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Schüder, Stefan

University of Goettingen (Gottingen) - Department of Economics

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by

Stefan Schüder

(University of Göttingen)

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This paper develops an open economy portfolio balance model with endogenous asset supply. Domestic producers choose an optimal capital structure and finance capital goods through credit, bonds and equity assets. Private households hold a portfolio of domestic and foreign assets, shift balances depending on risk-return considerations, and maximise real consumption in accordance with the law of one price.

Within this general equilibrium model, it will be shown that central bank interventions may promote an inefficient international allocation of real capital. The application of expansive monetary interventions throughout the course of economic crises maintains the domestic stock of real capital at the cost of inflation, currency devaluation, distortions of interest rates and asset prices, and risk clusters on the central bank's balance sheet. Exchange rate stabilising interventions have the result that the central bank can also stabilise the domestic stock of real capital. However, such interventions produce either risk clusters on the central bank's balance sheet or changes in the domestic price level.

JEL: E10, E44, E52

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Portfolio balance models have a long history in economic research and are widely used to explain the characteristics of exchange rates. The first significant models were developed, for example, by Grubel (1968), Dornbusch (1975), Girton and Henderson (1976), Branson (1977), Lucas (1982), Tobin (1983), Allen and Kenen (1983), and Branson and Henderson (1985). Within these models, private households choose an optimal portfolio based on risk-return considerations. This portfolio contains domestic and foreign assets, which are seen as imperfect substitutes. Other influential portfolio models, such as Tobin (1969) and Backus et al. (1980), only take domestic assets into account.

In the context of monetary policy, portfolio balance models are able to explain, through risk differences, why interest rate differentials may persist vis-à-vis the base country in the case of pegged floats and fixed exchange rate regimes (Frankel et al., 2004; Shambaugh, 2004; Obstfeld et al., 2005). However, Obstfeld (2004) remarks that further research is required as to date there is "no integrative general-equilibrium monetary model of

* University of Göttingen, Platz der Göttinger Sieben 3, 37073 Göttingen, Germany, stefan.schueder@googlemail.com. I would like to thank participants at the Global Conference on Business and Finance (Las Vegas 2011), the 13th IWB Workshop (Göttingen 2011), the 10th European Economics and Finance Society Conference (London 2011), the 13th INFER Annual Conference (London 2011), and, in particular, Carsten Eckel, Kenneth N. Kuttner, Herbert Möller-de-Beer, Renate Ohr, Gerhard Rübel, and Robert Schwager for valuable discussions and comments.

international portfolio choice, although we need one". Recent research has analysed the impact of different types of macroeconomic shocks on asset prices, the exchange rate and capital flows (Hau and Rey, 2006; Devereux and Sutherland, 2007; Gourinchas and Rey, 2007; Pavlova and Rigobon, 2007; Tille, 2008; Tille and van Wincoop, 2010), and placed emphasis on trying to explain the home bias in asset holdings (Heathcote and Perri, 2009, and references cited therein).

This paper considers the origin of financial assets and the implications this has for monetary policy transmission. To date, the amount of bonds and equity assets has not been treated as endogenous in the portfolio balance literature, with the exception of Tobin (1983) and Devereux and Saito (2006), whose asset supply still lacks microeconomic foundation.[1] Neither the determinants of producers' capital structure nor the special characteristics of equity assets are considered. The model developed here fills this gap. Looking at the economic literature, it is argued that producers maximise firm value and choose an optimal capital structure in accordance with the *static trade-off theory* (Modigliani and Miller, 1963; Jensen and Meckling, 1976), preferring the type of debt financing which requires the lowest capital costs (Bernanke and Blinder, 1988). Furthermore, equity assets contain call options on producers' real capital goods (Merton, 1974), and private households optimise their consumption of domestic and foreign goods through the *law of one price*. These relationships are integrated into a portfolio balance model of an open economy by strictly considering the balance sheet restrictions economic actors are facing in stock and flow figures, a requirement stressed by Brainard and Tobin (1968). Sims (1980) also sees this as necessary in order to avert a "bad *system* of restrictions". This approach reveals that portfolio adjustments have an impact on the domestic stock of real capital and consequently affect real domestic production. Since the central bank is able to influence the portfolio composition of private households through monetary interventions, the central bank has an indirect impact on the real economy. This impact needs to be considered if monetary policy trade-offs are to be comprehensively analysed in the context of portfolio balance models. Therefore, it is advisable to endogenise the domestic asset supply, as is done in this paper.

