in this vector are usually small and may only have a limited impact on consumption dynamics. Hence while the large decrease in the price level from the exchange rate shock places gains on the balance sheet of households holding nominal assets by raising their real returns, this is associated with an increase in real debt burdens for borrowers.

# Chapter 7

# Conclusion

This thesis focused on the role of heterogeneity in household consumption baskets across income groups in the transmission of exchange rate shocks. To this end, a standard New Keynesian open economy model with heterogeneous agents and nominal wage rigidities (SOE-HANK) was adapted to incorporate non-homothetic preferences, calibrated to match the empirical findings of Auer et al. (2024) who documents that higher-income households devote a larger share of their consumption to imported goods. The results shed light on the differences in expenditure-switching behavior that can emerge under non-homothetic preferences, across households at different income levels. This happens because the Stone–Geary threshold $\bar{c}$ represents a minimum consumption level for a luxury good, capturing the idea that import consumption only starts increasing significantly once a household reaches a certain income level. This means that rich households who allocate a larger share of spending to imports, will respond less to price changes. Poorer households, in contrast, are closer to the threshold and therefore exhibit higher elasticities. They consequently engage in greater expenditure switching in response to external shocks that alter the relative prices in their consumption baskets. It might be more useful to understand this through the lens of a contractionary foreign interest rate shock that causes a rise in relative prices. This means that poorer households who tend to consume near this threshold will now face a stronger constraint, leading them to substitute away from imports more sharply. In contrast, richer households, whose consumption of imports already exceeds the threshold, will exhibit a much more muted response.

In a second step, I also extend the baseline model with Stone–Geary preferences to allow for imperfect pass-through into import prices, drawing on related evidence from a companion paper by the authors (Auer et al., 2021). The results provide further insights into how differences in price pass-through can dampen the strength of the expenditure-switching channel. The findings further emphasize that the expenditure-switching channel becomes weaker when there is imperfect pass-through, in line with the empirical evidence. Further comparing the distributional effects shows that, when pass-through is imperfect and import prices fall only modestly, poor households are no longer able to meaningfully adjust their consumption baskets, and the non-homothetic price effect is consequently muted. In this case, price stickiness not only eliminates the gains that would have occurred through expenditure switching under full pass-through, but also dampens the income-dependent substitution effect,i.e, the non-homothetic price effect. This is because, as pass-through to import prices declines, poor households remain constrained near the import threshold. As a result, the difference between the non-homothetic and homothetic models becomes less pronounced. In this case, while consumption falls across all households, poorer households are hit the hardest.

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# Appendix A

# Model Derivations

This chapter presents the derivations of key equations and analytical results used throughout the thesis. The derivations are presented in the order in which they appear in the main text.

## A.1 Deriving Elasticity for CES preferences

We start by taking the ratio of goods:

$$\frac{C_F}{C_H} = \frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta} \tag{A.1}$$

$$\frac{d}{d\left(\frac{P_F}{P_H}\right)}\left(\frac{C_F}{C_H}\right) = -\eta\frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta-1} \tag{A.2}$$

Now dividing this by relative prices:

$$\left(\frac{C_F}{C_H}\right)\Big/\left(\frac{P_F}{P_H}\right) = \left[\frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta}\right]\Big/\left(\frac{P_F}{P_H}\right) = \frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta-1} \tag{A.3}$$

$$\frac{\frac{d}{d\left(\frac{P_F}{P_H}\right)}\left(\frac{C_F}{C_H}\right)}{\left(\frac{C_F}{C_H}\right)/\left(\frac{P_F}{P_H}\right)} = \frac{-\eta\frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta-1}}{\frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta-1}} \tag{A.4}$$

So the elasticity of substitution under CES preferences can be derived as:

$$\frac{\partial\left(\frac{C_F}{C_H}\right)/\partial\left(\frac{P_F}{P_H}\right)}{\left(\frac{C_F}{C_H}\right)/\left(\frac{P_F}{P_H}\right)} = -\eta \tag{A.5}$$

## Elasticity of Substitution for Stone–Geary Preferences

Writing the demand functions:

$$C_F = \alpha\left(\frac{P_F}{P}\right)^{-\eta} C + \bar{c} \tag{A.6}$$

$$C_H = (1-\alpha)\left(\frac{P_H}{P}\right)^{-\eta} C \tag{A.7}$$

$$\frac{C_F}{C_H} = \frac{\alpha\left(\frac{P_F}{P}\right)^{-\eta} C + \bar{c}}{(1-\alpha)\left(\frac{P_H}{P}\right)^{-\eta} C} \tag{A.8}$$

which gives:

$$\frac{C_F}{C_H} = \frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta} + \frac{\bar{c}}{(1-\alpha)\left(\frac{P_H}{P}\right)^{-\eta} C} \tag{A.9}$$

