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**Utility functions, fiscal shocks and the open  
economy**

In the search of a positive consumption multiplier

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**DISCUSSION PAPERS**

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# Utility functions, fiscal shocks and the open economy\*

## *In the search of a positive consumption multiplier*

Philipp Wegmueller\*\*

### Abstract

This paper analyzes the dynamic effects of a fiscal policy shock and its transmission mechanism in a small open economy and compares the responses under different specifications of the utility function. The traditional Mundell-Flemming model tells that fiscal policy is more effective under a peg than under a float. This result is not confirmed for a baseline small open economy model with *separable preferences*. The present paper offers a survey of non-separable utility found in the literature on fiscal policy shocks and compares their implications for the transmission mechanism. The aim is to overturn the negative wealth effect of an increase in government spending, which causes a decrease in private consumption under the baseline separable utility function. Using a plausible calibration of the model, I find that if the complementarity between consumption and hours worked is large enough, then the response of private consumption is likely to be positive, although the assumptions have to be strong. This result holds for any specification of exchange rate regime.

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# 1 Introduction

Is the response of private consumption to a fiscal policy shock positive in an open economy framework? The debate surrounding this question has received a renewed attention in empirical studies based on vector autoregressions (VAR). Most empirical studies applying a VAR based on a sluggish reaction of output, private consumption and other key variables to fiscal policy shocks<sup>1</sup> find a significant positive response of private consumption. The recent study by [Mountford and Uhlig \(2009\)](#) applying the approach of a fixed effects VAR with sign-restrictions finds that *“private consumption does not fall in response to an unexpected increase in government spending. However, in contrast to the other studies, we do not find that consumption rises strongly.”* In contrast to the effects of fiscal shocks to output and consumption, the effect of government spending shocks on the external sector has received considerably little attention. Notable exceptions are the studies by [Ilzetzi, Mendoza, and Végh \(2013\)](#), [Ravn, Schmitt-Grohé, and Uribe \(2012\)](#) and [Monacelli and Perotti \(2006\)](#), who find significant positive effects on consumption and apart a real depreciation of the exchange rate. These findings stand in contrast with the Mundel-Flemming model and call for a theoretic DSGE model with nominal rigidities and a well specified household sector.

The present paper has the aim to fill this gap and investigates the transmission mechanism of a fiscal policy shock in a DSGE small open economy framework by numerical simulations. A similar model approach has been followed by [Monacelli and Perotti \(2006\)](#), who show that a baseline small open economy model featuring non-separable preferences is able to generate a positive consumption response and induces a real exchange rate depreciation. The present paper is an extension to the existing literature on responses of fiscal policy shocks as it compares different specifications of utility functions frequently applied in the business cycle literature. I will show that the results obtained in [Monacelli and Perotti \(2006\)](#) cannot be generalized easily.

This paper demonstrates that a positive response of private consumption to an increase in government spending can be explained by adopting a utility function that satisfies the following conditions: First it is necessary that the utility function has to be additively non-separable in consumption and hours worked, so that households have the desire to consume more when they work more. Second, in order to obtain a positive response, the complementarity must be strong enough to offset the wealth effect implied by a fiscal spending shock. Particularly, the standard representative agent model with separable preferences predicts that as the government increases its spending, it withdraws resources from the private sector, reducing thereby private wealth. As households expect the government to increase the taxes to balance its budget, they increase labor supply through diminished demand for leisure, which decreases consequently the real wage and drives down private consumption.

In recent studies, [Linnemann \(2006\)](#), [Bilbiie \(2009\)](#), [Ravn, Schmitt-Grohé, and Uribe \(2012\)](#) as well as [Hall \(2009\)](#) put focus on the consumption response of a government spending shock in a closed economy. While these studies focus on the specification of the household sector, another approach

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<sup>1</sup>For example in [Blanchard and Perotti \(2002\)](#), [Fatas and Mihov \(2001\)](#) and [Gali, López-Salido, and Vallés \(2007\)](#)

that deserves to be mentioned has been successful in overcoming the negative wealth effect to a government spending shock. [Gali, López-Salido, and Vallés \(2007\)](#) show that with the inclusion of a fraction of consumers that cannot participate in international financial asset markets a positive response of consumption can be obtained. Notwithstanding the Rule-of-Thumb consumers contradict the rational expectations hypothesis and offset Ricardian equivalence, which is why I will not include such a consumer type in the present paper.

Furthermore, this paper confronts various utility functions with specific exchange rate regimes in order to analyze the transmission mechanism induced. [Corsetti, Meier, and Müller \(2012\)](#) and [Ilzetki, Mendoza, and Végh \(2013\)](#) perform empirical investigations of fiscal shocks under different exchange rates. While the former don't find a significant difference of the consumption response under a peg and float, the latter show a significantly higher consumption response under a peg. By extending the framework to an open economy, the transmission mechanism is amplified to have effects on the real exchange rate, as consumers are now able to buy goods in the domestic as well as in the foreign economy. The starting point for an analysis of open economy models is usually the textbook version of the Mundell-Flemming model. The model predicts that in a small open economy with the foreign interest rate and foreign prices given exogenously, an expansion in government consumption has a large multiplier effect on output under fixed exchange rates, whereas with floating exchange rates it just crowds out net exports one-to-one. The numerical simulations for the various utility functions under a floating exchange rate regime show, that the traditional wisdom of a total crowding-out of output is not supported. Nevertheless, the relative response of output and consumption are higher under a peg than under a float, reinforcing the result of the Mundell-Flemming model.

The remainder of the paper is structured as follows: in section 2, I present the basic structure of the model and its calibration. Section 3 outlines five types of utility functions and their ability to overturn the wealth effect. In section 4 the numerical simulations are performed under different exchange rate regimes, and section 5 extends the model with habits and another utility specification. Section 6 concludes.

## 2 Canonical model

I am considering an economic framework which is a variant of the basic small open economy studied in the paper by [Gali and Monacelli \(2005\)](#).<sup>2</sup> The present model implements nominal frictions with staggered price setting à la [Calvo \(1983\)](#) and portfolio adjustment costs. On the real side, the presented model deviates from the standard literature by imposing a variety of specifications of the utility function, or by the possibility of habit formation (see subsection 5.1). To keep things simple, I will stick to a general notation of the utility function in a first step and come back to the specific forms in the next section.

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<sup>2</sup>The theoretical model builds in large parts upon the Suite of Models for Dynare by F.Collard, H.Dellas and B.Diba, University of Bern, 2011

## 2.1 Households

The economy is composed of a continuum of infinitely-lived households, whose total is normalized to unity, and of a continuum of firms, who are owned by the households. The household in the representative domestic economy seeks to maximize lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t) \quad (2.1)$$

with  $0 \leq \beta \leq 1$  being a constant time discount factor.  $h_t$  denotes hours of work and  $c_t$  stands for consumption by each household. Period-by-period the households face a budget constraint given by

$$B_t^h + e_t B_t^f + P_t c_t + P_t i_t = R_{t-1} B_{t-1} + e_t R_{t-1}^* B_{t-1}^f + P_t w_t h_t + P_t z_t k_t - P_t \tau_t - P_t \frac{\chi}{2} (e_t B_t^f)^2, \quad (2.2)$$

with  $B_t^h, B_t^f$  being domestic and foreign currency bonds and  $R_t$  the interest received thereof. It is costly to hold foreign currency bonds as indicated by  $\frac{\chi}{2} (e_t B_t^f)^2$ . The foreigners do not hold any domestic bonds so aggregate  $B_t^h$  equals 0.  $P_t$  is the nominal price of the domestic final good and  $e_t$  the nominal exchange rate, i.e. the value of domestic currency in terms of foreign currency;  $w_t$  is the real wage;  $k_t$  the amount of physical capital held by households and leased to the firms for rental rate  $z_t$ . Finally,  $\tau_t$  is a lump-sum tax paid to the government and used to finance government consumption.

Physical capital is assumed to evolve according to

$$k_{t+1} = i_t \left( 1 - \frac{\varphi_k}{2} \left( \frac{i_t}{k_t} - \delta \right)^2 \right) + (1 - \delta) k_t, \quad (2.3)$$

and the parameter  $\varphi_k$  implies that capital accumulation is costly. Notice that  $\delta \in [0, 1]$  is the depreciation rate of capital. In the steady state, adjustment costs of capital are zero ( $\varphi_k$  equals 0).

The households choose a sequence for  $\{c_t, h_t, B_t^h, B_t^f, k_t$  and  $i_t\}$ , which yields the following first order conditions:

$$U_{c,t} = \Lambda_t P_t, \quad (2.4)$$

$$-U_{h,t} = \Lambda_t P_t w_t, \quad (2.5)$$

$$\Lambda_t P_t = Q_t \left( 1 - \varphi_k \left( \frac{i_t}{k_t} - \delta \right) \right), \quad (2.6)$$

$$\Lambda_t = \beta R_t \mathbb{E}_t \Lambda_{t+1}, \quad (2.7)$$

$$\Lambda_t (1 + \chi e_t B_t^f) = \beta R_t^* \mathbb{E}_t \frac{e_{t+1}}{e_t} \Lambda_{t+1}, \quad (2.8)$$

$$Q_t = \beta \mathbb{E}_t \left[ \Lambda_{t+1} P_{t+1} z_{t+1} + Q_{t+1} \left( 1 - \delta + \frac{\varphi_k}{2} \left( \left( \frac{i_{t+1}}{k_{t+1}} \right)^2 - \delta^2 \right) \right) \right], \quad (2.9)$$

where  $\Lambda_t$  and  $Q_t$  denote the Lagrange multipliers of the first and second constraint respectively.

## 2.2 Final goods firms

The economy is comprised of two types of firms, the first type producing final goods and the second intermediate goods. The retailer firm combines foreign and domestic goods to produce a non-tradable final good. It determines its optimal production plans by maximizing its profit

$$\max_{\{x_t^d, x_t^f\}} P_t y_t - P_{x,t} x_t^d - e_t P_{x,t}^* x_t^f, \quad (2.10)$$

where  $P_{x,t}$  and  $P_{x,t}^*$  denote the price of the domestic and foreign good respectively, denominated in terms of the currency of the *seller*. Particularly this means that I assume producer currency pricing and purchasing power parity for traded goods, i.e.  $P_{F,t} = e_t P_{x,t}^*$ , where a  $\star$  denotes foreign currency price. The final good production function is described by the following constant elasticities of scale (CES) function

$$y_t = \left( \omega^{\frac{1}{1-\rho}} x_t^{d\rho} + (1-\omega)^{\frac{1}{1-\rho}} x_t^{f\rho} \right)^{\frac{1}{\rho}}. \quad (2.11)$$

The elasticity of substitution between domestic and foreign goods is measured by parameter  $\rho \in (-\infty, 1)$ . Parameter  $\omega \in (0, 1)$  is inversely related to the degree of home bias in preferences and is thus a natural index of openness. As shown in the appendix (A.1), the optimal behavior of the retailer gives rise to the demand for the domestic and foreign goods

$$x_t^d = \left( \frac{P_{x,t}}{P_t} \right)^{\frac{1}{\rho-1}} \omega y_t \quad \text{and} \quad x_t^f = \left( \frac{e_t P_{x,t}^*}{P_t} \right)^{\frac{1}{\rho-1}} (1-\omega) y_t, \quad (2.12)$$

Foreign firms behave symmetrically to the domestic firms, such that their demand function for the domestic good reads

$$x_t^{d\star}(i) = \left( \frac{P_{xt}(i)}{e_t P_{xt}^*} \right)^{-\theta} x_t^{d\star}. \quad (2.13)$$

Plugging these demand functions in profits and using free entry in the final good sector, we get the following general price indexes:

$$P_{xt} = \left( \int_0^1 P_{xt}(i)^{1-\theta} di \right)^{\frac{1}{1-\theta}}, \quad (2.14)$$

$$P_t = \left( \omega P_{xt}^{\frac{\rho}{\rho-1}} + (1-\omega) (e_t P_{xt}^*)^{\frac{\rho}{\rho-1}} \right)^{\frac{\rho-1}{\rho}} \quad (2.15)$$

The latter equation (2.15) is the consumer price index (CPI).

### 2.3 Intermediate goods firms

The final goods firms buy the goods from intermediaries which all have monopoly power for the good they produce. Each domestic intermediate goods firm  $i \in [0, 1]$  producing an intermediate good  $x(i)$ , using physical capital  $k(i)$  and labor  $h(i)$  as input factors, faces a constant returns-to-scale production function of the form:

$$x_t(i) = a_t k_t(i)^\alpha h_t(i)^{1-\alpha} \quad (2.16)$$

where  $a_t$  is an exogenous stationary stochastic technology innovation to be specified latter on. The intermediate goods firms get their inputs of production from perfectly competitive markets, meaning that their production plan is determined by minimizing their real cost subject to (2.16). Minimized real total costs are then given by  $s_t x_t(i)$  where the real marginal cost,  $s_t$ , is given by

$$s_t = \frac{z_t^\alpha w_t^{1-\alpha}}{\zeta a_t}$$

with  $\zeta = \alpha^\alpha (1 - \alpha)^{1-\alpha}$ , and it therefor follows that  $w_t = (1 - \alpha) s_t \frac{p_{x,t} x_t}{h_t}$  and  $z_t = \alpha \frac{p_{x,t} x_t}{k_t}$

The price setting mechanism is the same as for a closed economy and is explained in detail in the appendix (A.2). I assume that firms set prices in a staggered fashion à la Calvo (1983). Firms adjust their prices infrequently, i.e. in each period there is a constant probability  $1 - \zeta$  that the firm will be able to adjust its price and a fraction  $\zeta$  to keep the price unchanged. The firms fix their price for a random number of periods.