The derived model is very useful in analysing the impact of conventional and unconventional expansive monetary interventions that have been applied by central banks during the current financial crisis (Klyuev et al., 2009). In times of crisis, a relative increase in the domestic macroeconomic risk level is prevalent (Schwert, 1989; Mishkin, 2001; Angeletos and Werning, 2006). Thus, the relative attractiveness of domestic investment declines compared to foreign investment. By analysing the model's results, one sees that this is followed by a long term reduction in the domestic stock of real capital. However, if the central bank reacts with open market purchases of domestic bonds or with an increase in the supply of credit, it takes on domestic risk on its balance sheet. Through expansive

[1]Tobin (1983) assumes that the domestic assets supply depends on the replacement costs of capital goods. Devereux and Saito (2006) assume that the supply of domestic bonds is determined by the bond interest rate.

monetary interventions, the central bank reduces the domestic risk premium and consequently prevents domestic disinvestment. There are related side effects, however, such as domestic inflation, currency devaluation, distortions in domestic interest rates and asset prices, and risk clusters on the central bank's balance sheet.

Moreover, the model illustrates the trade-offs that, for example, the Swiss National Bank (2011) has recently decided to accept through enforcing a minimum exchange rate of 1.20 Swiss Franc per Euro. Within the model, central banks are able to stabilise the exchange rate in reaction to external shocks through interventions in credit, domestic bond, and foreign asset markets. However, it is essential to choose the right intervention strategy due to the different causes of exchange rate fluctuations. Sterilised interventions are required and are only sustainably effective if changes in the foreign interest rate or in the relative macroeconomic risk are the cause of the fluctuation. Non-sterilised interventions only work in the case of changes in the relative price level. Both types of intervention have the side effect that they can also avert adjustments in the domestic stock of real capital. Furthermore, sterilised interventions promote risk clusters on the central bank's balance sheet, whereas non-sterilised interventions are primarily connected to changes in the domestic price level.

In sum, both expansive monetary interventions, being applied during economic crises, and exchange rate stabilising interventions can prevent economically appropriate adjustments in the domestic stock of real capital, which comes with a cost to foreign investment. The result is that these central bank interventions can cause an inefficient international allocation of real capital and may therefore lead to a negative impact on world welfare.

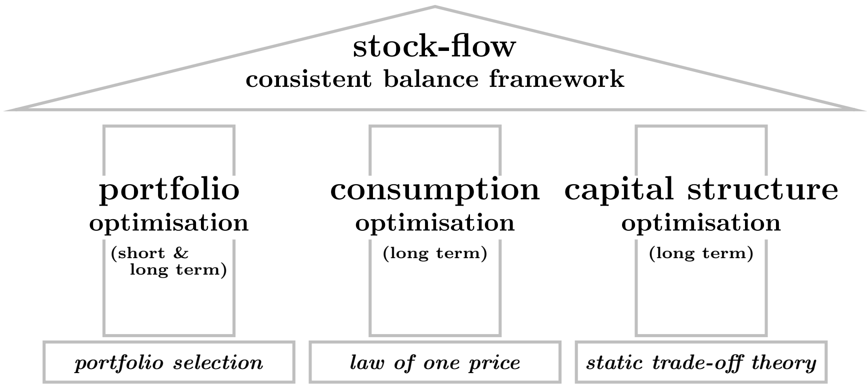
The paper is structured as follows; chapter I deals with the general model framework, followed by a detailed definition of the model assumptions. Thereupon, the model is solved and the different transmission channels of exogenous shocks are presented in chapter II. In chapter III, the trade-offs involved with monetary policy interventions are analysed. The extent to which expansive monetary interventions are able to neutralise the impact of an increase in domestic macroeconomic risk is discussed, and the possibilities available to avert exchange rate fluctuations are presented. Furthermore, impulse responses based on vector autoregressive estimations for three European countries are conducted for periods when pegged exchange rates existed, i. e., Austria (1989M06 - 1998M12), Belgium (1989M10 - 1998M12), and Denmark (1999M02 - 2011M3), providing empirical support for the theoretical assumptions. Reasons as to why simplifications do not reduce the general validity of the model are reconsidered in chapter IV, and the results are then summarised in the concluding chapter V.