So the numerator simplifies to:

$$\frac{d}{d\left(\frac{P_F}{P_H}\right)}\left(\frac{C_F}{C_H}\right) = -\eta\frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta-1} \tag{A.10}$$

In this case, the denominator that enters the fraction is now different compared to the CES case:

$$\left(\frac{C_F}{C_H}\right)\Big/\left(\frac{P_F}{P_H}\right) = \left(\frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta} + \bar{c}\right)\Big/\left(\frac{P_F}{P_H}\right) \tag{A.11}$$

Such that elasticity is now dependent on the non-homothetic component, $\bar{c}$:

$$\frac{\partial\left(\frac{C_F}{C_H}\right)/\partial\left(\frac{P_F}{P_H}\right)}{\left(\frac{C_F}{C_H}\right)/\left(\frac{P_F}{P_H}\right)} = \frac{-\eta\frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta-1}}{\left(\frac{\alpha}{1-\alpha}\left(\frac{P_F}{P_H}\right)^{-\eta} + \bar{c}\right)\Big/\left(\frac{P_F}{P_H}\right)} \tag{A.12}$$

## A.2 Derivation of Demand Curves

The household maximizes utility over $c_{Ht}$ and $c_{Ft}$:

$$c_t = \left[\alpha^{1/\eta}(c_{Ft} + \underline{c})^{(\eta-1)/\eta} + (1-\alpha)^{1/\eta} c_{Ht}^{(\eta-1)/\eta}\right]^{\eta/(\eta-1)} \tag{A.13}$$

subject to the budget constraint:

$$P_H c_{Ht} + P_F(c_{Ft} + \underline{c}) = X_t \tag{A.14}$$

The Lagrangian for this problem is:

$$\mathcal{L} = \left[(1-\alpha)^{1/\eta} c_{Ht}^{(\eta-1)/\eta} + \alpha^{1/\eta}(c_{Ft} + \underline{c})^{(\eta-1)/\eta}\right]^{\eta/(\eta-1)} + \lambda\left(X_t - P_H c_{Ht} - P_F(c_{Ft} + \underline{c})\right) \tag{A.15}$$

1. For $c_{Ht}$:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial c_{Ht}} = \frac{\eta}{\eta-1}\left[(1-\alpha)^{1/\eta} c_{Ht}^{(\eta-1)/\eta} + \alpha^{1/\eta}(c_{Ft} + \bar{c})^{(\eta-1)/\eta}\right]^{1/(\eta-1)} \\ (1-\alpha)^{1/\eta}\left(\frac{\eta-1}{\eta}\right) c_{Ht}^{-1/\eta} - \lambda P_H = 0 \end{aligned} \tag{A.16}$$

Rearranging:

$$\frac{\left[(1-\alpha)^{1/\eta} c_{Ht}^{(\eta-1)/\eta} + \alpha^{1/\eta}(c_{Ft} + \bar{c})^{(\eta-1)/\eta}\right]^{1/(\eta-1)} (1-\alpha)^{1/\eta}}{\lambda P_H} = c_{Ht}^{1/\eta} \tag{A.17}$$

$$c_{Ht} = \frac{(1-\alpha)C_t}{\lambda^\eta P_H^\eta} \tag{A.18}$$

2. For $c_{Ft}$:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial c_{Ft}} = \frac{\eta}{\eta-1}\left[(1-\alpha)^{1/\eta} c_{Ht}^{(\eta-1)/\eta} + \alpha^{1/\eta}(c_{Ft} + \tilde{c})^{(\eta-1)/\eta}\right]^{1/(\eta-1)} \\ \alpha^{1/\eta}\left(\frac{\eta-1}{\eta}\right)(c_{Ft} + \tilde{c})^{-1/\eta} - \lambda P_F = 0 \end{aligned} \tag{A.19}$$

Rearranging:

$$\frac{\left[(1-\alpha)^{1/\eta} c_{Ht}^{(\eta-1)/\eta} + \alpha^{1/\eta}(c_{Ft} + \bar{c})^{(\eta-1)/\eta}\right]^{1/(\eta-1)} \alpha^{1/\eta}}{\lambda P_F} = (c_{Ft} + \bar{c})^{1/\eta} \tag{A.20}$$

$$c_{Ft} + \bar{c} = \frac{\alpha C_t}{\lambda^\eta P_F^\eta} \tag{A.21}$$

Substituting $\lambda = 1/P_t$ into the FOCs, we get:

$$c_{Ht} = (1-\alpha)\left(\frac{P_t}{P_H}\right)^\eta C_t \quad \text{or} \quad c_{Ht} = (1-\alpha)\left(\frac{P_H}{P_t}\right)^{-\eta} C_t \tag{A.22}$$

$$c_{Ft} = \alpha\left(\frac{P_t}{P_F}\right)^\eta C_t - \bar{c} \quad \text{or} \quad c_{Ft} = \alpha\left(\frac{P_F}{P_t}\right)^{-\eta} C_t - \bar{c} \tag{A.23}$$