From equation (2.16) and (A.24) I obtain an expression for aggregate output,  $\Delta_t x_t = a_t k_t^\alpha h_t^{1-\alpha}$

### 2.4 Monetary policy

I will study the transmission mechanism of fiscal policy shocks under various specifications of monetary policy. The monetary policy itself depends on the way the exchange rate regime is characterized. Under flexible exchange rates, the central bank pursues an inflation and output stabilization target by setting the nominal short-term interest rate, given the policy by a typical Taylor-type rule:

$$\log(R_t) = \rho_r \log(R_{t-1}) + (1 - \rho) (\log(\bar{R}) + \gamma_\pi (\log(\pi_t) - \log(\bar{\pi})) + \gamma_y (\log(y_t) - \log(\bar{y}))) \quad (2.17)$$

where  $\rho_r$  is the persistence of the rule and  $\gamma_\pi, \gamma_y$  are the weights that the central bank assigns to the inflation rate  $\pi_t$  and output  $y_t$  to get as close to the targets  $\bar{\pi}$  and  $\bar{y}$ . In this case the nominal exchange rate is free to adjust in accordance with the equilibrium conditions of the model. Besides the policy of a Taylor rule, among others the central bank can also follow the policy of:

- stabilizing completely the CPI ( $\pi_t = P_t / P_{t-1} = 1$ )
- stabilizing the domestic price inflation ( $\pi_{x,t} = P_{x,t} / P_{x,t-1} = 1$ )

- or by giving the stabilization of exchange rate fluctuations a weight in the Taylor rule.

Under an exchange rate peg, the monetary authority is required to maintain the exchange rate stable at its steady state level. I will implement this by requiring that in equilibrium,  $\Delta_t^e = e_t/e_{t-1} = 1$ . For the government to fix the exchange rate, it must stand ready to buy or sell domestic currency to maintain the nominal exchange rate at its level. To do so, the central bank has to adjust its money supply or work with open market operations.

## 2.5 Fiscal policy

The government consumes a domestically produced final good and finances its expenditures by lump-sum taxes. I assume for simplicity that there is no government debt and that the stationary component of government expenditures follows an exogenous stochastic AR(1) process:

$$\log(g_{t+1}) = \rho_g \log(g_t) + (1 - \rho_g) \log(\bar{g}) + \varepsilon_{g,t+1} \quad (2.18)$$

where  $\rho_g$  is the persistence of the shock and  $\varepsilon_{g,t+1}$  is the exogenous shock.

## 2.6 Foreign economy

The behavior of the foreign economy is assumed to be very similar to the one observed domestically. For simplicity and because the foreign economy is assumed to be very large such that domestic shocks do not affect foreign output nor the price level, I model the foreign output and prices as exogenously determined AR(1) processes. Further I assume that the foreign countries internal price level is equal to its CPI, i.e.  $P_{x,t}^* = P_t^*$ . The foreign household's saving behavior is the same as in the domestic economy (absent preference shocks), such that the foreign nominal interest rate is given by

$$y_t^{*-1/\sigma} = \beta R_t^* \mathbb{E}_t y_{t+1}^{*-1/\sigma} \frac{P_t^*}{P_{t+1}^*} \quad (2.19)$$

where it is assumed that foreign households have a standard separable utility function<sup>3</sup> and where  $c^* = y^*$ .

## 2.7 Calibration

Before turning to the evaluation of different household preferences and the transmission of fiscal policy shocks under different exchange rate regimes, it is instructive to characterize the transmission mechanism under the baseline model outlined in this section and assuming a monetary policy of floating exchange rates. As I am mostly interested in investigating the effects of fiscal policy for a generic rather than a specific real world economy, I use parameter values that are commonly used in the literature.

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<sup>3</sup> $U = \frac{c^{1-\sigma}}{1-\sigma} - \frac{\psi}{1+\nu} h^{1+\nu}$



Table 1: Benchmark Parameters

Parameter	Value	Description
$\beta$	0.99	Subjective discount factor (quarterly)
$\delta$	0.025	Depreciation rate
$g/y$	0.200	Government share
$wh/y$	0.600	Labor share
$h$	1/3	Hours in steady state
$\omega$	0.850	Degree of openness
$\rho$	1/3	Substitutability between domestic and foreign good
$\chi$	0.010	Portfolio adjustment cost
$\varphi_k$	2.000	Capital adjustment
$\xi$	1-1/4	Price stickiness
$\theta$	6.000	Elasticity of substitution between differentiated goods
$\rho_r$	0.800	Persistence in interest rate rule
$\gamma_\pi$	1.500	Weight on inflation target
$\gamma_y$	0.100	Weight on output target
$\rho_g$	0.970	Fiscal shock: persistence
$\sigma_{\epsilon,g}$	0.008	Standard deviation of fiscal policy shock

The benchmark calibration of my baseline model is given in Table 1.<sup>4</sup> Note that the calibration of household preferences will be specified in the next section, as the corresponding parameters  $\sigma$ ,  $\nu$  and  $\psi$  depend crucially on the form of preferences assumed. Time is measured in quarters. The discount factor  $\beta$  is then set at a value which is consistent with a riskless interest rate of 4% per year. The parameter  $\xi$  for price stickiness implies that on average 75% of the prices adjust within one year. Also note that  $\theta$  equals 6 which leads to a constant steady state markup of 1.2. Government share in output is assumed to be 20% and we assume that the shock of fiscal policy is highly persistent with  $\rho_g$  equals 0.970. In the zero-inflation steady state these specifications lead to a consumption share  $c/y$  of 63% and a share of investment  $i/y$  of 17%.

Finally, if the monetary policy is given by a Taylor rule, then the central bank sets  $\gamma_\pi$  equals 1.5 and  $\gamma_y$  equals 0.1. By doing so, the central bank puts a high weight on the stabilization of inflation and a relatively low weight on the stabilization of output.

In what follows, I will use the canonical model outlined in this section and analyze, how the specification of the utility function and household preferences matters for the transmission mechanism of fiscal policy shocks.

<sup>4</sup>The steady state of the economic framework outlined above is outlined in the appendix (B.1).

### 3 Household preferences

In this section, I will analyze in detail various specifications of household preferences which appear frequently in the business cycle literature. Much of the literature concerning the transmission mechanism of fiscal policy shocks focuses on closed economy models. I will use the theoretical insights from the closed economy and apply them to the small open economy. The baseline assumption of additively separable preferences as in [Gali and Monacelli \(2005\)](#) are a good starting point and I will show the wealth effect, particularly the negative relation between hours worked and private consumption. Then I will depart from the assumption of additively separable utility functions and introduce complementarity between hours worked and consumption. There exists a necessary and a sufficient condition for which the wealth effect is overturned. I show by numerical simulations of the different utility functions and for various parameter values, that the wealth effect is crucial for the transmission mechanism of fiscal policy shocks to private consumption.

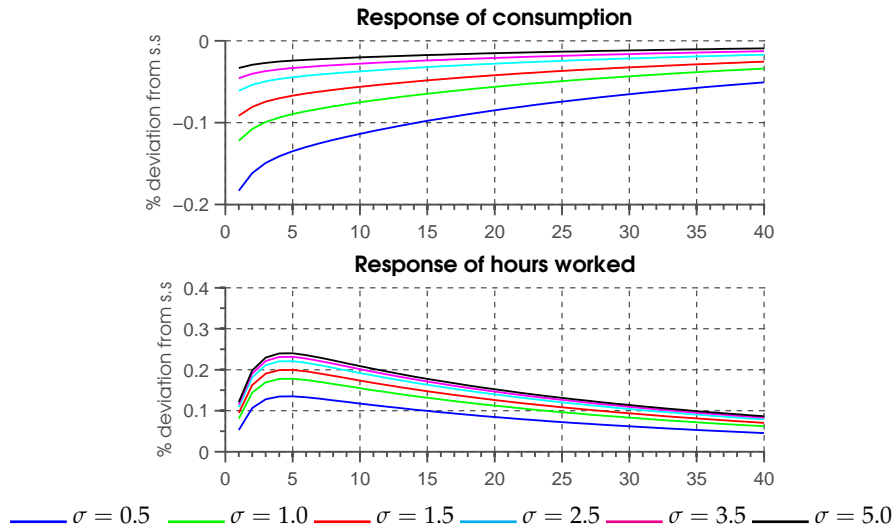
#### 3.1 Separable utility

I will call the model with separable preferences *baseline* because it is the standard case in the business cycle literature and it has some nice features to calculate the steady state and for linearization and simulation. Assume that households have preferences described by the within-period utility function

$$U(c_t, h_t) = \begin{cases} \ln(c_t) - \psi \frac{h_t^{1+v}}{1+v} & \text{if } \sigma = 1, \\ \frac{c_t^{1-\sigma}}{1-\sigma} - \psi \frac{h_t^{1+v}}{1+v} & \text{if } \sigma \neq 1, \end{cases} \quad (3.1)$$

with  $\sigma$  being the inverse of the intertemporal elasticity of substitution in consumption and  $v$  being the inverse of the Frish labor supply elasticity. It can be seen that  $U_c(c_t, h_t) > 0$  and  $U_h(c_t, h_t) < 0$ , but more importantly, it holds that  $U_{c,h}(c_t, h_t) = U_{h,c}(c_t, h_t) = 0$ , i.e. the separability assumption implies that the cross-derivatives are zero.

Figure 1: Baseline model, changing  $\sigma$



By combining equations (2.4) and (2.5), the condition for an efficient labor market is obtained

$$\psi c_t^\sigma h_t^\nu = w_t = (1 - \alpha) s_t \frac{p_{x,t} x_t}{h_t}. \quad (3.2)$$

From this condition the negative relation between hours worked and consumption is clearly visible. If a shock to government spending achieves an increase in hours worked, and thus the real wage falls, then for both sides of the equation to be equal,  $c_t^\sigma$  has to fall by more than  $w_t$  does. The dynamic effects of this baseline specification in equilibrium will be shown in section 4.1. The corresponding steady state conditions for  $\lambda$  and  $\psi$  come from equation (2.4), where I obtain a simple expression  $c^{-\sigma} = \lambda$ , and from equation (2.5), which can be solved for  $\psi = (1 - \alpha) \lambda y s / (h^{1+\nu})$ .

As mentioned by Hall (2009), changes in the parameter  $\sigma$  can alleviate but not avoid the property of consumption to decline with higher government purchases. For a low  $\sigma$  the decline is larger as for a high  $\sigma$ . Figure (1) shows the numerical simulation of the benchmark model for a change in parameter  $\sigma$ . For the small open economy it holds that government spending will crowd-out private consumption for any high values of  $\sigma$  or  $\nu$ . It can be concluded that for additively non-separable utility functions the wealth effect is also present in a model of a small open economy, and the intuition behind this outcome is the same as for the closed economy case.

### 3.2 Non-separability

An alternative to the preference relation that is additively separable is to introduce complementarity of consumption and hours worked. There are several different ways, this complementarity can be introduced and how the non-separable utility function can be specified. Most importantly, what all functions have in common is that the above stated condition  $U_{c,h}(c_t, h_t) = U_{h,c}(c_t, h_t) = 0$  does not hold anymore. The preference specifications outlined below pertain to a family of kernels that satisfy balanced growth conditions as mentioned in King, Plosser, and Rebelo (1988). For  $\sigma > 1$  the utility function is more curved than in the log-case, and  $U_{c,h} > 0$ , such that when a person moves from non-work to work or when hours worked increase, the marginal utility of consumption, and therefore consumption increases. In the case that  $\sigma < 1$  we get that  $U_{c,h} < 0$  and a raise in hours worked decreases marginal utility of consumption.

#### Preferences as in Hall (2009)

In a first step I will set out a general non-separable preference function as in Hall (2009) which is an ad-hoc variation of the separable case described above

$$U(c_t, h_t) = \frac{c_t^{1-\sigma}}{1-\sigma} - \varphi c_t^{1-\sigma} h_t^{1+\nu} - \psi \frac{h_t^{1+\nu}}{1+\nu}. \quad (3.3)$$

Here positive values of  $\varphi$  introduce an increase in the marginal utility of consumption that depends on hours of work. The labor market condition is then given by

$$h_t^{1+\nu} \left[ -\varphi(1+\nu)c_t^{1-\sigma} - \psi \right] = w_t c_t^{-\sigma} \left[ 1 - \varphi(1-\sigma)h_t^{1+\nu} \right]. \quad (3.4)$$

With this type of specification it is easy to see that for  $\sigma > 1$  it holds that

$$U_{c,h} = -\varphi(1-\sigma)c_t^{-\sigma}(1+\nu)h_t^\nu > 0. \quad (3.5)$$

For the closed economy it has been shown by [Linnemann \(2006\)](#) and [Bilbiie \(2009\)](#) that the condition  $U_{c,h} > 0$  is only a necessary but not a sufficient condition to be able to explain the crowding-in of private consumption in response to a fiscal policy shock. The sufficient condition has to link employment with the marginal utility of consumption and this link has to be strong enough to overturn the wealth effect and render positive impulse responses. To obtain a general expression for labor supply, in a first step the households efficiency conditions for consumption and employment choice (equations (2.4) and (2.5)) can be combined. Then the real wage can be eliminated through the marginal product of labor and by using the time constraint. Linearizing this expression around a constant steady state yields the following expression<sup>5</sup>

$$\alpha \hat{k}_t + \left[ \tilde{\xi}_h \left( \frac{h}{1-h} \right) - \alpha \right] \hat{n}_t = \tilde{\xi}_c \hat{c}_t, \quad (3.6)$$

with  $\tilde{\xi}_h = \left( \frac{U_{ll}(1-h)}{U_l} - \frac{U_{cl}(1-h)}{U_c} \right)$  and  $\tilde{\xi}_c = \left( \frac{U_{lc}}{U_l} - \frac{U_{cc}}{U_c} \right)$ . Given that the capital stock  $\hat{k}_t$  is a predetermined variable and is thus not affected on impact by a fiscal policy shock, equation (3.6) traces out an implicit relation between hours worked and consumption. Particularly, the sufficient condition for a shock to government purchases to have a positive effect on consumption is fulfilled if and only if  $\left[ \tilde{\xi}_h \left( \frac{h}{1-h} \right) - \alpha \right] > 0$ . With this condition given, I am now able to state for any specification of utility function what parameter values have to be assigned in order to get a positive consumption response.

