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Abstract

This paper analyzes the way in which international financial integration affects the transmission of monetary policy in a New Keynesian open economy framework. It extends Woodford's (2010) analysis to a model with a richer financial markets structure, allowing for international trading in multiple assets and subject to financial intermediation costs. Two different forms of financial integration are considered, in particular an increase in the level of gross foreign asset holdings and a decrease in the costs of international asset trading. The simulations in the calibrated model show that none of the analyzed forms of financial integration undermine the effectiveness of monetary policy in influencing domestic output and inflation. Under realistic parameterizations, monetary policy is *more*, rather than *less,* effective as the positive impact of strengthened exchange rate and wealth channels more than offsets the negative impact of weakened interest rate channels. The paper also analyzes the interaction of financial integration with trade integration, varying both the importance of trade linkages and the degree of exchange rate pass-through. These interactions show that the positive effects of financial integration are amplified by trade integration. Overall, monetary policy is most effective in parameterizations with the highest degree of both financial and real integration.

JEL classification: E52, F41, F42, F47
Keywords: Monetary policy transmission, International financial integration

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1 Introduction

This paper analyzes the way in which international financial integration affects the transmission of monetary policy in a New Keynesian DSGE framework. Financial integration has been one of the main developments in the world economy in recent decades and its potential implications for monetary policy transmission have raised several concerns. The basic concern is that financial integration has the potential to undermine monetary policy effectiveness, i.e. that in an environment of tightly integrated financial markets monetary policy might lose its ability to affect domestic output and inflation.

There is an active debate on this topic.[1] But there are relatively few formal analyses, especially in the theoretical literature.[2] Furthermore, existing contributions are focused on the implications of *real*, rather than *financial* integration. Erceg, Gust and López-Salido (2007) use an open economy DSGE model to explore the way in which trade openness affects the economy's responses to a monetary, a fiscal, and a supply shock. The main result regarding the monetary policy shock, defined as a reduction in the inflation target, is that, overall, the responses of aggregate output and inflation are quite unresponsive to trade openness. Cwik, Müller and Wolters (2010) explore the role of trade integration for monetary policy transmission in a medium-scale new Keynesian model. They find that a monetary policy shock has stronger output effects in more open economies, as real net exports react more strongly. At the same time CPI inflation and domestic inflation also react more strongly in more open economies, which, in the latter case, is the result of complementarities in price setting. Woodford (2010) offers an analysis of the consequences of a global integration of financial markets, final goods and factor markets for the monetary transmission mechanism in a canonical New Keynesian open economy model with complete asset markets and finds that integration is unlikely to weaken the ability of national central banks to control the dynamics of inflation.

This paper extends Woodford's analysis to a model with a richer structure in financial markets. Woodford's model is based on a preference specification with a unit elasticity of substitution between home and foreign goods. In the context of his model this assumption implies that the degree of international financial market completeness does not alter the equilibrium outcomes.[3] Financial integration is thus basically irrelevant and "has no consequences whatsoever for asset-price determination or aggregate demand under any monetary policies".[4] Woodford notes that this irrelevance result is "a fairly special one" but that it might indicate "that the effects of financial globalization need not be large".[5] In this paper I analyze the effects of financial globalization in a more general framework, based on an alternative preference specification, in which the nature of asset markets and the degree of integration might matter. The model I develop is an extension of a standard New Keynesian DSGE model with

[1] See e.g. Bernanke (2007), Gonzalez-Paramo (2007), Gudmundsson (2007, 2008), Mishkin (2007), Papademos (2007), Weber (2007), and Yellen (2006), BIS (2006, Chapter IV).

[2] This issue has also been raised by Romer (2007), Fisher (2006), and Mark Wynne on the occasion of the creation of the Federal Reserve Bank of Dallas' Globalization and Monetary Policy Institute (Federal Reserve Bank of Dallas, Southwest Economy, Issue 1, January/February 2008).

[3] See Woodford (2007, pp. 4-8) for a proof.

[4] See Woodford (2010, p. 19).

[5] Woodford (2010, p.19-20).

sticky prices, modified to allow for international trading in multiple assets and subject to financial intermediation costs.[6] I analyze two different forms of financial integration as well as the interaction of financial integration with trade integration, varying both the importance of trade linkages and the degree of exchange rate pass-through.

The two crucial modeling choices, allowing an analysis of two different forms of financial integration, are the inclusion of financial intermediation costs for trading assets and the linearization of the model around an exogenous steady state asset portfolio. The financial intermediation costs of trading assets are defined both with respect to deviation from the steady state level and with respect to changes from last period's holdings. The costs with respect to deviations from the steady state level are just a technical device introduced to ensure stationary responses to temporary shocks.[7] However, the costs with respect to changes from last period's holdings allow for an analysis of the impact of a variation in the costs of international asset trading and, in particular, a decrease in the costs of international asset trading which is interpreted as a first form of international financial integration. The second crucial modeling choice, the linearization of the model around an exogenous state asset portfolio, means that the steady state portfolio can be chosen exogenously as a particular solution among the set of feasible solutions. An alternative approach would be to solve for the portfolio endogenously in a fully optimizing framework.[8] However, the exogenous approach makes it possible to choose an international portfolio that is in line with the empirical evidence without having to specify all the possible shocks in the economy and adjust the model in such a way that it delivers that portfolio.[9] This approach therefore allows for an analysis of the impact of a variation in the level of steady state gross foreign asset positions and, in particular, an increase in steady state gross foreign asset positions, which is viewed as a second form of international financial integration.

The expected impact of these two forms of financial integration on the transmission of monetary policy is a priori ambiguous. Some of the potential effects of financial integration are expected to weaken the effectiveness of monetary policy in influencing domestic output and inflation, while others are expected to strengthen it. A decrease in the costs of international asset trading potentially affects both the demand and the supply side of monetary policy transmission. On the demand side, it could affect the interest and the exchange rate channel. The interest rate channel is a priori expected to be weakened by a decrease in the costs of international asset trading. Domestic interest rates might become less relevant for domestic spending decisions as in an integrated world consumers' should theoretically be able to engage in more consumption smoothing with the rest of the world. If the costs for trading foreign assets are low, agents will save and borrow more in the rest of the world to cushion the effects of shocks. A monetary policy-induced interest rate shock could thus have a lower impact on domestic spending decisions and aggregate demand. Furthermore, with globalized financial markets and tightened financial interdependence, domestic interest rates might increasingly be influenced by foreign factors. There is evidence suggesting that there are important linkages

[6] The model is also generalized to include capital as an additional production factor, a non-traded goods in addition to a traded goods sector and varying degrees of exchange rate pass-through.

[7] See Ghironi, Lee and Rebucci (2007) and Schmitt-Grohé and Uribe (2003).

[8] See e.g. Devereux and Sutherland (2011) and Tille and Van Wincoop (2010).

[9] See also Tille (2008).

between US and foreign long-term interest rates and that long-term rates seem to react less to changes in short-term rates than they used to.[10] The exchange rate channel is a priori expected to be strengthened by a decrease in the costs of international asset trading. The tendency for exchange rates to react to monetary policy might arguably be more pronounced in more closely integrated markets where the costs for trading foreign assets are low and capital flows are more responsive to perceived interest rate differentials. If the economy is open to trade, these reinforced exchange rate movements could in turn affect aggregate demand and output through their impact on the relative prices of domestic to foreign goods, i.e. net exports. Reinforced exchange rate movements can also have a direct impact on inflation through their impact on import prices.[11]

On the supply side, a decrease in the cost of international asset trading could potentially lead to a decline in the slope of the Phillips curve, i.e. a decrease in the sensitivity of domestic prices to domestic output gaps. A decline in the slope of the Phillips curve, in turn, could weaken monetary policy transmission as control over domestic aggregate spending would not necessarily imply control over domestic inflation because the domestic output gap would cease to be a significant determinant of domestic inflation.[12] A decrease in the sensitivity of domestic prices to domestic output gaps could arguably be the result of the integration of international financial markets as this process has facilitated the access of domestic firms to a global labor supply through offshoring. The threat of offshoring could contribute to a decrease in the sensitivity of real wages to changes in domestic labor market conditions (i.e. a flattening of the wage-price Phillips curve) as firms might become less willing to grant wage increases that would impair their cost competitiveness and wages and prices would react less to domestic labor market and demand conditions.[13] Recent empirical research seems to suggest that the sensitivity of inflation to domestic output gaps has indeed declined in many developed countries in the last two decades.[14] However, there is no consensus on the role of global forces in that process.[15] And there are factors other than (financial and real) globalization that might contribute to a lower sensitivity of prices to domestic output gaps. Flatter Phillips curves could be the result of better anchored inflation expectations and the global disinflation process in the last two decades, namely the fact that price adjustments are less frequent in a lower inflationary environment.[16]

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[10] See Kamin (2010) for an overview, Ehrman, Fratzscher and Rigobon (2005), Faust, Rogers, Wang and Wright (2007), and Warnock and Warnock (2006). Boivin and Giannoni (2008) find that a sizeable fraction of the variance of macroeconomic variables in the US are explained by foreign factors, but little evidence that this effect has become more important over time.

[11] See e.g. Yellen (2006), Bernanke (2007), Weber (2007), Mishkin (2007), Papademos (2007), Gudmundsson (2007), and Gonzalez-Paramo (2007).

[12] See Borio and Filardo (2007), IMF (2006), González-Páramo (2007), and Yellen (2006).

[13] See Yellen (2006) and Gonzalez-Paramo (2007).

[14] See e.g. Loungani, Razin and Yuen (2001), IMF (2006), Kohn (2006), Borio and Filardo (2007), Ihrig, Kamin, Lindner and Marquez (2007), Wynne and Kersting (2007), Guilloux and Kharroubi (2008), and Calza (2008).

[15] Rogoff (2003, 2006), for example, argues that trade integration should have increased rather than decreased the sensitivity of prices to domestic demand conditions. Greater competition should lead to lower profit margins and less room for maneuver for firms, which should speed up firms' responses to changes in cost structures or demand conditions.

[16] See e.g. Gonzalez-Paramo (2007) and Yellen (2006).

The second form of international financial integration analyzed is an increase in gross foreign asset holdings. Between 1970 and 2007 the average of the sum of gross foreign assets and liabilities of industrial countries increased from 60 to 600 percent of GDP.[17] This form of integration could potentially have an impact on the transmission of monetary policy through the demand side. It is expected to strengthen exchange rates-related wealth channels and thus, all else equal, expected to strengthen monetary policy effectiveness. With an increasing share of domestic savings invested in international financial markets, exchange rates-related wealth channels are expected to be strengthened as households' wealth and firms' balance sheets become more sensitive to (monetary policy-induced) fluctuations in exchange rates.[18] Exchange rate valuation effects might thus increase the impact of monetary policy on the wealth of domestic agents and hence their spending decisions and aggregate demand.[19]

The main result of the paper is that none of the analyzed forms of financial integration undermine monetary policy effectiveness. The simulations in the calibrated model show that, under realistic parameterizations, monetary policy is *more*, rather than *less,* effective as the positive impact of strengthened exchange rate and (foreign) wealth channels more than offsets the negative impact of weakened interest rate channels of monetary policy transmission. In the interaction of financial integration with trade integration I find that the positive effects of financial integration are amplified by trade integration. Overall, monetary policy is most effective in parameterizations with the highest degree of both financial and real integration.

The remainder of the paper is organized as follows. Section 2 outlines the model. Section 3 discusses the results, and the last section concludes.

2 Theoretical model

The model is a two-country variant of Gali's (2008) baseline New Keynesian DSGE model but extended to allow for international asset trading in both bonds and equities. Asset trading is subject to financial intermediation costs, following an approach along the lines of Ghironi, Lee, and Rebucci (2007). The model also includes investment in capital, which is an additional production factor besides labor. The exchange rate pass-through is modelled in a flexible manner following the approach of Corsetti and Pesenti (2005). In order to be able to replicate Woodford's (2010) exercise of analyzing different degrees of "trade integration" the traded goods basket is divided into Home and Foreign traded goods following his specification. In addition, in order to build in more realistic features I add a non-traded goods sector following the approach of Obstfeld and Rogoff (2005).

This section outlines the main blocks of the model using the example of the Home country. Analogous equations hold in the Foreign country. To distinguish Home from Foreign variables, variables for the Foreign country are denoted with a star superscript. The section is structured into four different subsections describing the behavior of households, firms, and monetary

[17] See updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007).

[18] See Gonzalez-Paramo (2007).

[19] Note, however, that if a higher share of domestic wealth is invested in foreign assets *domestic* wealth channels might become less effective.

authorities, as well as the solution method of the model and the calibration. A detailed derivation of the model is provided in appendix B.

2.1 Households

Each country is populated by a continuum of infinitely-lived, atomistic households indexed by j and j^*, respectively. Home households are assumed to be of a mass α while Foreign households are assumed to be of a mass $(1-\alpha)$. Households consume both Home and Foreign traded and domestic non-traded goods. In addition to consuming goods households also supply labor services.

An infinitely-lived representative Home household j maximizes the following utility function:

$$U(j) = E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma} \left(C_t(j)\right)^{1-\sigma} - \frac{\kappa}{1+\varphi} \left(N_t(j)\right)^{1+\varphi} \right] \tag{1}$$

where $C_t(j)$ is the consumption basket consumed by the household and $N_t(j)$ denotes the hours worked (or the measure of household members employed).

Following the approach of Obstfeld and Rogoff (2005) a fraction $\gamma \in [0,1]$ of brands consumed in a given country are traded goods. Furthermore, a fraction $\alpha \in [0,1]$ of the traded goods are produced in the Home country. γ therefore denotes the weight of the traded goods basket in the overall consumption basket and α denotes the weight of Home tradables in the traded goods basket. Note that a large value of α means that the Home country supplies most of the tradable goods on the world markets and not that few imported goods are consumed in either country.[20] Such a parameterization is employed in order to be able to replicate Woodford's (2010) exercise of analyzing different degrees of "trade integration" (and their interaction with financial integration), in particular the small open-economy limit ($\alpha \to 0$) and the case of two countries of equal size ($\alpha = \frac{1}{2}$). Figure 1 reports the distribution of brands along the unit interval in the Home consumption basket.

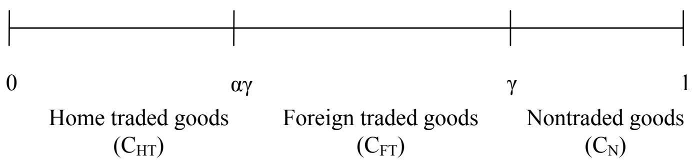

Figure 1: Distribution of brands in the Home consumption basket

The Home consumption basket is a standard CES consumption basket comprising Home and Foreign traded goods baskets and the Home non-traded goods basket:

$$C_t = \left[\gamma^{\frac{1}{\omega}} C_{Tt}^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}} C_{Nt}^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}}$$

[20] Thus, α should not be interpreted as measure of home bias in consumption.

where C_{Nt} is the non-tradables basket, C_{Tt} the tradables basket,γ the weight of the tradables basket, and ω the elasticity of substitution between tradable and non-tradable goods.

The tradables basket is defined as:

$$C_{Tt} = \left[\alpha^{\frac{1}{\phi}} C_{HTt}^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}} C_{FTt}^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}$$

where C_{HTt} is the consumption sub-basket of individual Home goods, C_{FTt} the consumption sub-basket of individual foreign goods, α the weight of Home tradables in the tradables basket and ϕ the elasticity of substitution between Home and Foreign tradables.

The consumption sub-baskets C_{Nt}, C_{HTt}, and C_{FTt} are defined as CES aggregates respectively:

$$C_{HTt} = \left[\left(\frac{1}{\alpha\gamma} \right)^{\frac{1}{\theta}} \int_0^{\alpha\gamma} \left(C_{HTt}(i) \right)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

$$C_{FTt} = \left[\left(\frac{1}{(1-\alpha)\gamma} \right)^{\frac{1}{\theta}} \int_{\alpha\gamma}^{\gamma} \left(C_{FTt}(i) \right)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

$$C_{Nt} = \left[\left(\frac{1}{(1-\gamma)} \right)^{\frac{1}{\theta}} \int_{\gamma}^{1} \left(C_{Nt}(i) \right)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

where θ is the elasticity of substitution between different brands within a sub-basket.

The following paragraphs outline the three optimization problems that a household faces: the allocation of expenditures across the different sectors and goods, the intertemporal consumption and asset allocation, and the wage setting.

2.1.1 Optimal allocation of expenditures

The solution of the optimal allocation of expenditures across different sectors and goods leads to the following aggregate demand equations that a firm i faces (note that, as explained in more detail below, in addition to the demand from households, firms face the demand for an investment input, I_t, from installment firms):

$$Y_{HTt}(i) = \left(\frac{P_{HTt}^{Opt}(i)}{P_{HTt}} \right)^{-\theta} \left(\frac{P_{HTt}}{P_{Tt}} \right)^{-\phi} \left(\frac{P_{Tt}}{P_t} \right)^{-\omega} (C_t + I_t) \tag{2}$$

$$Y_{HTt}^{*}(i) = \left(\frac{P_{HTt}^{Opt*}(i) S^{-\tau}}{P_{HTt}^{*}} \right)^{-\theta} \left(\frac{P_{HTt}^{*}}{P_{Tt}^{*}} \right)^{-\phi} \left(\frac{P_{Tt}^{*}}{P_t^{*}} \right)^{-\omega} (C_t^{*} + I_t^{*}) \tag{3}$$

$$Y_{Nt}(i) = \left(\frac{P_{Nt}^{Opt}(i)}{P_{Nt}} \right)^{-\theta} \left(\frac{P_{Nt}}{P_t} \right)^{-\omega} (C_t + I_t) \tag{4}$$

where $Y_{HTt}(i)$ denotes the demand a Home firm in the traded goods sector producing for the domestic market faces, $Y^*_{HTt}(i)$ the demand a Home firm in the traded goods sector producing for the foreign market faces, $Y_{Nt}(i)$ the demand a Home firm in the non-traded goods sector faces, S_t the nominal exchange rate (defined as units of Home currency per unit of Foreign currency), τ the degree of pass-through elasticity, which is exogenous and constant over time and across producers, C_t aggregate consumption and I_t aggregate investment.

2.1.2 Optimal intertemporal allocation

Asset markets comprise four assets: two one-period nominal bonds, denominated in Home and Foreign currency, respectively, and equity shares in Home and Foreign firms. (Nominal) bond holdings are denoted by $B_H(j)$ and $B_F(j)$.[21] (Real) Home and Foreign equity shares are denoted by Q_{Ht} and Q_{Ft}.[22] Equity shares are assumed to be claims on firms' profits as explained in more detail in appendix B. They are assumed to be a balanced portfolio across all firms in the respective country. The prices of equity shares in Home and Foreign firms are denoted by P_Q and P^*_Q, respectively.

Households pay quadratic financial transaction fees to domestic financial intermediaries when they adjust their asset holdings. The financial intermediation costs are defined both in terms of changes from last period's holdings and in terms of deviations from steady state levels. They are defined in the currency of the respective country and with respect to ratios to the respective country's GDP, Y_t or Y^*_t.[23] The definition is analogous for all assets (with the subscript denoting the respective asset). Using the example of Foreign equity holdings the financial intermediation costs are defined as:

$$\frac{\gamma_{Q_F}}{2} S_t P^*_{Qt} \frac{\left(Q_{Ft+1}(j) - Q_{Ft}(j)\right)^2}{Y^*_t} \text{ and } \frac{\psi_{Q_F}}{2} S_t P^*_{Qt} \frac{\left(Q_{Ft}(j) - \bar{Q}_F(j)\right)^2}{Y^*_t}$$

where γ_{Q_F} and ψ_{Q_F} are exogenous parameters and S_t is the nominal exchange rate (defined as units of Home currency per unit of Foreign currency).

As mentioned above, the financial intermediation costs on changes from last period's holdings (the first term in the above expression) ensure a well-defined demand for assets in a log-linearized version of the system and permit the study of scenarios differing with respect to the ease of financial transactions. A decrease in the parameter γ_{Q_F}, e.g., implies cheaper transaction costs for adjusting foreign asset holdings, which can be seen as one form of international financial integration. The costs with respect to deviations from the level of steady state asset holding (the second term in the above expression) are a technical device to ensure stationarity of the equilibrium dynamics.[24] As the financial intermediation costs

[21] They are denoted by $B^*_H(j^*)$ and $B^*_F(j^*)$ if they are held by Foreign households.

[22] They are denoted by Q^*_{Ht} and Q^*_{Ft} if they are held by Foreign households.

[23] This definition is used as asset holdings can take negative values (in the case of borrowing). Expressing changes in holdings (and deviations from the steady state) as ratios to holdings would thus not be a meaningful definition. To ensure measurement in equivalent units, assets issued in a given country are expressed in ratios to that country's GDP. Furthermore, to ensure that the system can be expressed in stationary variables, i.e. real variables or nominal variables either in ratios to the respective CPIs or in first differences, *nominal* bond holdings B_H and B_F are scaled by *nominal* GDP, while *real* equity holdings Q_{Ht} and Q_{Ft} are scaled by *real* GDP. (In the log-linearized system equity prices are scaled by the respective CPIs.)

[24] See Ghironi, Lee and Rebucci (2007) and Schmitt-Grohé and Uribe (2003).

are incurred on *changes* from last period's holdings and on *deviations from the steady state level*, the steady state of this model can be chosen exogenously as a particular solution among the set of feasible solutions. As mentioned above, this fact will be exploited to analyze a second form of international financial integration, in particular an increase of gross foreign asset holdings.

The financial costs are paid to financial intermediaries who are assumed to be local, perfectly competitive firms owned by domestic households. The financial transaction fees are rebated to households as lump-sum transfers and are therefore not destroyed resources.

Given the above definitions the budget constraint of a Home household j is:

$$\begin{aligned}
& P_t C_t(j) \\
& + P_{Qt} Q_{Ht+1}(j) + \frac{\gamma_{Q_H}}{2} P_{Qt} \frac{(Q_{Ht+1}(j) - Q_{Ht}(j))^2}{Y_t} + \frac{\psi_{Q_H}}{2} P_{Qt} \frac{\left(Q_{Ht}(j) - \bar{Q}_H(j)\right)^2}{Y_t} \\
& + S_t P_{Qt}^* Q_{Ft+1}(j) + \frac{\gamma_{Q_F}}{2} S_t P_{Qt}^* \frac{(Q_{Ft+1}(j) - Q_{Ft}(j))^2}{Y_t^*} + \frac{\psi_{Q_F}}{2} S_t P_{Qt}^* \frac{\left(Q_{Ft}(j) - \bar{Q}_F(j)\right)^2}{Y_t^*} \\
& + B_{Ht+1}(j) + \frac{\gamma_{B_H}}{2} \frac{(B_{Ht+1}(j) - B_{Ht}(j))^2}{P_t Y_t} + \frac{\psi_{B_H}}{2} \frac{\left(B_{Ht}(j) - \bar{B}_H(j)\right)^2}{P_t Y_t} \\
& + S_t B_{Ft+1}(j) + \frac{\gamma_{B_F}}{2} S_t \frac{(B_{Ft+1}(j) - B_{Ft}(j))^2}{P_t^* Y_t^*} + \frac{\psi_{B_F}}{2} S_t \frac{\left(B_{Ft}(j) - \bar{B}_F(j)\right)^2}{P_t^* Y_t^*} \\
= \; & W_t N_t(j) + \left(P_{Qt} + \left(\frac{V_t}{\bar{Q}}\right)\right) Q_{Ht}(j) + S_t \left(P_{Qt}^* + \left(\frac{V_t^*}{\bar{Q}^*}\right)\right) Q_{Ft}(j) \\
& + (1 + i_t) B_{Ht}(j) + S_t (1 + i_t^*) B_{Ft}(j) + T_{It}(j) + T_{\gamma t}(j)
\end{aligned} \tag{5}$$

where P_{Qt} and P_{Qt}^* are the nominal prices of Home and Foreign equity shares respectively, and $\frac{V_t}{\bar{Q}}$, and $\frac{V_t^*}{\bar{Q}^*}$ the dividend yields in local currency with V_t and V_t^* denoting the aggregate profits and $\bar{Q}$ and $\bar{Q}^*$ aggregate equity shares. Aggregate equity shares are fixed and given by $\bar{Q} = Q_{Ht} + Q_{Ht}^*$ and $\bar{Q}^* = Q_{Ft}^* + Q_{Ft}$ where Q_{Ht} and Q_{Ht}^* (Q_{Ft}^* and Q_{Ft}) denote aggregate Home (Foreign) equity shares held by Home and Foreign households. Note that equity shares are claims on profits (of production firms) not claims on capital. γ_{Q_H},γ_{Q_F},γ_{B_H}, and γ_{B_F} are the financial intermediation costs for Home households which can differ across assets, i_t and i_t^* are the nominal interest rates, S_t is the nominal exchange rate (defined as units of Home currency per unit of Foreign currency), and $T_{It}(j)$ are the lump-sum transfers from installment firms (see the details below in the section on firms). $T_{\gamma t}(j)$ are the lump-sum transfers from financial intermediaries, defined as:

$$T_{\gamma t}(j) = \frac{1}{\alpha} \left[\begin{array}{c}
+\frac{\gamma_{Q_H}}{2} \frac{\bar{P}_Q (Q_{Ht+1} - Q_{Ht})^2}{\bar{Y}} + \frac{\psi_{Q_H}}{2} \int_0^\alpha \frac{\bar{P}_Q \left(Q_{Ht} - \bar{Q}_H\right)^2}{\bar{Y}} \\
+\frac{\gamma_{Q_F}}{2} \frac{\bar{S}\bar{P}_Q^* (Q_{Ft+1} - Q_{Ft})^2}{\bar{Y}^*} + \frac{\psi_{Q_F}}{2} \frac{\bar{S}\bar{P}_Q^* \left(Q_{Ft} - \bar{Q}_F\right)^2}{\bar{Y}^*} \\
+\frac{\gamma_{B_H}}{2} \frac{\gamma_{B_H}}{2} \frac{\bar{P}\left(\frac{B_{Ht+1}}{P_t} - \frac{B_{Ht}}{P_t}\right)^2}{\bar{Y}} + \frac{\psi_{B_H}}{2} \frac{\bar{P}\left(\frac{B_{Ht}}{P_t} - \frac{\bar{B}_H}{\bar{P}}\right)^2}{\bar{Y}} \\
+\frac{\gamma_{B_F}}{2} \frac{\bar{S}\bar{P}^* \left(\frac{B_{Ft+1}}{P_t^*} - \frac{B_{Ft}}{P_t^*}\right)^2}{\bar{Y}^*} + \frac{\psi_{B_F}}{2} \int_0^\alpha \frac{\bar{S}\bar{P}^* \left(\frac{B_{Ft}}{P_t^*} - \frac{\bar{B}_F}{\bar{P}^*}\right)^2}{\bar{Y}^*}
\end{array} \right]$$

Optimal intertemporal asset and consumption allocations lead to the following Euler equations:

for Home equity holdings;

$$
\begin{aligned}
& E_t\left\{P_{Qt}+\gamma_{Q_H} P_{Qt}\frac{(Q_{Ht+1}(j)-Q_{Ht}(j))}{Y_t}\right\} \\
=\ & E_t\left\{D_{t,t+1}(j)\left(\begin{array}{c}\gamma_{Q_H}\frac{(Q_{Ht+2}(j)-Q_{Ht+1}(j))}{Y_{t+1}}-\psi_{Q_H}P_{Qt+1}\left(\frac{(Q_{Ht+1}(j)-\bar{Q}_H(j))}{Y_{t+1}}\right)\\ +\left(P_{Qt+1}+\left(\frac{V_{t+1}}{\bar{Q}}\right)\right)\end{array}\right)\right\}
\end{aligned}
\tag{6}
$$

for Foreign equity holdings;

$$
\begin{aligned}
& E_t\left\{S_tP^*_{Qt}+\gamma_{Q_F} S_tP^*_{Qt}\frac{(Q_{Ft+1}(j)-Q_{Ft}(j))}{Y_t}\right\} \\
=\ & E_t\left\{D_{t,t+1}(j)\left(\begin{array}{c}\gamma_{Q_F}S_{t+1}P^*_{Qt+1}\frac{(Q_{Ft+2}(j)-Q_{Ft+1}(j))}{Y_{t+1}}-\psi_{Q_H}S_{t+1}P^*_{Qt+1}\frac{(Q_{Ft+1}(j)-\bar{Q}_F(j))}{Y_{t+1}}\\ +\left(S_{t+1}\left(P^*_{Qt+1}+\left(\frac{V^*_{t+1}}{\bar{Q}^*}\right)\right)\right)\end{array}\right)\right\}
\end{aligned}
\tag{7}
$$

for Home bond holdings;

$$
\begin{aligned}
& E_t\left\{1+\gamma_{B_H}\frac{(B_{Ht+1}(j)-B_{Ht}(j))}{Y_t}\right\} \\
= \quad & E_t\left\{D_{t,t+1}(j)\left(\begin{array}{c}\gamma_{B_H}\frac{(B_{Ht+2}(j)-B_{Ht+1}(j))}{Y_{t+1}}-\psi_{B_H}\left(\frac{(B_{Ht+1}(j)-\bar{B}_H(j))}{Y_{t+1}}\right)\\ +(1+i_{t+1})\end{array}\right)\right\}
\end{aligned}
\tag{8}
$$

and for Foreign bond holdings,

$$
\begin{aligned}
& E_t\left\{S_t+\gamma_{B_F} S_t\frac{(B_{Ft+1}(j)-B_{Ft}(j))}{Y^*_t}\right\} \\
=\ & E_t\left\{D_{t,t+1}(j)\left(\begin{array}{c}\gamma_{B_F}S_{t+1}\frac{(B_{Ft+2}(j)-B_{Ft+1}(j))}{Y^*_t}-\psi_{B_F}S_{t+1}\frac{(B_{Ft+1}(j)-\bar{B}_F(j))}{Y^*_t}\\ +S_{t+1}(1+i^*_t)\end{array}\right)\right\}
\end{aligned}
\tag{9}
$$

with $E_t\left\{D_{t,t+1}(j)\right\}=\beta E_t\left\{\left(\frac{(C_{t+1}(j))}{(C_t(j))}\right)^{-\sigma}\frac{P_t}{P_{t+1}}\right\}$ denoting the discount factor of a representative Home household j.[25]

The Euler equations represent the fact that for an intertemporal allocation to be optimal the cost in terms of foregone utility of acquiring an additional equity share or bond has to

[25] An alternative discount factor could be a weighted average of Home and Foreign households' discount factors.

equal the discounted marginal utility of the increase in expected consumption derived from holding that additional asset. To gain a more detailed intuition for the Euler equations one can rewrite, for example, the Euler equation for Home bond holdings (equation (8)), as:

$$\begin{aligned} & E_t\left\{\left(\frac{C_{t+1}}{C_t}\right)^{\sigma}\right\} \\ = \; & \beta E_t \left\{ \begin{array}{c} \left(\frac{P_t}{P_{t+1}}\right)\left[(1+i_{t+1})+\gamma_{B_H}\frac{(B_{Ht+2}-B_{Ht+1})}{Y_{t+1}}-\psi_{B_H}\left(\frac{(B_{Ht+1}-\bar{B}_H)}{Y_{t+1}}\right)\right] \\ +\left(\frac{1}{1+\gamma_{B_H}\frac{(B_{Ht+1}-B_{Ht})}{Y_t}}\right) \end{array} \right\} \end{aligned} \tag{10}$$

Equation (10) states that, all else equal, Home households will be more willing to postpone consumption to the next period (i.e. increase the ratio $\left(\frac{C_{t+1}}{C_t}\right)$ on the left hand side), the higher the opportunity costs for consumption today. These opportunity costs are higher: a) the lower expected inflation (first (...) on the right hand side, b) the higher the expected interest rate at Home (first term in [...] on the right hand side), c) the higher the marginal decrease in transaction costs for Home bond holdings tomorrow (second term in [...] on the right hand side), due to the fact that an increase in bond holdings today decreases marginal transaction costs tomorrow, d) the lower the transaction costs for deviations of bond holdings from the steady state today (third term in [...] on the right hand side), or e) the lower the transaction costs for increasing Home bond holdings today (last (...) on the right hand side). Furthermore, households smooth consumption over time as, all else equal, an expected increase in consumption tomorrow (numerator of ratio $\left(\frac{C_{t+1}}{C_t}\right)$ on the left hand) increases consumption today.