## Relating $\lambda$ to the Consumer Price Index (CPI)

From the budget constraint:

$$P_H c_{Ht} + P_F(c_{Ft} + \bar{c}) = X_t \tag{A.24}$$

Substitute $X_t = P_t C_t$, where

$$P_t = \left[(1-\alpha)P_H^{1-\eta} + \alpha P_F^{1-\eta}\right]^{1/(1-\eta)} \tag{A.25}$$

is the CPI. The Lagrange multiplier $\lambda$ is given by:

$$\lambda = \frac{1}{P_t} \tag{A.26}$$

## A.3 Derivation of New Keynesian Wage Phillips Curve

In this section, I derive the New Keynesian Wage Phillips Curve following Auclert et al. (2024b). Each union $j$ maximizes the utility of its members by choosing wages $W_{j,t}$ and labor supply $L_{j,t}$ by solving the following optimization problem:

$$\max_{W_{j,t}, L_{j,t}} \sum_{t=0}^{\infty} \beta^t \left( \int \left[ u(c_{i,t}) - \nu(L_{j,t}) \right] dD_{i,t} - \frac{\theta^w}{2} \left( \frac{W_{j,t}}{W_{j,t-1}} - 1 \right)^2 \right) \tag{A.27}$$

subject to the labor demand function:

$$L_{j,t} = \left( \frac{W_{j,t}}{W_t} \right)^{-\varepsilon^w} L_t \tag{A.28}$$

where the quadratic adjustment cost of changing nominal wages is given by:

$$\frac{\theta^w}{2} \left( \frac{W_{j,t}}{W_{j,t-1}} - 1 \right)^2 \tag{A.29}$$

There is a continuum of such unions. Each household $i$ belongs to a union $j$, and each union $j$ aggregates the efficient units of work of its members into a union-specific task:

$$L_{j,t} = \int e_i l_{i,j,t} \, di \tag{A.30}$$

where $e_i$ is the efficiency unit of worker $i$. A competitive labor packer aggregates these union-specific tasks into total employment using a CES production function:

$$L_t = \left( \int L_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} \, dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{A.31}$$

where $\varepsilon > 1$ is the elasticity of substitution between union tasks. The competitive labor packer sells these aggregated employment services to firms at price $W_t$, where $W_t$ is the price index for aggregate labor services written as:

$$W_t = \left( \int W_{j,t}^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}} \tag{A.32}$$

Each union sets its wage $W_{j,t}$ to maximize the average utility of its members, taking as given the labor demand curve from the labor packers:

$$L_{j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{-\varepsilon} L_t \tag{A.33}$$

In equilibrium, all unions set the same wage, $W_{j,t} = W_t$. Earnings are determined by:

$$z_{i,t} = (1-\tau_t)\frac{W_t}{P_t} e_{i,t} L_{j,t} \tag{A.34}$$

which can be rewritten as:

$$z_{i,t} = (1-\tau_t)\frac{e_{i,t}}{P_t} W_{j,t} \left(\frac{W_{j,t}}{W_t}\right)^{-\varepsilon} L_t \tag{A.35}$$

where $\tau_t$ is household $i$'s tax rate at time $t$.

$$\frac{\partial z_{i,t}}{\partial W_{j,t}} = (1-\tau_t)\frac{e_{i,t}}{P_t} L_{j,t} \left[\left(\frac{W_{j,t}}{W_t}\right)^{-\varepsilon} - \varepsilon W_{j,t} \left(\frac{W_{j,t}}{W_t}\right)^{-\varepsilon-1} \left(\frac{1}{W_t}\right)\right] \tag{A.36}$$

which simplifies to:

$$\frac{\partial z_{i,t}}{\partial W_{j,t}} = (1-\tau_t)\frac{e_{i,t}}{P_t} L_{j,t} \left[\left(\frac{W_{j,t}}{W_t}\right)^{-\varepsilon} - \varepsilon W_{j,t}^{-\varepsilon} \left(\frac{1}{W_t}\right)^{-\varepsilon}\right] \tag{A.37}$$

Imposing symmetry $W_{j,t} = W_t$:

$$\frac{\partial z_{i,t}}{\partial W_{j,t}} = (1-\tau_t)\frac{e_{i,t}}{P_t} L_{j,t}(1-\varepsilon) \tag{A.38}$$