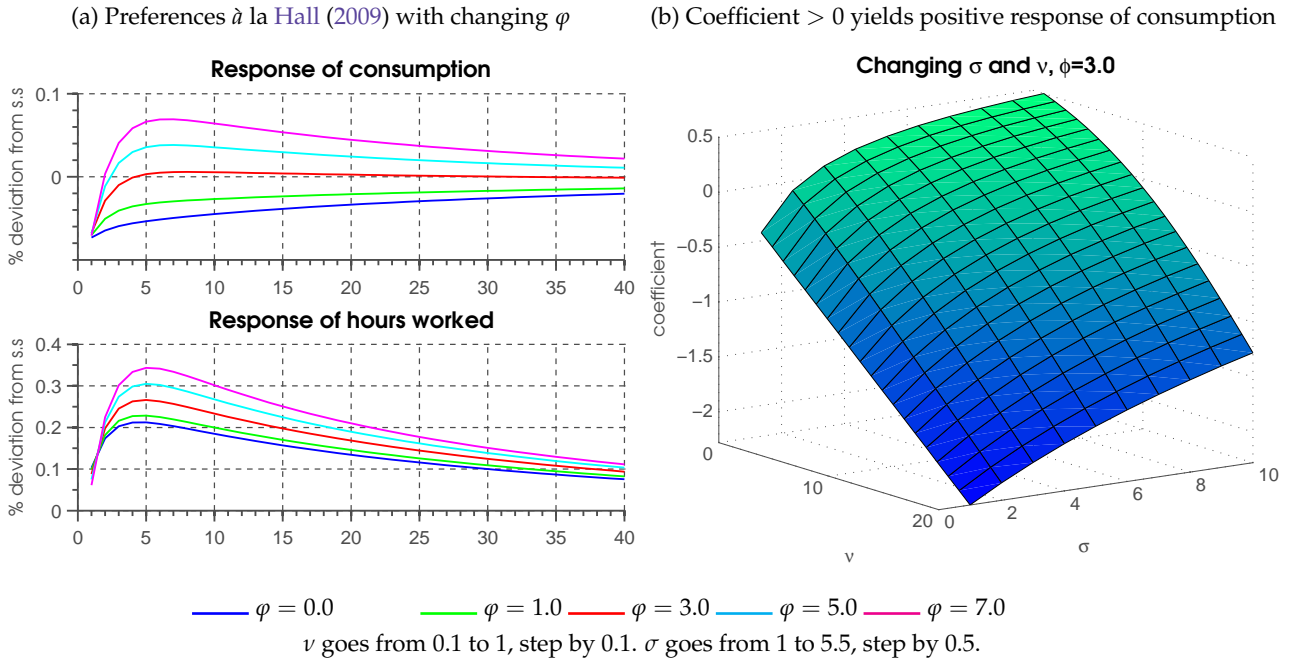
First, it is noteworthy to see that under the case of a separable utility function it holds that  $U_c > 0, U_h < 0$ .<sup>6</sup> Neither the necessary nor the sufficient condition are satisfied for this case, which leads to the conclusion that for neither value of  $\sigma$  nor  $\nu$  the response will be positive. For the form of preferences presented by [Hall \(2009\)](#), the point made by [Linnemann \(2006\)](#) shows exactly that complementarity needs to be strong enough. Complementarity is introduced through the parameter  $\varphi$ . It is straightforward that when  $\varphi$  equals 0 we are back in the separable framework.

A numerical simulation with the calibrated benchmark model and a preference specification according to [Hall \(2009\)](#) where  $\sigma$  equals 2.0,  $\nu$  equals 0.1 and  $\varphi$  equals 1.0 still leads to a negative response of private consumption (see Figure 2a). Hence the complementarity is not strong enough at unity. As shown in Figure 2b, complementarity needs to be unjustifiably high in order to return a positive response. It can be seen that if  $\nu$  is held constant, then a positive response is more likely to

<sup>5</sup>see Appendix C for details

<sup>6</sup>Together with  $U_{c,h}(c_t, h_t) = U_{h,c}(c_t, h_t) = 0$ .

Figure 2: Hall Preferences and Complementarity



be obtained for high values of  $\sigma$ . In Figure 2a the response becomes positive for a value of  $\varphi > 3$ , and this can be validated with Figure 2b, where the coefficient is slightly positive (0.1398).<sup>7</sup>

### Preferences as in Basu and Kimball (2002)

Another way of introducing complementarity to households preferences is proposed by Basu and Kimball (2002). They question the approach of assuming an additively separable utility function because maintaining it leads to an overestimation of the intertemporal elasticities of substitution in consumption which would make the income effect of a permanent increase in wages much stronger than the substitution effect. In contrast, empirical evidence on long-run labor supply suggests that both effects are approximately equal. They further recognize that the assumption of additively separable utility functions has been popular in the literature because of its simplicity.

The form of utility introduced in their paper is similar to the one in Linnemann (2006) and López-Salido and Rabanal (2006). It reads

$$U(c_t, h_t) = \frac{(c_t^\gamma (1 - h_t)^{1-\gamma})^{1-\sigma}}{1 - \sigma}. \quad (3.7)$$

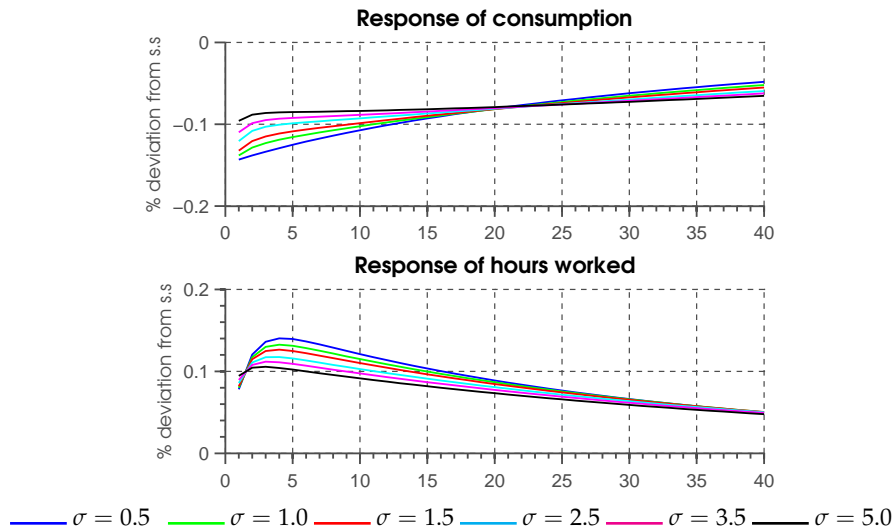
In this framework  $\sigma$  represents the relative risk aversion while  $0 < \gamma < 1$  is the weight the household puts on consumption and leisure respectively. The labor market equilibrium will be given by the expression

$$\frac{c_t}{1 - h_t} \frac{1 - \gamma}{\gamma} = w_t. \quad (3.8)$$

<sup>7</sup>The condition boils down to  $0 < (-\nu - \alpha) - \frac{(1-\sigma)\varphi(1+\nu)h^{1+\nu}}{(1-\varphi(1-\sigma)h^{1+\nu})}$ ; Further, for  $\varphi > 7$  the system is indeterminate.

As pointed out by [Linnemann \(2006\)](#), utility specifications of this form are not able to produce a positive impulse response. The reason thereof is because the composite parameter  $\xi_h = -1 < 0$  for the closed economy, and this also holds for the open economy. This can be underlined by numerical simulations for different values of  $\sigma$ , which show that the consumption response is getting closer to 0 by increasing  $\sigma$ , but remains negative (given in [Figure 3](#)).

Figure 3: Preferences à la [Basu and Kimball \(2002\)](#) with changing  $\sigma$



### Preferences à la [Greenwood, Hercowitz, and Huffman \(1988\)](#)

So far I have only considered utility functions which incorporate the Hicksian wealth effect: As government spending increases, the consumers face a negative wealth shock from higher taxes in the future and as a consequence, they consume less leisure today. Households allocate more hours to work and thus the labor supply curve shifts downward. If there is no wealth effect on labor supply, the curve does not shift, particularly, consumption responds to an increase in hours worked, while real wages do not inherit fluctuations in consumption. These preferences have been introduced by [Greenwood, Hercowitz, and Huffman \(1988\)](#) (GHH) and allow for an arbitrarily small Hicksian wealth effect on labor supply. Similar preferences have also been considered by [Schmitt-Grohe and Uribe \(2003\)](#) and [Jaimovich and Rebelo \(2009\)](#).

I assume the following period utility specification

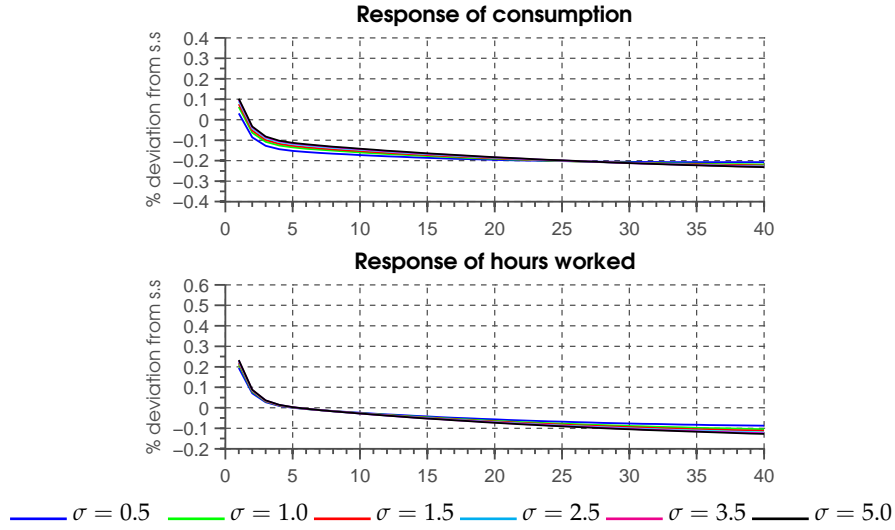
$$U(c_t, h_t) = \frac{1}{1-\sigma} \left[ c_t - \psi \left( \frac{h_t}{1+\nu} \right)^{1+\nu} \right]^{1-\sigma}. \quad (3.9)$$

The parameters assigned have the same interpretation as above, and the labor market equilibrium can be written as

$$\psi \frac{h_t^\nu}{1+\nu} = w_t. \quad (3.10)$$

It can be immediately seen that an increase in real wages has no direct effect on household consumption in this specification. For this kind of preferences one can show that  $U_{c,h} > 0$ , but  $\xi_h < 0$  depends on the values assigned to  $\nu$ . Thus, for low values of labor supply elasticity a positive response of consumption is obtained, which is confirmed by the numerical simulations (see Figure 4).

Figure 4: Preferences à la Greenwood, Hercowitz, and Huffman (1988) with changing  $\sigma$



The parameter on risk aversion only has a small influence on the models dynamics as it does not affect the wealth effect. Crucially, by this type of utility function the transmission mechanism of an expansion in fiscal policy is clearly visible. The wealth effect essentially works through the Frisch labor supply elasticity which in this case is exactly  $\nu$ . The higher this parameter is, the higher is the substitution effect when wages raise, i.e. in log-linear form equation 3.10 reads  $\nu \hat{h}_t = \hat{w}_t$ . When wages increase by 1%, then households allocate their time to hours worked proportionally by  $\nu \hat{h}$ .