I. Model Structure

A. General Framework

The architecture of the model is comparable to that of a Roman temple (see figure 1). It consists of one roof, that being the stock-flow consistent macroeconomic balance framework, which is sustained by three pillars. Each pillar represents an optimisation behaviour that is again based on a distinct microeconomic foundation.

Figure 1. : Model Structure



Each actor in the open economy considered, those being the central bank, producers, and private households, faces a balance sheet restriction, which shows its stock figures in the form of assets and liabilities, and an income balance restriction, which incorporates its specific inflows and outflows. The central bank represents the banking sector supplying credit, as well as trading domestic bonds and foreign assets in return for domestic money.[2] The producers generate real domestic production through the use of real capital. Real capital is the only factor of production and is financed by credit, bonds, and equity assets. Real domestic production consists of one single and homogenous good, which is also produced abroad. This good may either be used as real capital in the production process or be consumed by private households. Private households consume domestic and foreign goods and hold their wealth in the form of an asset portfolio. It is composed of the following gross substitutes; domestic money, domestic bonds, domestic equity, and foreign assets. The prices of domestic goods and financial assets are flexible. Domestic bonds and foreign assets are fixed interest bearing, whereas domestic equity assets pay out varying dividends. For the sake of simplicity, domestic actors are not able to influence variables of the foreign country, while foreign actors neither hold domestic assets nor consume domestic goods.

Each of the three optimisation behaviours implies that domestic actors maximise their utility with regard to one of three distinct economic areas, i. e., wealth management, consumption composition, and corporate financing. In accordance with Markowitz's (1952) *portfolio selection*, private households optimise their wealth structure in line with their

[2] Commercial banks are not explicitly considered since this would increase the complexity of the model without having an impact on the direction of the model results. For the same reason, the producers are not separated into government and private companies. See chapter IV and figure A.1 of the appendix for an in-depth discussion of this aspect.

risk-return objectives. Private households have direct access to the financial market and are therefore able to adjust their portfolio composition immediately. Furthermore, private households optimise their consumption composition and maximise real consumption of domestic and foreign goods following the *law of one price*. Producers optimise their capital structure and maximise firm value in accordance with the *static trade-off theory* (Modigliani and Miller, 1963; Jensen and Meckling, 1976). However, consumption optimisation and capital structure optimisation are connected to changes in the amount of domestic assets and producers' amount of real capital. These adjustments are time consuming and therefore not possible in the short term. Consequently, purchasing power parity and an optimal capital structure only persist in the long term.

Through these assumptions, four general equilibrium conditions for the money, domestic bond, domestic dividend, and foreign asset markets are obtained. These can be simultaneously solved for the reactions of the endogenous variables in the short term and the long term, respectively. An overview of all exogenous (roof-headed) and constant (line-headed) variables can be found in table A.1, and of all endogenous variables in table A.2, of the appendix. In the following sections, the assumptions are specified in detail.

B. Actors and Balance Restrictions

Central Bank

The central bank is the actor capable of conducting monetary policy operations. Depending on the preferred exchange rate regime, its main policy target may be either exchange rate stability or the stability of other variables like the domestic price level, real domestic production, or domestic interest rates. It is assumed that the central bank completely controls three variables which it uses independently to fulfil its mandate. First, it may change the volume of credit it supplies to producers ($\widehat{K}$).[3] Second, it is able to buy or sell domestic bonds ($\widehat{n^B_{CB}}$), and third, it can trade foreign bonds it holds as currency reserves ($\widehat{n^F_{CB}}$) in return for domestic money (M).