Then we can write the first-order condition for the union's maximization problem with respect to $W_{j,t}$:

$$\begin{aligned}&\left[u'(c_{i,t})(1-\tau_t)\frac{e_{i,t}}{P_t} L_{j,t}(1-\varepsilon) + v'(L_t)\frac{L_{j,t}}{W_{j,t}}\varepsilon\right] dD_{i,t} \\ &\quad - \theta^w \left(\frac{W_{j,t}}{W_{j,t-1}} - 1\right)\frac{1}{W_{j,t-1}} + \beta\theta^w \left(\frac{W_{j,t+1}}{W_{j,t}} - 1\right)\frac{W_{j,t+1}}{W_{j,t}}\frac{1}{W_{j,t}} = 0\end{aligned} \tag{A.39}$$

Multiplying through by $W_t$:

$$\begin{aligned}&\left[u'(c_{i,t})(1-\tau_t)e_{i,t}\frac{W_t}{P_t}L_{j,t}(1-\varepsilon)+v'(n)\frac{L_{j,t}}{W_{j,t}}\varepsilon W_t\right]dD_{i,t}\\&-\theta^w\left(\frac{W_{j,t}}{W_{j,t-1}}-1\right)\frac{W_{j,t}}{W_{j,t-1}}+\beta\theta^w\left(\frac{W_{j,t+1}}{W_{j,t}}-1\right)\frac{W_{j,t+1}}{W_{j,t}}\frac{W_t}{W_{j,t}}=0\end{aligned} \tag{A.40}$$

In equilibrium, all unions set the same wage, so $W_{j,t}=W_t$, and all workers supply the same hours $l_{i,t}=L_{j,t}=L_t$. Define wage inflation $\pi_t^w\equiv\frac{W_t}{W_{t-1}}-1$.

$$\varepsilon L_t\left[u'(c_{i,t})(1-\tau_t)e_{i,t}\frac{W_t}{P_t}\frac{(1-\varepsilon)}{\varepsilon}+v'(L_t)\right]dD_{i,t}-\theta^w\pi_t^w(1+\pi_t^w)+\beta\theta^w\pi_{t+1}^w(1+\pi_{t+1}^w)=0 \tag{A.41}$$

Rearranging:

$$\pi_t^w(1+\pi_t^w)=\frac{\varepsilon}{\theta^w}L_t\left[v'(L_t)-\frac{(\varepsilon-1)}{\varepsilon}(1-\tau_t)\frac{W_t}{P_t}e_{i,t}u'(c_{i,t})\right]dD_{i,t}+\beta\pi_{t+1}^w(1+\pi_{t+1}^w) \tag{A.42}$$

Which gives the wage Phillips curve:

$$\pi_t^w(1+\pi_t^w)=k^wL_t\left[v'(L_t)-\frac{1}{\mu^w}(1-\tau_t)w_tz_{i,t}u'(c_{i,t})\right]dD_{i,t}+\beta\pi_{t+1}^w(1+\pi_{t+1}^w) \tag{A.43}$$

where $k^w=\frac{\varepsilon}{\theta^w}$ is the slope and $\mu^w=\frac{\varepsilon}{\varepsilon-1}$ is the wage markup.

## A.4 Solving the Consumption-Savings Problem with Exogenous Labour Supply

Writing the modified budget constraint in real terms:

$$\frac{P_{Ft}}{P_t}\tilde{c}_F + \frac{P_{Ht}}{P_t}c_H + a_t = (1+r_t)a_{t-1} + (1-\tau_t)\frac{W_t}{P_t}L_t z_{it} + d_t z_{it} + \frac{P_{Ft}}{P_t}\underline{c} \tag{A.44}$$

where $\tilde{c}_F = c_F + \underline{c}$

$$\tilde{c}_t + a_t = (1+r_t)a_{t-1} + (1-\tau_t)w_{it}n_{it}z_{it} + \frac{P_{Ft}}{P_t}\underline{c} \tag{A.45}$$

$$\tilde{c}_t + a_t = (1+r_t)a_{t-1} + (1-\tau_t)w_t\ell_t z_t \tag{A.46}$$

Then writing the Lagrangian for the consumption-savings problem:

$$\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[u(\tilde{c}_t) + \lambda_t \left((1+r_t)a_{t-1} + \tilde{w}_t\ell_t z_t - \tilde{c}_t - a_t\right)\right] \tag{A.47}$$

where

$$(1-\tau_t)w_t = \tilde{w}_t \tag{A.48}$$

$$\frac{\partial \mathcal{L}}{\partial \tilde{c}_t} = u'(\tilde{c}_t) - \lambda_t = 0 \quad \Rightarrow \quad \lambda_t = u'(\tilde{c}_t) \tag{A.49}$$

Substituting $\lambda_t = u'(\tilde{c}_t)$:

$$u'(\tilde{c}_t) = \beta(1+\tilde{r}_{t+1})\mathbb{E}_t[u'(\tilde{c}_{t+1})] \tag{A.50}$$