### Preferences as in Linnemann (2006)

Finally, Linnemann (2006) imposes an utility function which satisfies the sufficient condition and treats consumption and hours worked as complements. He proposes to assume a period utility function of the following form

$$U(c_t, h_t) = \begin{cases} \ln(c_t) + h_t^{1+\nu} & \text{if } \sigma = 1, \\ \frac{1}{1-\sigma} c_t^{1-\sigma} h_t^{1+\nu} & \text{if } \sigma \neq 1. \end{cases} \quad (3.11)$$

It is straightforward to see that  $U_c > 0$ ,  $U_h < 0$  and  $U_{c,h} < 0$  which satisfies the necessary condition. The sufficient condition is satisfied as  $\xi_h = (1 - h)/h$ . It follows that the labor market clears with

$$\frac{1 + \nu}{\sigma - 1} h_t^{\nu+1} c_t^{1-\sigma} = w_t. \quad (3.12)$$

A result of this type of specification is that the parameters  $\sigma$  and  $\nu$  are not independent anymore. In the appendix (D) I will outline the derivation of the linkage which imposes the following restriction on  $\nu$ :

$$\nu = \frac{\mu_p^{-1}(\sigma - 1)(1 - \alpha)}{\gamma_c} - 1 \quad (3.13)$$

with  $\mu_p^{-1}$  being the inverse of the mark-up and has a value of 1.2 in the steady state,  $\gamma_c$  is the share of steady state consumption on output, and  $\alpha$  is the capital share in production. Hence, all else equal,  $\nu$  is increasing in  $\sigma$ .<sup>8</sup>

Figure 5: Preferences à la Linnemann (2006) and changing  $\sigma$

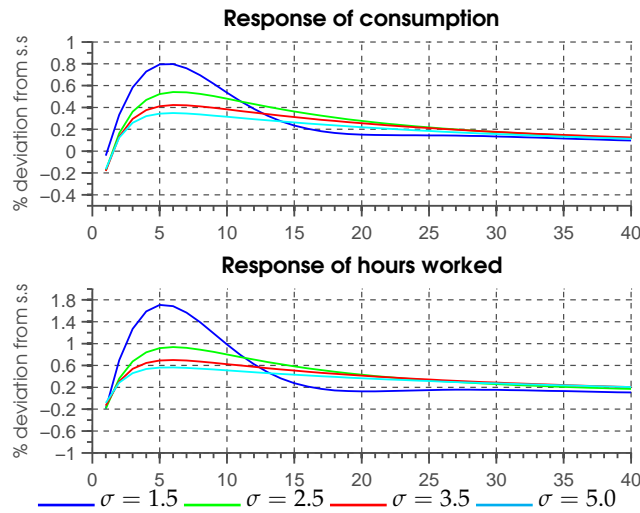


Figure 5 simulates the effect of government spending on consumption with the calibrated parameters from the benchmark model. It is clearly visible that the complementarity between consumption and employment is strong enough to offset the wealth effect and that it entails a positive hump-shaped response of private consumption, i.e. a positive cumulative multiplier. The intuition is that higher employment increases the marginal utility of consumption directly, which induces a higher private consumption all else left equal.

The analysis of the dynamics in Figure 5 shows that with an increasing value of  $\sigma$  the response of private consumption slightly decreases. Monacelli and Perotti (2006) simulate the model by letting  $\sigma$  vary and holding  $\nu$  constant and vice versa. The parameter  $\sigma$  characterizes the inverse of the intertemporal elasticity of substitution in consumption. A high value means a low elasticity and households strongly wish to smooth consumption over time. The savings motive is also related to the reaction of the real interest rate. When the real interest rate increases after a shock, then the consumer is induced to shift the consumption into the future and save today, i.e. current consumption would not raise as much. Hence, as with a higher  $\sigma$  the consumption response decreases, this must be either

<sup>8</sup>This part follows section 8.1 in Monacelli and Perotti (2006).



due to the real interest rate or the implied change in  $\nu$ .<sup>9</sup> The interdependence of  $\sigma$  and  $\nu$  through the steady state restriction implies that  $\nu$  must increase when  $\sigma$  increases. A higher value of  $\nu$  causes a lower impact of the wealth effect on hours worked and private consumption. In sum, a higher  $\sigma$  leads to a higher  $\nu$ , which decreases the wealth effect of a government spending shock and thus the complementarity effect on private consumption will be smaller.

## 4 The transmission mechanism under different exchange rate regimes

In what follows I will present in a first step the dynamics of the baseline model outlined in section 2 and compare the dynamic responses to a fiscal policy shock under different exchange rate regimes. A comparison across exchange rate regimes is meaningful since movements in the exchange rate play the stabilizing role of adjusting international relative prices in response to shocks, when prices are sticky and slow down the process of price adjustment in the local currency (Corsetti, 2007). In a second step I will compare the different specifications of utility functions and their dynamic impulse responses under a floating and pegged exchange rate regime.

### 4.1 Dynamic response in the baseline model

In the next two subsections I will focus on the equilibrium dynamics given by an exogenous fiscal spending shock. As I already explained the mechanism of the wealth effect in section 3, I will stick to the broader stylized facts here. Figure 6 shows the dynamic response of selected variables to a 1% shock to government spending in the domestic economy. The benchmark calibration is given in subsection 2.7 and the household adopts a felicity function as outlined in subsection 3.1. To understand the basic transmission mechanism it is instructive to start with the simplistic case of separable preferences. What happens when another form of preference function is assumed will be shown in the next subsection. The central bank can pursue different policy rules as mentioned in subsection 2.4. Standard is a floating exchange rate where the monetary authority has an inflation and output stabilization target given by a Taylor rule. All the responses are measured in percentage deviations from the steady state.

A first notable result is that, under either specification of monetary policy, the response of output is positive and smaller than unity throughout. This is already quite different from the predictions of the Mundell-Flemming model for a small open economy with perfect capital mobility. Nonetheless, if comparing the fixed exchange rate regime with a float under the Taylor rule, the response of output is larger in relative terms for the former. Under a floating regime, output raises on impact by roughly 0.1%, under a fixed exchange rate it is an increase of 0.17%.

On the real side of the model the dynamics are driven by the well-known wealth effect of government spending. An increase in government consumption withdraws resources from the private sector and reduces private wealth. As households smooth consumption over time, they will reduce current consumption because they assume that the government will increase taxes at some point

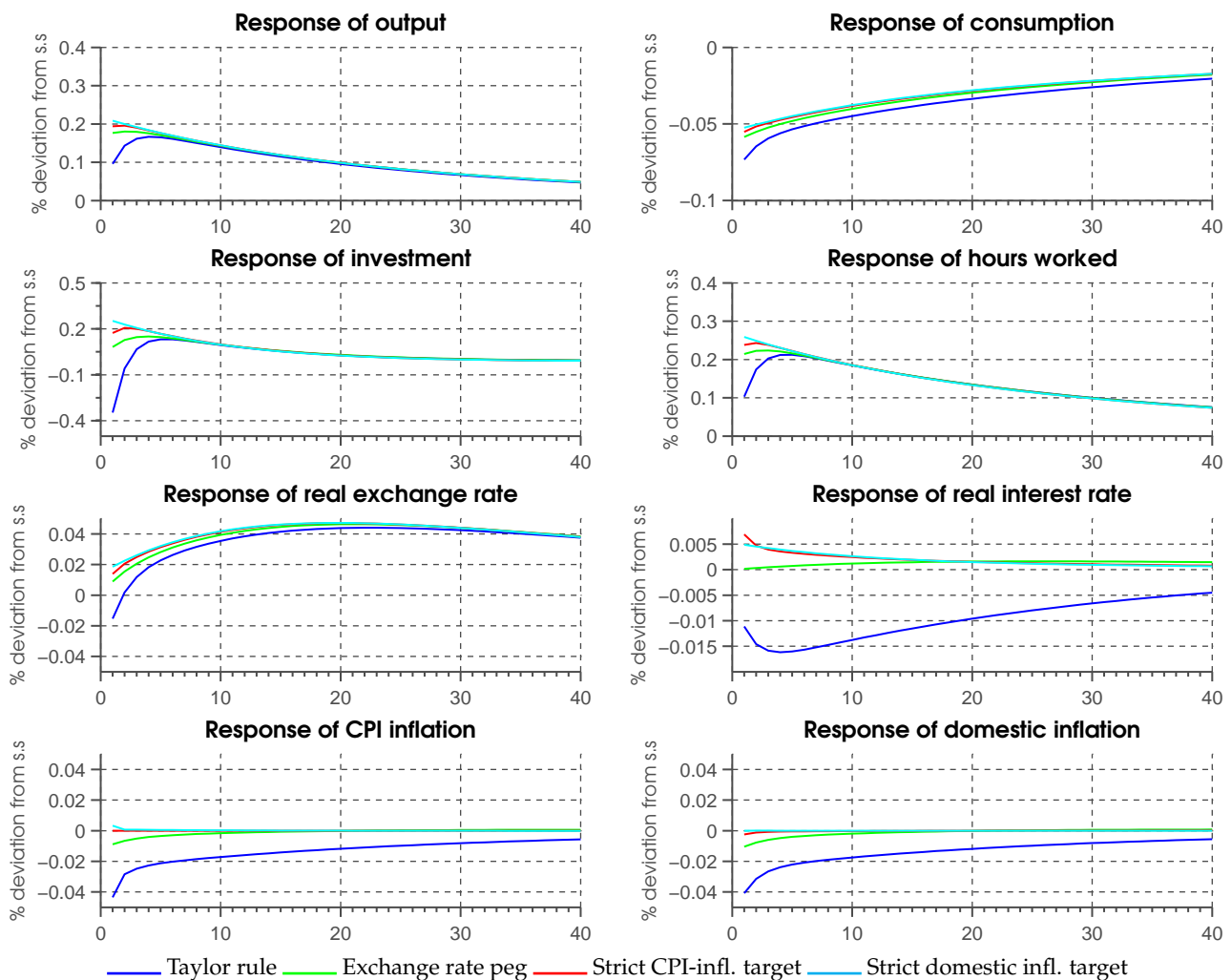
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<sup>9</sup>The effects of the real interest rate will be discussed in the next section

in the future to balance the budget and pay its spendings. Therefore, the households allocate time from leisure to work. The increase in labor supply causes real wages to fall and reduces households income. Under the assumption of separable preferences the standard result is obtained that consumption falls because of the reduced wealth. Quantitatively, the outcome does not depend on the monetary policy of the central bank. Only if the authority follows a Taylor rule, the effect is slightly more negative.

Further notable results in Figure 6 concern the response of the monetary sector. On impact, the response of domestic inflation and of CPI-inflation is negative under a float or for fixed exchange rates. The targeting of either of these two measurements of inflation does not have a quantitatively different effect. Under a peg, inflation falls beneath its steady state value for about ten quarters, whereas it takes much more time for accommodation under a float. The reason for the fall in prices comes from the firms sector: An increase in government spending lowers the real wage, which lowers the real marginal costs of the intermediate goods producing firms. The firms adjust their prices and because of price stickiness they adjust slowly.

Figure 6: Baseline SOE model with different monetary policies



This has direct effects for the policy rate. Under a float, the Taylor rule implies that the policy rate falls to stabilize inflation. As the coefficient in the rule  $\gamma_\pi$  equals 1.5 is larger than one, the interest rate will be lowered by more than the drop in inflation. If the central bank has a strict target of the CPI or of domestic inflation, then she wants to have  $\pi_t = \pi_{x,t} = 1$  to all ends. As an outcome of the general equilibrium, the real interest rate is no longer controlled by the central bank but depends on the households saving-consumption decision in order to ensure stable long-run consumption growth. If households consume less today then in order to smooth consumption over time the interest rate must raise and vice versa. When the exchange rate remains credibly pegged to its initial level, the long-run purchasing power parity requires domestic prices to revert to their initial steady state level.

Last, under a floating exchange rate regime, the real exchange rate appreciates on impact, i.e. the prices of the domestic economy relative to the foreign economy increase. This comes from the fact that under this regime, capital is moved to the foreign economy because the interest rate drops. In the case of an exchange rate peg or strict (CPI) inflation targeting, capital does not leave the domestic economy, rather there is a capital inflow and capital accumulates in the domestic economy, which leads to a real exchange rate depreciation on impact. Over time, the dynamics show that the real exchange rates converge to one path which is due to the fact, that under a float the interest rate raises again and leads to a capital inflow after five quarters.

## 4.2 Dynamic responses of different utility functions

After having described the dynamics under the benchmark model with separable preferences I will revisit in this subsection the effect of different preference specifications. I will simulate the system for a floating exchange rate given in Figure 7 and for an exchange rate peg shown in Figure 8. The calibration remains as outlined above, for the households I assume a standard value for  $\sigma$  equals 2. Where necessary,  $\nu$  equals 0.100 and in the non-separable utility function by Hall (2009) I assume a  $\varphi$  equals 3.<sup>10</sup>

Under a floating exchange rate regime, the dynamics are dominated by the utility specification mentioned in subsection 3.2. Under this type of nonseparability, the output response closely reaches 1 after several periods. Nevertheless it is the only function, which has a negative response on impact. This outcome is mainly driven through the negative response of investment, which falls sharply on impact. An increase in government spending produces a fall in the *Tobin's q*, which depends (via the asset price condition in equation (B.13)) on the current and future movements in the real marginal costs and the real interest rate. As mentioned above, the marginal costs decrease because of the decrease in the real wage.

For the GHH preferences, consumption raises above its steady state level on impact. After five periods, consumption falls below the steady state level, and so do investment and output. The preference specification by Hall (2009) is chosen so that the response is positive in the long-run and the complementarity between hours and private consumption is clearly visible. The preferences with

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<sup>10</sup>In a fixed exchange rate regime, the preference specification according to Linnemann (2006) has a unit root for  $\sigma$  equals 2, I thus adopt a value of 2.5.

wealth effect after [Basu and Kimball \(2002\)](#) show a negative response of private consumption and only a small positive effect on output. Investment deviates negatively from steady state on impact but returns quickly to its initial steady state level. These preferences are not very rich of dynamics and represent a very stable system of equations.

The analysis of monetary policy has several interesting features. First, the response of inflation is positive only for the GHH specification, where inflation does not return to its steady state level even after 40 quarters. The monetary policy weakly affects the households saving-consumption decision for this type of preferences. The real exchange rate appreciates over the observed time period, induced by an inflow of capital through the higher interest rate. The other specifications show contrary movements. For the non-separable preferences specified by [Linnemann \(2006\)](#), the real interest rate falls sharply on impact inducing an exchange rate depreciation. The monetary authority lowers the real interest rate to follow its monetary target of stabilizing inflation.