2.1.3 Optimal labor supply

The labor market is assumed to be perfectly competitive, i.e. households take wages as given. The optimality condition for the labor supply of a Home household j is:

$$\frac{W_t}{P_{t+k}} - \frac{\kappa N(j)_t^{\varphi}}{C(j)_t^{-\sigma}} = 0 \tag{11}$$

i.e. that the hours worked are optimal if the real wage is equal to the marginal rate of substitution between consumption and hours worked.

2.2 Firms

In each country there are two types of firms."Installment firms" using the consumption good to produce capital and "production firms" producing the consumption goods with a linear production technology using both labor and capital inputs.

The following paragraphs outline the optimal investment decision of installment firms and the optimal input demand and price setting decisions of production firms.

2.2.1 Optimal investment

Installment firms are competitive, i.e. they take prices as given. They are owned by domestic households who receive any profits in the form of lump-sum transfers. Installment firms are indexed by $I \in [0, \alpha]$ for the Home country and $I^* \in [\alpha, 1]$ for the Foreign country.

Installment firms purchase an investment good to produce new capital which they rent out to the production firms at the (nominal) rental rate $P_t r^k$. It is assumed that the investment good features the same composition as the consumption good, i.e. that the investment good is purchased in the goods market at a price P_t. Capital depreciates at a rate δ. Furthermore, the production technology for new capital involves non-linear capital-adjustment costs. These costs are introduced to smooth the investment dynamics. Capital accumulation takes the following form:

$$K_{t+1}(I) = (1-\delta)K_t(I) + I_t(I) - \frac{\xi}{2}\frac{(K_{t+1}(I) - K_t(I))^2}{K_t(I)} \tag{12}$$

An installment firm solves the following optimization problem:

$$\max_{K_{t+1}(I)} E_t \sum_{k=0}^{\infty} D_{t,t+k}(j) \left[P_{t+k} r^k_{t+k} K_{t+k.}(I) - P_{t+k} I_{t+k.}(I)\right]$$

s.t. equation (12), i.e. that I assume that an installment firm I's discount factor reflects the discount factor of a representative Home household j.[26] The profits $T_I(j) = P_t r^k_t K_{t.} - P_t I_{t.}$ of installment firms are assumed to be rebated to households as lump-sum transfers.

The optimality condition for investment of a firm I can be written as:

$$E_t\left\{\left(1+\xi\frac{(K_{t+1}(I)-K_t(I))}{K_t(I)}\right)\right\} = \beta E_t\left\{\left(\frac{(C_{t+1}(j))}{(C_t(j))}\right)^{-\sigma}\left[\begin{array}{c}(1-\delta)+r^k_{t+1}\\ +\frac{\xi}{2}\left(\frac{K(I)^2_{t+2}-K(I)^2_{t+1}}{K(I)^2_{t+1}}\right)\end{array}\right]\right\} \tag{13}$$

The optimal investment decision equalizes the cost to increase today's capital stock by one unit and tomorrow's discounted marginal utility derived from this investment. Today's cost of an additional unit of capital consist of the unit itself and the marginal capital adjustment cost. Tomorrow's revenues of this investment consist of the increase in the non-depreciated capital stock itself, the expected real interest payment plus the expected decrease in capital adjustment costs.

2.2.2 Optimal input demand

Production firms in the traded and non-traded goods sector are monopolistically competitive firms, i.e. each production firm is the sole producer of a differentiated brand. They are indexed by $i \in [0, \alpha\gamma; \gamma, 1]$ where $[0, \alpha\gamma]$ represents the Home traded goods sector and $[\gamma, 1]$ the non-traded goods sector. Foreign firms are distributed on the interval $i^* \in [\alpha\gamma + \gamma; \gamma, 1]$

[26] An alternative discount factor could be a weighted average of Home and Foreign households' intertemporal marginal rate of substitutions.

with $[\alpha\gamma, \gamma]$ representing the Foreign traded goods sector and $[\gamma, 1]$ the Foreign non-traded goods sector.

A representative Home production firm i (both in the traded and non-traded goods sector) produces under the following Cobb-Douglas constant-returns-to-scale technology:

$$Y_t(i) = A_t \left(K_t(i)\right)^{1-\mu} \left(N_t(i)\right)^{\mu}$$

where A_t is an exogenous technology parameter, $K_t(i)$ is the capital input used by firm i , μ is the share of labor used in the production process and $N_t(i)$ is the labor input used by firm i.

The solution of the cost minimization problem of a representative Home firm i with respect to factor inputs $N_t(i)$ and $K_t(i)$ can be written as:

$$N_{HTt}(i) = \frac{\mu MC_t}{W_t} Y_{HTt}(i) \tag{14}$$

$$N_{Nt}(i) = \frac{\mu MC_t}{W_t} Y_{Nt}(i) \tag{15}$$

$$K_{HTt}(i) = \frac{(1-\mu)\, MC_t}{P_t.r_t^k} Y_{HTt}(i) \tag{16}$$

$$K_{Nt}(i) = \frac{(1-\mu)\, MC_t}{P_t.r_t^k} Y_{Nt}(i) \tag{17}$$

where marginal costs, which are equal across firms, are

$$MC_t = \frac{(W_t)^{\mu} \left(P_t.r_t^k\right)^{1-\mu}}{(1-\mu)^{1-\mu} \mu^{\mu} A_t} \tag{18}$$

2.2.3 Optimal price setting

Prices are sticky where price setting is modelled as a staggered Calvo-type process where $(1-\theta_P)$ denotes the probability that a firm can reset its price in any given period.[27,28] The prices that Home consumers pay in Home currency for Home traded, Foreign traded and non-traded goods are denoted by $P_{HTt}(i), P_{FTt}(i)$ and $P_{Nt}(i)$, respectively, whereas the prices that Foreign consumers pay in Foreign currency for Home traded, Foreign traded and non-traded goods are denoted by a star superscript, namely, by $P_{HTt}^{*}(i), P_{FTt}^{*}(i)$ and $P_{Nt}^{*}(i)$, respectively. The prices that Home producers set are denoted by $P_{HTt}^{Opt}(i)$ for the Home traded goods market, $P_{HTt}^{Opt*}(i)$ for the Foreign traded goods market and $P_{Nt}^{Opt}(i)$ for the nontraded goods market, respectively, whereas the prices that Foreign producers set are denoted by $P_{FTt}^{Opt*}(i)$, $P_{FTt}^{Opt}(i)$, and $P_{Nt}^{*Opt}(i)$, respectively.

To be able to analyze various degrees of exchange rate pass-through a flexible approach following Corsetti and Pesenti (2005) is adopted. In particular, it is assumed that the degree

[27] This approach was developed by Calvo (1983).

[28] θ_P can be interpreted as a measure of price stickiness.

of pass-through elasticity, τ, is exogenous and constant over time and across producers. It varies between 0 and 1 such that both the case of complete exchange rate pass-through ("producer currency pricing" or PCP), $\tau = 1$, and the case of zero exchange rate pass-through ("local currency pricing" or LCP), $\tau = 0$, can be obtained as particular cases of a unified parameterization.[29]

The Foreign-currency price of a Home traded goods brand i, $P^*_{HT}(i)$, is defined as:

$$P^*_{HTt}(i) = \frac{P^{Opt*}_{HTt}(i)}{S^{\tau}_t}$$

where $P^{Opt*}_{HTt}(i)$ is the predetermined component of the Foreign-currency price of Home traded goods brand i that is not adjusted to variations of the exchange rate during period t. Home firms choose P^{Opt*}_{HTt} one period in advance at time $t-1$ in order to maximize their expected discounted future profits, while the actual price paid by consumers $P^*_{HTt}(i)$ depends on the realization of the exchange rate at time t.

Given this definition the price received by a Home firm from an export sales unit to the Foreign market is:[30]

$$S_t P^*_{HTt}(i) = P^{Opt*}_{HTt}(i) S^{1-\tau}_t$$

A representative firm in the Home traded goods sector sets prices $\left\{P^{Opt}_{HTt+k}(i), P^{Opt*}_{HTt+k}(i)\right\}^{\infty}_{k=0}$ that maximize its expected discounted future profits while these prices remain effective. Formally, it solves the following problem:

$$\max_{P^{Opt}_{HTt}(i), P^{Opt*}_{HTt}(i)} \sum^{\infty}_{k=0} \theta^k_P E_t \left\{ \begin{array}{c} D_{t,t+k} \\ \left(\begin{array}{c} \left(P^{Opt}_{HTt}(i) - MC_{t+k|t}\right) Y_{HTt+k|t} \\ + \left(P^{Opt*}_{HTt}(i) S^{1-\tau}_t - MC_{t+k|t}\right) Y^*_{HTt+k|t} \end{array} \right) \end{array} \right\}$$

subject to the respective demand schedules of Home households and installment firms, where $D_{t,t+k}(j)$ denotes the discount factor:

$$E_t \left\{D_{t,t+k}(j)\right\} = \beta^k E_t \left\{ \left(\frac{(C_{t+k}(j))}{(C_t(j))} \right)^{-\sigma} \frac{P_t}{P_{t+k}} \right\}$$

i.e. that it is assumed that a representative Home firm's discount factor represents the intertemporal marginal rate of substitution of a representative Home households j, and where MC_t denotes the (nominal) marginal cost function (see equation (18) above).[31]

Optimal prices in the three sectors at time t satisfy the following conditions:

[29] Note that, as Corsetti and Pesenti (2005, p. 289) mention, this approach should be viewed only as a crude approximation to the actual determinants of the degree of export price indexation to currency movements. Exchange-rate pass-through depends on many features of producers' market structure and should, eventually, be endogenized in a fully specified model.

[30] Similarly, the Home-currency price of a Foreign traded goods brand, $P_{FTt}(i)$, is $P_{FTt}(i) = P^{Opt}_{FTt}(i) S^{\tau}_t$ and the price received by a Foreign firm from an export sales unit to the Home market is $P^{Opt}_{FTt}(i) S^{\tau-1}_t$.

[31] A representative firm in the nontraded goods sector solves an analogous problem.

$$\sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k} Y_{HTt+k|t}(i) \left(P_{HTt}^{Opt} - \mu_P MC_{t+k} \right) \right\} = 0 \tag{19}$$

$$\sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k} Y_{HTt+k|t}^*(i) \left(S_t^{1-\tau} P_{HTt}^{Opt*} - \mu_P MC_{t+k} \right) \right\} = 0 \tag{20}$$

$$\sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k} Y_{Nt+k|t}(i) \left(P_{Nt}^{Opt} - \mu_P MC_{t+k} \right) \right\} = 0 \tag{21}$$

where

$$\mu_P = \frac{\theta}{\theta - 1}$$

i.e. that the prices set by Home firms represent a (constant) markup over expected future marginal costs.

2.3 Monetary policy

In order to close the model a behavioral rule for the monetary authorities needs to be defined. The monetary policy rule of the Home central bank is defined as

$$1 + i_t = (1 + i_{t-1})^{\rho} \left(\left(\frac{P_t}{P_{t-1}} \right)^{\phi_\pi} (Y_t)^{\phi_y} \right)^{(1-\rho)} R_t \tag{22}$$

where ρ captures the degree of interest-rate smoothing and R_t represents a time-varying, exogenous monetary policy shock that may, for example, represent changes in the inflation target. The monetary policy rule of the Foreign central bank is defined analogously. Simulations of innovations in R_t and their propagation on the other variables in the model are used as experiments to analyze the transmission of monetary policy.

2.4 Solution of the model

The model is defined by equations (2) to (22) together with the analogous equations for the foreign economy and the market clearing conditions in the goods and asset markets. It is solved by an aggregation and linearization of these equations around a symmetric steady state where the net foreign asset positions of both countries, inflation and technological progress are zero (see appendix B for a detailed derivation of the non-linearized model, the steady state, and the linearized model). As mentioned above, to ensure a stationary steady state financial intermediation costs are imposed on both the changes in asset holdings as well as deviations from the steady state. Furthermore, as a monetary policy shock would lead to non-stationary responses of nominal variables in levels, all Home and Foreign nominal variables are scaled by the Home and Foreign CPIs, respectively, and the two CPIs and the nominal exchange rate are linearized in first differences. As no analytical solution of the model can be obtained the calibrated model is solved and simulated numerically.[32] Particular

[32] The model is solved with Dynare (see Adjemian et al., 2011).

interest is focused on impulse response functions to monetary policy shocks, namely exogenous interest rate shocks on R_t, as defined above in the Taylor rule (equation 22). The impact of financial market integration is analyzed by comparing impulse response functions to such monetary policy shocks in scenarios that differ with respect to the calibration of financial market integration, trade linkages and exchange-rate pass-through. The calibration of the baseline and the integration scenarios is explained in the following paragraphs.

2.4.1 Baseline calibration

The calibration of model parameters is listed in Table 1. The calibration closely follows the standard values assumed in the New Keynesian and Real Business Cycle literature.[33] I assume a period length of one quarter and equal model parameters for both countries.

β	0.99	discount factor
σ	2	relative risk aversion coefficient
κ	1	coefficient determining the cost of effort
φ	1	labor supply elasticity
γ	0.25	weight of the tradables basket in the consumption basket
ω	2	elasticity of substitution between tradables and non-tradables
α	0.5	weight of Home tradables in the traded goods basket
ϕ	2	elasticity of substitution between Home and Foreign tradables
θ	6	elasticity of substitution between different brands within a sub-basket
ξ	8	coefficient determining the capital-adjustment costs
μ	0.6	labor share in the production function
δ	0.026	depreciation rate
θ_P	0.66	price stickiness parameter
τ	0.5	exchange rate pass-through elasticity
ϕ_π	1.5	interest rate rule coefficient on inflation
ϕ_y	0.125	interest rate rule coefficient on the output gap
ρ_r	0.6	coefficient determining the persistence of the interest rate shock

Table 1: Calibration of model parameters

The calibration of the discount factor β implies a steady state annual return on financial assets of about four percent. The assumption on the relative risk aversion coefficient σ implies a non-log-utility function. A labor supply elasticity coefficient φ of 1 implies a non-linear cost

[33] For example, the calibration of the discount factor β, the labor supply elasticity coefficient φ, the elasticity of substitution between different brands within a sub-basket θ, the price stickiness parameter θ_P, and the interest rate rule coefficients ϕ_π and ϕ_y are calibrated in line with Gali (2008). The elasticity of substitution between Home and Foreign tradables ϕ follows the calibrations of Obstfeld and Rogoff (2005), Coeurdacier, Kollman and Martin (2010), and Ghironi, Lee and Rebucci (2007). The parameters related to the modeling of the consumption basket, i.e. the weight of the tradables basket in the overall consumption basket γ, and the elasticity of substitution between tradables and non-tradables ω are calibrated according to Obstfeld and Rogoff (2005). The calibration of the relative risk aversion coefficient σ, the depreciation rate δ and the labor share μ is in line with Coeurdacier, Kollman and Martin (2010)'s (and Ghironi, Lee and Rebucci, 2007's) calibrations.

of effort. The calibration of the elasticity of substitution between different brands within a sub-basket θ implies a steady state markup of prices over marginal costs of 20 percent. A depreciation rate δ of 0.026 implies an annual depreciation rate of about 10 percent. Setting the production function parameter μ to 0.6 implies a ratio of wage earnings to GDP of 60 percent. The adjustment costs in investment are set such that the volatility of investment amounts to about four times the volatility of GDP. A price stickiness parameter θ_P of 0.66 implies average price duration of three quarters. The interest rate rule coefficients ϕ_π and ϕ_y are roughly consistent with observed variations in the Federal Funds rate over the Greenspan area. In order to make the interest rate shock relatively persistent I set $\rho_r = 0.6$. In the baseline simulations both countries are assumed to be of equal size, i.e. they have equal shares in the traded goods sector. α is therefore set to 0.5. The exchange rate elasticity is assumed to be 0.5, i.e. that half of the change in exchange rates are passed on to the local prices of imported goods. Furthermore, the steady state technology levels in both countries are normalized to 1.

By means of different calibrations of the remaining two parameter blocks, namely the steady state gross asset holdings and the parameters determining financial intermediation costs, different scenarios of international financial integration can be analyzed. In the baseline scenario (total) steady state gross foreign asset holdings amount to 60 percent of GDP (steady state net foreign asset are assumed to be zero in all scenarios). Such a calibration is roughly in line with the average gross foreign asset positions (in percent of GDP) of industrial economies between 1970 and 1990.[34] The total gross foreign asset holdings are split evenly between the two asset categories, i.e. total steady state bond and equity holdings each amount to 30 percent of GDP.[35]

Financial intermediation costs are calibrated such that the excess returns across different assets lie in a reasonable range. In a log-linearized version of the system the excess return for Home agents of, for example, Foreign with respect to Home bond holdings can be derived by combining the log-linearized versions of the respective Euler equations (equations (9) and (8) above):

$$
\begin{aligned}
& E_t\left\{\left(\widehat{xret}_{B_F}\right)_t\right\} \approx E_t\left\{\widehat{\Delta s}_{t+1} + \hat{\imath}^*_{t+1} - \hat{\imath}_{t+1}\right\} \qquad (23)\\
\approx \; & \gamma_{B_F} E_t\left\{\left(\hat{b}_{Ft+1} - \hat{b}_{Ft}\right) - \beta\begin{pmatrix} \gamma_{B_F}\left(\hat{b}_{Ft+2} - \hat{b}_{Ft+1}\right) \\ -\psi_{B_F}\hat{b}_{Ft+1}\end{pmatrix}\right\} \\
& -E_t\left\{\left[\gamma_{B_H}\left(\hat{b}_{Ht+1} - \hat{b}_{Ht}\right) - \beta\begin{pmatrix} \gamma_{B_H}\left(\hat{b}_{Ht+2} - \hat{b}_{Ht+1}\right) \\ -\psi_{B_H}\hat{b}_{Ht+1}\end{pmatrix}\right]\right\}
\end{aligned}
$$

[34] See updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007).

[35] Note that with the assumption that total net foreign assets are zero, i.e. the condition $\bar{S}\bar{P}^*_Q\bar{Q}_F - \bar{P}_Q\bar{Q}^*_H + \bar{S}\bar{B}_F - \bar{B}^*_H = 0$, together with the four asset market clearing conditions only three cross-border holdings have to be determined. The fourth cross-border holding and all domestic holdings can then be determined residually. As mentioned above, bonds are in zero net supply and the total amount of equity holdings is fixed.

If the differences across assets in actual and expected changes of holdings (here $\left(\hat{b}_{Ft+1} - \hat{b}_{Ht+1}\right)$ and $E_t\left[\left(\hat{b}_{Ft+2} - \hat{b}_{Ft+1}\right) - \left(\hat{b}_{Ht+2} - \hat{b}_{Ht+1}\right)\right]$) are assumed to be about 10 percent then excess returns of about 15 basis points would seem reasonable. Given that the costs with respect to the deviations from the steady state are just a technical device to induce stationarity they are kept close to zero, namely $\psi_{...} = 0.005$. Equation 23 then implies transaction costs for changing holdings of $\gamma_{_{B_F}} = \gamma_{_{B_H}} = 1$:

$$\underbrace{[0.0015]}_{\text{Excess return (LHS of above equations)}} \approx \underbrace{[(1^*0.1) - (0.99^*((1*0.1) - (0.005^*0.1)))]}_{\text{RHS of above equations}}$$

In other words, if Home households decide to adjust their Foreign bond holdings by 10 percent of GDP more than their Home bond holdings, they need to get an excess return on Foreign versus Home bond holdings of about 15 basispoints. Thus, in the scenario with low transaction costs, in line with this reasoning, I set the financial intermediation costs at $\gamma_{B_H} = \gamma_{B_F} = \gamma_{Q_H} = \gamma_{Q_F} = \gamma_{B_H^*} = \gamma_{B_F^*} = \gamma_{Q_H^*} = \gamma_{Q_F^*} = 1$. In the "pre-integration" baseline scenario the costs for foreign assets, i.e. the costs for Home (Foreign) agents of changing Foreign (Home) bonds and equity holdings, are increased threefold to a level of $\gamma_{B_F} = \gamma_{B_H^*} = \gamma_{Q_F} = \gamma_{Q_H^*} = 3$. In such a scenario, for the decision to adjust Foreign bond holdings by 10 percent more than Home bond holdings to be optimal, the excess return would need to be about 54 basis points.[36] An alternative way to check the validity of the calibration of transaction costs is to look at the actual response of excess returns to an interest rate shock. Figure 1 shows the response of the excess return of Foreign over Home bonds to a 25 basis points one-off exogenous positive shock on the nominal interest rate in the Home country in the Baseline scenario.[37] The excess return is around 6 basis points on impact, which appears to be reasonable.

[36] $[0.0054] \approx [(3^*0.2) - (0.99^*((3*0.2) - (0.005^*0.2)))] - [(1^*0.1) - (0.99^*((1*0.1) - (0.005^*0.1)))]$.

[37] Without any further changes induced by the Taylor rule this would correspond to an annualized increase in the policy rate of 100 basis points on impact.

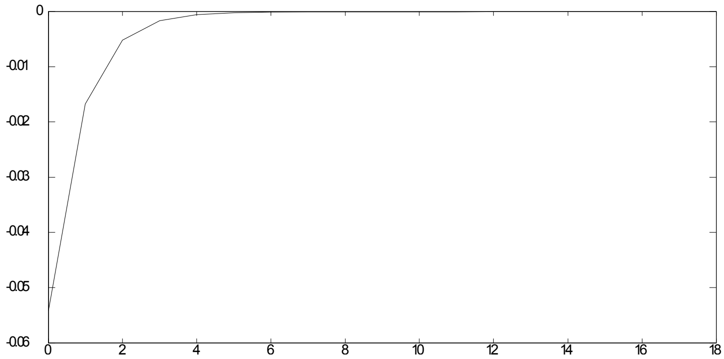

Figure 2: Response of the excess return of Foreign over Home bonds to an interest rate shock in the Baseline scenario

The impulse response is shown in percentage point deviations from the steady state.

2.4.2 Calibration of financial market integration and other scenarios

Moving away from this baseline calibration I study, in a first step, two different scenarios which I label "Higher gross foreign asset holdings" and "Lower costs". In the "Higher gross foreign asset holdings" experiment, the level of (total) gross foreign steady state asset holdings is increased from 60 to 200 percent of GDP, which corresponds to about a threefold increase in the baseline calibration and is roughly in line with the average gross foreign asset holdings (in percent of GDP) of industrial economies between 1990 and 2007.[38] In the second experiment, the "Lower costs" scenario, the financial intermediation costs of changing foreign asset positions, i.e. $\gamma_{B_F}, \gamma_{B_H^*}, \gamma_{Q_F}, \gamma_{Q_H^*}$, are reduced to the level of the costs for changing domestic asset holdings (for both Home and Foreign agents), i.e from 3 to 1. The robustness of both experiments is checked by additional variations of the parameters and both experiments are analyzed separately as well as in a combined experiment together.

In addition to analyzing these financial market integration experiments I study "trade" integration and a scenario of lower exchange rate pass-through (ERPT) and their interaction with the two forms of financial market integration. I study a scenario with a lower ERPT elasticity, as trade integration could arguably lead to a decrease in the ERPT through its effect of increasing competition in export markets. Increased competition in export markets could induce exporters to limit the fluctuations of the prices paid by consumers in response to exchange rate movements and therefore lead to a lower ERPT. A lower exchange rate pass-through could arguably also be the result of lower average inflation rates in the past decades, which in turn could be the result of the "discipline effect" of increasing international financial integration. The "discipline effect" is based on the hypothesis that a higher exposure of countries to international capital markets, i.e. a higher potential for cross-border capital flows,

[38] See updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007).

could induce central banks to maintain low inflation rates.[39] In principle, the competition to attract mobile capital could cause local governments to implement "good" policies in order to attract foreign investors ex ante and to maintain these good policies ex post in order to avoid a capital flight.[40]

The calibration of "trade integration" follows Woodford (2010) by lowering the share of traded goods produced in the Home country, i.e. lowering the size of the Home traded goods market relative to world traded goods markets. In the "integrated", "small open economy" scenario the share of Home traded goods in the overall traded goods basket, i.e. α, is lowered from 0.5 to 0.1. In the scenario with lower ERPT, the exchange rate pass-through elasticity, τ, is lowered from 0.5 to 0.1, i.e. only ten percent of an (unexpected) change in exchange rates is passed on to the local prices of imported goods.

3 Results

The simulations of the different experiments are reported in Figures A1 to A20 in appendix A. All impulse response functions show the dynamic reaction to a 25 basis-point one-off exogenous positive shock on the nominal interest rate in the Home country. Without any further changes induced by the Taylor rule this would correspond to an annualized increase in the policy rate of 100 basis points on impact. For reasons of space I do not report the dynamics of all variables of the model. In each scenario I report the impulse responses of 20 variables including the main macroeconomic variables of the model plus some additional variables (derived in detail in appendix B) such as the dynamics of the current account , its decomposition into the trade balance and net asset income, the terms of trade, as well as the net foreign asset position, and the decomposition of the change in the net foreign assets position into the current account, the change in local currency asset prices, and exchange rate valuation.[41] In the "Baseline" scenario I report, for intuitive purposes, an additional Figure with the reaction of a few further variables. Table A1 lists the notation of all reported variables.

The dynamic reaction of the model is as expected and intuitive. Figures A1 and A2 show the results for the "Baseline" scenario. The contractionary monetary policy shock leads to a reduction of Home inflation of about 0.8 percentage points on impact. As a consequence of the increase in the Home interest rate, the Home nominal (and real) exchange rate appreciate on impact after depreciating back to a new equilibrium. This is in line with some form of an uncovered interest rate parity condition which can be derived from the Euler equations. The increase in the Home nominal (and real) interest rate induces Home households to reduce

[39] Tytell and Wei (2005) provide some empirical evidence for this hypothesis.

[40] Kroszner (2007) argues that integration, deregulation and innovation in financial markets have fostered currency competition which has led to improved central bank performance.

[41] Note that as the model is linearized around stationary variables all variables except inflation and nominal exchange and interest rates are real variables, i.e. scaled by the Home and Foreign CPIs, respectively. For variables where the steady state is equal to zero, i.e. the trade balance, net foreign income, and net foreign assets, the steady state deviations of nominal and real variables are equivalent. Impulse response functions are shown in percentage point deviations from the steady state. Inflation and interest rates are shown in annualized rates (i.e. multiplied by four).

their domestic consumption spending, in line with the Euler equations. Home households also reduce their import spending. Thus, income-absorption effects (intertemporal substitution and negative wealth effects which, all else equal, induce Home households to import less) more than offset expenditure-switching effects (an appreciation of the Home currency which, all else equal, induces Home households to import more). Expenditure-switching effects also reduce exports, and as the fall in exports more than offsets the fall in imports, net exports fall. The negative demand shock stemming from the reduction in both consumption and exports leads to a fall in the return on investment and therefore investment itself. The combined fall in consumption, net exports, and investment leads to a fall in Home output of around 0.2 percentage points. In order to cushion the contractionary monetary policy shock and smooth consumption over time, Home consumers borrow from Foreign agents in all four asset categories, i.e. sell assets to Foreigners (as can be seen in the reduction of Home and Foreign bond as well as equity holdings reported in the fourth row). As a consequence, the current account and net foreign assets fall. The change in net foreign assets (as can be seen from the decomposition in the fifth row) is not only due to increased borrowing but also to negative exchange rate valuation effects stemming from the appreciation of the Home currency. Figure A2 reports the reaction of some additional variables in the "Baseline" scenario. As a consequence of the negative demand shock, Home firms reduce their labor and capital input demand, which leads to a reduction in both wages and rental rates of capital. The fall in wages and rental rates of capital in turn leads to a reduction in marginal costs. As prices are sticky, i.e. some prices cannot be adjusted immediately, Home profits rise. Over time, firms adjust their price setting to the reduction in marginal costs which, as reported in Figure A1, leads to a fall in Home inflation. Due to the increase in Home interest rates and to restore asset market equilibrium, equity prices fall. Furthermore, as a consequence of the appreciation of the Home currency and the fall in Home output, the Home terms of trade increase. For completeness, the third row reports the, generally very low, reaction of the main Foreign variables.

3.1 Lower costs

The first international financial integration experiment shows that integration in the form of lower financial intermediation costs for trading foreign assets does indeed weaken part of the interest rate channel due to an increase in Home consumers' consumption smoothing and a reduced reaction of consumption and investment spending. However, if an economy is open to trade, higher consumption smoothing also applies to spending on imported goods which, together with a strengthened exchange rate channel, reinforces the decrease in net exports and the overall (contractionary) impact of monetary policy on output and inflation. Figure A3 reports the differences in the impulse responses between the "Lower Costs" and the "Baseline" scenarios. There are no qualitative, but only quantitative differences in the reaction of all variables in the two scenarios. A reduction in financial intermediation costs for trading foreign assets induces Home households to increase their borrowing from abroad and to decrease their reduction in consumption and investment spending after a monetary policy contraction. Thus, in this respect, financial integration reduces the contractionary effect of monetary policy. However, a reduction in financial intermediation costs for trading foreign assets leads not only to a lower reduction in consumption and investment spending, but also to a lower reduction in import spending. A lower reduction in import spending, in turn, increases the contractionary effect of monetary policy (a reduction in imports has, all else equal, an expansionary effect on domestic output). Furthermore, a reduction in financial intermediation costs for trading foreign assets leads to higher appreciation, arguably due to the fact that in more integrated asset markets exchange rates react more to (monetary policy-induced) changes in interest rate differentials. This higher exchange rate appreciation further lowers the reduction in imports and raises the reduction in exports, i.e. further increases the contractionary effect of monetary policy. Overall, a lower reduction in imports together with a higher reduction in exports, and, thus, a higher reduction in net exports offsets the lower reduction in consumption and investment, and there is a slightly higher contraction of output as well as inflation (around 0.0025 and 0.02 percentage points, respectively, or 1 and 2 percent of the initial responses). Thus, even though monetary policy loses some control over consumption and investment due to the fact that Home consumers can borrow more easily from the rest of the world, the impact of monetary policy on net exports, output and inflation are higher in an economy where assets can be traded more easily with the rest of the world. It is important to check how the calibration of financial intermediation costs affects the robustness of this result. Figure A4 reports the sensitivity of the impulse responses to the calibration of financial intermediation costs. The responses are shown for the period of the shock as a function of γ_{B_F}(or $\gamma_{Q_F}, \gamma_{B^*_H}, \gamma_{Q^*_H}$). The costs for different categories of foreign assets are again the same and symmetric for the two countries. As found before, the lower the financial intermediation costs on foreign assets the more consumers can engage in consumption smoothing with the rest of the world and therefore the higher the reduction in asset holdings and the lower the reaction of consumption, investment and imports. Exports, the trade balance, output, and inflation react more when the costs for trading foreign assets are lower. The sensitivity of the reactions to the level of costs is not very high. Even if costs are reduced by a factor of 10, the responses of output and inflation are affected by less than 0.02 and 0.1 percentage points, respectively, or less than 10 and 13 percent of the initial responses.