The Euler equation for consumption is:

$$u'(\tilde{c}_t) = \beta(1+\tilde{r}_{t+1})\mathbb{E}_t[u'(\tilde{c}_{t+1})] \tag{A.51}$$

Assuming $u(\tilde{c}_t) = \frac{\tilde{c}_t^{1-\sigma}}{1-\sigma}$, we have $u'(\tilde{c}_t) = \tilde{c}_t^{-\sigma}$.
Substituting into the Euler equation:

$$\tilde{c}_t^{-\sigma} = \beta(1+\tilde{r}_{t+1})\mathbb{E}_t[\tilde{c}_{t+1}^{-\sigma}] \tag{A.52}$$

Rewriting:

$$\tilde{c}_t = \left[\beta(1+\tilde{r}_{t+1})\mathbb{E}_t[\tilde{c}_{t+1}^{-\sigma}]\right]^{-1/\sigma} \tag{A.53}$$

$$\tilde{c}_t = (\beta v_{a,t+1}(z_t, a_t))^{-\frac{1}{\sigma}} \tag{A.54}$$

We can then invert the Euler equation to obtain $\tilde{c}_t$:

$$\tilde{c}_t = \left(\beta \underline{v}_{a,t+1}(z_t, a_t)\right)^{-\frac{1}{\sigma}} \tag{A.55}$$

where

$$\underline{v}_{a,t+1}(z_t, a_t) = \mathbb{E}_t[v_{a,t+1}(z_{t+1}, a_t)] \tag{A.56}$$

and the first equation uses

$$\underline{v}_{a,t+1}(z_t, a_t) = (1 + \tilde{r}_{t+1})\mathbb{E}_t[u'(\tilde{c}_{t+1})] \tag{A.57}$$

from the envelope condition.

## A.5 Derivation of the New Keynesian Price Phillips Curve

### Intermediary Firms' Problem

Firms maximize:

$$J_t(p^F_{jt-1}) = \max_{p^F_{jt}} \left\{ \frac{p^F_{jt}}{P_{Ft}} y^F_{jt} - w^F_t l^F_{jt} - \Omega(p^F_{jt}, p^F_{jt-1}) + \mathbb{E}_t \left[ \frac{J_{t+1}(p^F_{jt})}{1 + r^F_{t+1}} \right] \right\} \tag{A.58}$$

subject to:

$$y^F_{jt} = \Gamma^F_t l^F_{jt}, \quad y^F_{jt} = \left( \frac{p^F_{jt}}{P_{Ft}} \right)^{-\epsilon} Y_{Ft} \tag{A.59}$$

and Rotemberg adjustment cost:

$$\Omega(p^F_{jt}, p^F_{jt-1}) = \frac{\theta}{2} \left( \frac{p^F_{jt}}{p^F_{jt-1}} - 1 \right)^2 Y_{Ft} \tag{A.60}$$

Substituting $l^F_{jt} = \frac{y^F_{jt}}{\Gamma^F_t}$ and $y^F_{jt} = \left( \frac{p^F_{jt}}{P_{Ft}} \right)^{-\epsilon} Y_{Ft}$, the objective becomes:

$$J_t(p^F_{jt-1}) = \max_{p^F_{jt}} \left\{ \frac{p^F_{jt}}{P_{Ft}} \left( \frac{p^F_{jt}}{P_{Ft}} \right)^{-\epsilon} Y_{Ft} - w^F_t \frac{y^F_{jt}}{\Gamma^F_t} - \frac{\theta}{2} \left( \frac{p^F_{jt}}{p^F_{jt-1}} - 1 \right)^2 Y_{Ft} + \mathbb{E}_t \left[ \frac{J_{t+1}(p^F_{jt})}{1 + r^F_{t+1}} \right] \right\} \tag{A.61}$$

Taking the derivative of $J_t(p^F_{jt-1})$ with respect to $p^F_{jt}$:

$$0 = \frac{\partial}{\partial p^F_{jt}} \left[ \frac{p^F_{jt}}{P_{Ft}} \left( \frac{p^F_{jt}}{P_{Ft}} \right)^{-\epsilon} Y_{Ft} - w^F_t \frac{y^F_{jt}}{\Gamma^F_t} - \theta \left( \frac{p^F_{jt}}{p^F_{jt-1}} - 1 \right) \frac{1}{p^F_{jt-1}} Y_{Ft} + \mathbb{E}_t \left[ \frac{J_{t+1}(p^F_{jt})}{1 + r^F_{t+1}} \right] \right] \tag{A.62}$$

Derivative of the adjustment cost:

$$\frac{\partial \Omega(p^F_{jt}, p^F_{jt-1})}{\partial p^F_{jt}} = \theta \left( \frac{p^F_{jt}}{p^F_{jt-1}} - 1 \right) \frac{1}{p^F_{jt-1}} Y_{Ft} \tag{A.63}$$