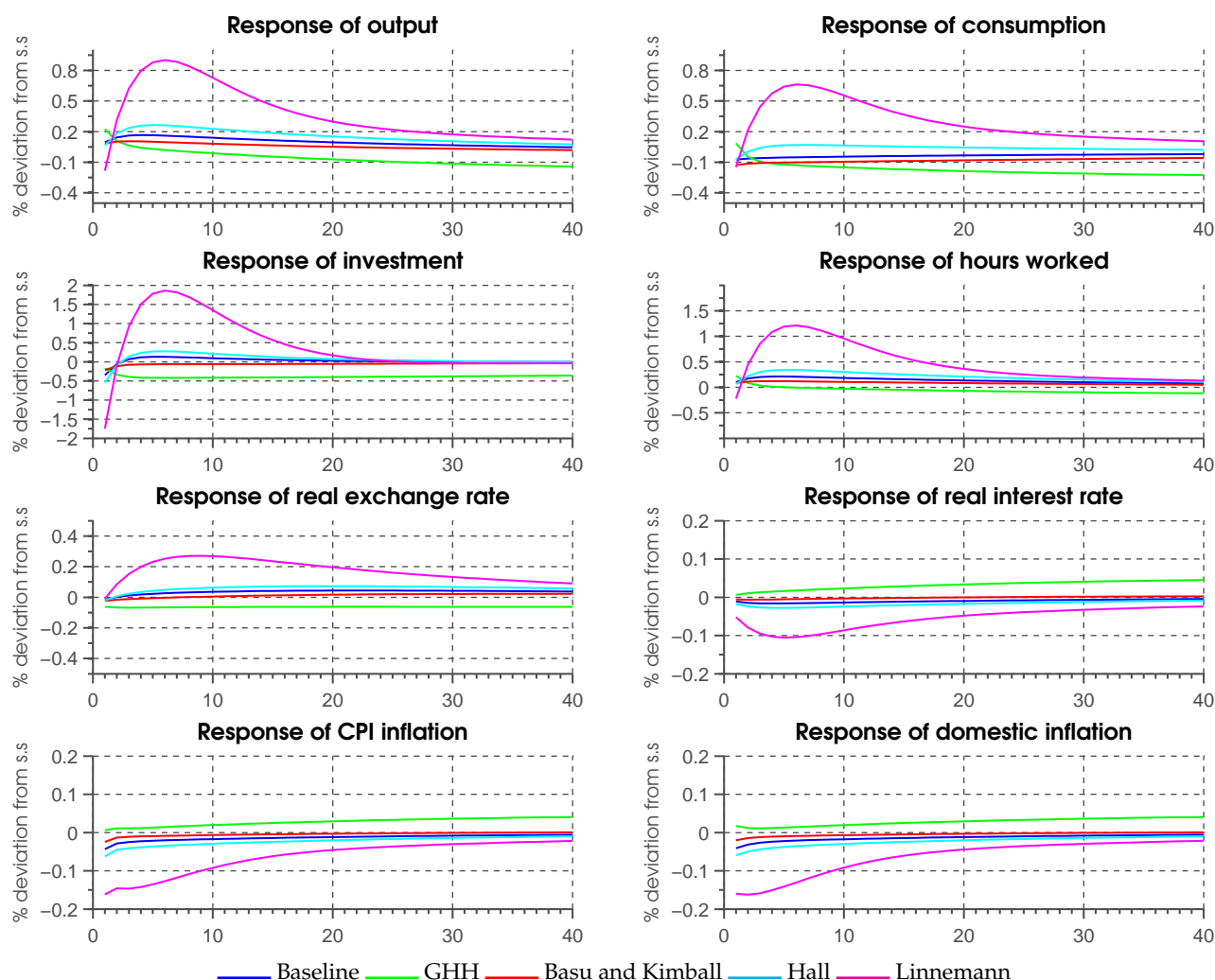
In comparison with the model dynamics of separable preferences described above it can be seen that the specification by [Hall \(2009\)](#) shows very similar results. The largest differences are obtained by the nonseparability according to [Linnemann \(2006\)](#), which goes back to the mentioned wealth effect. Under a floating exchange rate regime, the monetary authority accommodates through the adjustment of the interest rate the consumption response of households which leads to an assimilation in the long run.

What happens when the monetary authority drops the instrument of setting the interest rate and pegs the interest rate is given in [Figure 8](#). In this setup, private consumption has a positive response under GHH and Linnemann preferences, but the effect for GHH lasts only for a few quarters. The dynamics for output, investment and private consumption are similar to the ones under a floating exchange rate regime. The effect of a government spending shock on output is positive but smaller than one, which is a contradiction to the traditional Mundell-Flemming model outcome.

Monetary policy pegs the nominal exchange rate and loses control over the real interest rate. For all the specifications the response of the real interest rate is small but positive. The real exchange rate depreciates except for the GHH preferences, which is due to the outflow of capital. Inflation increases on impact for the [Basu and Kimball \(2002\)](#) and GHH preferences. This is due to the instantaneous increase in demand for goods and services, making them more scarce and lead producers to raise their prices. In the model with Linnemann preferences the impulse response is similar to the benchmark model but stronger. The real wage decreases due to the higher supply in labor which leads to lower marginal costs and a decrease in prices.

To sum up this section, the following points are noteworthy. First, the traditional results from the Mundell-Flemming model are rejected in a small open economy with rational expectations and nominal rigidities. The impulse responses to a transitory stochastic one percent increase in government spending lead to a positive output response under a floating exchange rate regime as well as under an exchange rate peg. The response of private consumption depends crucially on the assumptions made about the utility function. Under a float, monetary policy controls the real interest rate and dampens the effects on inflation and the real exchange rate. Under a peg, fiscal policy is more

Figure 7: Comparison of Utility Functions under a Float

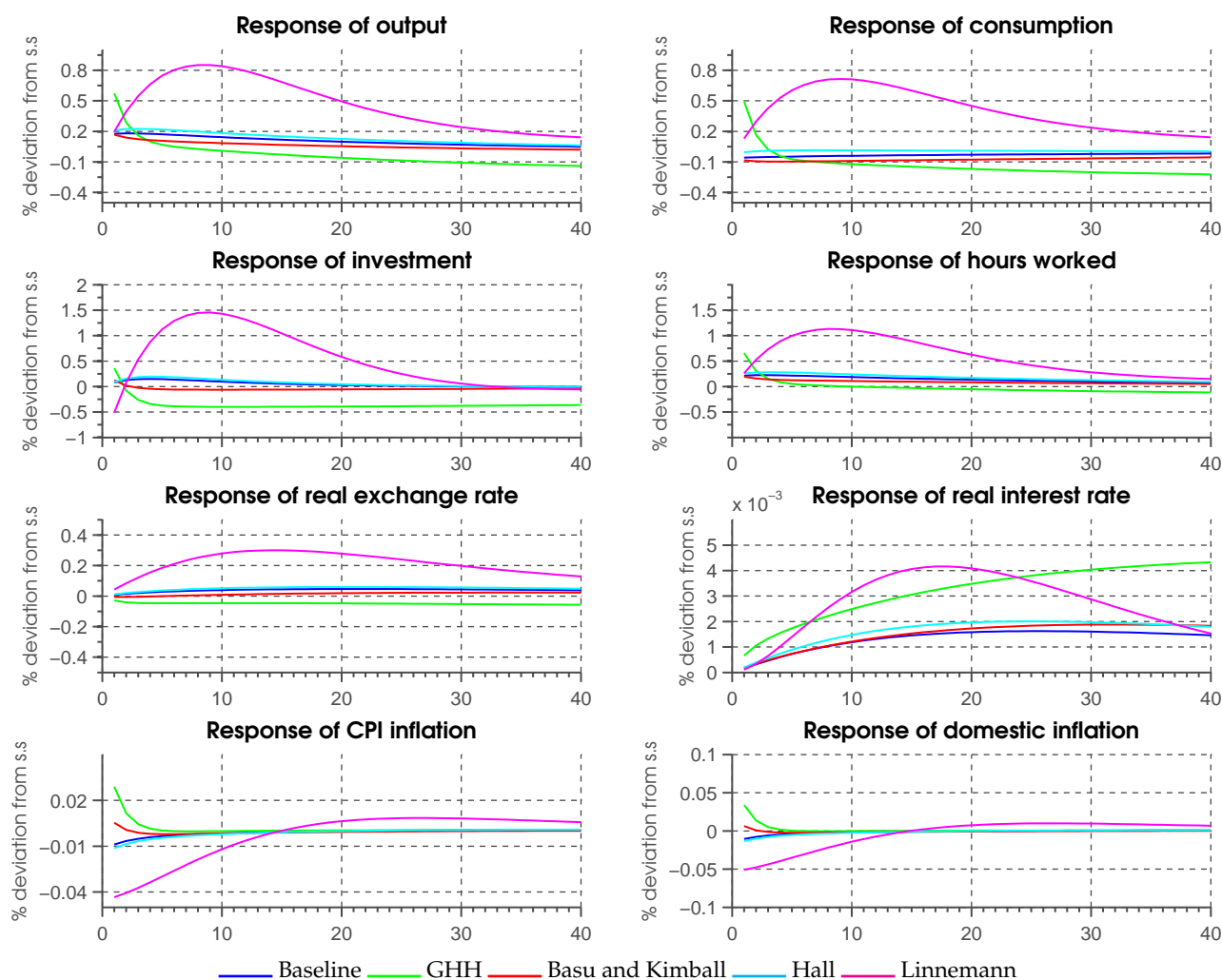


effective as the multiplier on output is relatively larger than under a float.

## 5 Robustness and extensions

First I will analyze the robustness of the obtained equilibrium dynamics by imposing real rigidities. So far the simulated models featured nominal rigidities in the form of sticky prices and I studied the effect of a 1% increase in government spending under different specifications of utility functions and different monetary policy choices. I now explore the effect of real rigidities based on the baseline model and the model with a preference specification according to [Linnemann \(2006\)](#). The real rigidities are imposed through a simple habit formation mechanism outlined in the next subsection. Monetary authority controls the real interest rate by following a Taylor rule. The calibration of the model remains unchanged. Second I will outline as an extension a further variant of utility function by assuming that government spending gives some utility to households and that there exists a complementarity between private consumption and public spending. For the analysis of the impulse responses to a government spending shock, the underlying framework is again the baseline model.

Figure 8: Comparison of Utility Functions under a Peg



## 5.1 Habit persistence

The objective of including a process of habit formation into the utility function is usually justified by looking at the aggregate data. Habit formation is a key to capture the *hump-shaped* gradual response of spending and inflation to shocks. The nominal side of the model stays as before, only the utility function for the consumers is slightly adjusted. Habit persistence is an ingredient which gives past consumption a weight in determining current utility. An individual's utility thus depends on current consumption relative to past consumption.<sup>11</sup>

### 5.1.1 The baseline model with habits

The model setup remains basically the same as in section 3. What changes is the utility function of households which for the benchmark case of separable utility reads

<sup>11</sup> Among many others the paper by [Christiano, Eichenbaum, and Evans \(2005\)](#) assumes this sort of preference specification with the aim of studying the dynamic effects of a shock to monetary policy.

$$U(c_t, h_t) = \frac{(c_t - bc_{t-1})^{1-\sigma}}{1-\sigma} - \psi \frac{h_t^{1+\nu}}{1+\nu}, \quad (5.1)$$

where  $0 < b < 1$  measures the degree of habit persistence. For a value of  $b$  equals 0 we obtain the standard benchmark model. As a consequence of this form of utility function, equation (B.1) adjusts to

$$(c_t - bc_{t-1})^{-\sigma} = \lambda_t. \quad (5.2)$$

In steady state  $c_t = c_{t-1} = c$  and thus  $(c - bc)^{-\sigma} = \lambda$ .

The equilibrium dynamics for a 1% increase in government expenditures and a range of values for  $b$  are given in Figure 9. At first sight it stands out that only the impulse response functions for consumption significantly change. This is because the nominal side of the model is left unaltered. Private consumption responds less negatively on impact the larger the degree of habit formation. It can be seen that if the degree for  $b$  equal to 0.9, then private consumption has almost a positive response on impact. The reason for these dynamics is that consumption is now a predetermined variable and its initial value is the steady state. On impact the response will always be negative because of the wealth effect, but the larger  $b$  the less is the deviation from steady state on impact. The smaller the degree of habit formation, the faster private consumption converges to the dynamics of the baseline model.