In total, the central bank holds assets in domestic currency to the value of the credit amount ($\widehat{K}$), the central bank's domestic bonds (B_{CB}), and foreign assets (sF_{CB}). Given that p^B denotes the price of one domestic bond, s the exchange rate in direct quotation, and p^F the price of one foreign asset in foreign currency, it holds that:

$$B_{CB} = \widehat{n^B_{CB}} \cdot p^B \tag{1}$$

$$sF_{CB} = \widehat{n^F_{CB}} \cdot s \cdot p^F \tag{2}$$

[3]Naturally, commercial banks supply credit to the producers within an economy. However, the central bank has a key impact on the amount of lending because it supplies credit to these commercial banks. Since the commercial banks are not considered in the model for the sake of simplicity, it is reasonable to assume that the central bank determines the credit supply (see figure A.1 of the appendix). Thereby, it is implied that the central bank represents the economy's aggregated banking sector within the model. For further discussion of this, see chapter IV.

In terms of liabilities, the central bank holds money (M) and net assets ($NetA$). Consequently, the balance sheet restriction of the central bank is:

$$\widehat{K} + B_{CB} + sF_{CB} = M + NetA \tag{3}$$

While the amount of money changes with the amount of credit, the amount of domestic bonds, or the amount of foreign assets, the net assets change if profits or losses occur due to a change in the valuation of domestic bonds or foreign assets:

$$dM = d\widehat{K} + d\widehat{n_{CB}^{B}} \cdot p^{B} + d\widehat{n_{CB}^{F}} \cdot s \cdot p^{F} \tag{4}$$

$$dNetA = dp^{B} \cdot \widehat{n_{CB}^{B}} + dp^{F} \cdot s \cdot \widehat{n_{CB}^{F}} + ds \cdot p^{F} \cdot \widehat{n_{CB}^{F}} \tag{5}$$

Equations 4 and 5 comprise the fundamental relations of the balance approach. Each increase in the amount of assets needs to be financed by an increase in the amount of liabilities[4], whereas an increase in the valuation of assets only positively affects the value of liabilities[5], without any impact on their amount, and vice versa.

Consequently, the total supply of domestic money (M^s) is completely controlled by the central bank. It is determined by the initial amount of money ($\overline{M}$) plus the changes in the money amount (see equation 4) caused by monetary policy interventions:

$$M^{s} = \overline{M} + d\widehat{K} + d\widehat{n_{CB}^{B}} \cdot p^{B} + d\widehat{n_{CB}^{F}} \cdot s \cdot p^{F} \tag{6}$$

Since the assets of the central bank bear interest, the central bank receives interest income ($i^K \cdot \widehat{K} + i^B \cdot B_{CB} + \widehat{i^F} \cdot sF_{CB}$). For the sake of simplicity, it is assumed that the central bank distributes its interest income immediately to the private households.[6] Thus, the central bank's balance of income is always balanced.

Private Households

It is assumed that private households hold their aggregated wealth (W) in the form of the domestic money amount (M), domestic bonds (B_P), domestic equity (E)[7], and foreign assets (sF_P). The value of each holding in domestic currency (B_P, E, sF_P) is the amount of private households' assets (n_P^B, n^E, n_P^F) multiplied by the relevant asset price

[4] The central bank is only able to adjust its amount of liabilities by changing the domestic money amount M.

[5] Since money is the numeraire, the value of money does not vary in absolute terms. Consequently, the residual position of net assets $NetA$ adjusts if the value of assets (measured in domestic currency) changes.

[6] This assumption does not reduce the general validity of the model seeing as in practice, the income of central banks is normally distributed to the respective governments, who then transfer it to private households, e. g., through salary payments or social benefits.

[7] Private households hold the total amount of domestic equity assets since the central bank does not hold domestic equity assets and foreign investors do not hold domestic assets at all. Therefore, $E = E_P$ and, respectively, $n^E = n_P^E$.

in domestic currency (p^B, p^E, $s \cdot p^F$):

$$B_P = n_P^B \cdot p^B \tag{7}$$

$$E = n^E \cdot p^E \tag{8}$$

$$sF_P = n_P^F \cdot s \cdot p^F \tag{9}$$

Hence, the balance sheet restriction of private households is expressed by:

$$M + B_P + E + sF_P = W \tag{10}$$

It follows that private households' wealth either changes with a varying amount or a varying valuation of domestic or foreign assets.