3.2 Higher gross foreign asset positions

The second international financial integration experiment shows that integration in the form of higher gross foreign asset holdings strengthens (foreign) wealth channels of monetary transmission. Strengthened wealth channels more than offset a weakened interest rate channel and therefore lead to a higher impact of monetary policy on domestic spending. At the same time these strengthened wealth channels, together with a slightly weakened exchange rate channel, lower the impact on net exports. In most of the cases, however, the higher impact on domestic spending outweighs the lower impact on net exports and thereby reinforces the overall impact of monetary policy on output. The impact on inflation is slightly lower initially, but more persistent. Figure A5 reports the differences in the reaction of the main variables between the "Higher gross foreign asset (GFA)" and the "Baseline" scenario. There are again no qualitative differences in the reaction of any variable, except, as discussed below, net exports. Despite the fact that in an integrated scenario Home households boost their consumption smoothing, i.e. increase their borrowings from foreigners (increase their reduction in asset holdings in all categories) after a monetary policy contraction, they increase their reduction of consumption, investment, and import spending. The higher reduction in consumption, investment and import spending is thus mainly due to much higher negative shocks on domestic households' foreign wealth. The negative responses of net foreign income and assets are increased by a factor of around three and two, respectively. These dynamics, in turn, are a consequence of higher negative exchange rate valuation effects. Despite a lower impact appreciation of the Home currency, exchange rate valuation effects are much higher (the responses are increased by a factor of two) as they affect much higher steady state gross positions. Only the contractionary impact of monetary policy on net exports is reduced. A positive interest rate shock now even leads to a slightly positive impact reaction of net exports. This is due to a lower appreciation of the Home currency, which lowers the reduction in exports and, together with higher negative (foreign) wealth effects, raises the reduction in imports. However, despite a lower impact on net exports, the overall impact of a monetary policy contraction on output is increased by about 0.005 percentage points or about 3 percent of the initial response. The response of inflation is slightly moderated on impact (a bit less than 0.01 percentage points or 1 percent of the initial response), due to a lower impact appreciation of the exchange rate, but it is more persistent. Figure A6 reports the sensitivity of the impulse responses to the calibration of the level of steady state gross foreign asset positions. The response functions are shown for the period of the shock as a function of $\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*} + \frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}$(or $\frac{\bar{B}_H^*}{\bar{P}\bar{Y}} + \frac{\bar{Q}_H^*}{\bar{Y}}$). The holdings of different categories of foreign assets are again the same and symmetric for the two countries. In line with the results above, higher gross foreign asset holdings increase the negative reaction of consumption, investment and imports, and output. Exports and the trade balance and inflation react less with increasing gross foreign asset holdings. The sensitivity of the reactions to the level of gross foreign assets is again quite low. If total gross foreign asset holdings are increased to over 900% of GDP, the impact of a monetary policy shock on output is increased by about 0.05 percentage points or about 25 percent of the initial response. The impact of a contractionary monetary policy shock on inflation is reduced by just over 0.05 percentage points or 6 percent of the initial response. However, monetary policy always retains its ability to affect inflation. Note that if total gross foreign asset holdings are more than around 500 percent of GDP, the real exchange rate depreciates on impact and there is a positive reaction of not only net exports, but also net foreign assets.

3.3 Both forms of financial integration combined

The experiment interacting both forms of financial market integration, i.e. a reduction of transaction costs for trading foreign assets combined with an increase in the level of steady state gross foreign asset holdings, increases the impact of monetary policy on both output and inflation as the "positive" effects of the two separate scenarios reinforce each other. Figure A7 reports the difference in the impulse responses between the two scenarios. A higher impact appreciation of the Home currency (arguably due to lower transaction costs, i.e. more integrated international asset markets, which make exchange rates more responsive to (monetary policy-induced) changes in interest rate differentials) now has a higher negative exchange rate valuation effect on Home households' wealth (due to higher gross foreign asset positions). This increases the negative impact of a contractionary monetary policy shock on consumption, investment, imports, output and inflation. Only the reduction in exports is lower, which leads, together with a higher reduction in imports, to a slightly lower reduction in the trade balance. However, the former effect outweighs the latter. Overall, this combined form of financial integration increases rather than decreases monetary policy effectiveness. The responses of output and inflation are affected by 0.01 and 0.025 percentage points, or about 5 and 3 percent of the initial responses, respectively. Figure A8 reports the sensitivity of the results to the calibration of the combination of the two forms of financial integration. In particular, it reports the impact reaction of inflation, output and a few additional variables for the interaction of further calibrations of the level of steady state gross foreign asset holdings and the costs for trading foreign assets. A monetary policy shock has the highest impact on inflation and output when gross foreign asset holdings are large and the costs for trading foreign assets are low. A reduction in the costs for trading foreign assets always, i.e. in combination with any level of gross foreign asset holdings, increases the impact of monetary policy on both output and inflation. In contrast, in a combination with certain levels of the costs for trading foreign assets an increase in foreign asset holdings leads not only to a lower effect on inflation (as seen above), but also a lower effect on output. This is specifically the case when the costs for trading foreign assets are very large, i.e. there is almost complete financial autarky. In such a situation an increase in gross foreign asset holdings leads to a large difference in the impact of a monetary policy shock on the exchange rate.[42] This leads to a decreasing impact on net exports which outweighs an increasing impact on domestic spending and therefore leads to an overall reduced impact of monetary policy on output and inflation. Thus, in a situation with high costs for trading foreign assets, an increase in gross foreign asset holdings may weaken the effectiveness of monetary policy in influencing output and inflation. However, even with very high costs for trading foreign assets and very high foreign asset holdings monetary policy effectiveness is maintained.

3.4 "Trade" integration and its interaction with financial integration

The "trade market" integration experiment (displayed in Figure A9), namely a reduction in the Home country's share in the overall traded goods sector, is in line with findings in the existing literature. Monetary policy retains its leverage over output and inflation even in an environment where the Home traded goods sector is small compared to world markets. Monetary policy's impact on the trade balance and inflation is reduced, but the impact on consumption, investment and output is slightly larger. The larger impact on domestic spending and output is due to larger negative (foreign) wealth effects. Despite a lower exchange rate appreciation, there is a larger fall in net foreign income and assets. The leverage over the trade balance is reduced as a lower impact appreciation of the exchange rate reduces the impact on exports, i.e. lowers the reduction of exports, and, together with higher negative income and wealth shocks, also leads to a higher reduction in import spending. The overall impact on output is increased by around 1 percent of the initial response, while the impact on inflation is decreased by around 1 percent of the initial response, initially. Figure A10

[42] As seen above, in a combination of (very) high steady state gross foreign asset holdings and (very) high costs for trading foreign assets, the exchange rate depreciates rather than appreciates on impact, which lowers the contractionary effect of monetary policy on net exports.

reports the experiment interacting "trade" integration with both forms of financial integration combined. As the differences in the impulse responses show, an interaction of all forms of integration leads to the highest "positive" impact on monetary policy effectiveness. Generally, strengthened income and wealth effects more than offset weakened exchange rate and interest rate channels of monetary transmission. The combined effect is not just the sum of all individual effects, but the interaction of financial and "trade" integration actually leads to an amplification of the effects. The impact of a monetary policy shock on output and inflation is reinforced by 0.025 and 0.05 percentage points (or around 12 and 6 percent of the initial responses, respectively). Figure A11 shows some further scenarios for the interaction of "trade" integration with financial integration in the form of lower costs for trading foreign assets, while Figure A12 shows some further scenarios for the interaction of "trade" integration with financial integration in the form of higher steady state gross foreign asset holdings. The impulse responses show that for any level of "trade" integration, a reduction in the costs for trading foreign assets leads to an increasing impact of monetary policy on output and inflation due to strengthened exchange rate and wealth channels which more than offset a weakening of interest rate channels. In contrast, for any given level of "trade" integration, an increase in gross foreign asset holdings leads to an increasing impact of monetary policy on domestic spending and output, but a decreasing impact on exchange rates, net exports and inflation. The higher the trade integration, the greater these effects are. However, even with a very low share of the Home country's share in the trade goods sector and very high gross foreign asset positions, monetary policy still retains its ability to affect inflation.

3.5 Lower exchange rate pass-through and its interaction with financial integration

Figures A13 to A16 show different scenarios with a reduction in the level of ERPT and its interaction with the two forms of financial integration. All experiments show that neither a decrease in the ERPT nor its interaction with financial integration materially affects the impact of monetary policy on output and inflation. Figure A13 shows that the differences in the responses between a scenario with an ERPT of 0.5 and one with an ERPT of 0.1 is extremely low. In general, a lower ERPT lowers monetary policy's impact on inflation, but increases its impact on output. Figure A14 reports the experiment interacting a lower ERPT with both forms of financial integration combined. As the differences in the impulse responses show, this leads to a reinforced impact on output and inflation of 0.01 and 0.025 percentage points respectively (or 5 percent and 3 percent of the initial responses). These results are equivalent to the results above. Thus, in this setting, a variation in the level of ERPT does not affect the impact of financial integration. Figures A15 and A16 show further calibrations of the interaction of a lower ERPT with the two forms of financial integration. Again, for any level of ERPT, a reduction in the costs for trading foreign assets always increases monetary policy's impact on output and inflation. In contrast, for any given level of ERPT, an increase in the level of gross foreign asset holdings always leads to an increasing impact of monetary policy on output, consumption and investment, but a decreasing impact on exchange rates, net exports and inflation.

3.6 Robustness checks

Figures A17 to A20 report two different robustness checks for the financial market integration scenarios. The robustness of the results for the two forms of financial integration is checked for varying degrees of the elasticity of substitution between Home and Foreign tradables as well as the elasticity of substitution between tradables and nontradables. The calibration of these two elasticities is varied between 2 (the baseline case) and 10.

As can be seen in the simulations in Figures A17 and A18, a variation in the elasticity of substitution between Home and Foreign tradables does not overturn the above results of both a decrease in the costs for trading foreign assets and an incease in gross foreign asset holdings. In all the scenarios monetary policy effectiveness is maintained. Figure A17 shows that the higher the elasticity of substitution between Home and Foreign tradables the greater the impact of a reduction in the costs for trading foreign assets on the effectiveness of monetary policy. A higher elasticity primarily increases the impact of monetary policy on (net) exports and output, as it increases the expenditure-switching effect of a monetary-policy induced appreciation. However, the difference in the responses does not exceed 0.2 percentage points for output as well as inflation. Figure A18 shows that a variation in the elasticity of substitution between Home and Foreign tradables has a negligible effect on the impact of an increase in gross foreign assets on monetary policy's effectiveness in influencing inflation. It has a somewhat higher effect on the impact of this form of integration on monetary policy's effectiveness in influencing output (and trade). In particular, in contrast to the above, for high levels of elasticity of substitution between Home and Foreign tradables an increase in gross foreign asset holdings reduces not only the initial impact of monetary policy on inflation but also its impact on output. However, the results are not affected by more than 0.2 percentage points either and monetary policy effectiveness is therefore guaranteed.

Figures A19 and A20 show the results for a variation in the elasticity of substitution between tradables and nontradables. The results are almost identical to the results for a variation in the elasticity of substitution between Home and Foreign tradables. An increase in the elasticity of substitution between tradables and nontradables also increases the expenditure-switching effects of a monetary-policy induced appreciation and therefore increases monetary policy's leverage over the trade balance and output. In general, for any level of the costs of trading foreign assets and the level of steady state gross foreign asset holdings, an increase in the elasticity of substitution between both tradables and nontradables and Home and Foreign tradables increases monetary policy effectiveness.

4 Conclusions

The simulations of the calibrated model show that none of the analyzed forms of international financial integration materially undermines the ability of monetary policy to affect output and inflation. In a medium-scale New Keynesian DSGE model as presented here, it is difficult to construct scenarios in which financial integration or an interaction of financial with trade integration or with a reduction in ERPT erodes monetary policy effectiveness. Thus, Woodford (2010)'s results carry over to a more general framework.

The simulations show three different aspects of the impact of financial integration on the transmission of monetary policy. First, the two forms of international financial integration have opposite effects on the impact of monetary policy on domestic spending. On the one hand, integration in the form of lower transaction costs reduces monetary policy's control over domestic spending as it increases the ability of domestic agents to smooth their consumption over time by borrowing from the rest of the world. This weakens the interest rate channel of monetary policy transmission. On the other hand, integration in the form of an increase in gross foreign asset holdings increases monetary policy's control over domestic spending as it strengthens the effect of (monetary policy-induced) exchange rate valuation effects on domestic agent's foreign income and wealth. This form of integration thus strengthens (foreign) wealth channels of monetary policy transmission.

Second, the effects of both forms of integration on the impact of monetary policy on domestic spending are counteracted by their effects on the impact of monetary policy on the trade balance. Under financial integration in the form of a reduction in transaction costs, a weakened interest rate channel reduces the impact not only on domestic spending but also on import spending which, together with a strengthened exchange rate channel *increases* monetary policy's leverage over net exports. Under financial integration in the form of higher gross foreign assets, strengthened wealth channels increase the impact not only on domestic spending but also on import spending, which in turn *reduces* monetary policy's leverage over net exports.

Third, overall, under realistic parameterizations, the "negative" effects of financial integration on monetary policy transmission are more than offset by the "positive" effects of integration. The "negative" effects of a reduction in the costs for trading foreign assets, i.e. a weaker impact on domestic spending (due to a weaker interest rate channel) are more than offset by its "positive" effects, i.e. a stronger impact on the trade balance (due to stronger exchange rate channels and the effect of a weaker interest rate channel on import spending). The "positive" effects of an increase in gross foreign assets, i.e. a stronger impact on domestic spending (due to stronger (foreign) wealth channels) outweigh its "negative" effects, i.e. a weaker impact on the trade balance (due to the effect of stronger (foreign) wealth channels applying equally on import spending). Only in a combination of very high gross foreign asset holdings with either very high costs for trading foreign assets, a very small share of the Home country's traded goods sector or a very low ERPT are the "positive" effects of stronger income and wealth channels on domestic spending either more than offset by their "negative" effects on the trade balance or by weaker exchange rate channels. However, none of the experiments leads to a material erosion of monetary policy effectiveness. Monetary policy always retains its ability to affect output and inflation. Furthermore, in scenarios with the highest integration (low costs, high gross foreign asset holdings and high trade integration) monetary policy is most effective.

This paper offers a theoretical analysis of the implications of international financial integration for the effectiveness of monetary policy in a standard New Keynesian DSGE framework. There are many possible avenues for future research. First, the analysis of this paper is based on a calibration exercise. This could be complemented not only by an estimation of the model but also by a less structural data-driven approach in a vector autoregression framework and a combination of the two along the lines of Boivin and Giannoni (2006). Second, the aim of this paper is to analyze the effects of financial integration in a richer theoretical framework than the one considered in Woodford (2010). In order to do so the paper develops a relatively comprehensive model. While this makes it possible to incorporate additional features of an economy, the model soon becomes rather complex, making some of the results difficult to understand. It would be interesting to complement the analysis with a simpler model, potentially yielding analytical results of conditions under which monetary policy effectiveness might be strengthened or weakened. Finally, a standard New Keynesian framework as presented here neglects non-neoclassical channels, such as bank lending and balance sheet channels. The role of non-neoclassical transmission channels and their interaction with financial globalization remains a very important open question for research.[43]

[43] See Boivin, Kiley and Mishkin (2010).

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Appendix A: Impulse response functions

i	interest rate	qh	real Home equity holdings
π	inflation	qf	real Foreign equity holdings
Δs	change in nominal exchange rate	Δnfa	change in net foreign assets
rer	real exchange rate	ca	real current account
y	real gross domestic product	$\Delta lcap$	change in local currency asset prices
c	real consumption	ev	real exchange rate valuation effect
inv	real investment	n	labor
nx	real net exports	k	capital
exp	real exports	w	real wages
imp	real imports	rk	real rental rate of capital
nai	real net asset income	mc	real marginal costs
nfa	real net foreign assets	v	real profits
bh	real holdings of Home bond	pq	real price of equities
bf	real holdings of Foreign bond	tot	terms of trade

Table A1: Notation of reported variables

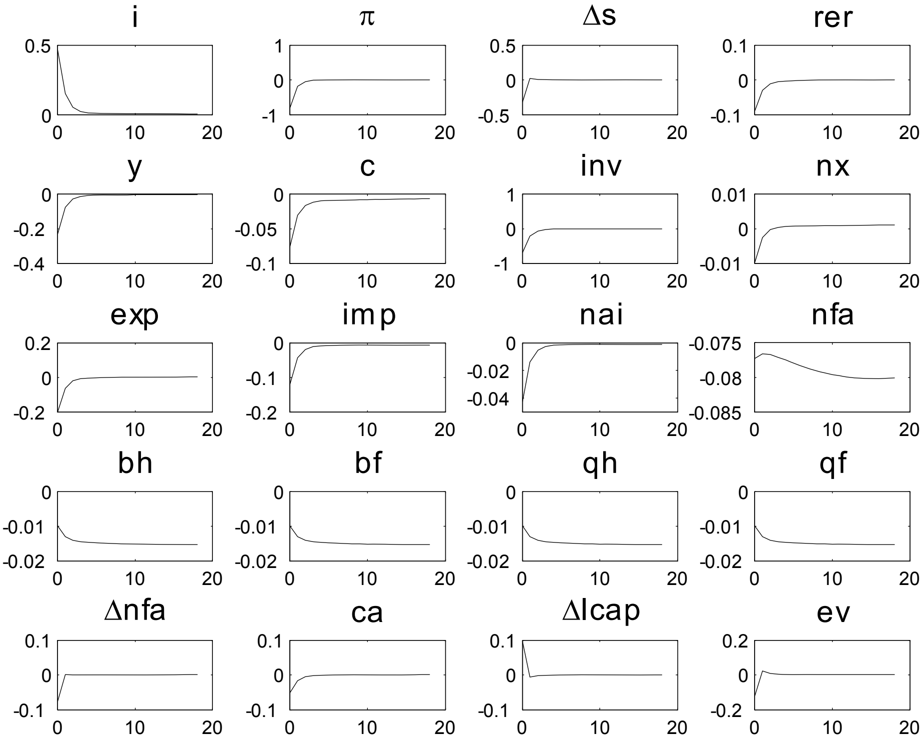

Figure A1: "Baseline"

Impulse responses are reported in percentage point deviations from the steady state.

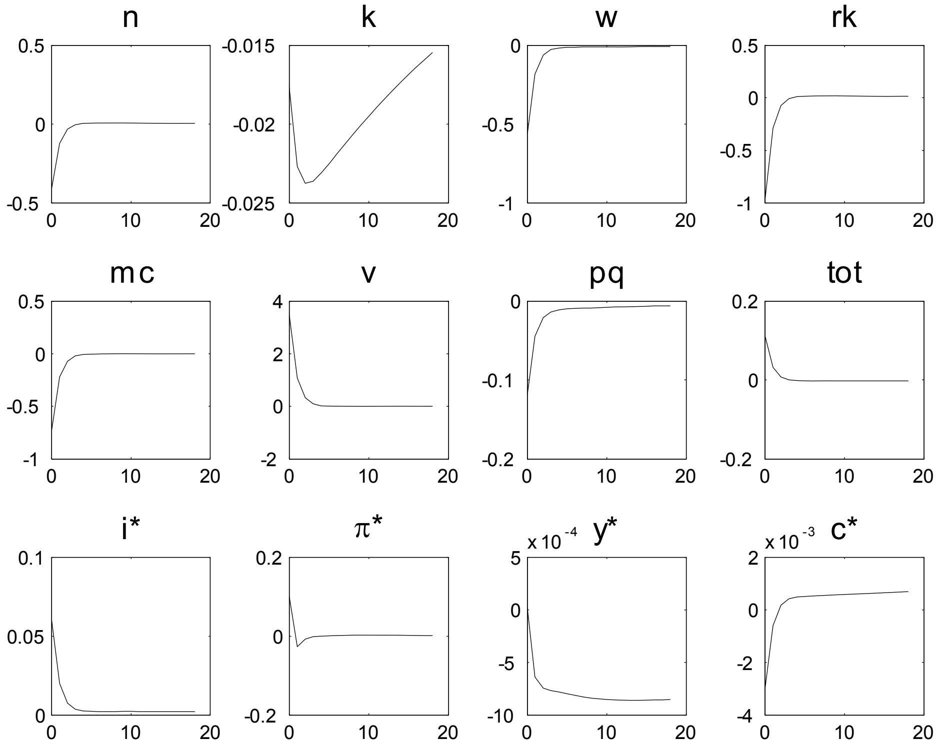

Figure A2: "Baseline"

Impulse responses are reported in percentage point deviations from the steady state.

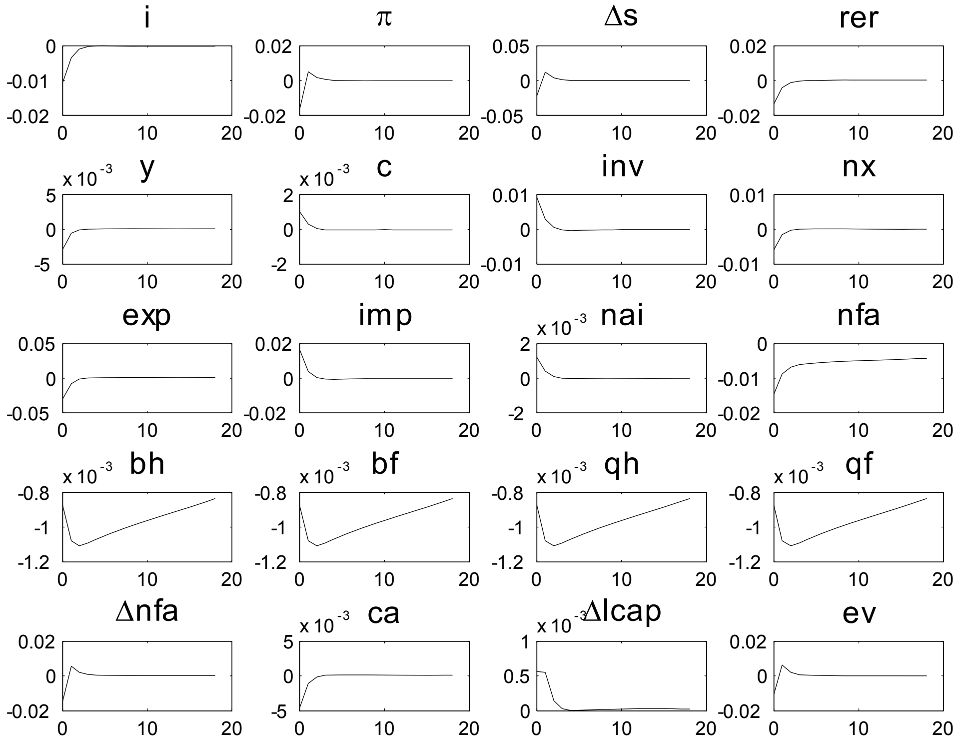

Figure A3: Difference "Lower Costs" to "Baseline"

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in differences between the "Lower Costs" and the "Baseline" scenario.

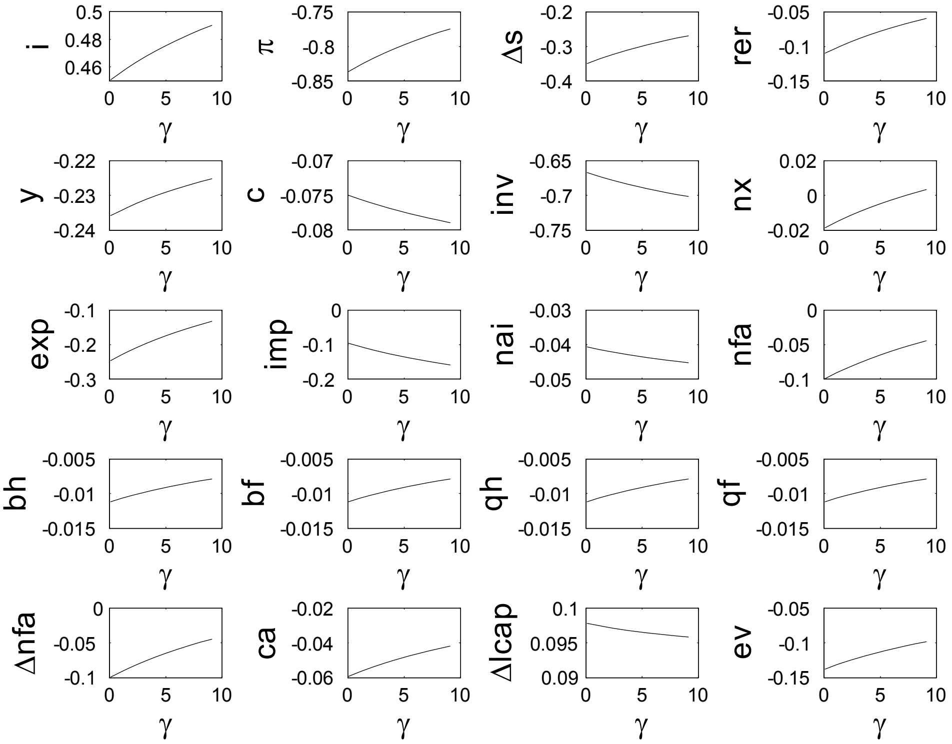

Figure A4: Further "Lower Costs" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of costs of trading foreign assets.

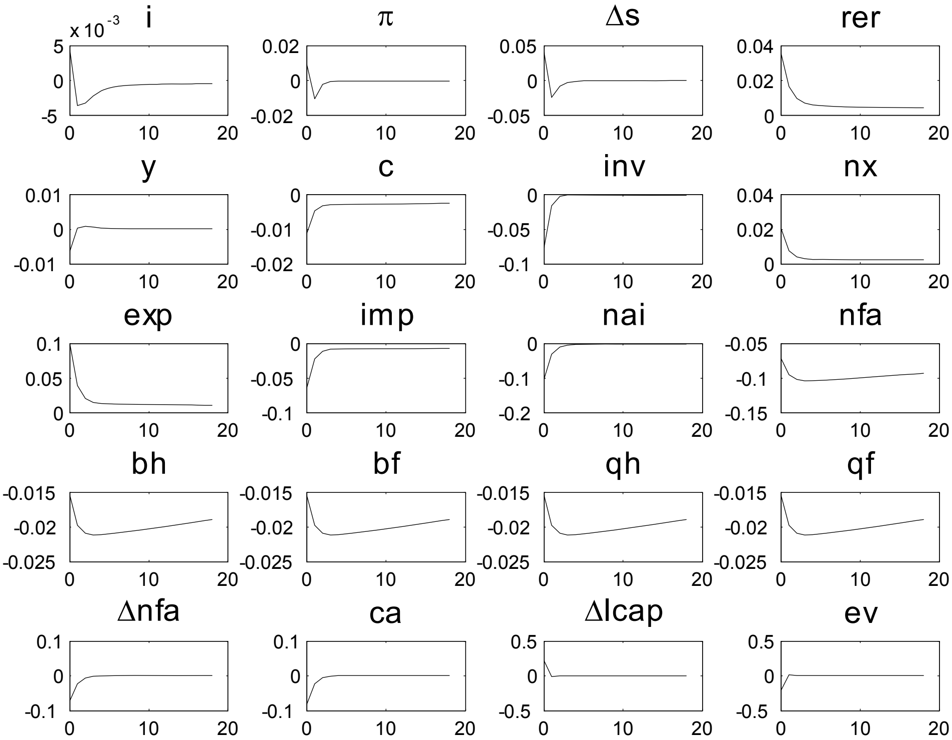

Figure A5: Difference "Higher GFA" to "Baseline"

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in differences between the "Higher Gross Foreign Assets" and the "Baseline" scenario.

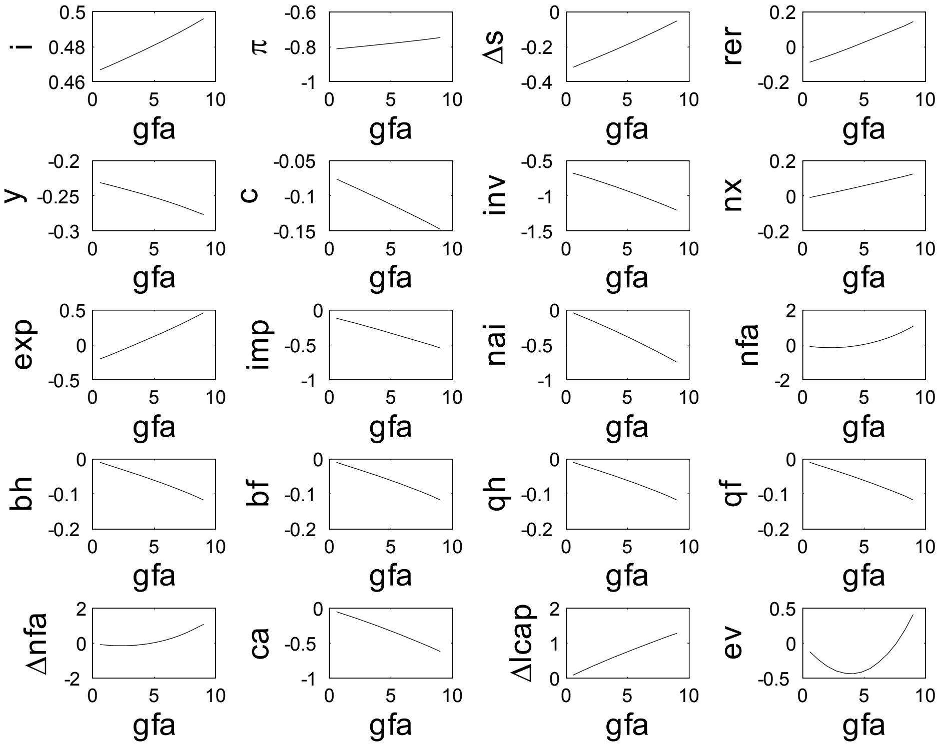

Figure A6: Further "Higher GFA" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of steady state gross foreign assets.

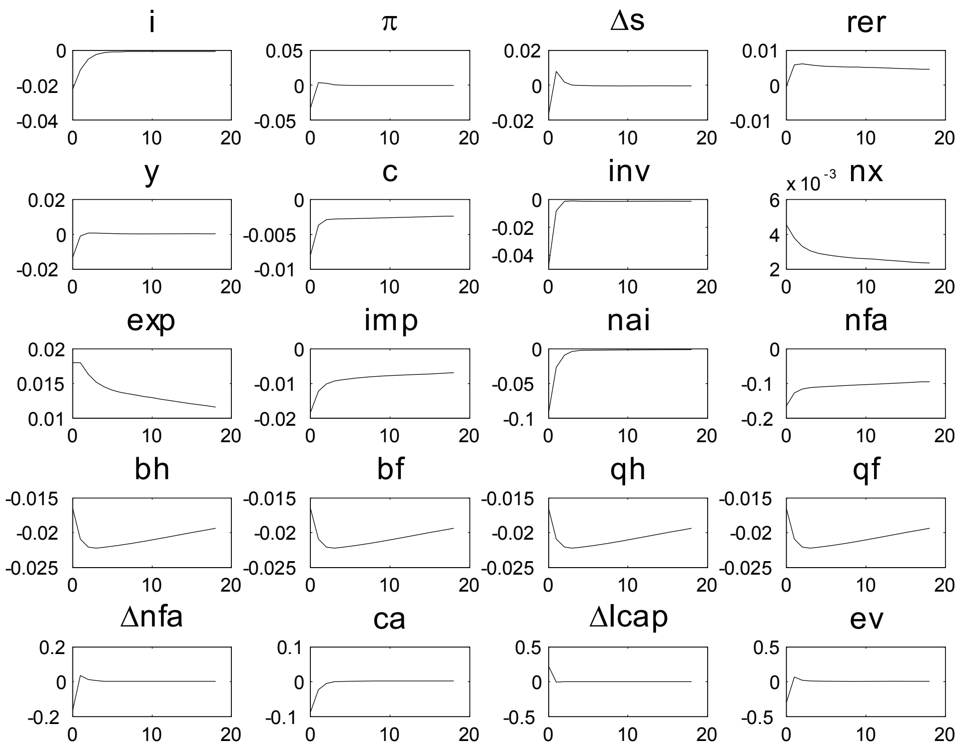

Figure A7: Difference "Higher GFA and Lower Costs" to "Baseline"

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in differences between the "Higher Gross Foreign Assets and Lower Costs" and the "Baseline" scenario.