### 5.1.2 Linnemann preferences with habits

To be able to compare the outcome of habit formation under separable preferences I use the preference specifications presented in subsection 3.2. Again, everything is left unchanged but the utility function which now reads

$$U(c_t, h_t) = \frac{1}{1-\sigma} (c_t - bc_{t-1})^{1-\sigma} h_t^{1+\nu}. \quad (5.3)$$

This implies a change not only in equation (B.1) but also in (B.2) as the cross-derivative  $U_{c,h}$  also changes. The two equations take the following forms

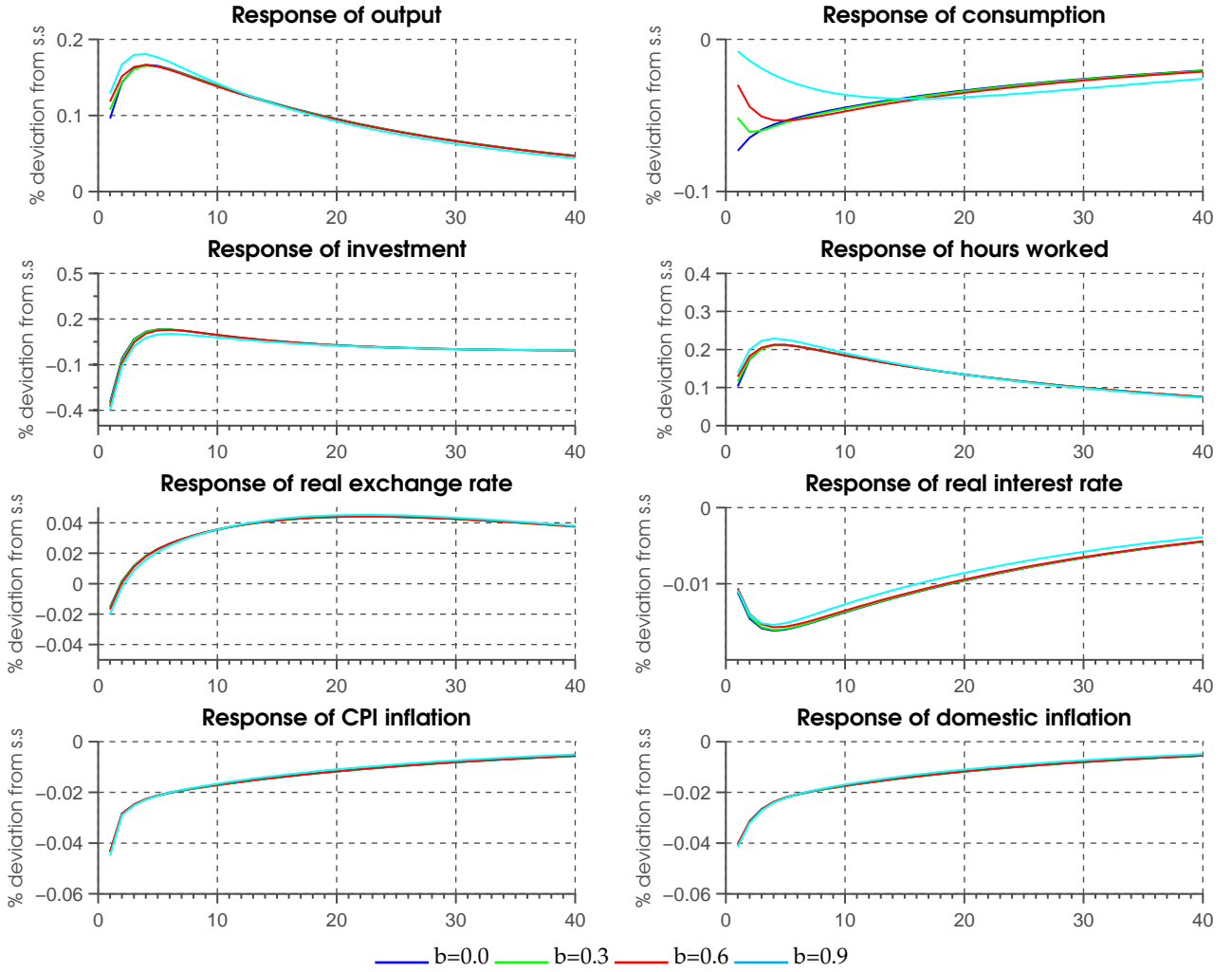
$$(c_t - bc_{t-1})^{-\sigma} h_t^{1+\nu} = \lambda_t, \quad (5.4)$$

$$\frac{1+\nu}{\sigma-1} h_t^{\nu+1} (c_t - bc_{t-1})^{1-\sigma} = w_t. \quad (5.5)$$

This means that through the complementarity between hours and private consumption the labor market is also affected through the habit formation and the response of private consumption when the real wage decreases through the increase in labor supply (wealth effect), the consumption response will be dampened. This means that the response of consumption is expected to be less strong



Figure 9: Baseline Model with Habit Persistence



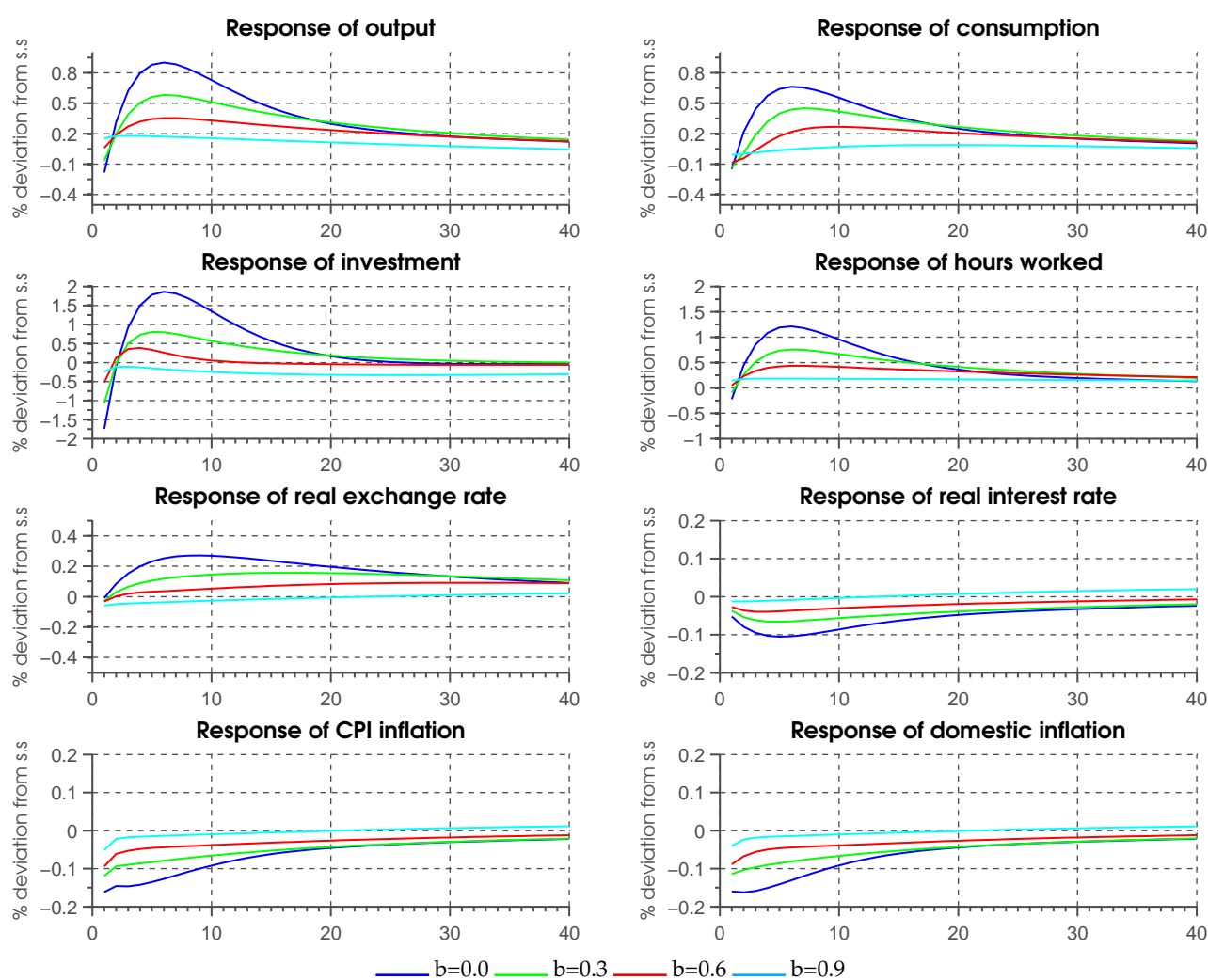
under the model with habit persistence than in the model where  $b$  equals 0. But before turning to the analysis of equilibrium dynamics, the steady state of the model has to be adjusted. In steady state, the parameters  $\nu$  and  $\sigma$  are interdependent through the relation

$$\nu = \frac{\mu_p^{-1}(\sigma - 1)(1 - \alpha)}{\gamma_c(1 - b)} - 1. \quad (5.6)$$

Figure 10 displays the equilibrium dynamics after the system was hit by a 1% shock in government spending. As described above, the response of private consumption gets smaller on impact but also the deviations are less strong over time. The habit formation absorbs the complementarity effect and dampens the effect of the shock. Generally it can be said that the larger the degree of habit persistence, the less the variables react. A difference to the model with separable preferences is given by the dynamics of the nominal variables. Because of the complementarity between hours worked and private consumption, not only the latter reacts to a shock but also the former. If the habit formation absorbs the wealth effect and consumption does not react by as much, then households will not



Figure 10: Linnemann Preferences with Habit Persistence



increase as much their labor efforts, which leads to a smaller reduction in the real wage and thus to a smaller decrease in prices and inflation.

## 5.2 Including government spending into the utility function

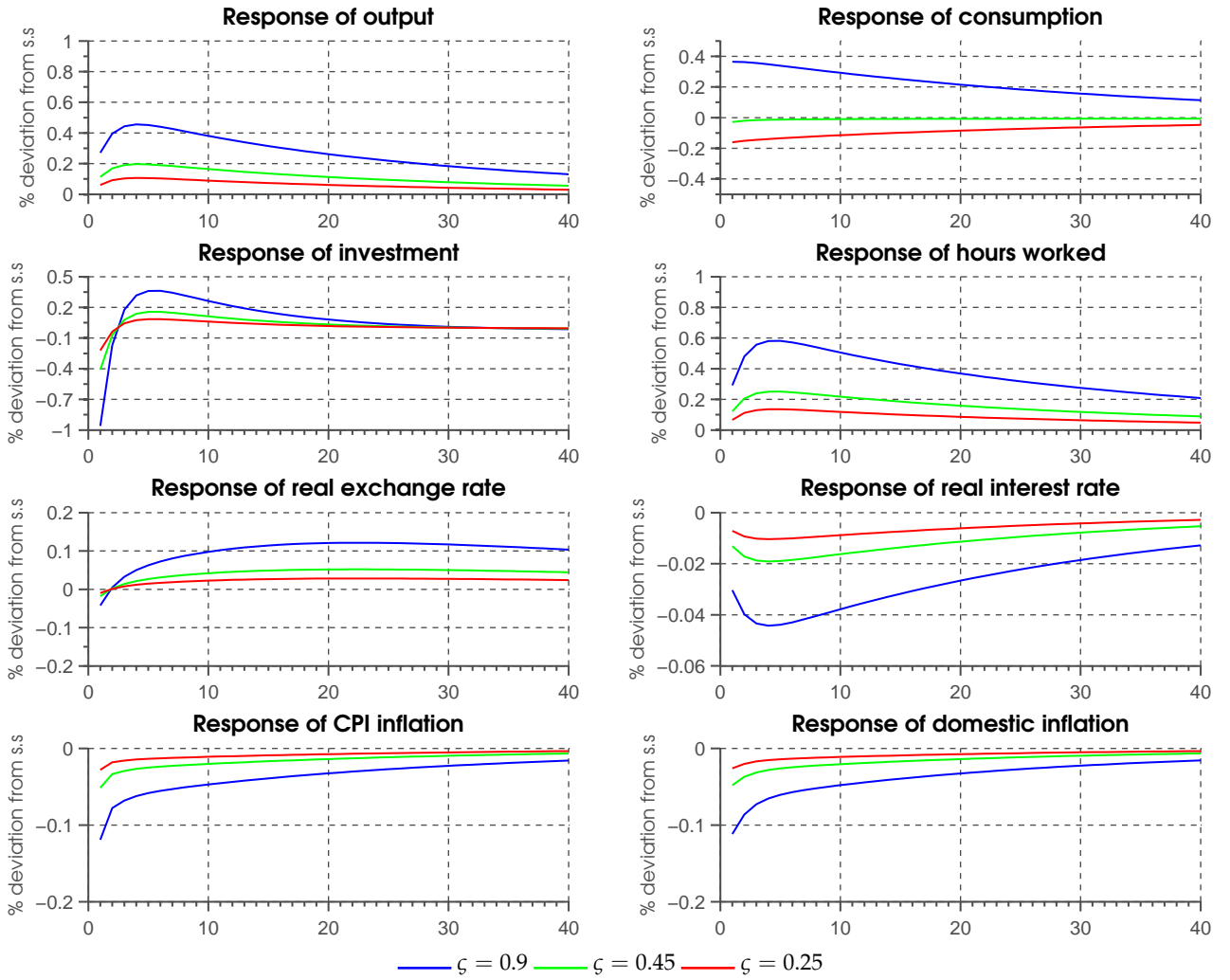
Another approach to overcome the crowding-out effect of government spending on private consumption is by assuming that public expenditures affect consumer preferences. It can be assumed that the government uses its expenditures for public goods which yield utility to the households. Bouakez and Rebei (2007) develop a simple business cycle model where they specify a utility function which depends on private consumption as well as on public spending.<sup>12</sup> In the literature there has been an ongoing discussion about whether private consumption and public spending are complements or substitutes.<sup>13</sup> For the purpose of the paper it is instructive to assume that they are complements, such that an increase in government spending will increase the marginal utility of

<sup>12</sup>Bouakez and Rebei (2007) introduce in their model habit persistence to obtain a persistent and hump-shaped consumption response as obtained in their VAR. I will restrict the analysis to a simple one period utility function.