The nominal income of the private households is the sum of domestic interest payments ($i^B \cdot B_P$), domestic dividend payments ($Div := i^E \cdot E$), foreign interest payments ($\widehat{i^F} \cdot sF_P$), and central bank distribution ($i^K \cdot \widehat{K} + i^B \cdot B_{CB} + \widehat{i^F} \cdot sF_{CB}$):

$$Inc_P = i^B \cdot B_P + Div + \widehat{i^F} \cdot sF_P + i^K \cdot \widehat{K} + i^B \cdot B_{CB} + \widehat{i^F} \cdot sF_{CB} \tag{11}$$

Below, it is assumed that the private households use all their income for the consumption of either domestic goods (C_D) or foreign goods (C_F):

$$Inc_P = C_D + C_F \tag{12}$$

Thereby, it is implied that private households do not have any incentive to shift consumption inter-temporarily through saving or dissaving. Furthermore, their balance of income is balanced.

Producers

Each producer in the economy produces a homogeneous good in a competitive environment. The homogenous good can either be consumed by private households or be used as a factor of production by the producers.[8] Capital, in terms of real capital goods, is considered as the only factor of production, and each producer finances its capital goods through credit, bonds, or equity assets. Consequently, the producers' balance restriction expresses that the aggregated value of domestic capital goods (CG) is equal to the aggregated value of domestic credit ($\widehat{K}$), domestic bonds (B), and domestic equity (E):

$$CG = \widehat{K} + B + E \tag{13}$$

[8] If the good is used in the production process, it becomes worn out and therefore depreciates over time.

The implicit value of one capital good (val^{CG}) is the total value divided by the real amount (n^{CG}):

$$val^{CG} = \frac{CG}{n^{CG}} \tag{14}$$

Naturally, the real amount of domestic capital goods is connected to producers' amount of liabilities (determined by $\widehat{K}$, n^B, and n^E). With respect to the short term, it is assumed that producers' amount of liabilities is constant. The economic reason for this is that it takes time to negotiate loan agreements, as well as to issue or reduce the number of bonds and equity assets. The rationale here is substantiated in detail in section D. If producers take on additional credit or issue additional assets over the long term, they acquire the financial means to increase real investment, and vice versa. The consequence is that in the long term, producers' stock of real capital goods (n^{CG}) changes by the value of the change in the amount of liabilities ($d\widehat{K} + dn^B \cdot p^B + dn^E \cdot p^E$) divided by the price level of domestic goods (p):

$$dn^{CG} = \frac{d\widehat{K} + dn^B \cdot p^B + dn^E \cdot p^E}{p} \tag{15}$$

The producers generate income[9] to the amount of nominal domestic production (Y), which consists of the domestic price level (p) multiplied by real domestic production (Y^r):

$$Y = Y^r \cdot p \tag{16}$$

Real domestic production depends on the amount of real capital goods held by the producers. Assuming a Cobb-Douglas production function with constant returns to scale and constant total factor productivity ($\overline{a}$), a linear relation between Y^r and n^{CG} results in the current case, with real capital being the only factor of production:[10]

$$Y^r = \overline{a} \cdot n^{CG} \tag{17}$$

Moreover, since capital is the only factor of production, producers' income in its entirety is used to remunerate the lenders of capital:

$$Y = i^K \cdot \widehat{K} + i^B \cdot B + Div \tag{18}$$

[9]The term 'income' is used in the sense of value added. In line with the model, this is equal to producers' revenue less the depreciations on capital investment.

[10]The amount of producers' liabilities does not change in the short term. Thus, it follows from equation 15 that in the short term $dn^{CG} = 0$, and consequently, $dY^r = 0$. However, if an exogenous shock affects the economy, n^{CG} may change during the transition process towards a new long term equilibrium since producers' amount of liabilities may adjust. Consequently, Y^r may change in the long term. The rationale for these relationships is substantiated in section D.

Consequently, producers' inflows are constantly equal to producers' outflows.

Consolidated Balances

Given the balance equations of the open economy's three actors (see overview in table 1), as well as the following relations:

$$(19)\qquad B = B_P + B_{CB} \qquad n^B = n_P^B + \widehat{n_{CB}^B} \qquad B = p^B \cdot n^B$$

$$(20)\qquad F = F_P + F_{CB} \qquad n^F = n_P^F + \widehat{n_{CB}^F} \qquad F = p^F \cdot n^F$$

one finds that through consolidation, the value of domestic capital goods (CG) and the value of foreign assets held by domestic actors in domestic currency (sF) are equal to the aggregated domestic wealth ($W + NetA$):

$$(21)\qquad CG + sF = W + NetA$$

Since all balances of income are balanced[11], the aggregated balance of income is also balanced.