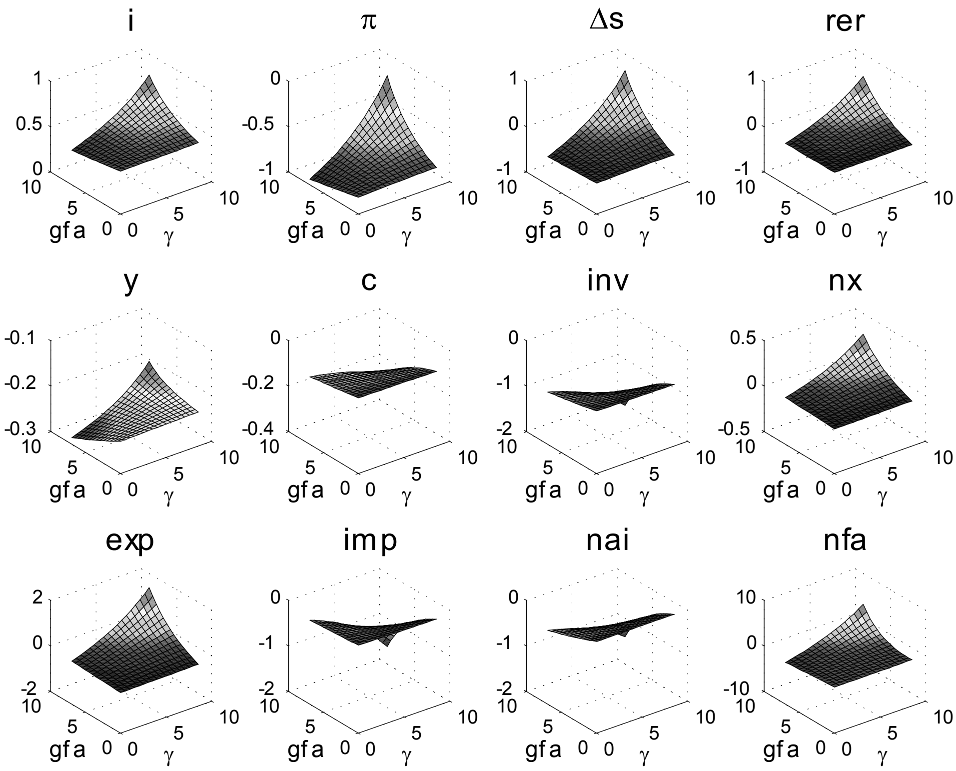

Figure A8: Further "Higher GFA" and "Lower Costs" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of steady state gross foreign assets and the costs of trading foreign assets.

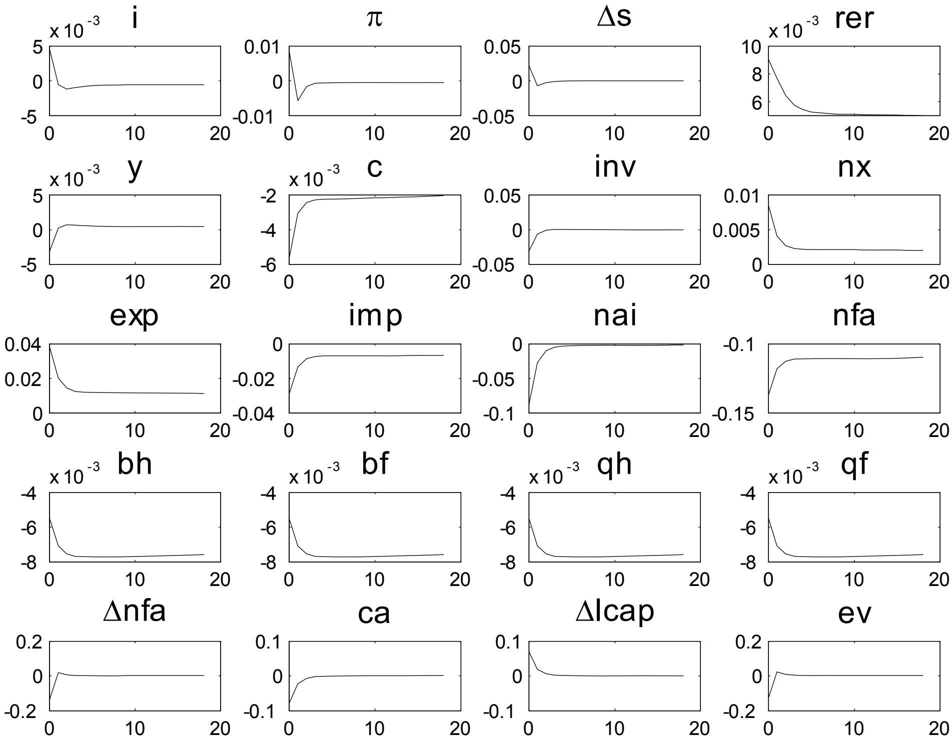

Figure A9: Difference "Higher trade integration" to "Baseline"

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in differences between the "Higher trade integration" and the "Baseline" scenario.

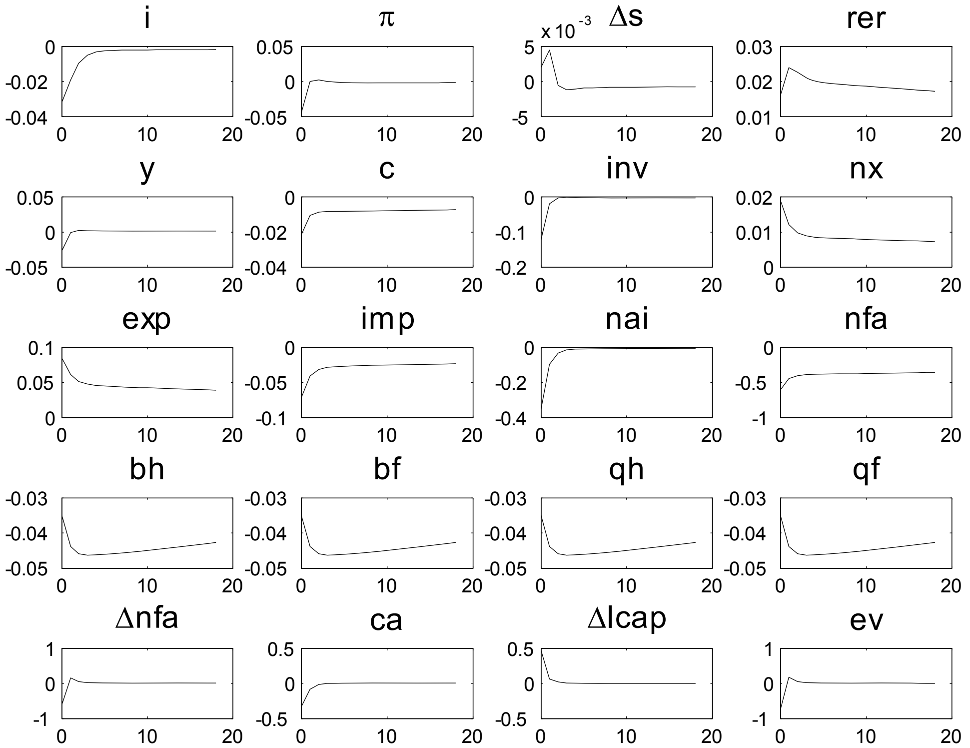

Figure A10: Difference "Higher trade integration, Higher GFA and Lower Costs" to "Baseline"

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in differences between the "Higher trade integration, Higher Gross Foreign Assets and Lower Costs" and the "Baseline" scenario.

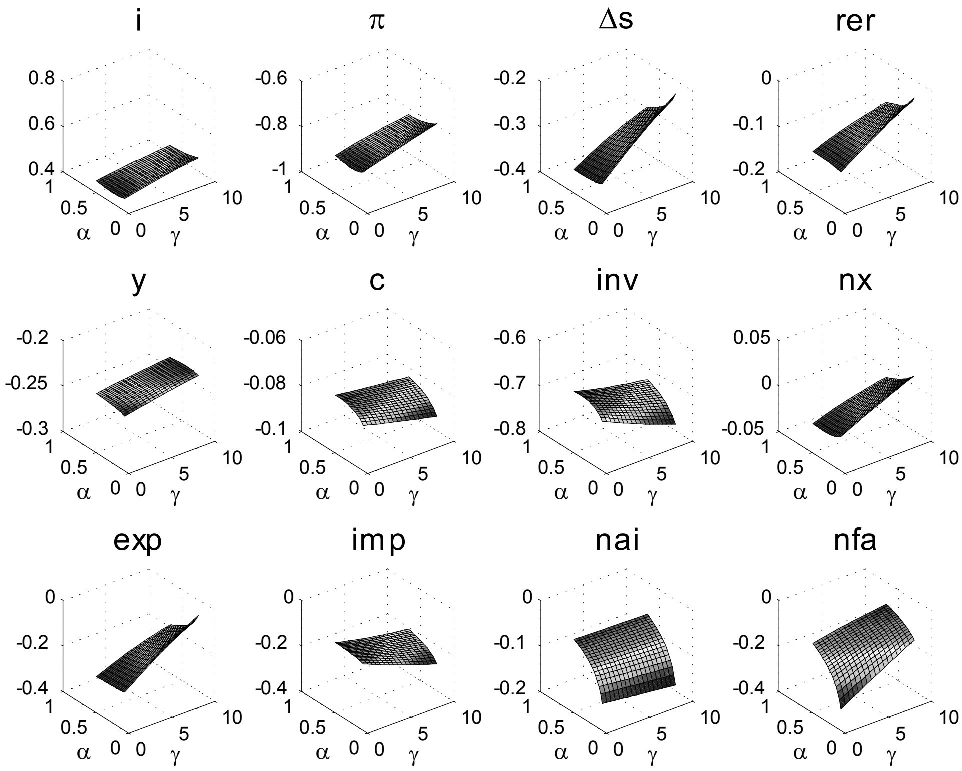

Figure A11: Further "Trade integration" and "Lower Costs" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of trade integration and of the costs of trading foreign assets.

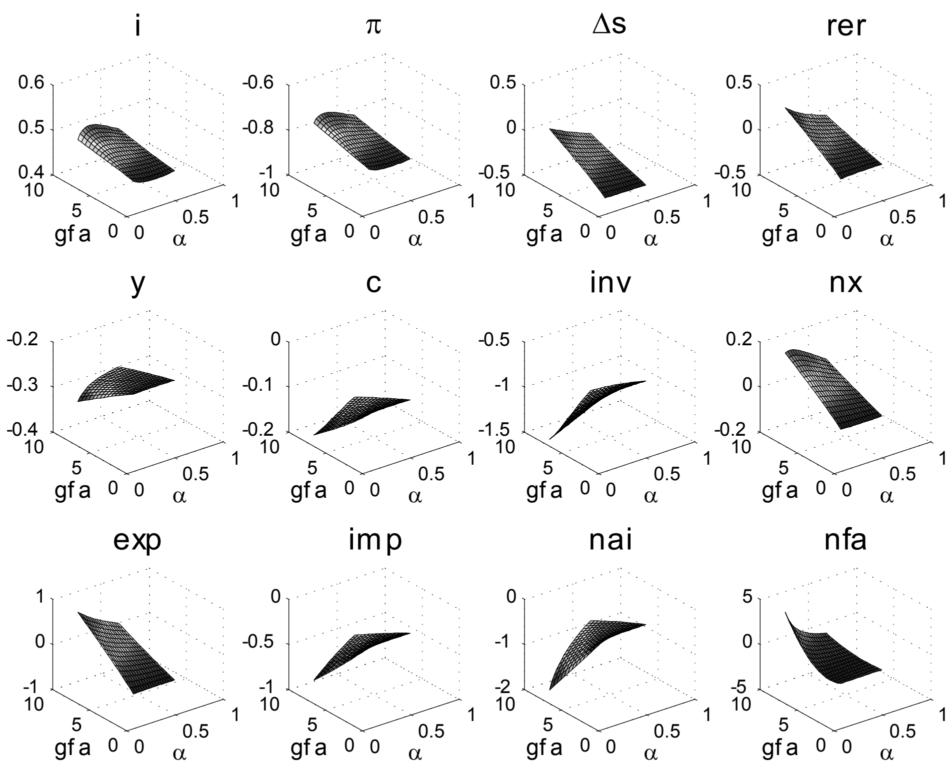

Figure A12: Further "Trade integration" and "Higher GFA" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of trade integration and of the level of gross foreign asset holdings.

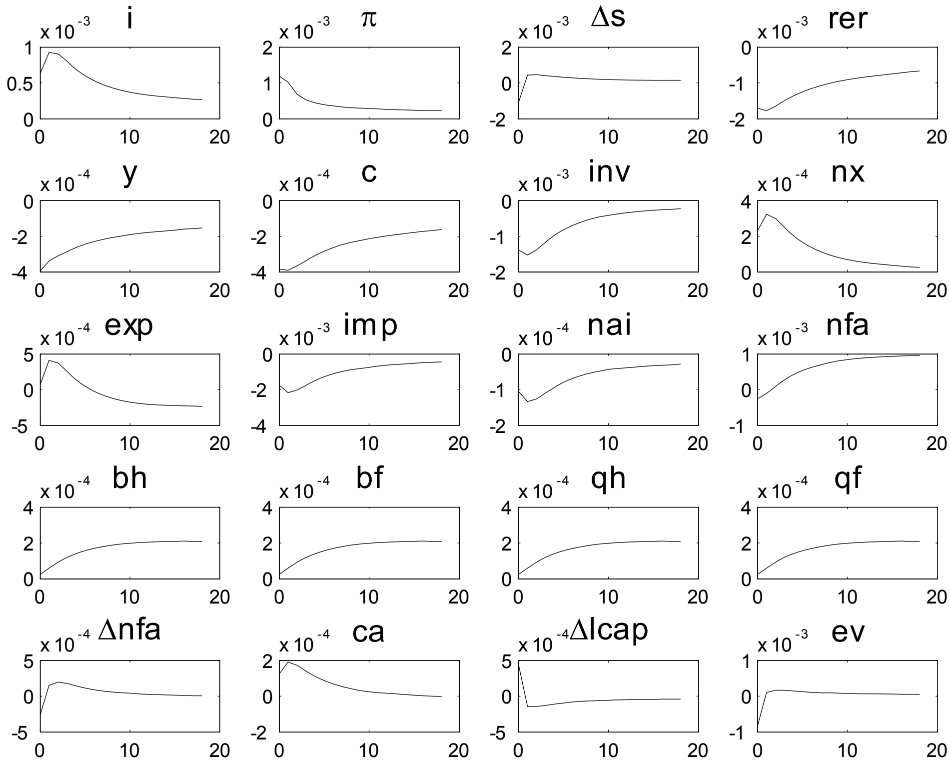

Figure A13: Difference "Lower ERPT" to "Baseline"

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in differences between the "Lower Exchange Rate Pass-through" and the "Baseline" scenario.

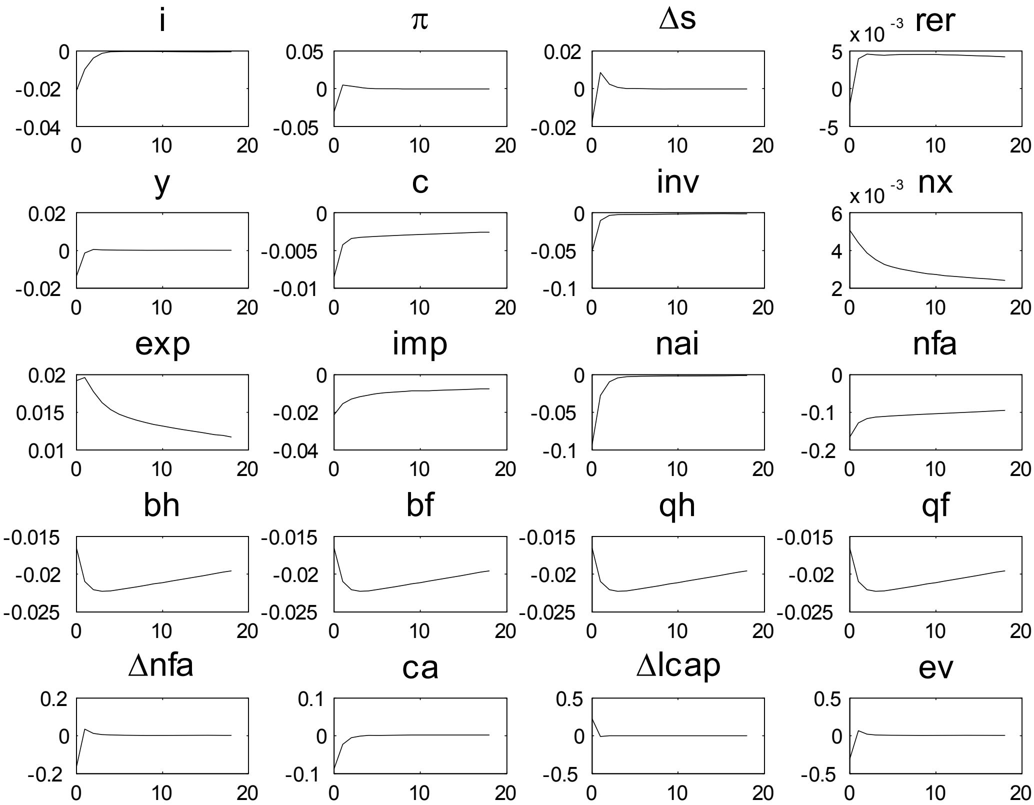

Figure A14: Difference "Lower ERPT, Higher GFA, and Lower Costs" to "Baseline"

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in differences between the "Lower Exchange Rate Pass-through, Higher Gross Foreign Assets, and Lower Costs" and the "Baseline" scenario.

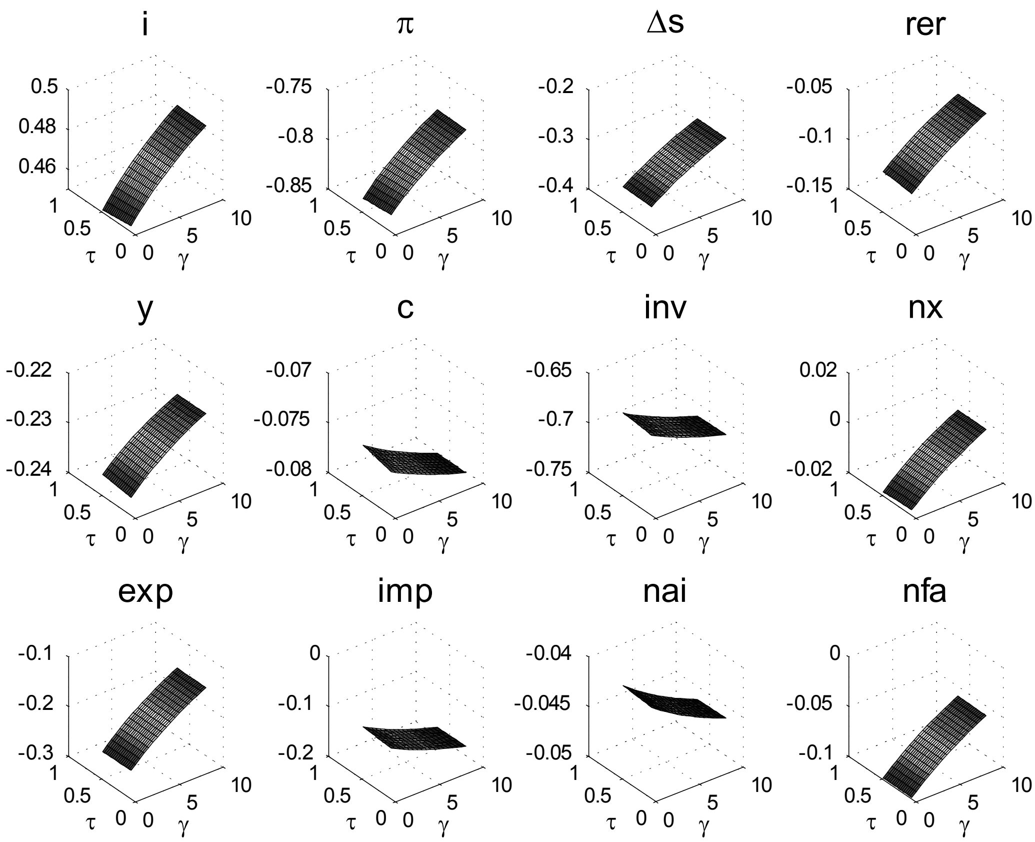

Figure A15: Further "Lower ERPT" and "Lower Costs" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of exchange rate pass-through and of the costs of trading foreign assets.

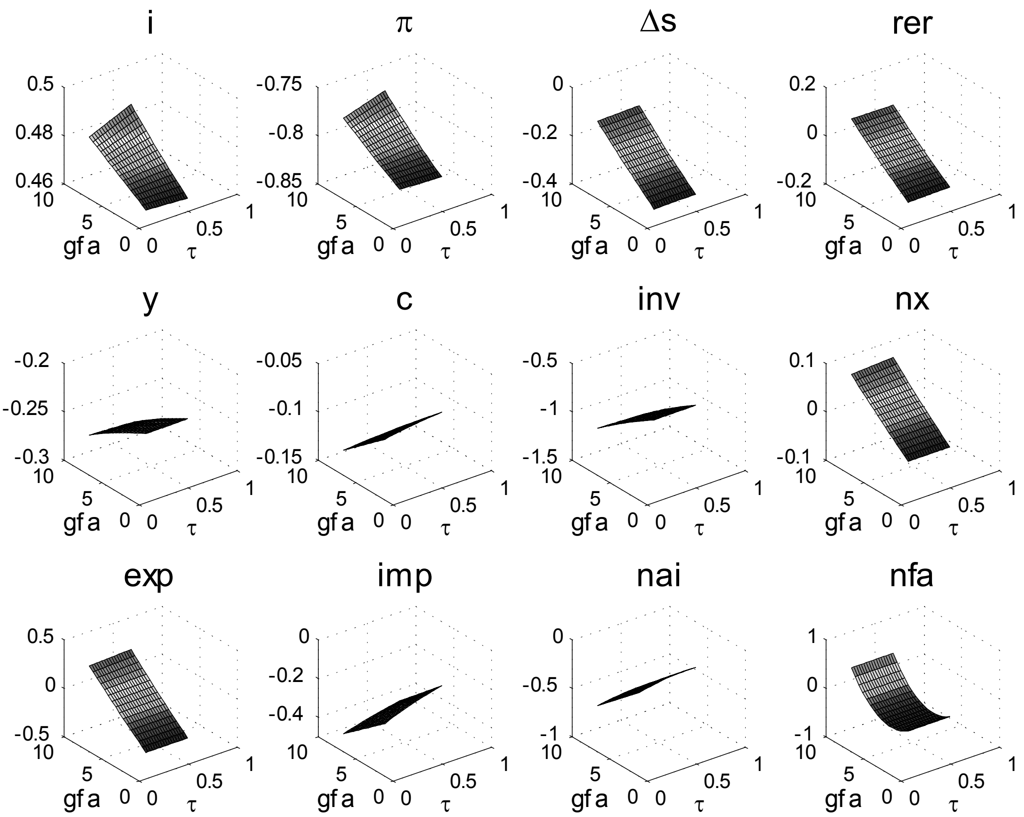

Figure A16: Further "Lower ERPT" and "Higher GFA" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of exchange rate pass-through and the level of gross foreign asset holdings.

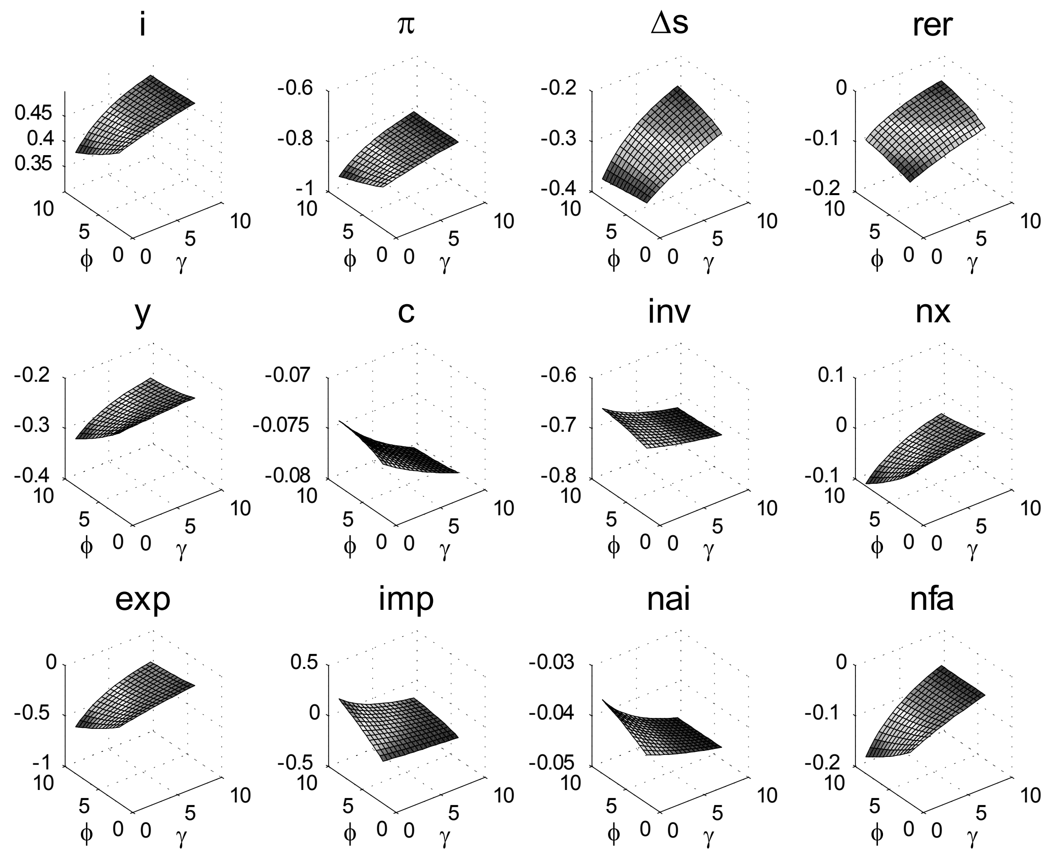

Figure A17: Robustness check for "Lower Costs" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of the elasticity btw. Home and Foreign tradables and of the level of costs of trading foreign assets.

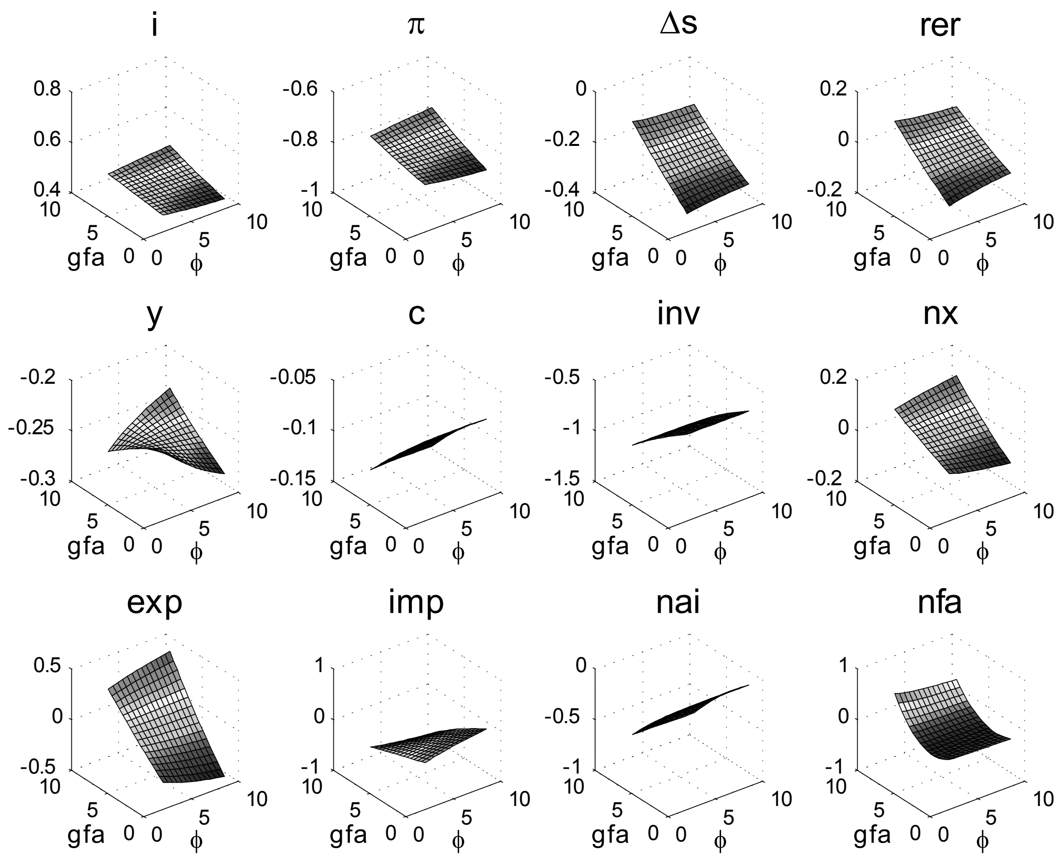

Figure A18: Robustness check for "Higher GFA" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of the elasticity btw. Home and Foreign tradables and the level of gross foreign asset holdings.

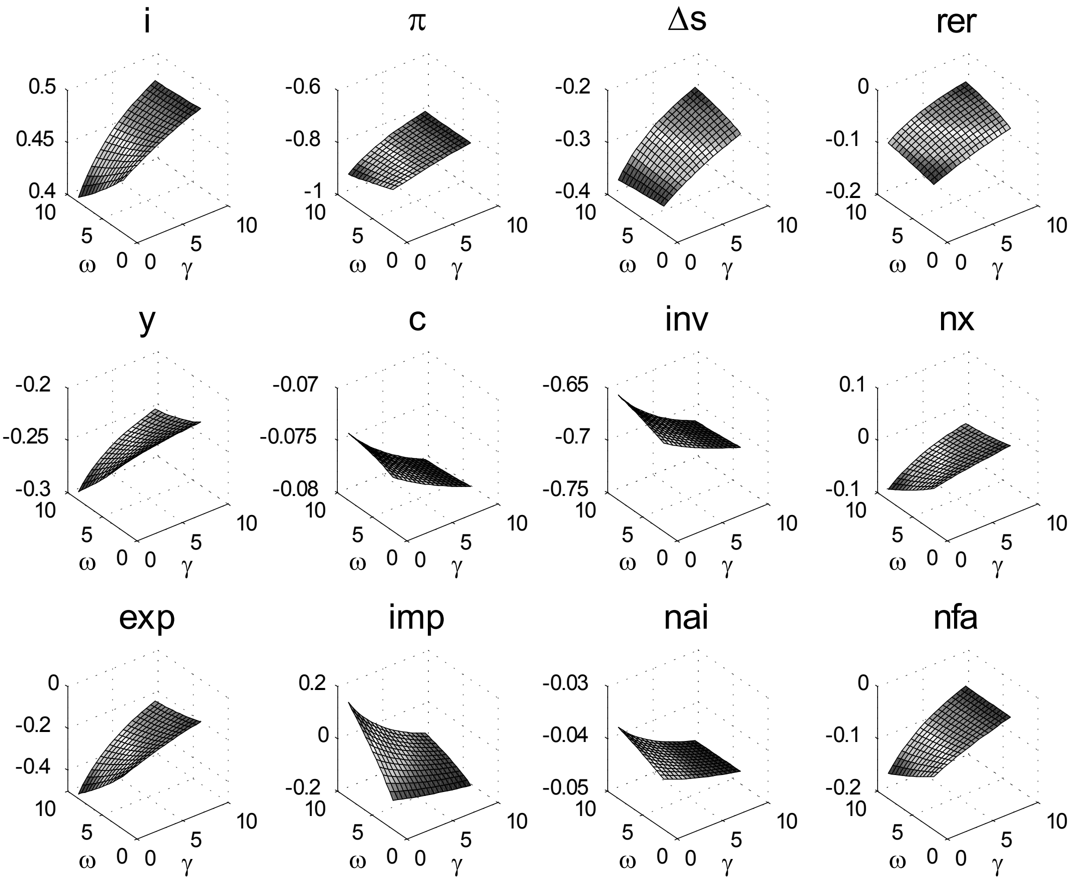

Figure A19: Robustness check for "Lower Costs" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of the elasticity btw. tradables and nontradables and the level of costs of trading foreign assets.