<sup>13</sup>See per example Amano and Wirjanto (1997) or Evans and Karras (1994) among others.

consumption, which in turn reduces the wealth effect.

Figure 11: Government Spending in Utility Function



Effective consumption takes the form of constant elasticities of scale and is a compound of private consumption and government spending:

$$\tilde{c}_t = \left[ \phi c_t^{\frac{\zeta-1}{\zeta}} + (1-\phi)g_t^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}}, \quad (5.7)$$

where  $\phi \in [0, 1]$  corresponds to the weight of private consumption in the effective consumption index, and  $\zeta > 0$  is the elasticity of substitution between private consumption and government spending.<sup>14</sup> The functional form of households instantaneous preference function is in line with the separable preferences from subsection 3.1

$$U(c_t, h_t) = \frac{\tilde{c}_t^{1-\sigma}}{1-\sigma} - \psi \frac{h_t^{1+\nu}}{1+\nu}. \quad (5.8)$$

<sup>14</sup>In the special case where  $\zeta$  is equal to 0,  $c_t$  and  $g_t$  become perfect complements; for  $\zeta \rightarrow \infty$  they become perfect substitutes.

The calibration of the model is standard as before. The central bank follows a Taylor rule and lets the exchange rate float. Household preferences are calibrated with  $\sigma$  equals 2,  $\nu$  equals 0.10 and  $\psi$  depends on the steady state value of  $\lambda$  which in turn depends on the parametrization of  $\zeta$  and  $\phi$ . I will simulate the model for three different scenarios as performed in [Bouakez and Rebei \(2007\)](#), by setting the elasticity of substitution  $\zeta$  to 0.9, 0.45, 0.25 respectively. The weight of private consumption  $\phi$  is set to 0.8.

The results from the simulations are displayed in [Figure 11](#). For  $\zeta$  equal to 0.9 the responses are very much alike to the benchmark model. Private consumption is crowded-out, hours worked increase by 0.1%, the central bank responds to the decrease of inflation by lowering the real interest rate and the real exchange rate depreciates, i.e. the foreign goods have become more expensive. By setting  $\zeta$  to 0.45 private consumption and government spending become complements and it can be clearly seen that the response on private consumption is close to zero. Overall, the dynamics are still similar to the dynamics described before, but the effect of a government spending shock is less strong. This means that in this case the complementarity is rather weak and cannot offset the wealth effect. What happens when the rate of complementarity is increased is given by the dynamics when  $\zeta$  is set to 0.25. As in [Bouakez and Rebei \(2007\)](#), it holds also for the small open economy that the complementarity effect is strong enough to dominate the wealth effect and the consumption response is positive from impact. The crowding-in of private consumption leads to a higher response of government spending on output. The households increase on impact their hours worked by 0.3%, which has consequences on the real side of the model. As prices decrease, the real interest rate is lowered sharply on impact. The decrease in domestic prices leads to a stronger depreciation of the real exchange rate.

In summary, the inclusion of habit formation to the separable baseline utility function does not help to obtain a positive response of private consumption to a government spending shock. Further, under the assumption of non-separable preferences, the habit leads to a lower response on private consumption as the households want to hold their consumption path flat over time. The larger the weight of the habit, the smaller the response on private consumption. By imposing that households get some utility from government spending, and by introducing a strong enough complementarity, the wealth effect on private consumption is overturned and the response is positive.

## 6 Conclusion

In this paper I have analyzed the impact of an expansionary fiscal policy shock in a small open economy. The transmission mechanism of such a shock is driven by the wealth effect, which causes households to shift their time allocation from leisure to work. In a baseline model with separable utility, the wealth effect and the consumption smoothing motive of households drive down private consumption, a finding which has been questioned in the recent empirical literature on the impact of fiscal policy shocks.

I have simulated the model for five different types of utility functions, four of which are addi-

tively non-separable and thus characterized by complementarity between hours worked and private consumption. In accordance with [Linnemann \(2006\)](#) and [Bilbiie \(2009\)](#), who show that complementarity can overturn the wealth effect under certain conditions, I contribute to the existing literature by extending the model to an open economy framework. Another innovation is to compare the response of selected variables under the different utility functions and exchange rate regimes.

Three important remarks about my results are worth noting. First, the simulations show that not for each non-separable specification of the utility function the response of consumption is positive. This result puts into perspective the conclusion by [Monacelli and Perotti \(2006\)](#), who state that non-separable preferences help to reconcile the theory with the data. Moreover, I found a sufficient and necessary condition to be satisfied by the utility function in order to obtain an effect of private consumption which is positive.

Second, it holds that for utility functions which fulfill the condition, the calibrated complementarity needs to be large. It is a finding of the paper, that the calibration of the parameters requires strong assumptions for all the specifications to render a positive response. Whether the required calibration and the outlined model assumptions can be justified by the data is left for future research.

Finally, I also found that by changing the exchange rate regime from a float to a peg, the response of private consumption and output are relatively stronger, which confirms the traditional findings of the Mundell-Flemming model. Nevertheless, the traditional wisdom that output is completely crowded-out under a floating exchange rate regime is not supported by the model with nominal rigidities and optimizing agents.

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## A Model

### A.1 Optimal expenditure allocation of retailer

The retailer produces the final good according to the following CES function

$$y_t = \left( \omega^{\frac{1}{1-\rho}} x_t^d{}^\rho + (1-\omega)^{\frac{1}{1-\rho}} x_t^f{}^\rho \right)^{\frac{1}{\rho}} \quad (\text{A.1})$$

The composite index  $y_t$  consists of  $x_t^d$ , being an index of consumption of domestic goods and  $x_t^f$  respective for foreign goods. Both indexes are described by a constant elasticities of scale (CES) function. For the domestic good this reads  $x_t^d \equiv \left( \int_0^1 x_t^d(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}$ , with  $i \in [0, 1]$  denoting the good variety consumed.  $x_t^f$ , the index for imported foreign goods, reads similarly  $x_t^f = \left( \int_0^1 x_t^f(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}$  where  $\theta \in (-\infty, 1)$ .

Assuming the case of monopolistic competition where agents set the prices of goods and inputs in order to maximize their objectives, here firms are going to choose optimal production of  $x_t^d$  and  $x_t^f$  subject to their expenditures,  $z_t$ . Let's take by way of example production of the domestic good  $x_t^d(i)$ :

The problem of maximization of  $x_t^d(i)$  for any given expenditure level

$$\int_0^1 P_{x,t}(i) x_t^d(i) di + \int_0^1 e_t P_{x,t}^*(i) x_t^f(i) di \equiv z_t \quad (\text{A.2})$$

can be formalized by means of the Lagrangian

$$\mathcal{L} = \left[ \int_0^1 x_t^d(i)^{\frac{\theta-1}{\theta}} + x_t^f(i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}} - \lambda \left( \int_0^1 P_{x,t}(i) x_t^d(i) di + \int_0^1 e_t P_{x,t}^*(i) x_t^f(i) di - z_t \right) \quad (\text{A.3})$$

The associated first order condition (FOC) for  $x_t^d(i)$  is

$$x_t^d(i)^{-\frac{1}{\theta}} x_t^d{}^{\frac{1}{\theta}} = \lambda P_{x,t}(i) \quad (\text{A.4})$$

for all  $i \in [0, 1]$ . Thus for any two goods  $(i, j)$ ,

$$x_t^d(i) = x_t^d(j) \left( \frac{P_{x,t}(i)}{P_{x,t}(j)} \right)^{-\theta} \quad (\text{A.5})$$

After some substitution we obtain the demand function for

$$x_t^d(i) = \left( \frac{P_{x,t}(i)}{P_{x,t}} \right)^{-\theta} x_t^d, \quad x_t^f(i) = \left( \frac{P_{x,t}^*(i)}{P_{x,t}^*} \right)^{-\theta} x_t^f$$

Analogously, the problem of maximization of  $x_t^d$  and  $x_t^f$  can be solved similarly using the composite consumption index  $y_t$ . This yields the optimal allocation of expenditures between domestic and foreign goods:

$$x_t^d = \left( \frac{P_{x,t}}{P_t} \right)^{\frac{1}{\rho-1}} \omega y_t \text{ and } x_t^f = \left( \frac{e_t P_{x,t}^*}{P_t} \right)^{\frac{1}{\rho-1}} (1 - \omega) y_t \quad (\text{A.6})$$

The domestic price index is given by

$$P_{x,t} = \left( \int_0^1 P_{x,t}(i)^{1-\theta} di \right)^{\frac{1}{1-\theta}} \quad (\text{A.7})$$

## A.2 Pricing mechanism

The price setting behavior is essentially the same as in a closed economy. The expected profit flow generated by setting  $\tilde{P}_t(i)$  in period  $t$  writes

$$\max_{\tilde{P}_{x,t}(i)} E_t \sum_{j=0}^{\infty} \Phi_{t,t+j} \xi^j \Pi(\tilde{P}_{x,t}(i)) \quad (\text{A.8})$$

subject to the total demand it faces:

$$x_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\theta} x_t \text{ with } x_t = x_t^d + x_t^{d*} \quad (\text{A.9})$$

and where  $\Pi(\tilde{P}_{x,t}(i)) = (\tilde{P}_{x,t}(i) - P_{t+j} s_{t+j}) x_{t+j}(i)$ .  $\Phi_{t,t+j}$  is an appropriate discount factor related to the way the household value future as opposed to current consumption, such that

$$\Phi_{t,t+j} \propto \beta^j \frac{\Lambda_{t+j}}{\Lambda_t} \quad (\text{A.10})$$

This leads to the price setting equation

$$E_t \left[ \sum_{j=0}^{\infty} (\beta \xi)^j \frac{\Lambda_{t+j}}{\Lambda_t} \left( (1 - \theta) \left( \frac{\tilde{P}_{x,t}(i)}{P_{x,t+j}} \right)^{-\theta} y_{t+j} + \theta \frac{P_{t+j}}{P_{x,t+j}(i)} \left( \frac{\tilde{P}_{x,t}(i)}{P_{x,t+j}} \right)^{-\theta} s_{t+j} x_{t+j} \right) \right] = 0 \quad (\text{A.11})$$

from which it shall be clear that all firms that reset their price in period  $t$  set it at the same level ( $\tilde{P}_t(i) = \tilde{P}_t$ , for all  $i \in (0, 1)$ ). This implies that

$$\tilde{P}_{x,t} = \frac{P_{x,t}^N}{P_{x,t}^D} \quad (\text{A.12})$$

where

$$P_{x,t}^n = E_t \left[ \sum_{j=0}^{\infty} (\beta \xi)^j \Lambda_{t+j} \frac{\theta}{\theta - 1} P_{t+j} P_{x,t+j}^{\theta} s_{t+j} x_{t+j} \right] \quad (\text{A.13})$$

and

$$P_{x,t}^d = E_t \left[ \sum_{j=0}^{\infty} (\beta \xi)^j \Lambda_{t+j} P_{x,t+j}^{\theta} x_{t+j} \right] \quad (\text{A.14})$$



Fortunately, both  $P_{x,t}^N$  and  $P_{x,t}^D$  admit a recursive representation, such that

$$P_{x,t}^n = \frac{\theta}{\theta - 1} \Lambda_t P_t P_{x,t}^\theta s_t x_t + \beta \zeta \mathbb{E}_t [P_{x,t+1}^n] \quad (\text{A.15})$$

$$P_{x,t}^d = \Lambda_t P_{x,t}^\theta x_t + \beta \zeta \mathbb{E}_t [P_{x,t+1}^d] \quad (\text{A.16})$$

Recall now that the price index is given by

$$P_{x,t} = \left( \int_0^1 P_{x,t}(i)^{1-\theta} di \right)^{\frac{1}{1-\theta}} \quad (\text{A.17})$$

In fact it is composed of surviving contracts and newly set prices. Given that in each an every period a price contract has a probability  $1 - \zeta$  of ending, the probability that a contract signed in period  $t - j$  survives until period  $t$  and ends at the end of period  $t$  is given by  $(1 - \zeta)\zeta^j$ . Therefore, the aggregate price level may be expressed as the average of all surviving contracts

$$P_{x,t} = \left( \sum_{j=0}^{\infty} (1 - \zeta)\zeta^j \tilde{P}_{x,t-j}^{1-\theta} \right)^{\frac{1}{1-\theta}} \quad (\text{A.18})$$

which can be expressed recursively as

$$P_{x,t} = \left( (1 - \zeta)\tilde{P}_{x,t}^{1-\theta} + \zeta P_{x,t-1}^{1-\theta} \right)^{\frac{1}{1-\theta}} \quad (\text{A.19})$$

Note that since the wage rate is common to all firms, the capital labor ratio is the same for any firm:

$$\frac{k_t(i)}{h_t(i)} = \frac{k_t(j)}{h_t(j)} = \frac{k_t}{h_t} \quad (\text{A.20})$$

we therefore have

$$x_t(i) = a_t \left( \frac{k_t}{h_t} \right)^\alpha h_t(i) \quad (\text{A.21})$$

integrating across firms, we obtain

$$\int_0^1 x_t(i) di = a_t \left( \frac{k_t}{h_t} \right)^\alpha \int_0^1 h_t(i) di \quad (\text{A.22})$$

denoting  $h_t = \int_0^1 h_t(i) di$ , and making use of the demand for  $y_t(i)$ , we have

$$\int_0^1 \left( \frac{P_{x,t}(i)}{P_{x,t}} \right)^{-\theta} di y_t = a_t k_t^\alpha h_t^{1-\alpha} \quad (\text{A.23})$$