Table 1—The Balance Sheets of the Economic Actors

Central Bank (Eq. 3)

assets	liabilities
$\widehat{K}$	M
$B_{CB} = p^B \cdot \widehat{n_{CB}^B}$	$NetA$
$sF_{CB} = s \cdot p^F \cdot \widehat{n_{CB}^F}$	

Private Households (Eq. 10)

assets	liabilities
M	W
$B_P = p^B \cdot n_P^B$	
$E = \frac{Div}{i^E}$	
$sF_P = s \cdot p^F \cdot n_P^F$	

Producers (Eq. 13)

assets	liabilities
$CG = val^{CG} \cdot n^{CG}$	$\widehat{K}$
	$p^B \cdot n^B = B$
	$\frac{Div}{i^E} = E$

. . . .

Consolidated (Eq. 21)

assets	liabilities
$CG = val^{CG} \cdot n^{CG}$	W
$sF = s \cdot p^F \cdot n^F$	$NetA$

[11] The income of the central bank is distributed to private households. Private households' income is equal to their consumption expenditures (see equation 12). Producers distribute nominal domestic production to the lenders of capital, i. e., central bank and private households (see equation 18).

C. *Prices of Domestic Bonds, Foreign Assets, and Domestic Goods*

As is the case in traditional finance, the price of a financial asset is determined by the present value of its future cash flow. Concerning domestic bonds, it is assumed that the time to maturity of an average domestic bond is indefinite. Therefore, the cash flow of one fixed interest bearing domestic bond is characterised by a constant perpetuity of coupon payments ($\overline{q^B}_{t+n} = \overline{q^B}$ for $n = 0, 1, ..., \infty$). By implying that interest rates are positive and that the term structure of interest rates is flat, the price of one domestic bond in domestic currency (p^B) is:

$$p^B = \frac{\overline{q^B}}{i^B} \tag{22}$$

The price of one foreign asset in foreign currency (p^F) results analogically:

$$p^F = \frac{\overline{q^F}}{\widehat{i^F}} \tag{23}$$

Whereas the price level of foreign goods ($\widehat{p^*}$) is exogenously given, it is assumed that the price level of domestic goods (p) is determined through the relations of the Quantity Theory. The Quantity Equation expresses that the domestic money amount (M) is used with a constant velocity ($\overline{v}$) in order to conduct a desired amount of real domestic good transactions (approximated by Y^r), which are connected to the domestic price level (p):

$$M \cdot \overline{v} = p \cdot Y^r \tag{24}$$

Consequently, the domestic price level is determined by:

$$p = \frac{M \cdot \overline{v}}{Y^r} \tag{25}$$

D. *Domestic Asset Supply*

The Optimal Capital Structure

Producers finance themselves through capital forms debt ($\widehat{K} + B$) and equity (E). According to the *static trade-off theory*, an optimal debt to equity ratio exists when producer value ($\widehat{K} + B + E$) is maximised. It focuses on the benefits and costs of debt financing.

First, Modigliani and Miller (1958) showed that the capital structure is irrelevant for firms' total value. However, this is not the case if the general framework is extended to include taxes, agency costs, and costs of financial distress. Primarily, the use of debt is favoured if interest payments can be deducted from corporate tax (Modigliani and Miller, 1963). In addition, debt financing reduces the agency conflict between firms' managers and shareholders. Managers have the incentive to misuse a firm's free cash flow on supplementary grants and unprofitable investment at the expense of equity holders. Debt financing reduces the free cash flow available to managers, thereby limiting this agency conflict (Jensen and Meckling, 1976; Jensen, 1986). However, issuing debt causes agency costs due to conflicts between shareholders and debtors (Jensen and Meckling, 1976). Furthermore, there are other costs associated with issuing debt, i. e., the costs of financial distress (Modigliani and Miller, 1963; Myers, 1977). These costs will arise if a firm uses excessive debt, putting it in danger of failing to meet interest and principal payments. Even before bankruptcy, costs occur because a firm in distress will lose valuable customers, creditors, employees, and suppliers to more secure competitors.