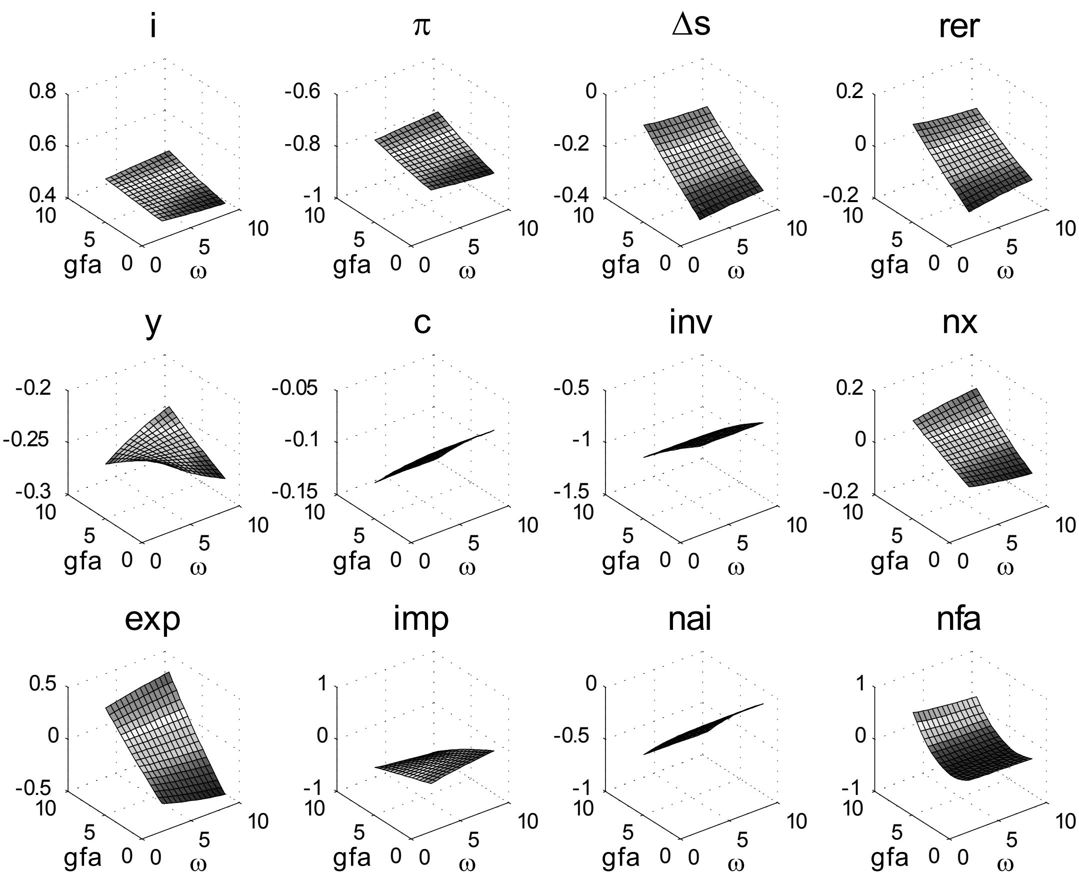

Figure A20: Robustness check for "Higher GFA" scenarios

Impulse responses are reported in percentage point deviations from the steady state. The responses are reported in the period of the shock as functions of the level of the elasticity btw. tradables and nontradables and the level of gross foreign asset holdings.

Appendix B: Technical Appendix of the Model

This technical appendix derives the theoretical model in more detail. Section 1 outlines the derivation of the optimality conditions of households and firms. Section 2 outlines the aggregation of the optimality conditions. Section 3 lists the market clearing conditions. Section 4 restates the behavior of the monetary authorities. Section 5 derives the steady state. Section 6 log-linearizes the system, and the last section derives some additional variables of interest.

B.1 Optimality Conditions

B.1.1 Optimal allocation of expenditures

The optimization problem with regards to the optimal allocation of consumption involves three stages. The first stage is the optimal allocation of consumption across the brands of the three different sub-baskets, i.e. the minimization of the costs of purchasing a given aggregate traded or nontraded goods index. For example, for the Home traded goods basket, a representative Home household j faces the following optimization problem:

$$\min_{C_{HTt}(j,i)} \int_0^{\alpha\gamma} P_{HTt}(i) C_{HTt}(j,i) di$$

$$s.t. \left[\left(\frac{1}{\alpha\gamma} \right)^{\frac{1}{\theta}} \int_0^{\alpha\gamma} (C_{HTt}(j,i))^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}} = \bar{C}_{HTt}(j)$$

The FOC with respect to $C_{HTt}(j,i)$ is:

$$\begin{aligned} -P_{HTt}(i) &= \lambda \left[\frac{\theta}{\theta-1} \left[\left(\frac{1}{\alpha\gamma} \right)^{\frac{1}{\theta}} \int_0^{\alpha\gamma} (C_{HTt}(j,i))^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}-1} \right] \\ & \left(\frac{1}{\alpha\gamma} \right)^{\frac{1}{\theta}} \left(\frac{\theta-1}{\theta} \right) (C_{HTt}(j,i))^{\frac{\theta-1}{\theta}-1} \end{aligned}$$

Multiplying both sides by $C_{HTt}(j,i)$ and integrating over $\int_0^{\alpha\gamma} ...di$:

$$P_{HTt} = -\lambda$$

Combining:

$$P_{HTt}(i) = P_{HTt} \left[\left[\left(\frac{1}{\alpha\gamma} \right)^{\frac{1}{\theta}} \int_0^{\alpha\gamma} (C_{HTt}(j,i))^{\frac{\theta-1}{\theta}} di \right]^{\frac{1}{\theta-1}} \right] \left(\frac{1}{\alpha\gamma} \right)^{\frac{1}{\theta}} (C_{HTt}(j,i))^{-\frac{1}{\theta}}$$

Replacing the Home traded goods consumption basket:

$$C_{HTt}(j,i) = \left(\frac{1}{\alpha\gamma}\right)\left(\frac{P_{HTt}(i)}{P_{HTt}}\right)^{-\theta} C_{HTt}(j)$$

Aggregating over all Home households:

$$\begin{aligned}\int_0^{\alpha} C_{HTt}(j,i)dj &= \int_0^{\alpha}\left(\frac{1}{\alpha\gamma}\right)\left(\frac{P_{HTt}(i)}{P_{HTt}}\right)^{-\theta} C_{HTt}(j)dj \\ C_{HTt}(i) &= \left(\frac{1}{\alpha\gamma}\right)\left(\frac{P_{HTt}(i)}{P_{HTt}}\right)^{-\theta} C_{HTt}\end{aligned}$$

where the aggregate consumption of good i and the aggregate Home traded consumption basket are defined as:

$$C_{HTt}(i) \equiv \int_0^{\alpha} C_{HTt}(j,i)dj$$

$$C_{HTt} = \int_0^{\alpha} C_{HTt}(j)dj$$

The Home traded goods price index can be computed by plugging this aggregate optimality condition into the definition of the Home traded goods consumption basket:

$$C_{HTt} = \left[\left(\frac{1}{\alpha\gamma}\right)^{\frac{1}{\theta}} \int_0^{\alpha\gamma} \left(C_{HTt}(i)\right)^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}}$$

yielding:

$$P_{HTt} = \left[\left(\frac{1}{\alpha\gamma}\right)\int_0^{\alpha\gamma} P_{HTt}(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$$

By analogous optimization problems one can derive the optimal consumption allocations and price indices for the Foreign traded goods basket and the Home nontraded goods basket:

$$C_{FTt}(j,i) = \left(\frac{1}{(1-\alpha)\gamma}\right)\left(\frac{P_{FTt}(i)}{P_{FTt}}\right)^{-\theta} C_{FTt}(j)$$

$$C_{Nt}(j,i) = \left(\frac{1}{(1-\gamma)}\right)\left(\frac{P_{Nt}(i)}{P_{Nt}}\right)^{-\theta} C_{Nt}(j)$$

and

$$P_{FTt} \equiv \left[\left(\frac{1}{(1-\alpha)\gamma}\right)\int_{\alpha\gamma}^{\gamma} \left(P_{FTt}(i)\right)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$$

$$P_{Nt} \equiv \left[\left(\frac{1}{(1-\gamma)}\right)\int_{\gamma}^{1} \left(P_{Nt}(i)\right)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$$

The second stage is the optimal allocation of consumption between the Home and Foreign traded goods baskets for a given aggregate traded goods basket, i.e. the minimization of the costs of purchasing a given traded goods basket. A representative Home household j faces the following optimization problem:

$$\min_{C_{HTt}, C_{FTt}} \left[P_{HTt} C_{HTt}(j) + P_{FTt} C_{FTt}(j) \right]$$
$$s.t. \left[\alpha^{\frac{1}{\phi}} \left(C_{HTt}(j) \right)^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}} \left(C_{FTt}(j) \right)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}} = \bar{C}_{Tt}(j)$$

The FOC with respect to $C_{HTt}(j)$ is:

$$\begin{aligned} -P_{HTt} &= \lambda \left[\left[\alpha^{\frac{1}{\phi}} \left(C_{HTt}(j) \right)^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}} \left(C_{FTt}(j) \right)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}-1} \right] \\ & \left[\alpha^{\frac{1}{\phi}} \left(C_{HTt}(j) \right)^{\frac{\phi-1}{\phi}-1} \right] \end{aligned}$$

Multiplying by $C_{HTt}(j)$:

$$\begin{aligned} P_{HTt} C_{HTt}(j) &= -\lambda \left[\left[\alpha^{\frac{1}{\phi}} \left(C_{HTt}(j) \right)^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}} \left(C_{FTt}(j) \right)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}-1} \right] \\ & \left[\alpha^{\frac{1}{\phi}} \left(C_{HTt}(j) \right)^{\frac{\phi-1}{\phi}} \right] \end{aligned}$$

The FOC with respect to $C_{FTt}(j)$ is:

$$\begin{aligned} -P_{FTt} &= \lambda \left[\left[\alpha^{\frac{1}{\phi}} \left(C_{HTt}(j) \right)^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}} \left(C_{FTt}(j) \right)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}-1} \right] \\ & \left[(1-\alpha)^{\frac{1}{\phi}} \left(C_{FTt}(j) \right)^{\frac{\phi-1}{\phi}-1} \right] \end{aligned}$$

Multiplying by $C_{FTt}(j)$:

$$\begin{aligned} P_{FTt} C_{FTt}(j) &= -\lambda \left[\left[\alpha^{\frac{1}{\phi}} \left(C_{HTt}(j) \right)^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}} \left(C_{FTt}(j) \right)^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}-1} \right] \\ & \left[(1-\alpha)^{\frac{1}{\phi}} \left(C_{FTt}(j) \right)^{\frac{\phi-1}{\phi}} \right] \end{aligned}$$

Adding the two FOCs:

$$P_{Tt} = -\lambda$$

Combining:

$$C_{HTt}(j) = \alpha \left(\frac{P_{HTt}}{P_{Tt}} \right)^{-\phi} C_{Tt}(j)$$

and similarly for the foreign traded goods basket:

$$C_{FTt}(j) = (1-\alpha)\left(\frac{P_{FTt}}{P_{Tt}}\right)^{-\phi} C_{Tt}(j)$$

Aggregating these optimality conditions over all Home households yields the following for the aggregate Home traded goods consumption in the Home economy:

$$\int_0^{\alpha} C_{HTt}(j)dj = \int_0^{\alpha} (1-\alpha)\left(\frac{P_{HTt}}{P_{Tt}}\right)^{-\phi} C_{Tt}(j)dj$$

$$C_{HTt} = (1-\alpha)\left(\frac{P_{HTt}}{P_{Tt}}\right)^{-\phi} C_{Tt}$$

and similarly for the aggregate Foreign traded goods consumption in the Home economy:

$$C_{HTt} = (1-\alpha)\left(\frac{P_{FTt}}{P_{Tt}}\right)^{-\phi} C_{Tt}$$

The traded goods price index can be computed by plugging these aggregate optimality conditions into the definition of the traded goods consumption basket:

$$C_{Tt} = \left[\alpha^{\frac{1}{\phi}}\left(\alpha\left(\frac{P_{HTt}}{P_{Tt}}\right)^{-\phi} C_{Tt}\right)^{\frac{\phi-1}{\phi}} + (1-\alpha)^{\frac{1}{\phi}}\left((1-\alpha)\left(\frac{P_{FTt}}{P_{Tt}}\right)^{-\phi} C_{Tt}\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}$$

$$P_{Tt} = \left[\alpha P_{HTt}^{1-\phi} + (1-\alpha) P_{FTt}^{1-\phi}\right]^{\frac{1}{1-\phi}}$$

The third stage is the optimal allocation of expenditures between traded and non-traded goods for a given overall consumption basket, i.e. the minimization of the costs for purchasing a given overall aggregate consumption basket. A representative Home household j faces the following optimization problem:

$$\min_{C_{Tt}(j), C_{Nt}(j)} \left[P_{Tt}C_{Tt}(j) + P_{Nt}C_{Nt}(j)\right]$$

$$s.t. \left[\gamma^{\frac{1}{\omega}}\left(C_{Tt}(j)\right)^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}}\left(C_{Nt}(j)\right)^{\frac{\omega-1}{\omega}}\right]^{\frac{\omega}{\omega-1}} = \bar{C}_t(j)$$

The FOC with respect to $C_{Tt}(j)$ is:

$$\begin{aligned} -P_{Tt} &= \lambda\left[\left[\gamma^{\frac{1}{\omega}}\left(C_{Tt}(j)\right)^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}}\left(C_{Nt}(j)\right)^{\frac{\omega-1}{\omega}}\right]^{\frac{\omega}{\omega-1}-1}\right] \\ &\quad \left[\gamma^{\frac{1}{\omega}}\left(C_{Tt}(j)\right)^{\frac{\omega-1}{\omega}-1}\right] \end{aligned}$$

Multiplying by $C_{Tt}(j)$:

$$P_{Tt}C_{Tt}(j) = -\lambda \left[\left[\gamma^{\frac{1}{\omega}} \left(C_{Tt}(j) \right)^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}} \left(C_{Nt}(j) \right)^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}-1} \right] \left[\gamma^{\frac{1}{\omega}} \left(C_{Tt}(j) \right)^{\frac{\omega-1}{\omega}} \right]$$

The FOC with respect to $C_{Nt}(j)$ is:

$$-P_{Nt} = \lambda \left[\left[\gamma^{\frac{1}{\omega}} \left(C_{Tt}(j) \right)^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}} \left(C_{Nt}(j) \right)^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}-1} \right] \left[(1-\gamma)^{\frac{1}{\omega}} \left(C_{Nt}(j) \right)^{\frac{\omega-1}{\omega}-1} \right]$$

Multiplying by $C_{Nt}(j)$:

$$P_{Nt}C_{Nt} = -\lambda \left[\left[\gamma^{\frac{1}{\omega}} \left(C_{Tt}(j) \right)^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}} \left(C_{Nt}(j) \right)^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}-1} \right] \left[(1-\gamma)^{\frac{1}{\omega}} \left(C_{Nt}(j) \right)^{\frac{\omega-1}{\omega}} \right]$$

Adding the two FOCs:

$$P_t = -\lambda$$

Combining:

$$C_{Tt}(j) = \gamma \left(\frac{P_{Tt}}{P_t} \right)^{-\omega} C_t(j)$$

An analogous condition holds for the nontraded goods basket:

$$C_{Nt}(j) = (1-\gamma) \left(\frac{P_{Nt}}{P_t} \right)^{-\omega} C_t(j)$$

Aggregating these optimality conditions over all Home consumers:

$$\int_0^\alpha C_{Tt}(j)dj = \int_0^\alpha \gamma \left(\frac{P_{Tt}}{P_t} \right)^{-\omega} C_t(j)dj$$

$$C_{Tt} = \gamma \left(\frac{P_{Tt}}{P_t} \right)^{-\omega} C_t$$

$$C_{Nt} = (1-\gamma) \left(\frac{P_{Nt}}{P_t} \right)^{-\omega} C_t$$

Plugging these aggregate optimality conditions into the definition of the overall aggregate consumption basket:

$$C_t = \left[\gamma^{\frac{1}{\omega}} C_{Tt}^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}} C_{Nt}^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}}$$

yields:

$$P_t = \left[\gamma P_{Tt}^{1-\omega} + (1-\gamma) P_{Nt}^{1-\omega} \right]^{\frac{1}{1-\omega}}$$

Combining the optimality conditions of these three stages yields:

$$C_{HTt}(j,i)=\left(\frac{P_{HTt}(i)}{P_{HTt}}\right)^{-\theta}\left(\frac{P_{HTt}}{P_{Tt}}\right)^{-\phi}\left(\frac{P_{Tt}}{P_t}\right)^{-\omega}C_t(j)$$

$$C_{FTt}(j,i)=\left(\frac{P_{FTt}(i)}{P_{FTt}}\right)^{-\theta}\left(\frac{P_{FTt}}{P_{Tt}}\right)^{-\phi}\left(\frac{P_{Tt}}{P_t}\right)^{-\omega}C_t(j)$$

$$C_{Nt}(j,i)=\left(\frac{P_{Nt}(i)}{P_{Nt}}\right)^{-\theta}\left(\frac{P_{Nt}}{P_t}\right)^{-\omega}C_t(j)$$

and as derived above the following aggregate price indices:

$$P_{HTt}=\left[\left(\frac{1}{\alpha\gamma}\right)\int_0^{\alpha\gamma}P_{HTt}(i)^{1-\theta}di\right]^{\frac{1}{1-\theta}} \tag{B.1}$$

$$P_{FTt}\equiv\left[\left(\frac{1}{(1-\alpha)\gamma}\right)\int_{\alpha\gamma}^{\gamma}\left(P_{FTt}(i)\right)^{1-\theta}di\right]^{\frac{1}{1-\theta}} \tag{B.2}$$

$$P_{Nt}\equiv\left[\left(\frac{1}{(1-\gamma)}\right)\int_{\gamma}^{1}\left(P_{Nt}(i)\right)^{1-\theta}di\right]^{\frac{1}{1-\theta}} \tag{B.3}$$

$$P_{Tt}=\left[\alpha P_{HTt}^{1-\phi}+(1-\alpha)\,P_{FTt}^{1-\phi}\right]^{\frac{1}{1-\phi}} \tag{B.4}$$

$$P_t=\left[\gamma P_{Tt}^{1-\omega}+(1-\gamma)P_{Nt}^{1-\omega}\right]^{\frac{1}{1-\omega}} \tag{B.5}$$

B.1.2 Optimal intertemporal allocation

Maximizing the utility function subject to the budget constraint with respect to $C_t(j)$, $Q_{Ht+1}(j)$, $Q_{Ft+1}(j)$, $B_{Ht+1}(j)$, and $B_{Ft+1}(j)$ yields the following FOCs:

$$C_t(j):(C_t(j))^{-\sigma}-\lambda_t P_t=0$$

$$Q_{Ht+1}(j):-\lambda_t E_t\left\{P_{Qt}+\gamma_{Q_H}P_{Qt}\frac{(Q_{Ht+1}(j)-Q_{Ht}(j))}{Y_t}\right\}$$

$$-\beta E_t\left\{\lambda_{t+1}\left(\begin{array}{c}\gamma_{Q_H}P_{Qt+1}\frac{(Q_{Ht+2}(j)-Q_{Ht+1}(j))}{Y_{t+1}}(-1)+\psi_{Q_H}P_{Qt+1}\frac{(Q_{Ht+1}(j)-\bar{Q}_H(j))}{Y_{t+1}}\\-\left(P_{Qt+1}+\left(\frac{V_{t+1}}{\bar{Q}}\right)\right)\end{array}\right)\right\}=0$$

$$Q_{Ft+1}(j) : -\lambda_t E_t \left\{ S_t P^*_{Qt} + \gamma_{Q_F} S_t P^*_{Qt} \frac{(Q_{Ft+1}(j) - Q_{Ft}(j))}{Y^*_t} \right\}$$

$$-\beta E_t \left\{ \lambda_{t+1} \left(\begin{array}{c} \gamma_{Q_F} S_{t+1} P^*_{Qt+1} \frac{(Q_{Ft+2}(j) - Q_{Ft+1}(j))}{Y^*_{t+1}} (-1) + \psi_{Q_F} S_{t+1} P^*_{Qt+1} \frac{\left(Q_{Ft+1}(j) - \bar{Q}_F(j)\right)}{Y^*_{t+1}} \\ -\left(S_{t+1} \left(P^*_{Qt+1} + \left(\frac{V^*_{t+1}}{\bar{Q}^*} \right) \right) \right) \end{array} \right) \right\} = 0$$

$$B_{Ht+1}(j) : -\lambda_t E_t \left\{ 1 + \gamma_{B_H} \frac{(B_{Ht+1}(j) - B_{Ht}(j))}{P_t Y_t} \right\}$$

$$-\beta E_t \left\{ \lambda_{t+1} \left(\begin{array}{c} \gamma_{B_H} \frac{(B_{Ht+2}(j) - B_{Ht+1}(j))}{P_{t+1} Y_{t+1}} (-1) + \psi_{B_H} \frac{\left(B_{Ht+1}(j) - \bar{B}_H(j)\right)}{P_{t+1} Y_{t+1}} \\ -(1 + i_{t+1}) \end{array} \right) \right\} = 0$$

$$B_{Ft+1}(j) : -\lambda_t E_t \left\{ S_t + \gamma_{B_F} S_t \frac{(B_{Ft+1}(j) - B_{Ft}(j))}{P^*_t Y^*_t} \right\}$$

$$-\beta E_t \left\{ \lambda_{t+1} \left(\begin{array}{c} \gamma_{B_F} S_{t+1} \frac{(B_{Ft+2}(j) - B_{Ft+1}(j))}{P^*_{t+1} Y^*_{t+1}} (-1) + \psi_{B_F} S_{t+1} \frac{\left(B_{Ft+1}(j) - \bar{B}_F(j)\right)}{P^*_{t+1} Y^*_{t+1}} \\ -S_{t+1}(1 + i^*_{t+1}) \end{array} \right) \right\} = 0$$

Combining these equations yields the following Euler equations (for Home equity holdings, Foreign equity holdings, Home bond holdings, and Foreign bond holdings, respectively):

$$E_t \left\{ P_{Qt} + \gamma_{Q_H} P_{Qt} \frac{(Q_{Ht+1}(j) - Q_{Ht}(j))}{Y_t} \right\} \tag{B.6}$$

$$= E_t \left\{ D_{t,t+1}(j) \left(\begin{array}{c} \gamma_{Q_H} P_{Qt+1} \frac{(Q_{Ht+2}(j) - Q_{Ht+1}(j))}{Y_{t+1}} - \psi_{Q_H} P_{Qt+1} \frac{\left(Q_{Ht+1}(j) - \bar{Q}_H(j)\right)}{Y_{t+1}} \\ + \left(P_{Qt+1} + \left(\frac{V_{t+1}}{\bar{Q}} \right) \right) \end{array} \right) \right\}$$

where

$$E_t \left\{ D_{t,t+1}(j) \right\} = \beta E_t \left\{ \left(\frac{(C_{t+1}(j))}{(C_t(j))} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\}$$

$$E_t \left\{ S_t P^*_{Qt} + \gamma_{Q_F} S_t P^*_{Qt} \frac{(Q_{Ft+1}(j) - Q_{Ft}(j))}{Y^*_t} \right\} \tag{B.7}$$

$$= E_t \left\{ D_{t,t+1}(j) \left(\begin{array}{c} \gamma_{Q_F} S_{t+1} P^*_{Qt+1} \frac{(Q_{Ft+2}(j) - Q_{Ft+1}(j))}{Y^*_{t+1}} (-1) + \psi_{Q_F} S_{t+1} P^*_{Qt+1} \frac{\left(Q_{Ft+1}(j) - \bar{Q}_F(j)\right)}{Y^*_{t+1}} \\ -\left(S_{t+1} \left(P^*_{Qt+1} + \left(\frac{V^*_{t+1}}{\bar{Q}^*} \right) \right) \right) \end{array} \right) \right\}$$

$$E_t\left\{1+\gamma_{_{B_H}}\frac{(B_{Ht+1}(j)-B_{Ht}(j))}{P_tY_t}\right\} \tag{B.8}$$

$$= \quad E_t\left\{D_{t,t+1}(j)\left(\begin{array}{c}\gamma_{_{B_H}}\frac{(B_{Ht+2}(j)-B_{Ht+1}(j))}{P_{t+1}Y_{t+1}}-\psi_{B_H}\frac{\left(B_{Ht+1}(j)-\bar{B}_H(j)\right)}{P_{t+1}Y_{t+1}}\\+(1+i_{t+1})\end{array}\right)\right\}$$

$$E_t\left\{S_t+\gamma_{_{B_F}}S_t\frac{(B_{Ft+1}(j)-B_{Ft}(j))}{P_t^*Y_t^*}\right\} \tag{B.9}$$

$$=E_t\left\{D_{t,t+1}(j)\left(\begin{array}{c}\gamma_{_{B_F}}S_{t+1}\frac{(B_{Ft+2}(j)-B_{Ft+1}(j))}{P_{t+1}^*Y_{t+1}^*}-\psi_{_{B_F}}S_{t+1}\frac{\left(B_{Ft+1}(j)-\bar{B}_F(j)\right)}{P_{t+1}^*Y_{t+1}^*}\\+S_{t+1}(1+i_{t+1}^*)\end{array}\right)\right\}$$

B.1.3 Optimal labor supply

Maximizing the utility function subject to the budget constraint with respect to $N_t(j)$ yields:

$$-\kappa N_t(j)^{\varphi}+\lambda_tW_t=0$$

which, combined with the FOC of $C_t(j)$ can be rewritten as:

$$\frac{\kappa N_t(j)^{\varphi}}{(C_t(j))^{-\sigma}}=\frac{W_t}{P_t} \tag{B.10}$$

where $\frac{\kappa N_t(j)^{\varphi}}{(C_t(j))^{-\sigma}}=MRS_{t+k|t}(j)=-\frac{U_{N_{t+k|t}(j)}}{U_{C_{t+k|t}(j)}}$.

B.1.4 Optimal investment

An installment firm solves the following optimization problem:

$$\begin{aligned}&\max_{K_{t+1}(I)} E_t\sum_{k=0}^{\infty}D_{t,t+k}\left[P_{t+k}r_{t+k}^kK_{t+k.}(I)-P_{t+k}I_{t+k.}(I)\right]\\&s.t.\\K_{t+k+1}(I) \quad = \quad &(1-\delta)K_{t+k}(I)+I_{t+k}(I)-\frac{\xi}{2}\frac{\left(K_{t+k+1}(I)-K_{t+k}(I)\right)^2}{K_{t+k}(I)}\end{aligned}$$

i.e. that we assume that an installment firm I's discount factor reflects the average intertemporal marginal rate of substitution of Home households.