Using the symmetry assumption $p^F_{jt} = P_{Ft}$, $p^F_{jt-1} = P_{Ft-1}$, and defining $\pi^F_t = \frac{P_{Ft}}{P_{Ft-1}} - 1$:

$$\frac{\partial \Omega(p^F_{jt}, p^F_{jt-1})}{\partial p^F_{jt}} = \theta \frac{\pi^F_t}{1 + \pi^F_t} Y_{Ft} \tag{A.64}$$

The envelope condition is:

$$\frac{\partial J_{t+1}}{\partial p_{jt}^F} = -\frac{\theta}{p_{jt}^F}\left(\frac{p_{jt+1}^F}{p_{jt}^F} - 1\right) Y_{Ft+1} \tag{A.65}$$

Substitute this into the expectation term:

$$\mathbb{E}_t\left[\frac{\partial J_{t+1}}{\partial p_{jt}^F}\frac{1}{1+r_{t+1}^F}\right] = -\mathbb{E}_t\left[\frac{\theta}{p_{jt}^F}\left(\frac{p_{jt+1}^F}{p_{jt}^F} - 1\right)\frac{Y_{Ft+1}}{1+r_{t+1}^F}\right] \tag{A.66}$$

Using symmetry $p_{jt}^F = P_{Ft}$:

$$\mathbb{E}_t\left[\frac{\partial J_{t+1}}{\partial p_{jt}^F}\frac{1}{1+r_{t+1}^F}\right] = -\mathbb{E}_t\left[\theta\frac{\pi_{t+1}^F}{1+\pi_{t+1}^F}\frac{Y_{Ft+1}}{1+r_{t+1}^F}\right] \tag{A.67}$$

Substitute everything into the first-order condition:

$$0 = \frac{1-\epsilon}{P_{Ft}}Y_{Ft} + \theta\frac{\pi_t^F}{1+\pi_t^F}Y_{Ft} - \mathbb{E}_t\left[\theta\frac{\pi_{t+1}^F}{1+\pi_{t+1}^F}\frac{Y_{Ft+1}}{1+r_{t+1}^F}\right] \tag{A.68}$$

Divide through by $Y_{Ft}$:

$$\frac{\pi_t^F}{1+\pi_t^F} = \frac{\kappa^F}{1+\pi_t^F}\left(\frac{w_t^F}{\Gamma_t^F} - \frac{1}{\mu}\right) + \mathbb{E}_t\left[\frac{\pi_{t+1}^F(1+\pi_{t+1}^F)Y_{Ft+1}}{Y_{Ft}(1+r_{t+1}^F)}\right] \tag{A.69}$$

where:

$$\kappa^F = \frac{\epsilon}{\theta}, \quad \mu = \frac{\epsilon}{\epsilon - 1} \tag{A.70}$$

which can be simplified as:

$$\pi_t^F(1+\pi_t^F) = \kappa^F\left(\frac{w_t^F}{\Gamma_t^F} - \frac{1}{\mu}\right) + \mathbb{E}_t\left[\pi_{t+1}^F(1+\pi_{t+1}^F)\frac{Y_{Ft+1}}{Y_{Ft}}\frac{1}{1+r_{t+1}^F}\right] \tag{A.71}$$

## A.6 Deriving $dY$ from Goods Market Clearing

From the price index:

$$P_t = \left[\alpha P_{F,t}^{1-\eta} + (1-\alpha) P_{H,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{A.72}$$

Linearising this gives:

$$dP_t = \alpha dP_{F,t} + (1-\alpha) dP_{H,t} \tag{A.73}$$

Writing the linearised version of the law of one price:

$$dP_{F,t} = dP_{F,t}^{*} + dE_t \tag{A.74}$$

The real exchange rate can also be linearised:

$$dQ = dP_{F,t}^{*} + dE_t - dP_t \tag{A.75}$$

$\Rightarrow$

$$dQ + dP_t = dP_{F,t}^{*} + dE_t \tag{A.76}$$

Inserting this into Equation (A.73):

$$dP_t = \alpha(dQ + dP_t) + (1-\alpha) dP_{H,t} \tag{A.77}$$

$\Leftrightarrow$

$$dP_t(1-\alpha) = \alpha dQ + (1-\alpha) dP_{H,t} \tag{A.78}$$

$$dP_{H,t} - dP_t = -\frac{\alpha}{1-\alpha} dQ \tag{A.79}$$

It also follows from the law of one price:

$$dP_{H,t}^{*} = dP_{H,t} - dE_t \tag{A.80}$$

$$dP_{H,t}^{*} = dP_{H,t} - dP_t - dQ \tag{A.81}$$

Inserting Equation (A.79) into (A.82):