Even though taxes, agency costs, and the risk of bankruptcy are not explicitly modeled, they can be seen as the reason why a target capital structure exists, which the producers tend to achieve. By implying that taxes and agency costs do not change, the costs of financial distress are higher the lower producers' income (Y) is, and the higher producers' interest payments on debt capital ($i^K \cdot \widehat{K} + \overline{q^B} \cdot n^B$) are. The optimal capital structure is achieved when the marginal benefits of debt financing are equal to the marginal costs of financial distress. Consequently, it is reasonable to assume that this is the case if the debt capital costs reach a certain proportion ($\overline{dc}$) of producers' income (Y):

$$i^K \cdot \widehat{K} + \overline{q^B} \cdot n^B = \overline{dc} \cdot Y \qquad 0 < \overline{dc} < 1 \tag{26}$$

If $i^K \cdot \widehat{K} + \overline{q^B} \cdot n^B > \overline{dc} \cdot Y$, the marginal benefits of debt financing are lower than the marginal costs, and producers tend to reduce leverage over time. The reverse relationship also holds.

Domestic Bond Supply and Credit Demand

The macroeconomic literature offers both the *credit view* and the *money view* to characterise producers' choice of debt capital (Bernanke and Blinder, 1988; Bolton and Freixas, 2006). In a nutshell, the *credit view* implies that firms cannot easily substitute bank loans for bonds. Economic reasons for this are, for example, that assessments of creditworthiness or the issuance of bonds are time consuming, as well as credit agreements and bond issues having a time constraint. Hence, the *money view* considers bank loans and bonds to be perfect substitutes since both are similar forms of debt capital.

Below, it is assumed that producers' choice of debt capital follows the *credit view* in the short term so that bond supply and credit demand are constant. Consequently, producers' short term supply of domestic bonds vis-à-vis the private households is implicitly expressed by equation 19. It is the total amount of domestic bonds (n^B) less the holdings of the central bank ($\widehat{n^B_{CB}}$):

$$(27) \qquad (n^B_P)^s = n^B - \widehat{n^B_{CB}}$$

Regarding the credit market, the *credit view* implies that the central bank faces a constant demand for credit in the short term, thus being able to cause infinite changes in the credit interest rate through infinitesimal changes in the credit supply. As a consequence, the credit interest rate (i^K) can be arbitrarily set. Therefore, it can be considered as exogenously determined by the central bank's monetary policy interventions in the short term. As a result, the target capital structure of the producers is not necessarily matched in the short term because deviations from equation 26 are possible.[12]

Hence, credit demand and bond supply become more and more elastic over time, as indicated by Bernanke and Blinder (1992) and Kashyap et al. (1993). In the long term, it is therefore reasonable to assume that the *money view* holds, eventually allowing the producers to adjust their capital structure until it reaches its optimum following the rationale of the *static trade-off theory*.[13] Thereby, it is implied that over the long term producers invest efficiently in order to obtain the highest possible output (see equation 17), given the financial constraint expressed in equation 26. In other words, producers maximise the amount of real capital goods (n^{CG}) they are able to finance through debt capital ($\frac{\widehat{K}+B}{p}$) in accordance with equation 26. It follows that producers' demand for credit (K^d) and supply of domestic bonds ($(n^B)^s$) negatively depend on the credit interest rate (i^K). The reason for this is that an increase in the credit interest rate increases debt capital costs, with producers tending to reduce the total amount of debt liabilities to again reach their optimal debt capital budget ($\overline{dc} \cdot Y$).[14] In addition, the demand for credit positively depends, and the supply of bonds negatively, on the interest rate difference between the bond interest rate and the credit interest rate ($i^B - i^K$). This is due to the resulting arbitrage behaviour. If the interest rate on credit is higher than that on bonds, producers issue additional bonds and try to substitute the relatively expensive credit to maximise $\frac{\widehat{K}+B}{p}$, and vice versa. Consequently, during the transition process towards an

[12]Since $\widehat{K}$ and n^B are constant in the short term due to the *credit view*, the producers are not able to avert an increase in the debt capital costs ($i^K \cdot \widehat{K} + \overline{q^B} \cdot n^B$) if the central bank increases i^K, and vice versa. Thus, it is not possible that equation 26 holds in any short term situation.