Optimization with respect to $K_{t+1}(I)$ leads to the following FOC:

$$-P_t\left(1+\xi\frac{(K_{t+1}(I)-K_t(I))}{K_t(I)}\right)$$

$$+E_t\left\{D_{t,t+1}P_{t+1}\left[\begin{array}{c} r_{t+1}^k+(1-\delta) \\ -\frac{\xi}{2}\left(\frac{-2(K_{t+2}(I)-K_{t+1}(I))K_{t+1}(I)-(K_{t+2}(I)-K_{t+1}(I))^2}{(K_{t+1}(I))^2}\right)\end{array}\right]\right\}=0$$

Replacing the discount factors and rearranging:

$$\begin{aligned}&1+\xi\frac{(K_{t+1}(I)-K_t(I))}{K_t(I)} \\ &=\beta E_t\left\{\left(\frac{(C_{t+1})}{(C_t)}\right)^{-\sigma}\left[(1-\delta)+r_{t+1}^k+\frac{\xi}{2}\left(\frac{K_{t+1}(I)^2-K_{t+1}(I)^2}{(K_{t+1}(I))^2}\right)\right]\right\}\end{aligned} \tag{B.11}$$

The profits of Installment firms are assumed to be rebated to households as lump-sum transfers, T_I. The per capita lump-sum transfer T_I^j is:

$$T_I^j=\frac{1}{\alpha}\int_0^\alpha V_t(j)dj=\frac{1}{\alpha}\int_0^\alpha\left(P_tr_t^kK_{t.}(j)-P_tI_{t.}(j)\right)dj=\left[P_tr_t^kK_{t.}-P_tI_{t.}\right]$$

B.1.5 Optimal input demand

A Home firm i chooses its factor inputs $N_t(i)$ and $K_t(i)$ in order to solve the following cost minimization problem:

$$\begin{aligned}&\min_{N_t(i),K_t(i)}\left[W_tN_t(i)+P_{t.}r_t^kK_t(i)\right] \\ &s.t.\ A_t\left(K_t(i)\right)^{1-\mu}\left(N_t(i)\right)^\mu=\bar{Y}_t(i)\end{aligned}$$

The optimal factor demands can be written as (note that this is just one equation, written in two ways):

$$N_t(i)=\frac{\mu}{(1-\mu)}\frac{P_{t.}r_t^k}{W_t}K_t(i)\text{ and }K_t(i)=\frac{(1-\mu)}{\mu}\frac{W_t}{P_{t.}r_t^k}N_t(i)$$

Combining these with the production function, and an expression for marginal costs, two factor demand equations can be combined in the following way:
Substituting the two optimal factor demands into the production function:

$$Y_t(i)=A_t\left(K_t(i)\right)^{1-\mu}\left(N_t(i)\right)^\mu$$

yields:

$$N_t(i) = \left(\frac{\mu}{(1-\mu)}\frac{P_t.r_t^k}{W_t}\right)^{1-\mu}\frac{Y_t(i)}{A_t} \text{ and } K_t(i) = \left(\frac{(1-\mu)}{\mu}\frac{W_t}{P_t.r_t^k}\right)^{\mu}\frac{Y_t(i)}{A_t}$$

Substituting the rewritten optimal factor demands in the total cost function yields:

$$\begin{aligned} TC_t(i) &= W_t N_t(i) + P_t.r_t^k K_t(i) \\ &= W_t\left(\frac{\mu}{(1-\mu)}\frac{P_t.r_t^k}{W_t}\right)^{1-\mu}\frac{Y_t(i)}{A_t} + P_t.r_t^k\left(\frac{(1-\mu)}{\mu}\frac{W_t}{P_t.r_t^k}\right)^{\mu}\frac{Y_t(i)}{A_t} \\ &= \left[\frac{1}{(1-\mu)^{1-\mu}\mu^{\mu}}\right](W_t)^{\mu}\left(P_t.r_t^k\right)^{1-\mu}\frac{Y_t(i)}{A_t} \end{aligned}$$

The marginal costs, which are equal for all firms, can then be derived as:

$$MC_t = \frac{\delta TC_t(i)}{\delta Y_t(i)} = \frac{(W_t)^{\mu}\left(P_t.r_t^k\right)^{1-\mu}}{(1-\mu)^{1-\mu}\mu^{\mu}A_t} \tag{B.12}$$

Given these marginal costs the optimal factor demands can be written as

$$N_t(i) = \mu MC_t\frac{Y_t(i)}{W_t} \tag{B.13}$$

$$K_t(i) = (1-\mu)\,MC_t\frac{Y_t(i)}{P_t.r_t^k} \tag{B.14}$$

B.1.6 Optimal price setting

Traded goods sector

A representative firm in the Home traded goods sector sets prices $\left\{P_{HTt+k}^{Opt}(i), P_{HTt+k}^{Opt*}(i)\right\}_{k=0}^{\infty}$ that maximize its expected discounted future profits while these prices remain effective. Formally, it solves the following problem for the domestic market:

$$\max_{P_{HTt}^{Opt}(i)}\sum_{k=0}^{\infty}\theta_P^k E_t\left\{\begin{array}{c} D_{t,t+k}(j) \\ \left(\begin{array}{c}\left(P_{HTt}^{Opt}(i) - MC_{t+k|t}\right)Y_{HTt+k|t} \\ +\left(P_{HTt}^{Opt*}(i)S_{t+k}^{1-\tau} - MC_{t+k|t}\right)Y_{HTt+k|t}^{*}\end{array}\right)\end{array}\right\}$$

where $D_{t,t+k}(j) = \beta^k\left(\frac{(C_{t+k}(j))}{(C_t(j))}\right)^{-\sigma}\frac{P_t}{P_{t+k}}$

i.e. that it is assumed that a representative Home firm's discount factor represents the intertemporal marginal rate of substitution of a representative Home household j,

and where MC_t denotes the (nominal) marginal cost function

subject to the respective demand schedules of the Home and Foreign households and installment firms, respectively:

$$Y_{HTt+k|t}(i) = \int_0^{\alpha} \left[\begin{array}{c} \left(\frac{P_{HTt}(i)}{P_{HTt+k}}\right)^{-\theta} \left(\frac{P_{HTt+k}}{P_{Tt+k}}\right)^{-\phi} \left(\frac{P_{Tt+k}}{P_{t+k}}\right)^{-\omega} (C_{t+k}(j)) \\ + \left(\frac{P_{HTt}(i)}{P_{HTt+k}}\right)^{-\theta} \left(\frac{P_{HTt+k}}{P_{Tt+k}}\right)^{-\phi} \left(\frac{P_{Tt+k}}{P_{t+k}}\right)^{-\omega} (I(j)) \end{array} \right] dj$$

or aggregated:

$$Y_{HTt+k|t}(i) = \left(\frac{P_{HTt}^{Opt}(i)}{P_{HTt+k}}\right)^{-\theta} \left(\frac{P_{HTt+k}}{P_{Tt+k}}\right)^{-\phi} \left(\frac{P_{Tt+k}}{P_{t+k}}\right)^{-\omega} (C_{t+k} + I_{t+k}) \tag{B.15}$$

and

$$Y_{HTt+k|t}^{*}(i) = \int_{\alpha}^{1} \left[\begin{array}{c} \left(\frac{P_{HTt}^{*}(i)}{P_{HTt+k}^{*}}\right)^{-\theta} \left(\frac{P_{HTt+k}^{*}}{P_{Tt+k}^{*}}\right)^{-\phi} \left(\frac{P_{Tt+k}^{*}}{P_{t+k}^{*}}\right)^{-\omega} (C_{t+k}^{*}(j)) \\ + \left(\frac{P_{HTt}^{*}(i)}{P_{HTt+k}^{*}}\right)^{-\theta} \left(\frac{P_{HTt+k}^{*}}{P_{Tt+k}^{*}}\right)^{-\phi} \left(\frac{P_{Tt+k}^{*}}{P_{t+k}^{*}}\right)^{-\omega} (I_{t+k}^{*}(j)) \end{array} \right] dj$$

or aggregated:

$$Y_{HTt+k|t}^{*}(i) = \left(\frac{P_{HTt}^{Opt*}(i) S_{t+k}^{-\tau}}{P_{HTt+k}^{*}}\right)^{-\theta} \left(\frac{P_{HTt+k}^{*}}{P_{Tt+k}^{*}}\right)^{-\phi} \left(\frac{P_{Tt+k}^{*}}{P_{t+k}^{*}}\right)^{-\omega} (C_{t+k}^{*} + I_{t+k}^{*}) \tag{B.16}$$

The FOC with respect to $P_{HTt}^{Opt}(i)$ is:

$$\sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k}(j) \left(\begin{array}{c} P_{HTt}^{Opt}(i) \frac{\delta Y_{HTt+k|t}(i)}{\delta P_{HTt}^{Opt}(i)} + Y_{HTt+k|t}(i) \\ -MC_{t+k} \frac{\delta Y_{HTt+k|t}(i)}{\delta P_{HTt}^{Opt}(i)} \end{array} \right) \right\} = 0$$

Using the fact that:

$$\frac{\delta Y_{HTt+k|t}(i)}{\delta P_{HTt}^{Opt}(i)} = -\theta Y_{HTt+k|t}(i) \left(\frac{1}{P_{HTt}^{Opt}(i)}\right)$$

one can rewrite as:

$$\sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k}(j) \left(\begin{array}{c} -\theta Y_{HTt+k|t}(i) + Y_{HTt+k|t}(i) \\ +MC_{t+k} \theta Y_{HTt+k|t}(i) \left(\frac{1}{P_{HTt}^{Opt}(i)}\right) \end{array} \right) \right\} = 0$$

or

$$\sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k}(j) Y_{HTt+k|t}(i) \left(P_{HTt}^{Opt}(i) - \mu_P MC_{t+k} \right) \right\} = 0 \tag{B.17}$$

where $\mu_P = \frac{\theta}{\theta - 1}$

Analogously a representative firm in the Home traded goods sector solves the following problem for the other countries:

$$\max_{P_{HTt}^{Opt*}(i)} \sum_{k=0}^{\infty} \theta_P^k E_t \left\{ \begin{array}{c} D_{t,t+k} \\ \left(\begin{array}{c} \left(P_{HTt}^{Opt}(i) - MC_{t+k|t}\right) Y_{HTt+k|t} \\ + \left(P_{HTt}^{Opt*}(i) S_{t+k}^{1-\tau} - MC_{t+k|t}\right) Y_{HTt+k|t}^{*} \end{array} \right) \end{array} \right\}$$

The optimality condition is:

$$\sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k}(j) Y_{HTt+k|t}^{*}(i) \left(S_{t+k}^{1-\tau} P_{HTt}^{Opt*}(i) - \mu_P MC_{t+k} \right) \right\} = 0 \qquad \text{(B.18)}$$

Nontraded goods sector

A representative firm in the Home nontraded goods sector sets a price $P_{NTt}(i)$ that maximizes its expected discounted future profits while that price remains effective. Formally, it solves the following problem:

$$\max_{P_{Nt}^{Opt}(i)} \sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k}(j) \left(\left(P_{Nt}^{Opt}(i) - MC_{t+k} \right) Y_{Nt+k|t}(i) \right) \right\}$$

subject to the demand schedules:

$$Y_{Nt+k|t}(i) = \int_0^{\alpha} \left[\begin{array}{c} \left(\frac{P_{Nt}(i)}{P_{Nt}}\right)^{-\theta} \left(\frac{P_{Nt}}{P_t}\right)^{-\omega} C_{t+k}(j) \\ + \left(\frac{P_{Nt}(i)}{P_{Nt}}\right)^{-\theta} \left(\frac{P_{Nt}}{P_t}\right)^{-\omega} I_{t+k}(j) \end{array} \right] dj$$

or aggregated:

$$Y_{Nt+k|t}(i) = \left(\frac{P_{Nt}^{Opt}(i)}{P_{Nt}} \right)^{-\theta} \left(\frac{P_{Nt}}{P_t} \right)^{-\omega} (C_{t+k} + I_{t+k}) \qquad \text{(B.19)}$$

The optimality condition can be written as:

$$\sum_{k=0}^{\infty} \theta_P^k E_t \left\{ D_{t,t+k}(j) Y_{Nt+k|t}(i) \left(P_{Nt}^{Opt}(i) - \mu_P MC_{t+k} \right) \right\} = 0 \qquad \text{(B.20)}$$

B.1.7 Monetary policies

The monetary policy rule of the Home central bank is defined as:

$$1 + i_t = (1 + i_{t-1})^{\rho} \left(\left(\frac{P_t}{P_{t-1}} \right)^{\phi_\pi} (Y_t)^{\phi_y} \right)^{(1-\rho)} R_t \qquad \text{(B.21)}$$

where ρ captures the degree of interest-rate smoothing, R_t represents a time-varying exogenous factor that may, for example, represent changes in the inflation target.

Analogously, the monetary policy rule of the Foreign central bank is defined as:

$$1+i_t^* = (1+i_t^*)^{\rho^*}\left(\left(\frac{P_t^*}{P_{t-1}^*}\right)^{\phi_\pi^*}(Y_t^*)^{\phi_y^*}\right)^{(1-\rho^*)} \tag{B.22}$$

B.2 Aggregation

As all firms and households are symmetric, equations (B.4) to (B.20) can be rewritten in aggregate terms by replacing every variable indexed by j, i, or I with the aggregate, e.g. for consumption: $\int_0^\alpha C_t(j)dj \equiv C_t$.

By taking into account price stickiness equations (B.1) to (B.3) can be aggregated to:

$$P_{HTt} = \left(\theta_P\left(P_{HTt-1}\right)^{1-\theta} + (1-\theta_P)\left(P_{HTt}^{Opt}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}} \tag{B.23}$$

$$P_{Nt} \equiv \left(\theta_P P_{Nt-1}^{1-\theta} + (1-\theta_P)\left(P_{Nt}^{Opt}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}} \tag{B.24}$$

and

$$P_{FTt} \equiv S_t P_{FTt}^{AVG} \tag{B.25}$$

where

$$P_{FTt}^{AVG} = \left(\theta_P\left(P_{FTt-1}^{AVG}\right)^{1-\theta} + (1-\theta_P)\left(P_{FTt}^{OPT}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}} \tag{B.26}$$

and

$$P_{FTt}^{OPT} = S_t^{\tau-1} P_{FTt}^{Opt} \tag{B.27}$$

Total aggregate demand in the Home economy can be written as:

$$Y_t = \frac{1}{P_t}\left(\alpha\gamma\left(P_{HTt}\cdot Y_{HTt}^{Avg} + P_{HTt}^{AVG*}\cdot Y_{HTt}^{Avg*}\right) + (1-\gamma)\left(P_{Nt}\cdot Y_{Nt}^{Avg}\right)\right) \tag{B.28}$$

where

$$Y_{HTt}^{Avg} = \left(\frac{\left(\theta_P\left(P_{HTt-1}\right)^{1-\theta} + (1-\theta_P)\left(P_{HTt}^{Opt}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}}}{P_{HTt}}\right)^{-\theta} \left(\frac{P_{HTt}}{P_{Tt}}\right)^{-\phi}\left(\frac{P_{Tt}}{P_t}\right)^{-\omega}(C_t+I_t)$$

$$Y_{HTt}^{Avg*} = \left(\frac{\left(\left(\theta_P \left(P_{HTt-1}^{AVG*}\right)^{1-\theta} + (1-\theta_P)\left(P_{HTt}^{OPT*}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}}\right) S^{-1}}{P_{HTt}^{*}} \right)^{-\theta}$$

$$\left(\frac{P_{HTt}^{*}}{P_{Tt}^{*}}\right)^{-\phi}\left(\frac{P_{Tt}^{*}}{P_{t}^{*}}\right)^{-\omega}(C_t^{*}+I_t^{*})$$

$$= \left(\frac{P_{HTt}^{AVG*}S^{-1}}{P_{HTt}^{*}}\right)^{-\theta}\left(\frac{P_{HTt}^{*}}{P_{Tt}^{*}}\right)^{-\phi}\left(\frac{P_{Tt}^{*}}{P_{t}^{*}}\right)^{-\omega}(C_t^{*}+I_t^{*})$$

$$Y_{Nt}^{Avg} = \left(\frac{\left(\theta_P P_{Nt-1}^{1-\theta} + (1-\theta_P)\left(P_{Nt}^{Opt}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}}}{P_{Nt}} \right)^{-\theta}$$

$$\left(\frac{P_{Nt}}{P_t}\right)^{-\omega}(C_t+I_t)$$

Equity shares in a given country are assumed to be claims on profits and represent a balanced portfolio across all firms of both the traded and nontraded goods sector in that country. The per period profits of a firm in the traded goods sector which can reset its price in period t is:

$$\underbrace{V_{HTt}(i)}_{\text{for all } i\notin\theta_P} = P_{HTt}^{Opt}(i)Y_{HTt}(i) + S_t^{1-\tau}P_{HTt}^{Opt*}(i)Y_{HTt}^{*}(i) - \left[W_tN_t(i) + P_{t.}r_t^kK_t(i)\right]$$

The profits of a firm in the traded goods sector that cannot reset its price is:

$$\underbrace{V_{HTt}(i)}_{\text{for all } i\epsilon\theta_P} = P_{HTt-1}(i)Y_{HTt}(i) + P_{HTt-1}^{AVG*}(i)Y_{HTt}^{*}(i) - \left[W_tN_t(i) + P_{t.}r_t^kK_t(i)\right]$$

where

$$P_{HTt}^{AVG*} = \left(\theta_P \left(P_{HTt-1}^{AVG*}\right)^{1-\theta} + (1-\theta_P)\left(P_{HTt}^{OPT*}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}}$$

The total aggregate profits in the Home economy are:

$$V_t = \int_0^{\alpha\gamma}\left[\underbrace{V_{HTt}(i)}_{\text{for all } i\notin\theta_P} + \underbrace{V_{HTt}(i)}_{\text{for all } i\epsilon\theta_P}\right]di + \int_{\gamma}^{1}\left[\underbrace{V_{Nt}(i)}_{\text{for all } i\notin\theta_P} + \underbrace{V_{Nt}(i)}_{\text{for all } i\epsilon\theta_P}\right]di$$

Similarly, the aggregate profits in the Foreign country are:

$$
\begin{aligned}
V_t^* \quad = \quad & \int_{\alpha\gamma}^{\gamma} \left[\underbrace{V_{FTt}^*(i)}_{\text{for all i}\notin\theta_P} + \underbrace{V_{FTt}^*(i)}_{\text{for all i}\epsilon\theta_P} \right] di \\
& + \int_{\gamma}^{1} \left[\underbrace{V_{Nt}^*(i)\, di}_{\text{for all i}\notin\theta_P} + \underbrace{V_{Nt}^*(i)}_{\text{for all i}\epsilon\theta_P} \right] di
\end{aligned}
$$

which can be rewritten as:

$$
\begin{aligned}
V_t \quad = \quad & \alpha\gamma \left(P_{HTt} \cdot Y_{HTt}^{Avg} + P_{HTt}^{AVG*} \cdot Y_{HTt}^{Avg*} \right) + (1-\gamma) \left(P_{Nt} \cdot Y_{Nt}^{Avg} \right) \\
& - \left[W_t N_t + P_{t.} r_t^k K_t \right]
\end{aligned}
\tag{B.29}
$$

where

$$N_t = N_{HTt} + N_{Nt} \tag{B.30}$$

$$K_t = K_{HTt} + K_{Nt} \tag{B.31}$$

The rewritten aggregate profits in the Foreign country are:

$$
\begin{aligned}
V_t^* \quad = \quad & (1-\alpha)\,\gamma \left(P_{FTt}^* Y_{FTt}^{Avg*} + P_{FTt}^{AVG} Y_{FTt}^{Avg} \right) + (1-\gamma) \left(P_{Nt}^* Y_{Nt}^{Avg*} \right) \\
& - \left(W_t^* N_t^* + P_{t.}^* r_t^{k*} K_t^* \right)
\end{aligned}
\tag{B.32}
$$

B.3 Market clearing conditions

Bonds are assumed to be in zero net supply, hence:

$$B_{Ht} = -B_{Ht}^* \tag{B.33}$$

and

$$B_{Ft} = -B_{Ft}^* \tag{B.34}$$

The aggregate equity supplies are fixed and given by $\bar{Q}$ and $\bar{Q}^*$:

$$\bar{Q} = Q_{Ht} + Q_{Ht}^* \tag{B.35}$$

$$\bar{Q}^* = Q_{Ft}^* + Q_{Ft} \tag{B.36}$$

Goods market clearing conditions imply that the aggregate supplies in the different sectors (taken account of in the derivation of the optimal factor demands above) are equal to the following aggregate demands (in the Home traded goods, the Foreign traded goods, and the two nontraded goods sectors, respectively):

$$Y_{HTt} \equiv \alpha\gamma \left(Y^{Avg}_{HTt} + Y^{Avg*}_{HTt}\right) \tag{B.37}$$

$$Y^*_{FTt} = (1-\alpha)\,\gamma \left(Y^{Avg*}_{FTt} + Y^{Avg}_{FTt}\right) \tag{B.38}$$

$$Y_{Nt} = (1-\gamma)P_{Nt}Y^{Avg}_{Nt} \tag{B.39}$$

$$Y^*_{Nt} = (1-\gamma)\,P^*_{Nt}Y^{Avg*}_{Nt} \tag{B.40}$$

B.4 Steady state

The model is defined by equations (B.1) to (B.40) together with, where relevant, the analogous equations for the Foreign country. The model is linearized around a steady state where the net foreign asset position of both countries and inflation are zero. To ensure a stationary steady state all nominal Home and Foreign variables are scaled by the Home and Foreign CPIs, respectively, and the CPIs and the nominal exchange rate are expressed in first differences.

The steady state discount factor for the period t,t+k is $\bar{D}_{t,t+k} = \beta^k \left(\frac{(\bar{C})}{(\bar{C})}\right)^{-\sigma} \frac{\bar{P}}{\bar{P}} = \beta^k$. The steady state interest rates can be derived from the Euler equation on Home bond holdings

$$\bar{\imath} = \frac{1-\beta}{\beta} \tag{B.41}$$

The steady state rental rate of capital can be derived from the investment condition

$$\bar{r}^k = \left(\frac{1-\beta}{\beta}\right) + \delta \tag{B.42}$$

From the optimal goods price equations the following steady state relation can be derived: $\frac{\bar{P}^{Opt}_{HT}}{\bar{P}} = \frac{\bar{P}^{Opt}_{N}}{\bar{P}} = \mu_P \frac{\overline{MC}}{\bar{P}}$. From the aggregate goods price relations one can derive $\frac{\bar{P}_N}{\bar{P}} = \frac{\bar{P}^{Opt}_{N}}{\bar{P}} = \frac{\bar{P}_{HT}}{\bar{P}} = \frac{\bar{P}^{Opt}_{HT}}{\bar{P}} = \mu_P \frac{\overline{MC}}{\bar{P}}$. Solving for marginal costs yields:

$$\frac{\overline{MC}}{\bar{P}} = \frac{\frac{\bar{P}_{HT}}{\bar{P}}}{\mu_P} \tag{B.43}$$

The steady state Home producers PPI in the Foreign country is $\frac{\bar{P}^{Avg*}_{HT}}{\bar{P}} = \frac{\bar{P}^{Opt*}_{HT}}{\bar{P}} = \mu_P \frac{\overline{MC}}{\bar{P}}$. The Foreign consumers' price index of the Home traded good is $\frac{\bar{P}^*_{HT}}{\bar{P}^*} = \frac{1}{\overline{RER}}\mu_P \frac{\overline{MC}}{\bar{P}}$. The analogous condition in the Home country is therefore:

$$\frac{\bar{P}_{FT}}{\bar{P}} = \overline{RER}\mu_P \frac{\overline{MC}^*}{\bar{P}^*} \tag{B.44}$$

The relative traded goods index can be derived from the definition of the CPI:[44]

$$\frac{\bar{P}_T}{\bar{P}} = \left[\frac{1-(1-\gamma)\left(\frac{\bar{P}_{HT}}{\bar{P}}\right)^{1-\omega}}{\gamma} \right]^{\frac{1}{1-\omega}} \tag{B.45}$$

The relative traded goods price of the imported good can be derived from the definition of the traded goods price index $\frac{\bar{P}_{FT}}{\bar{P}} = \left[\frac{\left(\frac{\bar{P}_T}{\bar{P}}\right)^{1-\phi} - \alpha\left(\frac{\bar{P}_{HT}}{\bar{P}}\right)^{1-\phi}}{(1-\alpha)} \right]^{\frac{1}{1-\phi}}$. Solving for the price of home traded goods yields:

$$\frac{\bar{P}_{HT}}{\bar{P}} = \left[\frac{\left(\frac{\bar{P}_T}{\bar{P}}\right)^{1-\phi} - (1-\alpha)\left(\frac{\bar{P}_{FT}}{\bar{P}}\right)^{1-\phi}}{\alpha} \right]^{\frac{1}{1-\phi}} \tag{B.46}$$

The definition of marginal costs $\frac{\overline{MC}}{\bar{P}} = \frac{\left(\frac{\bar{W}}{\bar{P}}\right)^{\mu}\left(\bar{r}^k\right)^{1-\mu}}{(1-\mu)^{1-\mu}\mu^{\mu}}$ can be solved for real wages as follows:

$$\frac{\bar{W}}{\bar{P}} = \left(\frac{\frac{\overline{MC}}{\bar{P}}(1-\mu)^{1-\mu}\mu^{\mu}}{\left(\bar{r}^k\right)^{1-\mu}} \right)^{\frac{1}{\mu}} \tag{B.47}$$

Optimal labor supply where $\bar{N} = \bar{N}_{HT} + \bar{N}_N$, can be solved for $\bar{N}_N$ as:

$$\bar{N}_N = \left(\frac{\frac{\bar{W}}{\bar{P}}\left(\bar{C}\right)^{-\sigma}}{\kappa} \right)^{\frac{1}{\varphi}} - \bar{N}_{HT} \tag{B.48}$$

From the capital accumulation equation one can derive:

$$\bar{I} = \delta\bar{K} \tag{B.49}$$

where $\bar{K} = \bar{K}_{HT} + \bar{K}_N$ and $\bar{Y} = \bar{Y}_{HT} + \bar{Y}_N$.
Factor market clearing conditions in the traded goods sector are:

$$\bar{N}_{HT} = \frac{\mu\frac{\overline{MC}}{\bar{P}}}{\frac{\bar{W}}{\bar{P}}}\alpha\gamma\left(\bar{Y}_{HT}^{Avg} + \bar{Y}_{HT}^{Avg*}\right) \tag{B.50}$$

and

$$\bar{K}_{HT} = \frac{(1-\mu)}{\bar{r}^k}\frac{\overline{MC}}{\bar{P}}\alpha\gamma\left(\bar{Y}_{HT}^{Avg} + \bar{Y}_{HT}^{Avg*}\right) \tag{B.51}$$

[44] The analogous condition in the Foreign country is $\frac{\bar{P}_T^*}{\bar{P}^*} = \left[\frac{1-(1-\gamma)\left(\frac{\bar{P}_{FT}^*}{\bar{P}^*}\right)^{1-\omega}}{\gamma} \right]^{\frac{1}{1-\omega}}$.

Similar conditions in the nontraded goods sector, i.e. $\bar{Y}_N = (1-\gamma)\bar{Y}_N^{Avg}$, yield

$$\bar{K}_N = \frac{(1-\mu)}{\bar{r}^k}\frac{\overline{MC}}{\bar{P}}(1-\gamma)\bar{Y}_N^{Avg} \tag{B.52}$$

and

$$\bar{Y}_N^{Avg} = \frac{\bar{N}_N \frac{\bar{W}}{\bar{P}}}{(1-\gamma)\mu\frac{\overline{MC}}{\bar{P}}} \tag{B.53}$$

where

$$\bar{Y}_{HT}^{Avg} = \left(\frac{\bar{P}_{HT}}{\bar{P}}\right)^{-\phi}\left(\frac{\bar{P}_T}{\bar{P}}\right)^{\phi-\omega}\left(\bar{C} + \delta\left(\bar{K}_{HT} + \bar{K}_N\right)\right) \tag{B.54}$$

$$\bar{Y}_{FT}^{Avg} = \left(\frac{\bar{P}_{FT}}{\bar{P}}\right)^{-\phi}\left(\frac{\bar{P}_T}{\bar{P}}\right)^{\phi-\omega}\left(\bar{C} + \delta\left(\bar{K}_{HT} + \bar{K}_N\right)\right) \tag{B.55}$$

$$\bar{C} = \frac{\bar{Y}_N^{Avg}}{\left(\frac{\bar{P}_{HT}}{\bar{P}}\right)^{-\omega}} - \delta\left(\bar{K}_{HT} + \bar{K}_N\right) \tag{B.56}$$

The budget constraint:

$$\begin{aligned} & \bar{P}\bar{C} + \bar{P}_Q\bar{Q}_H + \bar{S}\bar{P}_Q^*\bar{Q}_F + \bar{B}_H + \bar{S}\bar{B}_F \\ \approx\ & \bar{W}\bar{N} + \left(\bar{P}_Q + \left(\frac{\bar{V}}{\bar{Q}}\right)\right)\bar{Q}_H + \bar{S}\left(\bar{P}_Q^* + \left(\frac{V^*}{\bar{Q}^*}\right)\right)\bar{Q}_F \\ & +(1+\bar{\imath})\bar{B}_H + \bar{S}(1+\bar{\imath}^*)\bar{B}_F + \bar{P}\bar{r}^k\bar{K} - \bar{P}\bar{I} \end{aligned}$$

can be solved for the real exchange rate as follows:

$$\overline{RER} = \frac{\frac{1}{\alpha\gamma}\bar{C} - \frac{\bar{P}_{HT}}{\bar{P}}\bar{Y}_{HT}^{Avg} - \frac{1}{\alpha\gamma}\frac{\bar{P}_{HT}}{\bar{P}}(1-\gamma)\bar{Y}_N^{Avg} + \frac{1}{\alpha\gamma}\delta\left(\bar{K}_{HT} + \bar{K}_N\right)}{\frac{\bar{P}_{HT}^*}{\bar{P}^*}\bar{Y}_{HT}^{Avg*}} \tag{B.57}$$

With the interest rate and the rental rate of capital defined exogenously (equations B.41 and B.42), a system of 27 equations (equations B.43 and B.56 together with the analogous equations for the foreign country and equation B.57) in the following 27 unknowns can be derived:

$\frac{\bar{P}_{HT}}{\bar{P}}, \frac{\bar{P}_{FT}^*}{\bar{P}^*}, \frac{\bar{P}_T}{\bar{P}}, \frac{\bar{P}_T^*}{\bar{P}^*}, \frac{\bar{P}_{FT}}{\bar{P}_T}, \frac{\bar{P}_{HT}^*}{\bar{P}_T^*}, \overline{RER}, \frac{\bar{W}}{\bar{P}}, \frac{\bar{W}^*}{\bar{P}^*}, \frac{\overline{MC}}{\bar{P}}, \frac{\overline{MC}^*}{\bar{P}^*}, \bar{C}, \bar{C}^*,$

$\bar{N}_{HT}, \bar{N}_{FT}^*, \bar{N}_N, \bar{N}_N^*, \bar{K}_{HT}, \bar{K}_{FT}^*, \bar{K}_N, \bar{K}_N^*, \bar{Y}_{HT}^{Avg}, \bar{Y}_{FT}^{Avg*}, \bar{Y}_{HT}^{Avg*}, \bar{Y}_{FT}^{Avg}, \bar{Y}_N^{Avg}, \bar{Y}_N^{Avg*}$

This system is solved numerically. Given the solution of the system, aggregate factors, $\bar{N}$

and $\bar{K}$, aggregate outputs, $\bar{Y}_{HT}, \bar{Y}_{FT}, \bar{Y}_N, \bar{Y}$, and real profits, $\frac{\bar{V}}{\bar{P}}$ can be defined recursively.[45],[46]

Note that the calibration of the asset holdings has to satisfy the net foreign asset condition:

$$\bar{S}\bar{P}_Q^*\bar{Q}_F - \bar{P}_Q\bar{Q}_H^* + \bar{S}\bar{B}_F - \bar{B}_H^* = 0$$

which can be reexpressed in real terms as: $\overline{RER}\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\frac{\bar{Y}^*}{\bar{Y}} - \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H^*}{\bar{Y}} + \overline{RER}\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\frac{\bar{Y}^*}{\bar{Y}} - \frac{\bar{B}_H^*}{\bar{P}\bar{Y}} = 0$, as well as the market clearing conditions, i.e. $\frac{\bar{B}_H}{\bar{P}\bar{Y}} = -\frac{\bar{B}_H^*}{\bar{P}\bar{Y}}$ and $\frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H}{\bar{Y}} = \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}}{\bar{Y}} - \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H^*}{\bar{Y}}$, and $\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F^*}{\bar{Y}^*} = \frac{\bar{P}_Q^*\bar{Q}^*}{\bar{P}^*\bar{Y}^*} - \frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}$. Thus, if $\frac{\bar{P}_Q\bar{Q}_F}{\bar{P}\bar{Y}}$, $\frac{\bar{P}_Q\bar{Q}_H^*}{\bar{P}\bar{Y}}$ and $\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}$ are calibrated the following asset holdings are residually determined as

$$\frac{\bar{B}_H^*}{\bar{P}\bar{Y}} = \overline{RER}\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\frac{\bar{Y}^*}{\bar{Y}} - \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H^*}{\bar{Y}} + \overline{RER}\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\frac{\bar{Y}^*}{\bar{Y}}$$

$$\frac{\bar{B}_H}{\bar{P}\bar{Y}} = -\frac{\bar{B}_H^*}{\bar{P}\bar{Y}}$$

$$\frac{\bar{B}_F^*}{\bar{P}^*\bar{Y}^*} = -\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}$$

$$\frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H}{\bar{Y}} = \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}}{\bar{Y}} - \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H^*}{\bar{Y}}$$

$$\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F^*}{\bar{Y}^*} = \frac{\bar{P}_Q^*\bar{Q}^*}{\bar{P}^*\bar{Y}^*} - \frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}$$

B.5 Linearized model

The model is solved by linearizing the stationary versions of equations (B.1) to (B.40) together with, where relevant, the analogous equations for the Foreign country around the symmetric steady state outlined above. The variables of the linearized system are expressed in percentage

[45] The steady state aggregate profits in real terms are $\frac{\bar{V}}{\bar{P}} = \alpha\gamma\left(\bar{P}_{HT}^{Avg}\bar{Y}_{HT}^{Avg} + P_{HT}^{AVG*}Y_{HT}^{AVG*}\right) + \alpha(1-\gamma)\bar{Y}_N^{Avg} - \left[\frac{\bar{W}}{\bar{P}}\bar{N} + \bar{r}^k\bar{K}\right]$. Steady state Home equity prices in real terms can be derived from the Euler equation on Home equity holdings: $\frac{\bar{P}_Q}{\bar{P}} = \frac{\beta}{(1-\beta)}\left(\frac{\frac{\bar{V}}{\bar{P}}}{\bar{Q}}\right)$. The total stock market capitalization can be written as: $\frac{\bar{P}_Q\bar{Q}}{\bar{P}\bar{Y}} = \frac{\beta}{(1-\beta)}\left(\frac{\frac{\bar{V}}{\bar{P}}}{\bar{Y}}\right)$.