$$dP_{H,t}^{*} = -\frac{\alpha}{1-\alpha} dQ - dQ \tag{A.82}$$

$\Rightarrow$

$$dP_{H,t}^{*} = -\frac{1}{1-\alpha} dQ \tag{A.83}$$

Linearising $C_{H,t}$:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \tag{A.84}$$

$$dC_{H,t} = (1-\alpha)\eta(dP_t - dP_{H,t}) + (1-\alpha)dC_t \tag{A.85}$$

Similarly, the foreign demand function can be written as:

$$C^*_{H,t} = \alpha\left(\frac{P^*_{H,t}}{P^*_{F,t}}\right)^{-\eta} C^*_t \tag{A.86}$$

$$= \alpha\left(\frac{1}{E_t}\frac{P_{H,t}}{P^*_{F,t}}\right)^{-\eta} C^*_t \tag{A.87}$$

$\Rightarrow$

$$= \alpha\left(\frac{1}{Q_t}\frac{P_{H,t}}{P_t}\right)^{-\eta} C^*_t \tag{A.88}$$

$$dC^*_{H,t} = \alpha dC^*_t + \alpha\eta(dQ + dP_t - dP_{H,t}) \tag{A.89}$$

Assuming $dC^* = 0$ and substituting Equations (A.85) into market clearing, gives:

$$Y_t = C_{H,t} + C^*_{H,t} \tag{A.90}$$

$$dY_t = (1-\alpha)\eta(dP_t - dP_{H,t}) + (1-\alpha)dC_t + \alpha\eta(dQ + dP_t - dP_{H,t}) \tag{A.91}$$

Using Equation (A.79) for $dP_{H,t} - dP_t$:

$$dY_t = (1-\alpha)\eta\left(\frac{\alpha}{1-\alpha}dQ\right) + (1-\alpha)dC_t + \alpha\eta\left(dQ + \frac{\alpha}{1-\alpha}dQ\right) \tag{A.92}$$

$$= (1-\alpha)dC_t + \eta\alpha dQ + \left(\frac{\alpha(1-\alpha)}{1-\alpha} + \frac{\alpha^2}{1-\alpha}\right)\eta dQ \tag{A.93}$$

$$dY = (1-\alpha)dC_t + \frac{\alpha}{1-\alpha}\chi dQ \tag{A.94}$$

Where trade elasticity:

$$\chi \equiv \eta(1-\alpha) + \gamma \tag{A.95}$$

From the budget constraint:

$$\frac{P_{F,t}}{P_t}\tilde{c}_{F,t} + \frac{P_{H,t}}{P_t}c_{H,t} + a_t = (1+r_t)a_{t-1} + (1-\tau_t)w_t L_t z_t + \frac{P_{F,t}}{P_t}\underline{c} \tag{A.96}$$

Where $\tilde{c}_{F,t} = c_{F,t} + \underline{c}$

The household consumption function $C^{hh}(\{\mathbf{r}_s, \mathbf{Z}_s, \mathbf{P}_{F,s}/\mathbf{P}_s\}_{s=0}^{\infty})$ can be linearised as:

$$d\mathbf{C}^{hh} = \mathbf{M}^r\, d\mathbf{r} + \mathbf{M}\, d\mathbf{Z} + \mathbf{M}^p\, d\left(\frac{\mathbf{P}_{F,s}}{\mathbf{P}_s}\right) \tag{A.97}$$

Where $\mathbf{M}^r, \mathbf{M}, \mathbf{M}^p$ are the Jacobians of consumption with respect to interest rates, income, and prices respectively.

Using firm FOC for real income:

$$Z_t = \frac{W_t N_t}{P_t} \tag{A.98}$$

We can also write:

$$Z_t = Y_t \frac{P_{H,t}}{P_t} \tag{A.99}$$

Linearising:

$$dZ_t = dY_t - (dP_t - dP_{H,t}) \Rightarrow dZ_t = dY_t - \frac{\alpha}{1-\alpha}dQ \tag{A.100}$$

It also follows from Equation (A.75):

$$dQ = dP_{F,t} - dP_t \tag{A.101}$$

Then $dC$ can be written as:

$$dC^{hh} = M^r dr + M dY_t - M\frac{\alpha}{1-\alpha}dQ + M^p dQ \tag{A.102}$$

Substituting this into the expression for $dY$ from Equation (A.94):

$$dY = (1-\alpha)(M^r dr + M dY_t - M\frac{\alpha}{1-\alpha}dQ + M^p dQ) + \frac{\alpha}{1-\alpha}\chi dQ \tag{A.103}$$

The Intertemporal Keynesian Cross can then be written as:

$$dY = \underbrace{(1-\alpha)M^r dr}_{\text{Interest rate}} + \underbrace{(1-\alpha)M dY}_{\text{Multiplier}} - \underbrace{\alpha M dQ}_{\text{Real income}} + \underbrace{\frac{\alpha}{1-\alpha}\chi dQ}_{\text{Expenditure switching}} \tag{A.104}$$

# Appendix B

# Additional Tables and Figures

Here I present additional figures and tables referenced in the main text.