Denote

$$\begin{aligned}
\Delta_t &= \int_0^1 \left( \frac{P_{x,t}(i)}{P_{x,t}} \right)^{-\theta} di \\
&= \sum_{j=0}^{\infty} (1-\zeta)\zeta^j \left( \frac{\tilde{P}_{x,t-j}}{P_{x,t}} \right)^{-\theta} \\
&= (1-\zeta) \left( \frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \sum_{j=1}^{\infty} (1-\zeta)\zeta^j \left( \frac{\tilde{P}_{x,t-j}}{P_{x,t}} \right)^{-\theta} \\
&= (1-\zeta) \left( \frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \sum_{\ell=0}^{\infty} (1-\zeta)\zeta^{\ell+1} \left( \frac{\tilde{P}_{x,t-\ell-1}}{P_{x,t}} \right)^{-\theta} \\
&= (1-\zeta) \left( \frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \zeta \left( \frac{P_{x,t-1}}{P_{x,t}} \right)^{-\theta} \sum_{\ell=0}^{\infty} (1-\zeta)\zeta^{\ell} \left( \frac{\tilde{P}_{x,t-\ell-1}}{P_{x,t-1}} \right)^{-\theta} \\
&= (1-\zeta) \left( \frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \zeta \left( \frac{P_{x,t-1}}{P_{x,t}} \right)^{-\theta} \Delta_{t-1}
\end{aligned}$$

and we get

$$\Delta_t = (1-\zeta) \left( \frac{\tilde{P}_{x,t}}{P_{x,t}} \right)^{-\theta} + \zeta \pi_{x,t}^{\theta} \Delta_{t-1} \tag{A.24}$$

## B General equilibrium

The *deflated* general equilibrium is then given by

$$U_{c,t} = \lambda_t \tag{B.1}$$

$$-U_{h,t} = \lambda_t (1-\alpha) s_t \frac{p_{x,t} x_t}{h_t} \tag{B.2}$$

$$\lambda_t = q_t \left( 1 - \varphi_k \left( \frac{i_t}{k_t} - \delta \right) \right) \tag{B.3}$$

$$y_t = c_t + i_t + g_t + \frac{\chi}{2} b_t^{f2} \tag{B.4}$$

$$\Delta_t x_t = a_t k_t^{\alpha} h_t^{1-\alpha} \tag{B.5}$$

$$x_t^d = p_{x,t}^{\frac{1}{\rho-1}} \omega y_t \tag{B.6}$$

$$x_t^{d*} = \left( \frac{p_{x,t}}{rer_t} \right)^{\frac{1}{\rho-1}} (1-\omega) y_t^* \tag{B.7}$$

$$x_t^f = (rer_t p_{x,t}^*)^{\frac{1}{\rho-1}} (1-\omega) y_t \tag{B.8}$$

$$x_t = x_t^d + x_t^{d*} \tag{B.9}$$

$$1 = \omega p_{x,t}^{\frac{\rho}{\rho-1}} + (1-\omega) (rer_t p_t^*)^{\frac{\rho}{\rho-1}} \tag{B.10}$$

$$\lambda_t = \beta R_t \mathbb{E}_t \frac{\lambda_{t+1}}{\pi_{t+1}} \tag{B.11}$$

$$\lambda_t(1 + \chi b_t^f) = \beta R_t^* \mathbb{E}_t \frac{\Delta_{t+1}^e}{\pi_{t+1}} \lambda_{t+1} \quad (\text{B.12})$$

$$q_t = \beta \mathbb{E}_t \left[ \lambda_{t+1} \alpha s_{t+1} \frac{p_{x,t+1} x_{t+1}}{k_{t+1}} + q_{t+1} \left( 1 - \delta + \frac{\varphi_k}{2} \left( \left( \frac{i_{t+1}}{k_{t+1}} \right)^2 - \delta^2 \right) \right) \right] \quad (\text{B.13})$$

$$b_t^f = \frac{\Delta_t^e}{\pi_t} R_{t-1}^* b_{t-1}^f + p_{x,t} x_t - y_t \quad (\text{B.14})$$

$$k_{t+1} = i_t \left( 1 - \frac{\varphi_k}{2} \left( \frac{i_t}{k_t} - \delta \right)^2 \right) + (1 - \delta) k_t \quad (\text{B.15})$$

$$rer_t = \frac{\Delta_t^e p_t^*}{\pi_t p_{t-1}^*} rer_{t-1} \quad (\text{B.16})$$

$$p_{x,t} = \frac{\pi_{x,t}}{\pi_t} p_{x,t-1} \quad (\text{B.17})$$

$$\log(R_t) = \rho_r \log(R_{t-1}) + (1 - \rho) (\log(\bar{R}) + \gamma_\pi (\log(\pi_t) - \log(\bar{\pi})) + \gamma_y (\log(y_t) - \log(\bar{y}))) \quad (\text{B.18})$$

$$p_{x,t}^n = \frac{\theta}{\theta - 1} \lambda_t p_{x,t}^\theta s_t x_t + \beta \zeta \mathbb{E}_t [p_{x,t+1}^n \pi_{t+1}^\theta] \quad (\text{B.19})$$

$$p_{x,t}^d = \lambda_t p_{x,t}^\theta x_t + \beta \bar{\zeta} \mathbb{E}_t [p_{x,t+1}^d \pi_{t+1}^{\theta-1}] \quad (\text{B.20})$$

$$p_{x,t} = \left( (1 - \bar{\zeta}) \left( \frac{p_{x,t}^n}{p_{x,t}^d} \right)^{1-\theta} + \bar{\zeta} \left( \frac{p_{x,t-1}}{\pi_t} \right)^{1-\theta} \right)^{\frac{1}{1-\theta}} \quad (\text{B.21})$$

$$\Delta_t = (1 - \bar{\zeta}) \left( \frac{p_{x,t}^n}{p_{x,t} p_{x,t}^d} \right)^{-\theta} + \bar{\zeta} \Delta_{t-1} \pi_{x,t}^\theta \quad (\text{B.22})$$

$$y_t^{*\frac{-1}{\sigma}} = \beta R^* \mathbb{E}_t y_{t+1}^{*\frac{-1}{\sigma}} \frac{p_t^*}{p_{t+1}^*} \quad (\text{B.23})$$

where  $\lambda_t = \Delta_t P_t$ ,  $rer_t = e_t P_t^* / P_t$ ,  $p_{x,t} = P_{x,t} / P_t$ ,  $p_t^n = P_t^n / P_t^\theta$ ,  $p_t^d = P_t^d / P_t^{\theta-1}$ ,  $\pi_t = P_t / P_{t-1}$ ,  $\pi_{x,t} = P_{x,t} / P_{x,t-1}$ ,  $\Delta_t^e = e_t / e_{t-1}$ .

All possible shocks follow AR(1) processes of the type

$$\log(a_{t+1}) = \rho_a \log(a_t) + \varepsilon_{a,t+1} \quad (\text{B.24})$$

$$\log(g_{t+1}) = \rho_g \log(g_t) + (1 - \rho_g) \log(\bar{g}) + \varepsilon_{g,t+1} \quad (\text{B.25})$$

$$\log(y_{t+1}^*) = \rho_y \log(y_t^*) + (1 - \rho_y) \log(\bar{y}) + \varepsilon_{y,t+1}^* \quad (\text{B.26})$$

$$\log(p_{t+1}^*) = \rho_p \log(p_t^*) + (1 - \rho_p) \log(\bar{p}) + \varepsilon_{p,t+1}^* \quad (\text{B.27})$$

but in this paper I will only focus on shocks to government expenditures (B.25)

## B.1 Steady state

Next follows a characterization of the zero inflation ( $\pi_t = P_t / P_{t-1} = 1$ ) perfect foresight steady state for the canonical small open economy model outlined above. This is needed in order to be able to linearize the system around the deterministic steady state, as the system outlined above is non-linear. Foreign output  $y^*$  is taken as given and there is no shock  $\tilde{\varepsilon}_{a,t} = 0$ ,  $\tilde{\varepsilon}_{g,t} = 0$ ,  $\tilde{\varepsilon}_{af,t} = 0$  so  $g_t = 1$ , for all  $t$ . Standard arguments establish the existence of a steady state with  $y_t = y$ ,  $\pi_t = P_t / P_{t-1} = P_{x,t} / P_{x,t-1} = P_{x,t}^* / P_{x,t-1}^* = 1$ , hence the real exchange rate is also 1 in steady state.

The variables in the steady state have no time subscript. From equation (B.11) it follows that the steady state real interest rate is,  $R = 1/\beta$ , the inverse of the time discount rate.

From the pricing mechanism (equations (B.19) and (B.20)) in steady state it holds that  $p_x^n = p_x^d$ , and thus I obtain the common result that in the steady state the real marginal costs are constant  $s = \frac{(\theta-1)}{\theta}$ , i.e. the inverse of the mark-up. The wage paid by firms is equal to all households and reads  $w = (1 - \alpha)s \frac{p_x^x}{h}$ . The steady state amount of working hours supplied by households  $h$  as well as the labor share  $wh/y$  are values to be calibrated and hence given. Knowing this I can solve for the elasticity of substitution between capital and labor  $\alpha$  which is  $\alpha = 1 - (wh)/(ys)$

In steady state, capital adjustment costs are assumed to be zero, i.e.  $\left(1 - \frac{\phi_k}{2} \left(\frac{i_t}{k_t} - \delta\right)^2\right) = 1$ , thus with equation (B.13) I can solve for the capital to output ratio  $k/y$ :

$$k/y = \alpha\beta s / (1 - \beta(1 - \delta)) \quad (\text{B.28})$$

and with equation (B.15) for the investment to output ratio  $i/y = \delta(k/y)$ . From the market clearing equation (B.4), given that in steady state portfolio adjustment costs  $\chi = 0$ , I obtain the consumption to output ratio:  $c/y = 1 - i/y - g/y$  where we know that  $g/y$  is calibrated prior to the simulation. Given these great ratios, I am now able to solve for steady state output  $y$ , capital  $k$ , investment  $i$ , consumption  $c$  and government spending  $g$ :

$$y = (k/y)^{\frac{\alpha}{1-\alpha}} h \quad \text{and then} \quad k = (k/y)y, i = (i/y)y, c = (c/y)y, g = (g/y)y \quad (\text{B.29})$$

Note that these steady state values so far do not depend on the specification of the utility function. Yet, to get an expression for  $\lambda, p_x^d, p_x^n$  the form of specification matters. Generally, it holds that

$$\lambda = U_c \quad \text{and} \quad p_x^d = (\lambda y) / (1 - \beta\zeta) \quad \text{with} \quad p_x^d = p_x^n \quad (\text{B.30})$$

## C Relation between consumption and hours worked

Combining equations (B.1) and (B.2) yields

$$w_t U_{c,t}(c_t, 1 - h_t) = U_{l,t}(c_t, 1 - h_t) \quad (\text{C.1})$$

By linearizing this equation around its non-stochastic steady state, I obtain:

$$\hat{w}_t w U_{c,t} + w U_{cc,t} c \hat{c}_t - w U_{cl,t} h \hat{h}_t = U_{lc,t} c \hat{c}_t - U_{ll,t} h \hat{h}_t \quad (\text{C.2})$$

Dividing equation (C.2) by (C.1) and including  $\hat{w}_t = \alpha \hat{k}_t - \alpha \hat{h}_t$ , after some rearranging equation 3.6 in the text is obtained.

## D Interdependence of $\nu$ and $\sigma$

In steady state we know the capital to output ratio  $k/y$  given in equation (B.28). We also know that in steady state marginal costs are equal to the inverse of the mark-up:  $s \equiv \mu^{-1}$ . From the production function we know that  $y = k^\alpha h^{1-\alpha}$  which leads to the capital-labor ratio:

$$k/h = \left(\frac{y}{k}\right)^{\frac{1}{\alpha-1}} = \left(\frac{1 - \beta(1 - \delta)}{\alpha\beta\mu^{-1}}\right)^{\frac{1}{\alpha-1}} \quad (\text{D.1})$$

From the household optimization and the labor market clearing we know that equation 3.12 in steady state reads

$$w = \frac{1 + \nu}{\sigma - 1}(c/h) = (1 - \alpha)\mu^{-1}(k/h)^\alpha \quad (\text{D.2})$$

whereas it is possible to solve for the consumption-employment ratio:

$$(c/h) = w = \frac{\sigma - 1}{1 + \nu}(1 - \alpha)\mu^{-1}(k/h)^\alpha \quad (\text{D.3})$$

Making use of the market clearing equation (B.4) in steady state we can write

$$((k/h)^\alpha - \delta(k/h))h - g = c \quad (\text{D.4})$$

Combining the last two equations an expression for steady state employment can be obtained:

$$h = \frac{g}{(k/h)^\alpha \left[1 - \frac{\sigma-1}{1+\nu}(1-\alpha)\mu^{-1}\right] - \delta(k/h)} \quad (\text{D.5})$$

and from the consumption to employment ratio we can solve for an expression of consumption to output  $(c/y) \equiv \gamma_c$ :

$$\gamma_c = \frac{\sigma - 1}{1 + \nu}(1 - \alpha)\mu^{-1} \quad (\text{D.6})$$

which finally leads to an expression where the interdependence of  $\sigma$  and  $\nu$  gets clear and is equation (3.13) in the text:

$$\nu = \frac{\mu_p^{-1}(\sigma - 1)(1 - \alpha)}{\gamma_c} - 1 \quad (\text{D.7})$$