[46] Note that in a symmetric steady state where $\alpha = 0.5$ all prices in the Home and Foreign country are equal and $\bar{S} = 1$ the following variables (or ratios) can derived analytically: $\frac{\overline{MC}}{\bar{P}} = \frac{1}{\mu_P}$ (where $\mu_P = \frac{\theta}{\theta-1}$), $\frac{\bar{K}}{\bar{Y}} = \frac{(1-\mu)}{\left(\frac{1-\beta}{\beta}\right)+\delta}\frac{1}{\mu_P}$, $\frac{\bar{N}}{\bar{Y}} = \left(\frac{(1-\mu)}{\left(\frac{1-\beta}{\beta}\right)+\delta}\frac{1}{\mu_P}\right)^{\frac{\mu-1}{\mu}}$, $\frac{\bar{W}}{\bar{P}} = \frac{\mu\frac{1}{\mu_P}}{\left(\frac{(1-\mu)}{\left(\frac{1-\beta}{\beta}\right)+\delta}\frac{1}{\mu_P}\right)^{\frac{\mu-1}{\mu}}}$, $\frac{\bar{C}}{\bar{Y}} = 1 - \delta\left(\frac{(1-\mu)}{\left(\frac{1-\beta}{\beta}\right)+\delta}\frac{1}{\mu_P}\right)$

(or log-) deviations from the steady state.[47]

Stationarizing and linearizing equations (B.1) to (B.40) and the relevant Foreign equations yields a system of 52 equations (equations B.58 to B.109 below) in 52 unknown variables: $\hat{p}_{Qt}$, $\hat{p}^*_{Qt}$, $\hat{q}_{Ft}$, $\hat{q}^*_{Ht}$, $\hat{c}_t$, $\hat{c}^*_t$, $\hat{b}_{Ft}$, $\hat{b}^*_{Ht}$, $\widehat{rer}_t$, $\hat{w}_t$, $\hat{w}^*_t$, $\hat{I}_t$, $\hat{I}^*_t$, $\hat{k}_t$, , $\hat{k}^*_t$, $\hat{p}_{HTt}$, $\hat{p}^*_{FTt}$, $\hat{\pi}_t$, Π^*, $\hat{p}^*_{HTt}$, $\hat{p}_{FTt}$, $\hat{p}_{Tt}$, $\hat{p}^*_{Tt}$, $\widehat{\Delta s}_t$, $\widehat{mc}_t$, $\widehat{mc}^*_t$, $\hat{n}_{Nt}$, $\hat{n}^*_{Nt}$, $\hat{n}_{HTt}$, $\hat{n}^*_{FTt}$, $\hat{r}^k_t$, $\hat{r}^{k*}_t$, $\hat{k}_{HTt}$, $\hat{k}^*_{FTt}$, $\hat{v}_t$, $\hat{v}^*_t$, $\hat{n}_t$, $\hat{n}^*_t$, $\hat{k}_{Nt}$, $\hat{k}^*_{Nt}$, $\hat{y}_t$, $\hat{y}^*_t$, $\hat{b}_{Ht}$, $\hat{b}^*_{Ft}$, $\hat{q}_{Ht}$, $\hat{q}^*_{Ft}$, $\hat{y}_{HTt}$, $\hat{y}^*_{FTt}$, $\hat{y}_{Nt}$, $\hat{y}^*_{Nt}$, $\hat{i}_t$, $\hat{i}^*_t$. The following paragraphs list the whole system with all non-linearized and linearized equations.

Aggregate Euler equations

The linearized version of:

$$\left(1+\gamma_{Q_H}\frac{(Q_{Ht+1}-Q_{Ht})}{Y_t}\right)$$
$$=D_{t,t+1}\left(\begin{array}{c}\gamma_{Q_H}\frac{P_{Qt+1}}{P_{Qt}}\frac{(Q_{Ht+2}-Q_{Ht+1})}{Y_{t+1}}-\gamma_{Q_H}\frac{P_{Qt+1}}{P_{Qt}}\frac{(Q_{Ht+1}-\bar{Q}_H)}{Y_{t+1}}\\ +\frac{\left(\frac{P_{Qt+1}}{P_{t+1}}\frac{P_{t+1}}{P_t}+\left(\frac{\frac{V_{t+1}}{P_{t+1}}\frac{P_{t+1}}{P_t}}{\bar{Q}}\right)\right)}{\frac{P_{Qt}}{P_t}}\end{array}\right)$$

where

$$D_{t,t+1}=\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{P_t}{P_{t+1}}$$

is:

$$\begin{array}{c}\gamma_{Q_H}\left(\hat{Q}_{Ht+1}-\hat{Q}_{Ht}\right)\\ =\sigma\left(\hat{c}_t-E_t\left\{\hat{c}_{t+1}\right\}\right)+\beta\left(\begin{array}{c}\gamma_{Q_H}\left(E_t\left\{\hat{Q}_{Ht+2}\right\}-\hat{Q}_{Ht+1}\right)\\ -\psi_{Q_H}\hat{Q}_{Ht+1}+E_t\left\{\hat{p}_{Qt+1}\right\}\end{array}\right)\\ +(1-\beta)E_t\left\{\hat{v}_{t+1}\right\}-\hat{p}_{Qt}\end{array}\qquad\text{(B.58)}$$

[47] Thus, for a variable x: $\hat{x}\equiv\frac{X-\bar{X}}{\bar{X}}\equiv\frac{dX}{\bar{X}}\approx\ln X-\ln\bar{X}$. All prices and wages are expressed in relation to the CPI, e.g. $\hat{p}_{Qt}\equiv\frac{\frac{P_{Qt}}{P_t}-\frac{\bar{P}_Q}{\bar{P}}}{\frac{\bar{P}_Q}{\bar{P}}}\equiv\frac{d\frac{P_{Qt}}{P_t}}{\frac{\bar{P}_Q}{\bar{P}}}\approx\ln\left(\frac{P_{Qt}}{P_t}\right)-\ln\left(\frac{\bar{P}_Q}{\bar{P}}\right)$. Asset holdings are expressed in relation to real GDP, e.g. $\hat{Q}_{Ht}\equiv\frac{Q_{Ht}-\bar{Q}_H}{\bar{Y}}\equiv\frac{dQ_{Ht}}{\bar{Y}}$. Inflation is defined as $\Pi_t\equiv\frac{P_t}{P_{t-1}}$and $\hat{\pi}_t\approx\ln\left(\frac{P_t}{P_{t-1}}\right)$.

The linearized version of:

$$\left(1+\gamma_{_{QF}}\frac{(Q_{Ft+1}-Q_{Ft})}{Y_t^*}\right)$$
$$= D_{t,t+1}\left(\begin{array}{c}\gamma_{_{Q_F}}\frac{S_{t+1}P^*_{Qt+1}}{S_tP^*_{Qt}}\frac{(Q_{Ft+2}-Q_{Ft+1})}{Y^*_{t+1}}-\psi_{Q_F}\frac{S_{t+1}P^*_{Qt+1}}{S_tP^*_{Qt}}\frac{\left(Q_{Ft+1}-\bar{Q}_F\right)}{Y^*_{t+1}}\\ +\left(\frac{S_{t+1}}{S_t}\frac{\left(\frac{P^*_{Qt+1}}{P^*_{t+1}}\frac{P^*_{t+1}}{P^*_t}+\left(\frac{\frac{V^*_{t+1}}{P^*_{t+1}}\frac{P^*_{t+1}}{P^*_t}}{\bar{Q}^*}\right)\right)}{\frac{P^*_{Qt}}{P^*_t}}\right)\end{array}\right)$$

is:

$$\begin{array}{c}\gamma_{_{QF}}\left(\hat{Q}_{Ft+1}-\hat{Q}_{Ft}\right)\\ =\sigma\left(\hat{c}_t-E_t\left\{\hat{c}_{t+1}\right\}\right)-E_t\left\{\hat{\pi}_{t+1}\right\}\\ +\beta\left(\gamma_{_{Q_F}}\left(E_t\left\{\hat{Q}_{Ft+2}\right\}-\hat{Q}_{Ft+1}\right)-\psi_{Q_H}\left(\hat{Q}_{Ft+1}\right)+E_t\left\{\hat{p}^*_{Qt+1}\right\}\right)\\ +E_t\left\{\hat{\pi}^*_{t+1}\right\}+E_t\left\{\widehat{\Delta s}_{t+1}\right\}+(1-\beta)E_t\left\{\hat{v}^*_{t+1}\right\}-\hat{p}^*_{Qt}\end{array} \quad \text{(B.59)}$$

The linearized version of:

$$\left(1+\gamma_{_{B_H}}\frac{(B_{Ht+1}-B_{Ht})}{P_tY_t}\right)$$
$$= \quad D_{t,t+1}\left(\begin{array}{c}\gamma_{_{B_H}}\frac{(B_{Ht+2}-B_{Ht+1})}{P_{t+1}Y_{t+1}}\\ -\psi_{B_H}\frac{\left(B_{Ht+1}-\bar{B}_H\right)}{P_{t+1}Y_{t+1}}+(1+i_{t+1})\end{array}\right)$$

is:

$$\begin{array}{c}\gamma_{_{B_H}}\left(E_t\left\{\hat{b}_{Ht+1}\right\}-\hat{b}_{Ht}\right)\\ =\sigma\left(\hat{c}_t-E_t\left\{\hat{c}_{t+1}\right\}\right)-E_t\left\{\hat{\pi}_{t+1}\right\}+\beta\left(\begin{array}{c}\gamma_{_{B_H}}E_t\left\{\hat{b}_{Ht+2}-\hat{b}_{Ht+1}\right\}\\ -\psi_{B_H}E_t\left\{\hat{b}_{Ht+1}\right\}\end{array}\right)\\ +E_t\left\{\hat{\imath}_{t+1}\right\}\end{array} \quad \text{(B.60)}$$

The linearized version of:

$$\left(1+\gamma_{_{B_F}}\frac{(B_{Ft+1}-B_{Ft})}{P_t^*Y_t^*}\right)$$
$$= D_{t,t+1}\left(\begin{array}{c}\gamma_{_{B_F}}\frac{S_{t+1}}{S_t}\frac{(B_{Ft+2}-B_{Ft+1})}{P^*_{t+1}Y^*_{t+1}}\\ -\psi_{_{B_F}}\frac{S_{t+1}}{S_t}\frac{\left(B_{Ft+1}-\bar{B}_F\right)}{P^*_{t+1}Y^*_{t+1}}+\frac{S_{t+1}}{S_t}(1+i^*_{t+1})\end{array}\right)$$

$$\left(1+\frac{\gamma_{_{B_F}}\bar{P}^*\bar{S}}{\bar{Y}^*S_t}\left(\frac{B_{Ft+1}}{P_t^*}-\frac{B_{Ft}}{P_t}\right)\frac{1}{P_t^*}\right)$$
$$=E_t\left\{\beta\left(\frac{(C_{t+1})}{(C_t)}\right)^{-\sigma}\frac{P_t}{P_{t+1}}\left(\begin{array}{c}\frac{\gamma_{_{B_F}}\bar{P}^*\bar{S}}{\bar{Y}^*S_t}\left(\frac{B_{Ft+2}}{P_{t+1}^*}-\frac{B_{Ft+1}}{P_{t+1}^*}\right)\left(\frac{1}{P_{t+1}^*}\right)\\-\frac{\gamma_{_{B_F}}\bar{P}^*\bar{S}}{\bar{Y}^*S_t}\left(\frac{B_{Ft+1}}{P_{t+1}^*}-\frac{\bar{B}_F}{\bar{P}^*}\right)\frac{1}{P_{t+1}^*}\\+\frac{S_{t+1}}{S_t}(1+i_t^*)\end{array}\right)\right\}$$

is:

$$\begin{gathered}\gamma_{_{B_F}}\left(E_t\left\{\hat{b}_{Ft+1}\right\}-\hat{b}_{Ft}\right)\\=\sigma\left(\hat{c}_t-E_t\left\{\hat{c}_{t+1}\right\}\right)-E_t\left\{\hat{\pi}_{t+1}\right\}+\beta\left(\begin{array}{c}\gamma_{_{B_F}}E_t\left\{\hat{b}_{Ft+2}-\hat{b}_{Ft+1}\right\}\\-\psi_{B_F}E_t\left\{\hat{b}_{Ft+1}\right\}\end{array}\right)\\+E_t\left\{\widehat{\Delta s}_{t+1}\right\}+E_t\left\{\hat{\imath}_{t+1}^*\right\}\end{gathered}\tag{B.61}$$

The analogous Foreign Euler equations in linearized terms are:

$$\begin{gathered}\gamma_{_{Q_H}^*}\left(\hat{Q}_{Ht+1}^*-\hat{Q}_{Ht}^*\right)\\=\sigma\left(\hat{c}_t^*-E_t\left\{\hat{c}_{t+1}^*\right\}\right)-E_t\left\{\hat{\pi}_{t+1}^*\right\}\\+\beta\left(\gamma_{_{Q_H}^*}\left(E_t\left\{\hat{Q}_{Ht+2}^*\right\}-\hat{Q}_{Ht+1}^*\right)-\psi_{Q_H^*}\left(\hat{Q}_{Ht+1}^*\right)+E_t\left\{\hat{p}_{Qt+1}\right\}\right)\\+E_t\left\{\hat{\pi}_{t+1}\right\}-E_t\left\{\widehat{\Delta s}_{t+1}\right\}+(1-\beta)\,E_t\left\{\hat{v}_{t+1}\right\}-\hat{p}_{Qt}\end{gathered}\tag{B.62}$$

$$\begin{gathered}\gamma_{_{Q_F}}^*\left(\hat{Q}_{Ft+1}^*-\hat{Q}_{Ft}^*\right)\\=\sigma\left(\hat{c}_t^*-E_t\left\{\hat{c}_{t+1}^*\right\}\right)+\beta\left(\begin{array}{c}\gamma_{_{Q_F}}^*\left(E_t\left\{\hat{Q}_{Ft+2}^*\right\}-\hat{Q}_{Ft+1}^*\right)\\-\psi_{Q_F}^*\hat{Q}_{Ft+1}^*+E_t\left\{\hat{p}_{Qt+1}^*\right\}\end{array}\right)\\+(1-\beta)\,E_t\left\{\hat{v}_{t+1}^*\right\}-\hat{p}_{Qt}^*\end{gathered}\tag{B.63}$$

$$\begin{gathered}\gamma_{_{B_H}^*}\left(E_t\left\{\hat{b}_{Ht+1}^*\right\}-\hat{b}_{Ht}^*\right)\\=\sigma\left(\hat{c}_t^*-E_t\left\{\hat{c}_{t+1}^*\right\}\right)-E_t\left\{\hat{\pi}_{t+1}^*\right\}+\beta\left(\begin{array}{c}\gamma_{_{B_H}^*}E_t\left\{\hat{b}_{Ht+2}^*-\hat{b}_{Ht+1}^*\right\}\\-\psi_{B_H^*}E_t\left\{\hat{b}_{Ht+1}^*\right\}\end{array}\right)\\-E_t\left\{\widehat{\Delta s}_{t+1}\right\}+E_t\left\{\hat{\imath}_{t+1}\right\}\end{gathered}\tag{B.64}$$

$$\begin{aligned}
&\gamma_{B_F}^{*}\left(E_t\left\{\hat{b}_{Ft+1}^{*}\right\}-\hat{b}_{Ft}^{*}\right) \\
&=\sigma\left(\hat{c}_t^{*}-E_t\left\{\hat{c}_{t+1}^{*}\right\}\right)-E_t\left\{\hat{\pi}_{t+1}^{*}\right\}+\beta\left(\begin{array}{c}\gamma_{B_F}^{*}E_t\left\{\hat{b}_{Ft+2}^{*}-\hat{b}_{Ft+1}^{*}\right\} \\ -\psi_{B_F}^{*}E_t\left\{\hat{b}_{Ft+1}^{*}\right\}\end{array}\right) \\
&+E_t\left\{\hat{\imath}_{t+1}^{*}\right\}
\end{aligned} \tag{B.65}$$

Aggregate Home consumer's budget constraint

The linearized version of:

$$\begin{aligned}
& C_t \\
& +\frac{P_{Qt}}{P_t}Q_{Ht+1}+\frac{\gamma_{Q_H}}{2}\frac{\bar{P}_Q\left(Q_{Ht+1}-Q_{Ht}\right)^2}{P_t\bar{Y}}+\frac{\psi_{Q_H}}{2}\frac{\bar{P}_Q\left(Q_{Ht}-\bar{Q}_H\right)^2}{P_t\bar{Y}} \\
& +\frac{S_tP_t^{*}}{P_t}\frac{P_{Qt}^{*}}{P_t^{*}}Q_{Ft+1}+\frac{\gamma_{Q_F}}{2}\frac{\bar{S}\bar{P}_Q^{*}\left(Q_{Ft+1}-Q_{Ft}\right)^2}{P_t\bar{Y}}+\frac{\psi_{Q_F}}{2}\frac{\bar{S}\bar{P}_Q^{*}\left(Q_{Ft}-\bar{Q}_F\right)^2}{P_t\bar{Y}} \\
& +\frac{B_{Ht+1}}{P_t}+\frac{\gamma_{B_H}}{2}\frac{\bar{P}\left(\frac{B_{Ht+1}}{P_t}-\frac{B_{Ht}}{P_t}\right)^2}{P_t\bar{Y}}+\frac{\psi_{B_H}}{2}\frac{\bar{P}\left(\frac{B_{Ht}}{P_t}-\frac{\bar{B}_H}{\bar{P}}\right)^2}{P_t\bar{Y}} \\
& +\frac{S_tP_t^{*}}{P_t}\frac{B_{Ft+1}}{P_t^{*}}+\frac{\gamma_{B_F}}{2}\frac{\bar{S}\bar{P}^{*}\left(\frac{B_{Ft+1}}{P_t^{*}}-\frac{B_{Ft}}{P_t^{*}}\right)^2}{P_t\bar{Y}}+\frac{\psi_{B_F}}{2}\frac{\bar{S}\bar{P}^{*}\left(\frac{B_{Ft}}{P_t^{*}}-\frac{\bar{B}_F}{\bar{P}^{*}}\right)^2}{P_t\bar{Y}} \\
= & \frac{W_t}{P_t}N_t+\left(\frac{P_{Qt}}{P_t}+\left(\frac{\frac{V_t}{P_t}}{\bar{Q}}\right)\right)Q_{Ht}+\frac{S_tP_t^{*}}{P_t}\left(\frac{P_{Qt}^{*}}{P_t^{*}}+\left(\frac{\frac{V_t^{*}}{P_t^{*}}}{\bar{Q}^{*}}\right)\right)Q_{Ft} \\
& +(1+i_t)\frac{B_{Ht}}{P_t}+\frac{S_tP_t^{*}}{P_t}(1+i_t^{*})\frac{B_{Ft}}{P_t^{*}}+\left[r_t^kK_{t.}-I_{t.}\right]+T_{\gamma t}
\end{aligned}$$

is:

$$
\begin{aligned}
& \bar{C}\hat{c}_t \qquad \text{(B.66)} \\
& +\frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H}{\bar{Y}}\bar{Y}\hat{p}_{Qt}+\frac{\bar{P}_Q}{\bar{P}}\bar{Y}\hat{q}_{Ht+1} \\
& +\frac{\overline{SP^*}}{P}\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\bar{Y}^*\widehat{rer}_t+\frac{\overline{SP^*}}{P}\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\bar{Y}^*\hat{p}_{Qt}^*+\frac{\overline{SP^*}}{P}\frac{\bar{P}_Q^*}{\bar{P}^*}\bar{Y}^*\hat{Q}_{Ft+1} \\
& +\bar{Y}\hat{b}_{Ht+1}+\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\bar{Y}^*\frac{\overline{SP^*}}{P}\widehat{rer}_t+\frac{\overline{SP^*}}{P}\bar{Y}^*\hat{b}_{Ft+1} \\
= \; & \frac{\bar{W}}{\bar{P}}\bar{N}\hat{w}_t+\frac{\bar{W}}{\bar{P}}\bar{N}\hat{n}_t+\frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H}{\bar{Y}}\bar{Y}\hat{p}_{Qt}+\left(\frac{(1-\beta)}{\beta}\right)\frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H}{\bar{Y}}\bar{Y}\hat{v}_t+\frac{1}{\beta}\frac{\bar{P}_Q}{\bar{P}}\bar{Y}\hat{Q}_{Ht} \\
& +\frac{1}{\beta}\frac{\overline{SP^*}}{P}\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\bar{Y}^*\widehat{rer}_t+\frac{\overline{SP^*}}{P}\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\bar{Y}^*\hat{p}_{Qt}^* \\
& +\left(\frac{(1-\beta)}{\beta}\right)\frac{\overline{SP^*}}{P}\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\bar{Y}^*\hat{v}_t^*+\frac{1}{\beta}\frac{\overline{SP^*}}{P}\frac{\bar{P}_Q^*}{\bar{P}^*}\bar{Y}^*\hat{Q}_{Ft} \\
& +\frac{1}{\beta}\frac{\bar{B}_H}{\bar{P}\bar{Y}}\bar{Y}\hat{\imath}_t+\frac{1}{\beta}\bar{Y}\hat{b}_{Ht}+\frac{1}{\beta}\frac{\overline{SP^*}}{P}\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\bar{Y}^*\widehat{rer}_t+\frac{1}{\beta}\frac{\overline{SP^*}}{P}\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\bar{Y}^*\hat{\imath}_t^*+\frac{1}{\beta}\frac{\overline{SP^*}}{P}\bar{Y}^*\hat{b}_{Ft} \\
& +\bar{r}^k\bar{K}\hat{r}_t^k+\bar{r}^k\bar{K}\hat{k}_t-\bar{I}\hat{I}_{t.}
\end{aligned}
$$

Labor supply

Equation:

$$\frac{\kappa N_t^{\varphi}}{C_t^{-\sigma}}=\frac{W_t}{P_t}$$

can be linearized and combined to:

$$\hat{w}_t\approx\varphi\hat{n}_t+\sigma\hat{c}_t \qquad \text{(B.67)}$$

and, analogously:

$$\hat{w}_t^*\approx\varphi\hat{n}_t^*+\sigma\hat{c}_t^* \qquad \text{(B.68)}$$

Capital accumulation

The linearized version of:

$$K_{t+1}=(1-\delta)K_t+I_t-\frac{\xi}{2}\frac{(K_{t+1}-K_t)^2}{K_t}$$

is:

$$\hat{k}_{t+1}\approx(1-\delta)\,\hat{k}_t+\delta\hat{I}_t \qquad \text{(B.69)}$$

and, analogously:

$$\hat{k}_{t+1}^*\approx(1-\delta)\,\hat{k}_t^*+\delta\hat{I}_t^* \qquad \text{(B.70)}$$

Optimal investment

The linearized version of:

$$\left(1+\xi\frac{(K_{t+1}-K_t)}{K_t}\right)$$
$$=\beta E_t\left\{\left(\frac{(C_{t+1})}{(C_t)}\right)^{-\sigma}\left[(1-\delta)+r^k_{t+1}+\frac{\xi}{2}\left(\frac{K^2_{t+2}-K^2_{t+1}}{K^2_{t+1}}\right)\right]\right\}$$

is:

$$\xi\left(\hat{k}_{t+1}-\hat{k}_t\right)\approx E_t\left\{\sigma\left(\hat{c}_t-\hat{c}_{t+1}\right)+\beta\bar{r}^k\hat{r}^k_{t+1}+\beta\xi\left(\hat{k}_{t+2}-\hat{k}_{t+1}\right)\right\} \tag{B.71}$$

and, analogously:

$$\xi\left(\hat{k}^*_{t+1}-\hat{k}^*_t\right)\approx E_t\left\{\sigma\left(\hat{c}^*_t-\hat{c}^*_{t+1}\right)+\beta\bar{r}^k\hat{r}^{k*}_{t+1}+\beta\xi\left(\hat{k}^*_{t+2}-\hat{k}^*_{t+1}\right)\right\} \tag{B.72}$$

Price dynamics

Combining the linearized version of:

$$\sum_{k=0}^{\infty}\theta^k_P E_t\left\{\beta^k\left(\frac{(C_{t+k})}{(C_t)}\right)^{-\sigma}\frac{P_t}{P_{t+k}}Y_{HTt+k|t}\left(\frac{P^{Opt}_{HTt}}{P_t}-\mu_P\frac{MC_{t+k}}{P_{t+k}}\frac{P_{t+k}}{P_t}\right)\right\}=0$$

$$\sum_{k=0}^{\infty}\theta^k_P E_t\left\{\begin{array}{c}\beta^k\left(\frac{(C_{t+k})}{(C_t)}\right)^{-\sigma}\frac{P_t}{P_{t+k}}Y^*_{HTt+k|t}\\ \left(\left(\frac{S_{t-1}}{S_t}\right)^{1-\tau}\left(\frac{S_t^{1-\tau}P^{Opt*}_{HTt}}{P_t}\right)-\mu_P\left(\frac{S_{t+k}}{S_{t-1}}\right)^{\tau-1}\frac{MC_{t+k}}{P_{t+k}}\frac{P_{t+k}}{P_t})\right)\end{array}\right\}=0$$

$$\sum_{k=0}^{\infty}\theta^k_P E_t\left\{\beta^k\left(\frac{(C_{t+k})}{(C_t)}\right)^{-\sigma}\frac{P_t}{P_{t+k}}Y_{Nt+k|t}\left(\frac{P^{Opt}_{Nt}}{P_t}-\mu_P\frac{MC_{t+k}}{P_{t+k}}\frac{P_{t+k}}{P_t})\right)\right\}=0$$

$$\left(\frac{P_{HTt}}{P_t}\right)^{1-\theta}=\left(\theta_P\left(\frac{P_{HTt-1}}{P_{t-1}}\frac{1}{\frac{P_t}{P_{t-1}}}\right)^{1-\theta}+(1-\theta_P)\left(\frac{P^{Opt}_{HTt}}{P_t}\right)^{1-\theta}\right)$$

$$\left(\frac{P^{AVG*}_{HTt}}{P_t}\right)^{1-\theta}=\left(\theta_P\left(\frac{P^{AVG*}_{HTt}}{P_{t-1}}\frac{1}{\frac{P_t}{P_{t-1}}}\right)^{1-\theta}+(1-\theta_P)\left(\frac{S_t^{1-\tau}P^{Opt*}_{HTt}}{P_t}\right)^{1-\theta}\right)$$

$$\frac{P^*_{HTt}}{P^*_t}=\left(\frac{1}{\frac{S_tP^*_t}{P_t}}\right)\frac{P^{AVG*}_{HTt}}{P_t}$$

$$\left(\frac{P_{Nt}}{P_t}\right)^{1-\theta}=\left(\theta_P\left(\frac{P_{Nt-1}}{P_{t-1}}\frac{1}{\frac{P_t}{P_{t-1}}}\right)^{1-\theta}+(1-\theta_P)\left(\frac{P^{Opt}_{Nt}}{P_t}\right)^{1-\theta}\right)$$

$$\left(\frac{P_{Tt}}{P_t}\right)^{1-\phi}=\left[\alpha\left(\frac{P_{HTt}}{P_t}\right)^{1-\phi}+(1-\alpha)\left(\frac{P_{FTt}}{P_t}\right)^{1-\phi}\right]$$

$$1=\left[\gamma\left(\frac{P_{Tt}}{P_t}\right)^{1-\omega}+(1-\gamma)\left(\frac{P_{Nt}}{P_t}\right)^{1-\omega}\right]$$

and the analogous Foreign equations yields a system of the following eight price equations:[48]

Domestic traded goods price index

$$\begin{aligned}\hat{p}_{HTt} &\approx \left(\frac{\theta_P}{1+\beta(\theta_P)^2}\right)\hat{p}_{HTt-1}-\left(\frac{\theta_P}{1+\beta(\theta_P)^2}\right)\hat{\pi}_t \\ &+\beta\left(\frac{\theta_P}{1+\beta(\theta_P)^2}\right)E_t\left\{\hat{p}_{HTt+1}+\hat{\pi}_{t+1}\right\}+\frac{(1-\theta_P)(1-\theta_P\beta)}{\left(1+\beta(\theta_P)^2\right)}\widehat{mc}_t\end{aligned} \tag{B.73}$$

$$\begin{aligned}\hat{p}^*_{FTt} &\approx \left(\frac{\theta_P}{1+\beta(\theta_P)^2}\right)\hat{p}^*_{FTt-1}-\left(\frac{\theta_P}{1+\beta(\theta_P)^2}\right)\hat{\pi}^*_t \\ &+\beta\left(\frac{\theta_P}{1+\beta(\theta_P)^2}\right)E_t\left\{\hat{p}^*_{FTt+1}+\hat{\pi}^*_{t+1}\right\}+\frac{(1-\theta_P)(1-\theta_P\beta)}{\left(1+\beta(\theta_P)^2\right)}\widehat{mc}^*_t\end{aligned} \tag{B.74}$$

Domestic traded goods price index in the other country

The domestic traded goods price index in the other country can be solved for inflation:

$$\begin{aligned}&\hat{\pi}_t \approx \widehat{p^*_{HTt-1}}+\widehat{rer}_{t-1}-\left(\frac{1+\beta(\theta_P)^2}{\theta_P}\right)\left(\widehat{p^*_{HTt}}+\widehat{rer}_t\right) \\ &+\beta E_t\left\{\widehat{p^*_{HTt+1}}+\widehat{rer}_{t+1}-(1-\theta_P)(1-\tau)\widehat{\Delta s}_{t+1}+\hat{\pi}_{t+1}\right\} \\ &+\frac{(1-\theta_P)(1-\theta_P\beta)}{\theta_P}\widehat{mc}_t\end{aligned} \tag{B.75}$$

$$\begin{aligned}&\hat{\pi}^*_t \approx \widehat{p_{FTt-1}}-\widehat{rer}_{t-1}-\left(\frac{1+\beta(\theta_P)^2}{\theta_P}\right)\left(\widehat{p_{FTt}}-\widehat{rer}_t\right) \\ &+\beta E_t\left\{\widehat{p_{FTt+1}}-\widehat{rer}_{t+1}+(1-\theta_P)(1-\tau)\widehat{\Delta s}_{t+1}+\hat{\pi}^*_{t+1}\right\} \\ &+\frac{(1-\theta_P)(1-\theta_P\beta)}{\theta_P}\widehat{mc}^*_t\end{aligned} \tag{B.76}$$

[48] Note that the domestic traded goods price and the nontraded goods price are equivalent. Thus, the nontraded goods price will be dropped in the final system

Traded goods price index

The traded goods price index can be solved for the other country's traded goods price index:

$$\hat{p}_{FTt} \approx \frac{1}{(1-\alpha)\left(\frac{\bar{P}_{FT}}{\bar{P}}\frac{1}{\left(\frac{\bar{P}_T}{\bar{P}}\right)}\right)^{1-\phi}}\hat{p}_{Tt} - \frac{\alpha\left(\frac{\bar{P}_{HT}}{\bar{P}}\frac{1}{\left(\frac{\bar{P}_T}{\bar{P}}\right)}\right)^{1-\phi}}{(1-\alpha)\left(\frac{\bar{P}_{FT}}{\bar{P}}\frac{1}{\left(\frac{\bar{P}_T}{\bar{P}}\right)}\right)^{1-\phi}}\hat{p}_{HTt} \tag{B.77}$$

$$\hat{p}^*_{HTt} \approx \frac{1}{\alpha\left(\frac{\bar{P}^*_{HT}}{\bar{P}^*}\frac{1}{\left(\frac{\bar{P}^*_T}{\bar{P}^*}\right)}\right)^{1-\phi}}\hat{p}^*_{Tt} - \frac{(1-\alpha)\left(\frac{\bar{P}^*_{FT}}{\bar{P}^*}\frac{1}{\left(\frac{\bar{P}^*_T}{\bar{P}^*}\right)}\right)^{1-\phi}}{\alpha\left(\frac{\bar{P}^*_{HT}}{\bar{P}^*}\frac{1}{\left(\frac{\bar{P}^*_T}{\bar{P}^*}\right)}\right)^{1-\phi}}\hat{p}^*_{FTt} \tag{B.78}$$