### B.0.1 Estimates from Auer et al. (2024)

The following tables present key estimates from Auer et al. (2024) used in the calibration and validation of the model.

Table B.1: Import shares by income group and sector

| **Annual income (CHF)** | **Grocery** | **Other goods** | **Services** | **All** |
|---|---|---|---|---|
| – 60,252 | 36.6 | 66.9 | 2.2 | 21.1 |
| 60,252 – 88,032 | 37.2 | 71.1 | 3.3 | 24.2 |
| 88,032 – 119,736 | 37.6 | 72.6 | 3.6 | 25.7 |
| 119,736 – 164,244 | 37.4 | 74.7 | 4.2 | 27.0 |
| 164,244 – | 40.2 | 75.3 | 5.1 | 28.3 |
| All | 37.9 | 73.3 | 4.0 | 26.1 |

Table B.2: Heterogeneous elasticities: Income and elasticity values

| **Income (CHF)** | **Elasticity** |
|---|---|
| 20,000 | 6.6 |
| 60,000 | 4.4 |
| 120,000 | 3.0 |

### B.0.2 Additional Results

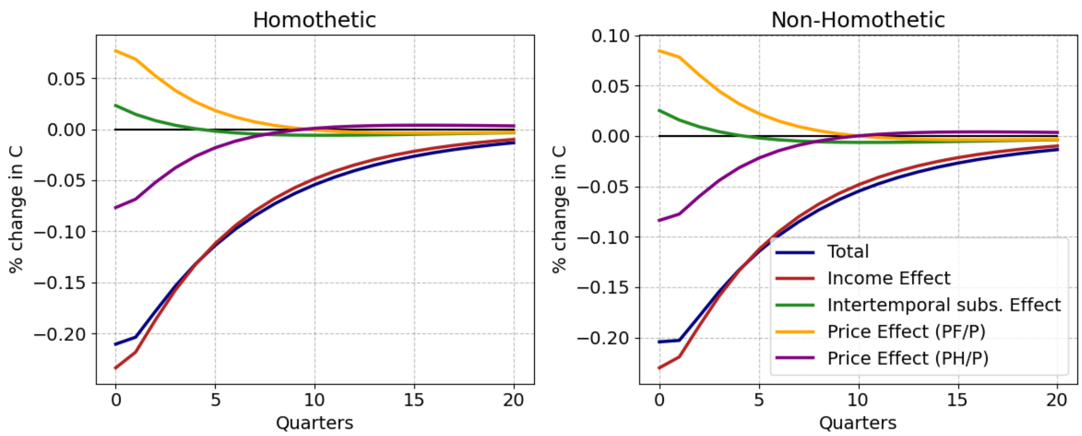


Figure B.1: Decomposition of consumption response comparing homothetic and non-homothetic models.

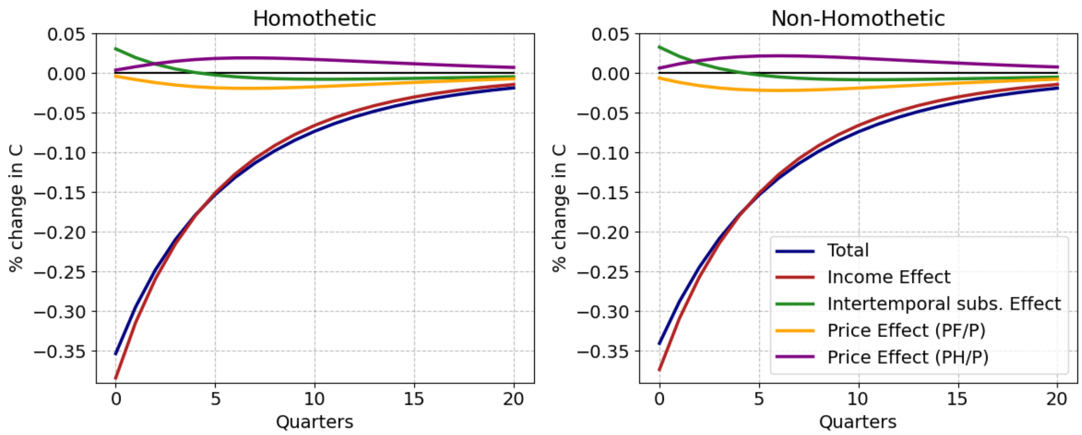


Figure B.2: Decomposition of consumption response comparing homothetic and non-homothetic models under imperfect price pass-through.

As a result of low import price pass-through, the price effects are muted. The fall in consumption is largely driven by the decline in real income resulting from lower employment.