Consumer price index

The consumer price index can be solved for the traded goods price index:

$$\hat{p}_{Tt} \approx \frac{(\gamma-1)}{\gamma}\left(\frac{\frac{\bar{P}_{HT}}{\bar{P}}}{\frac{\bar{P}_T}{\bar{P}}}\right)^{1-\omega}\hat{p}_{HTt} \tag{B.79}$$

$$\hat{p}^*_{Tt} \approx \frac{(\gamma-1)}{\gamma}\left(\frac{\frac{\bar{P}^*_{FT}}{\bar{P}^*}}{\frac{\bar{P}^*_T}{\bar{P}^*}}\right)^{1-\omega}\hat{p}^*_{FTt} \tag{B.80}$$

Change in nominal exchange rate

The linearized version of a rewritten definition of the change in the nominal exchange rate:

$$\frac{S_t}{S_{t-1}} = \left(\frac{S_t P^*_t}{P_t}\right)\left(\frac{P_{t-1}}{S_{t-1}P^*_{t-1}}\right)\left(\frac{P_t}{P_{t-1}}\right)\left(\frac{P^*_{t-1}}{P^*_t}\right)$$

yields:

$$\widehat{\Delta s}_t \approx \widehat{rer}_t - \widehat{rer}_{t-1} + \hat{\pi}_t - \hat{\pi}^*_t \tag{B.81}$$

Marginal costs

The linearized version of:

$$\frac{MC_t}{P_t} = \frac{\left(\frac{W_t}{P_t}\right)^{\mu}\left(r^k_t\right)^{1-\mu}}{(1-\mu)^{1-\mu}\mu^{\mu}A_t}$$

is:

$$\widehat{mc}_t = \mu \hat{w}_t + (1-\mu)\,\hat{r}^k_t - \hat{a}_t \tag{B.82}$$

and, analogously:

$$\widehat{mc}^*_t = \mu \hat{w}^*_t + (1-\mu)\,\hat{r}^{k*}_t - \hat{a}^*_t \tag{B.83}$$

Labor market clearing

The linearized version of:

$$N_{HTt} = \frac{\mu \frac{MC_t}{P_t}}{\frac{W_t}{P_t}} Y_{HTt}$$

$$N_{Nt} = \frac{\mu \frac{MC_t}{P_t}}{\frac{W_t}{P_t}} Y_{Nt}$$

is:

$$\hat{n}_{Nt} \approx \left(\widehat{mc}_t + \hat{y}_{Nt} - \hat{w}_t\right) \tag{B.84}$$

and, analogously:

$$\hat{n}^*_{Nt} \approx \left(\widehat{mc}^*_t + \hat{y}^*_{Nt} - \hat{w}^*_t\right) \tag{B.85}$$

as well as:

$$\hat{n}_{HTt} \approx \left(\widehat{mc}_t + \hat{y}_{HTt} - \hat{w}_t\right) \tag{B.86}$$

and

$$\hat{n}^*_{FTt} \approx \left(\widehat{mc}^*_t + \hat{y}^*_{FTt} - \hat{w}^*_t\right) \tag{B.87}$$

Capital market clearing

The linearized version of:

$$K_{HTt} = \frac{(1-\mu)}{r^k_t} \frac{MC_t}{P_t} Y_{HTt}$$

$$K_{Nt} = \frac{(1-\mu)}{r^k_t} \frac{MC_t}{P_t} Y_{Nt}$$

is:

$$\hat{k}_{Nt} \approx \left(\widehat{mc}_t + \hat{y}_{Nt} - \hat{r}^k_t\right) \tag{B.88}$$

and, analogously:

$$\hat{k}^*_{Nt} \approx \left(\widehat{mc}^*_t + \hat{y}^*_{Nt} - \hat{r}^{k*}_t\right) \tag{B.89}$$

as well as:

$$\hat{k}_{HTt} \approx \left(\widehat{mc}_t + \hat{y}_{HTt} - \hat{r}^k_t\right) \tag{B.90}$$

and:

$$\hat{k}^*_{FTt} \approx \left(\widehat{mc}^*_t + \hat{y}^*_{FTt} - \hat{r}^{k*}_t\right) \tag{B.91}$$

Aggregate labor

The linearized version of:

$$N_t = N_{HTt} + N_{Nt}$$

is:

$$\hat{n}_t \approx \frac{\bar{N}_{HT}}{\bar{N}}\hat{n}_{HTt} + \frac{\bar{N}_N}{\bar{N}}\hat{n}_{Nt} \tag{B.92}$$

and, analogously:

$$\hat{n}^*_t \approx \frac{\bar{N}^*_{HT}}{\bar{N}^*}\hat{n}^*_{FTt} + \frac{\bar{N}^*_N}{\bar{N}^*}\hat{n}^*_{Nt} \tag{B.93}$$

Aggregate capital

The linearized version of:

$$K_t = K_{HTt} + K_{Nt}$$

is:

$$\hat{k}_t \approx \frac{\bar{K}_{HT}}{\bar{K}}\hat{k}_{HTt} + \frac{\bar{K}_N}{\bar{K}}\hat{k}_{Nt} \tag{B.94}$$

and, analogously:

$$\hat{k}^*_t \approx \frac{\bar{K}^*_{FT}}{\bar{K}^*}\hat{k}^*_{FTt} + \frac{\bar{K}^*_N}{\bar{K}^*}\hat{k}^*_{Nt} \tag{B.95}$$

Aggregate output

The linearized version of:

$$\begin{aligned} Y_t \quad = \quad & \alpha\gamma \begin{pmatrix} \left(\frac{P_{HTt}}{P_t}\right)^{1-\phi}\left(\frac{P_{Tt}}{P_t}\right)^{\phi-\omega}(C_t + I_t) \\ +\left(\frac{S_t P^*_t}{P_t}\right)\left(\frac{P^*_{HTt}}{P^*_t}\right)^{1-\phi}\left(\frac{P^*_{Tt}}{P^*_t}\right)^{\phi-\omega}(C^*_t + I^*_t) \end{pmatrix} \\ & +(1-\gamma)\left(\left(\frac{P_{Nt}}{P_t}\right)^{1-\omega}(C_t + I_t)\right) \end{aligned}$$

is:

$$
\hat{y}_t \approx \left(\alpha\gamma \left(\begin{array}{c} \frac{\left(\frac{\bar{P}_{HT}}{P}\right)^{1-\phi}\left(\frac{\bar{P}_T}{P}\right)^{\phi-\omega}(\bar{C}+\bar{I})}{\bar{Y}} \\ \left(\begin{array}{c} (1-\phi)\hat{p}_{HTt} + (\phi-\omega)\,\hat{p}_{Tt} \\ +\frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t + \frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t \end{array} \right) \\ +\frac{\left(\frac{\overline{SP^*}}{P}\right)\left(\frac{\bar{P}^*_{HT}}{P^*}\right)^{1-\phi}\left(\frac{\bar{P}^*_T}{P^*}\right)^{\phi-\omega}(\bar{C}^*+\bar{I}^*)}{\bar{Y}} \\ \left(\begin{array}{c} \widehat{rer}_t + (1-\phi)\hat{p}^*_{HTt} + (\phi-\omega)\,\hat{p}^*_{Tt} \\ +\frac{\bar{C}^*}{(\bar{C}^*+\bar{I}^*)}\hat{c}^*_t + \frac{\bar{I}^*}{(\bar{C}^*+\bar{I}^*)}\hat{I}^*_t \end{array} \right) \end{array} \right) \right) \tag{B.96}
$$

$$
+ \left(\left((1-\gamma)\frac{\left(\frac{\bar{P}_{HT}}{\bar{P}}\right)^{1-\omega}(\bar{C}+\bar{I})}{\bar{Y}} \right) \left((1-\omega)\,\hat{p}_{HTt} + \frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t + \frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t \right) \right)
$$

and, analogously:

$$
\hat{y}^*_t \approx \left((1-\alpha)\gamma \left(\begin{array}{c} \frac{\left(\frac{\bar{P}^*_{FT}}{P^*}\right)^{1-\phi}\left(\frac{\bar{P}^*_T}{P^*}\right)^{\phi-\omega}(\bar{C}^*+\bar{I}^*)}{\bar{Y}^*} \\ \left(\begin{array}{c} (1-\phi)\,\hat{p}^*_{FTt} + (\phi-\omega)\,\hat{p}^*_{Tt} \\ +\frac{\bar{C}^*}{(\bar{C}^*+\bar{I}^*)}\hat{c}^*_t + \frac{\bar{I}^*}{(\bar{C}^*+\bar{I}^*)}\hat{I}^*_t \end{array} \right) \\ +\frac{\left(\frac{\overline{SP^*}}{P}\right)^{-1}\left(\frac{\bar{P}_{FT}}{P}\right)^{1-\phi}\left(\frac{\bar{P}_T}{P}\right)^{\phi-\omega}(\bar{C}+\bar{I})}{\bar{Y}^*} \\ \left(\begin{array}{c} -\widehat{rer}_t + (1-\phi)\,\hat{p}_{FTt} + (\phi-\omega)\,\hat{p}_{Tt} \\ +\frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t + \frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t \end{array} \right) \end{array} \right) \right) \tag{B.97}
$$

$$
+ \left(\left((1-\gamma)\frac{\left(\frac{\bar{P}^*_{FT}}{\bar{P}^*}\right)^{1-\omega}(\bar{C}^*+\bar{I}^*)}{\bar{Y}^*} \right) \left((1-\omega)\,\hat{p}^*_{FTt} + \frac{\bar{C}^*}{(\bar{C}^*+\bar{I}^*)}\hat{c}^*_t + \frac{\bar{I}^*}{(\bar{C}^*+\bar{I}^*)}\hat{I}^*_t \right) \right)
$$

Aggregate profits

The linearized version of:

$$
\frac{V_t}{P_t} = \alpha\gamma \left(\begin{array}{c} \left(\frac{P_{HTt}}{P_t}\right)^{1-\phi}\left(\frac{P_{Tt}}{P_t}\right)^{\phi-\omega}(C_t+I_t) \\ +\frac{S_tP^*_t}{P_t}\left(\frac{P^*_{HTt}}{P^*_t}\right)^{1-\phi}\left(\frac{P^*_{Tt}}{P^*_t}\right)^{\phi-\omega}(C^*_t+I^*_t) \end{array} \right)
$$

$$
+(1-\gamma)\left(\left(\frac{P_{Nt}}{P_t}\right)^{1-\omega}(C_t+I_t)\right) - \left[\frac{W_t}{P_t}N_t + r^k_tK_t\right]
$$

is:

$$\hat{v}_t = \alpha\gamma\left(\begin{array}{c}\frac{\left(\frac{\bar{P}_{HT}}{\bar{P}}\right)^{1-\phi}\left(\frac{\bar{P}_T}{\bar{P}}\right)^{\phi-\omega}(\bar{C}+\bar{I})}{\frac{\bar{V}}{\bar{P}}}\left(\begin{array}{c}(1-\phi)\,\hat{p}_{HTt}+(\phi-\omega)\,\hat{p}_{Tt}\\+\frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t+\frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t\end{array}\right)\\+\frac{\left(\frac{\overline{SP^*}}{\bar{P}}\right)\left(\frac{\bar{P}^*_{HT}}{\bar{P}^*}\right)^{1-\phi}\left(\frac{\bar{P}^*_T}{\bar{P}^*}\right)^{\phi-\omega}(\bar{C}^*+\bar{I}^*)}{\frac{\bar{V}}{\bar{P}}}\\\left(\begin{array}{c}\widehat{rer}_t+(1-\phi)\,\hat{p}^*_{HTt}+(\phi-\omega)\,\hat{p}^*_{Tt}\\+\frac{\bar{C}^*}{(\bar{C}^*+\bar{I}^*)}\hat{c}^*_t+\frac{\bar{I}^*}{(\bar{C}^*+\bar{I}^*)}\hat{I}^*_t\end{array}\right)\end{array}\right) \tag{B.98}$$

$$+(1-\gamma)\frac{\left(\frac{\bar{P}_{HT}}{\bar{P}}\right)^{1-\omega}\left(\bar{C}+\bar{I}\right)}{\frac{\bar{V}}{\bar{P}}}\left(\begin{array}{c}(1-\omega)\,\hat{p}_{HTt}\\+\frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t+\frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t\end{array}\right)$$

$$-\frac{\frac{\bar{W}}{\bar{P}}\bar{N}}{\frac{\bar{V}}{\bar{P}}}\left(\hat{w}_t+\hat{n}_t\right)-\frac{\bar{r}^k\bar{K}}{\frac{\bar{V}}{\bar{P}}}\left(\hat{r}^k_t+\hat{k}_t\right)$$

and, analogously:

$$\hat{v}^*_t = (1-\alpha)\gamma\left(\begin{array}{c}\frac{\left(\frac{\bar{P}^*_{FT}}{\bar{P}^*}\right)^{1-\phi}\left(\frac{\bar{P}^*_T}{\bar{P}^*}\right)^{\phi-\omega}(\bar{C}^*+\bar{I}^*)}{\frac{\bar{V}^*}{\bar{P}^*}}\left(\begin{array}{c}(1-\phi)\,\hat{p}^*_{FTt}+(\phi-\omega)\,\hat{p}^*_{Tt}\\+\frac{\bar{C}^*}{(\bar{C}^*+\bar{I}^*)}\hat{c}^*_t+\frac{\bar{I}^*}{(\bar{C}^*+\bar{I}^*)}\hat{I}^*_t\end{array}\right)\\+\frac{\left(\frac{1}{\frac{\overline{SP^*}}{\bar{P}}}\right)\left(\frac{\bar{P}_{FT}}{\bar{P}}\right)^{1-\phi}\left(\frac{\bar{P}_T}{\bar{P}}\right)^{\phi-\omega}(\bar{C}+\bar{I})}{\frac{\bar{V}^*}{\bar{P}^*}}\\\left(-\widehat{rer}_t+(1-\phi)\,\hat{p}_{FTt}+(\phi-\omega)\,\hat{p}_{Tt}+\frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t+\frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t\right)\end{array}\right) \tag{B.99}$$

$$+(1-\gamma)\frac{\left(\frac{\bar{P}^*_{FT}}{\bar{P}^*}\right)^{1-\omega}\left(\bar{C}^*+\bar{I}^*\right)}{\frac{\bar{V}^*}{\bar{P}^*}}\left((1-\omega)\,\hat{p}^*_{FTt}+\frac{\bar{C}^*}{(\bar{C}^*+\bar{I}^*)}\hat{c}^*_t+\frac{\bar{I}^*}{(\bar{C}^*+\bar{I}^*)}\hat{I}^*_t\right)$$

$$-\frac{\frac{\bar{W}^*}{\bar{P}^*}\bar{N}^*}{\frac{\bar{V}^*}{\bar{P}^*}}\left(\hat{w}^*_t+\hat{n}^*_t\right)-\frac{\bar{r}^{k*}\bar{K}^*}{\frac{\bar{V}^*}{\bar{P}^*}}\left(\hat{r}^{k*}_t+\hat{k}^*_t\right)$$

Asset market clearings

The linearized versions of:

$$\frac{B_{Ht}}{P_t\bar{Y}} = -\frac{B^*_{Ht}}{P_t\bar{Y}}$$

$$B_{Ft} = -B^*_{Ft}$$

$$\bar{Q} = Q_{Ht} + Q^*_{Ht}$$
$$\bar{Q}^* = Q^*_{Ft} + Q_{Ft}$$

are:

$$\hat{b}_{Ht} = -\hat{b}^*_{Ht} \tag{B.100}$$

$$\hat{b}_{Ft} = -\hat{b}^*_{Ft} \tag{B.101}$$

$$\hat{q}_{Ht} \approx -\hat{q}^*_{Ht} \tag{B.102}$$

$$\hat{q}_{Ft} \approx -\hat{q}^*_{Ft} \tag{B.103}$$

Goods market clearings

The linearized versions of:

$$Y_{HTt} = \alpha\gamma \begin{pmatrix} \left(\frac{P_{HTt}}{P_t}\right)^{-\phi} \left(\frac{P_{Tt}}{P_t}\right)^{\phi-\omega} (C_t + I_t) \\ + \left(\frac{P^*_{HTt}}{P^*_t}\right)^{-\phi} \left(\frac{P^*_{Tt}}{P^*_t}\right)^{\phi-\omega} (C^*_t + I^*_t) \end{pmatrix}$$

$$Y^*_{FT} = (1-\alpha)\gamma \begin{pmatrix} \left(\frac{P_{FTt}}{P_t}\right)^{-\phi} \left(\frac{P_{Tt}}{P_t}\right)^{\phi-\omega} (C_t + I_t) \\ + \left(\frac{P^*_{FTt}}{P^*_t}\right)^{-\phi} \left(\frac{P^*_{Tt}}{P^*_t}\right)^{\phi-\omega} (C^*_t + I^*_t) \end{pmatrix}$$

$$Y_{Nt} = \alpha(1-\gamma) \left(\frac{1}{\alpha} \left(\frac{P_{Nt}}{P_t}\right)^{-\omega} (C_t + I_t) \right)$$

are:

$$\begin{aligned} &\hat{y}_{HTt} \\ = \quad &\alpha\gamma \begin{pmatrix} \frac{\left(\frac{\bar{P}_{HT}}{\bar{P}}\right)^{-\phi}\left(\frac{\bar{P}_T}{\bar{P}}\right)^{\phi-\omega}(\bar{C}+\bar{I})}{\bar{Y}_{HT}} \begin{pmatrix} (-\phi)\,\hat{p}_{HTt} + (\phi-\omega)\,\hat{p}_{Tt} \\ + \frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t + \frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t \end{pmatrix} \\ + \frac{\left(\frac{\bar{P}^*_{HT}}{\bar{P}^*}\right)^{-\phi}\left(\frac{\bar{P}^*_T}{\bar{P}^*}\right)^{\phi-\omega}(\bar{C}^*+\bar{I}^*)}{\bar{Y}_{HT}} \begin{pmatrix} (-\phi)\,\hat{p}^*_{HTt} + (\phi-\omega)\,\hat{p}^*_{Tt} \\ + \frac{\bar{C}^*}{(\bar{C}^*+\bar{I}^*)}\hat{c}^*_t + \frac{\bar{I}^*}{(\bar{C}^*+\bar{I}^*)}\hat{I}^*_t \end{pmatrix} \end{pmatrix} \end{aligned} \tag{B.104}$$

$$\begin{aligned} &\hat{y}^*_{FTt} \\ = \quad &(1-\alpha)\gamma \begin{pmatrix} \frac{\left(\frac{\bar{P}^*_{FT}}{\bar{P}^*}\right)^{-\phi}\left(\frac{\bar{P}^*_T}{\bar{P}^*}\right)^{\phi-\omega}(\bar{C}^*+\bar{I}^*)}{\bar{Y}^*_{FT}} \begin{pmatrix} (-\phi)\,\hat{p}^*_{FTt} + (\phi-\omega)\,\hat{p}^*_{Tt} \\ + \frac{\bar{C}^*}{(\bar{C}^*+\bar{I}^*)}\hat{c}^*_t + \frac{\bar{I}^*}{(\bar{C}^*+\bar{I}^*)}\hat{I}^*_t \end{pmatrix} \\ + \frac{\left(\frac{\bar{P}_{FT}}{\bar{P}}\right)^{-\phi}\left(\frac{\bar{P}_T}{\bar{P}}\right)^{\phi-\omega}(\bar{C}+\bar{I})}{\bar{Y}^*_{FT}} \begin{pmatrix} (-\phi)\,\hat{p}_{FTt} + (\phi-\omega)\,\hat{p}_{Tt} \\ + \frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t + \frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t \end{pmatrix} \end{pmatrix} \end{aligned} \tag{B.105}$$

$$\hat{y}_{Nt} \approx (-\omega)\,\hat{p}_{HTt} + \frac{\bar{C}}{(\bar{C}+\bar{I})}\hat{c}_t + \frac{\bar{I}}{(\bar{C}+\bar{I})}\hat{I}_t \tag{B.106}$$

and, analogously:

$$\hat{y}^*_{Nt} \approx (-\omega)\,\hat{p}^*_{FTt} + \frac{\bar{C}^*}{(\bar{C}^* + \bar{I}^*)}\hat{c}^*_t + \frac{\bar{I}^*}{(\bar{C}^* + \bar{I}^*)}\hat{I}^*_t \tag{B.107}$$

Taylor rules

The linearized versions of:

$$1 + i_t = (1 + i_{t-1})^{\rho}\left(\left(\frac{P_t}{P_{t-1}}\right)^{\phi_\pi}(Y_t)^{\phi_y}\right)^{(1-\rho)} R_t$$

$$1 + i^*_t = (1 + i^*_t)^{\rho^*}\left(\left(\frac{P^*_t}{P^*_{t-1}}\right)^{\phi^*_\pi}(Y^*_t)^{\phi^*_y}\right)^{(1-\rho^*)}$$

are:

$$\hat{\imath}_t \approx \rho\hat{\imath}_{t-1} + (1-\rho)\left(\phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t\right) + \hat{r}_t \tag{B.108}$$

$$\hat{\imath}^*_t \approx \rho^*\hat{\imath}^*_{t-1} + (1-\rho^*)\,\phi^*_\pi\hat{\pi}^*_t + \phi^*_y\hat{y}^*_t \tag{B.109}$$

B.6 Additional variables

The current account is defined as:

$$\begin{aligned} CA_t &= B_{Ht+1} - B_{Ht} + S_t\,(B_{Ft+1} - B_{Ft}) \\ &\quad + P_{Qt}\,(Q_{Ht+1} - Q_{Ht}) + S_t P^*_{Qt}\,(Q_{Ft+1} - Q_{Ft}) \end{aligned}$$

Using the asset market clearing conditions the current account can also be written as the sum of the trade balance and net asset income:

$$CA_t = \underbrace{S_t i^*_t B_{Ft} - i_t B^*_{Ht} + S_t\left(\frac{V^*_t}{\bar{Q}^*}\right)Q_{Ft} - \left(\frac{V_t}{\bar{Q}}\right)Q^*_{Ht}}_{\text{Net asset income}}$$
$$+\underbrace{\underbrace{V_t + W_t N_t + P_t r^k_t K_{t.}}_{P_t Y_t} - P_t I_{t.} - P_t C_t}_{\text{Trade balance}}$$

The net foreign asset position of the Home country (at the end of period t) is:

$$NFA_{t+1} = S_t B_{Ft+1} - B^*_{Ht+1} + S_t P^*_{Qt} Q_{Ft+1} - P_{Qt} Q^*_{Ht+1}$$

The dynamics in the net foreign asset position are:

$$
\begin{aligned}
NFA_{t+1} - NFA_t &= S_t B_{Ft+1} - B^*_{Ht+1} + S_t P^*_{Qt} Q_{Ft+1} - P_{Qt} Q^*_{Ht+1} \\
&\quad - \left[S_{t-1} B_{Ft} - B^*_{Ht} + S_{t-1} P^*_{Qt-1} Q_{Ft} - P_{Qt-1} Q^*_{Ht}\right]
\end{aligned}
$$

Using the asset market clearing conditions this can also be written as the sum of the current account, changes in local currency asset prices, and exchange rate valuation effects (note that the asset position that Home consumers accumulate today until the end of the period depends on today's current account and the valuation changes to last period and therefore price changes with respect to last period):

$$
\begin{aligned}
NFA_{t+1} - NFA_t &= CA_t \\
&\quad \underbrace{-\left(P_{Qt} - P_{Qt-1}\right) Q^*_{Ht} + \left(P^*_{Qt} - P^*_{Qt-1}\right) S_{t-1} Q_{Ft}}_{\text{Changes in local currency asset prices}} \\
&\quad \underbrace{+\left(S_t - S_{t-1}\right) B_{Ft} + \left(S_t - S_{t-1}\right) P^*_{Qt} Q_{Ft}}_{\text{Exchange rate valuation}}
\end{aligned}
$$

If the linearized version of the current account, the net foreign asset positions and their subcomponents are defined in terms of a stationary variable such as output, i.e. $\widehat{ca}_t \equiv \frac{d\frac{CA_t}{P_t}}{\bar{Y}}$, $\widehat{nai}_t \approx \frac{d\frac{NAI_t}{P_t}}{\bar{Y}}$, $\widehat{tb}_t \approx \frac{d\frac{TB_t}{P_t}}{\bar{Y}}$, $\widehat{nfa}_{t+1} \approx \frac{d\left(\frac{NFA_{t+1}}{P_t}\right)}{\bar{Y}}$, $\widehat{\Delta nfa}_{t+1} \approx \frac{d\left(\frac{NFA_{t+1}}{P_t} - \frac{NFA_{t-1}}{P_{t-1}}\right)}{\bar{Y}}$, $\widehat{clcap}_t \equiv \frac{d\frac{CLCAP_t}{P_t}}{\bar{Y}}$, and $\widehat{ev}_t \equiv \frac{d\frac{EV_t}{P_t}}{\bar{Y}}$, then they can be derived as:

$$
\begin{aligned}
\widehat{ca}_t &\approx \hat{b}_{Ht+1} - \hat{b}_{Ht} + \overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\left(\hat{b}_{Ft+1} - \hat{b}_{Ft}\right) \\
&\quad + \frac{\bar{P}_Q}{\bar{P}}\left(\hat{Q}_{Ht+1} - \hat{Q}_{Ht}\right) + \frac{\bar{P}^*_Q}{\bar{P}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\left(\hat{Q}_{Ft+1} - \hat{Q}_{Ft}\right)
\end{aligned}
$$

and

$$\widehat{nai}_t \approx \widehat{ca}_t - \widehat{tb}_t$$

where[49]

$$
\begin{aligned}
\widehat{tb}_t &= \alpha\gamma \left(\begin{array}{c} \frac{\left(\frac{SP^*}{P}\right)\left(\frac{\bar{P}^*_{HT}}{\bar{P}^*}\right)^{1-\phi}\left(\frac{\bar{P}^*_T}{\bar{P}^*}\right)^{\phi-\omega}\left(\bar{C}^*+\bar{I}^*\right)}{\bar{Y}} \\ \left(\begin{array}{c} \widehat{rer}_t + (1-\phi)\hat{p}^*_{HTt} + (\phi-\omega)\,\hat{p}^*_{Tt} \\ +\frac{\bar{C}^*}{\left(\bar{C}^*+\bar{I}^*\right)}\hat{c}^*_t + \frac{\bar{I}^*}{\left(\bar{C}^*+\bar{I}^*\right)}\hat{I}^*_t \end{array} \right) \end{array} \right) \\
&\quad -(1-\alpha)\gamma \left(\begin{array}{c} \frac{\left(\frac{SP^*}{P}\right)^{-1}\left(\frac{\bar{P}_{FT}}{\bar{P}}\right)^{1-\phi}\left(\frac{\bar{P}_T}{\bar{P}}\right)^{\phi-\omega}\left(\bar{C}+\bar{I}\right)}{\bar{Y}} \\ \left(\begin{array}{c} -\widehat{rer}_t + (1-\phi)\,\hat{p}_{FTt} + (\phi-\omega)\,\hat{p}_{Tt} \\ +\frac{\bar{C}}{\left(\bar{C}+\bar{I}\right)}\hat{c}_t + \frac{\bar{I}}{\left(\bar{C}+\bar{I}\right)}\hat{I}_t \end{array} \right) \end{array} \right)
\end{aligned}
$$

and

$$
\begin{aligned}
\widehat{nfa}_{t+1} &\approx \frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{rer}_t + \overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\hat{b}_{Ft+1} - \hat{b}^*_{Ht+1} \\
&\quad + \frac{\bar{P}^*_Q}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{rer}_t + \frac{\bar{P}^*_Q}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\hat{p}^*_{Qt} + \frac{\bar{P}^*_Q}{\bar{P}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\hat{Q}_{Ft+1} \\
&\quad - \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}^*_H}{\bar{Y}}\hat{p}_{Qt} - \frac{\bar{P}_Q}{\bar{P}}\hat{Q}^*_{Ht+1}
\end{aligned}
$$

and

$$
\widehat{\Delta nfa}_{t+1} \approx \widehat{nfa}_{t+1} - \widehat{nfa}_t
$$

or

$$
\begin{aligned}
\widehat{\Delta nfa}_{t+1} &\approx \underbrace{\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\hat{b}_{Ft+1} - \overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\hat{b}_{Ft} + \hat{b}_{Ht+1} - \hat{b}_{Ht}}_{\text{CA...}} \\
&\quad \underbrace{+\frac{\bar{P}^*_Q}{\bar{P}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\hat{Q}_{Ft+1} - \frac{\bar{P}^*_Q}{\bar{P}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\hat{Q}_{Ft} - \frac{\bar{P}_Q}{\bar{P}}\hat{Q}^*_{Ht+1} + \frac{\bar{P}_Q}{\bar{P}}\hat{Q}^*_{Ht}}_{\text{...CA}} \\
&\quad \underbrace{+\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\left(\widehat{\Delta s}_t - \widehat{\pi}_t + \widehat{\pi}^*_t\right) + \overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\frac{\bar{P}^*_Q}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\widehat{\Delta s}_t}_{\text{EV}} \\
&\quad \underbrace{+\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\frac{\bar{P}^*_Q}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\widehat{rer}_t - \overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\frac{\bar{P}^*_Q}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\widehat{rer}_{t-1} - \overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\frac{\bar{P}^*_Q}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\widehat{\Delta s}_t}_{\Delta\text{LCAP...}} \\
&\quad \underbrace{+\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\frac{\bar{P}^*_Q}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\hat{p}^*_{Qt} - \overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\frac{\bar{P}^*_Q}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\hat{p}^*_{Qt-1} - \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}^*_H}{\bar{Y}}\hat{p}_{Qt} + \frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}^*_H}{\bar{Y}}\hat{p}_{Qt-1}}_{\text{...}\Delta\text{LCAP}}
\end{aligned}
$$

[49] Note that the log-linearized version of real exports in terms of Home currency is $\widehat{exp}_t = \widehat{rer}_t + (1-\phi)\,\hat{p}^*_{HTt} + (\phi-\omega)\,\hat{p}^*_{Tt} + \frac{\bar{C}^*}{\left(\bar{C}^*+\bar{I}^*\right)}\hat{c}^*_t + \frac{\bar{I}^*}{\left(\bar{C}^*+\bar{I}^*\right)}\hat{I}^*_t$, while the log-linearized version of real imports in terms of Home currency is $\widehat{imp}_t = (1-\phi)\,\hat{p}_{FTt} + (\phi-\omega)\,\hat{p}_{Tt} + \frac{\bar{C}}{\left(\bar{C}+\bar{I}\right)}\hat{c}_t + \frac{\bar{I}}{\left(\bar{C}+\bar{I}\right)}\hat{I}$.

where

$$
\begin{aligned}
\widehat{clcap}_t \approx & -\frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H^*}{\bar{Y}}\hat{p}_{Qt}+\frac{\bar{P}_Q}{\bar{P}}\frac{\bar{Q}_H^*}{\bar{Y}}\hat{p}_{Qt-1} \\
& +\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{p_{Q}^*}_t-\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{\Delta s}_t+\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{rer}_t \\
& -\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{rer}_{t-1}-\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{p_{Q}^*}_{t-1}
\end{aligned}
$$

and

$$
\widehat{ev}_t \approx \frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{\Delta s}_t-\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{\pi}_t+\frac{\bar{B}_F}{\bar{P}^*\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{\pi}_t^*+\frac{\bar{P}_Q^*}{\bar{P}^*}\frac{\bar{Q}_F}{\bar{Y}^*}\overline{RER}\frac{\bar{Y}^*}{\bar{Y}}\widehat{\Delta s}_t
$$

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