[13]Maximising the firm value through an optimal capital structure, which will be obtained if equation 26 is satisfied.

[14]This effect is comparable to the income effect with regard to the consumption of two goods. If the price of one good increases (here: increase in i^K), the demand for both goods (here: credit demand and bond supply) decreases.

optimal amount of debt capital, the following equations hold:

$$K^d = K(i^K, i^B - i^K) \tag{28}$$
$$\frac{\partial K^d}{\partial i^K} < 0,\ \frac{\partial K^d}{\partial (i^B - i^K)} > 0$$

$$(n^B)^s = n^B(i^K, i^B - i^K) \tag{29}$$
$$\frac{\partial n^B}{\partial i^K} < 0,\ \frac{\partial n^B}{\partial (i^B - i^K)} < 0$$

The *money view* implies that credit demand and bond supply adjust until bond and credit interest rates are equal in the long term. Thus, the long-term optimum is characterised by budget constraint 26, equilibrium on the credit market (equation 30), and the bond and credit interest rates being equal (equation 31).

$$K^d = \widehat{K} \tag{30}$$

$$i^K = i^B \tag{31}$$

By solving equations 26, 30, and 31 for n^B, under consideration of equations 16 and 24, it implicitly follows for producers' long term total supply of domestic bonds that:

$$(n^B)^s = \frac{\overline{dc} \cdot M \cdot \overline{v} - i^B \cdot \widehat{K}}{\overline{q^B}} \tag{32}$$

Consequently, producers' long term supply of domestic bonds vis-à-vis the private households is the total supply, less the holdings of the central bank:

$$(n^B_P)^s = \frac{\overline{dc} \cdot M \cdot \overline{v} - i^B \cdot \widehat{K}}{\overline{q^B}} - \widehat{n^B_{CB}} \tag{33}$$

Domestic Equity Assets

The price of one domestic equity asset (p^E) is the net present value of its dividend cash flow. By assumption, dividend payments are positive and private households regard the dividend cash flow as a constant perpetuity ($div_{t+n} = div$ for $n = 0, 1, ..., \infty$). Furthermore, the equity discount rate is positive and its term structure is flat. Accordingly, the price of one domestic equity asset (p^E) is:

$$p^E = \frac{div}{i^E} \tag{34}$$

Hence, the dividend payment per equity asset (div) is the aggregated amount of domestic dividend payments ($Div := i^E \cdot E$) divided by the total amount of equity assets (n^E):

$$div = \frac{Div}{n^E} \tag{35}$$

Taking the producers' income (equation 18), the aggregated domestic dividend payments (Div) have to be equal to producers' residual income (Magni, 2009).[15] By transposing equation 18 under consideration of equation 16, it follows in general that:

$$Div = p \cdot Y^r - i^K \cdot \widehat{K} - i^B \cdot B \tag{36}$$

Taking equations 19, 22, and Quantity Equation 24, it follows for the short term that Div is completely determined by variables which are constant ($\overline{v}$, $\widehat{K}$, $\overline{q^B}$, n^B) or exogenously determined by the domestic central bank (M, i^K):

$$Div = M \cdot \overline{v} - i^K \cdot \widehat{K} - \overline{q^B} \cdot n^B \tag{37}$$

This also turns out to be the case in the long term, seeing as through consideration of the producers' target capital structure constraint in equation 26, one obtains:

$$Div = M \cdot \overline{v} \cdot (1 - \overline{dc}) \tag{38}$$

If domestic equity assets are compared with domestic bonds and foreign assets, what they have in common is that their values only depend on their cash flows, not on the amount of real capital goods held by domestic or foreign producers (see equations 22, 23, and 34). However, they are also different in several crucial ways. The cash flow stream of domestic bonds is given by $\overline{q^B}$ and is independent of other variables. If domestic producers are able to issue additional domestic bonds (increase in n^B) without affecting the interest rate (i^B)[16], the aggregated value of domestic bonds (B) increases (see equations 19 and 22). This is not the case for domestic equity assets. Producers cannot change the total equity value through an issue or buyback of equity assets since the aggregated amount of dividend payments (Div) is independent of the amount of equity assets in the short term, as well as in the long term (see equations 37 and 38). If producers increase the amount of equity assets, the amount of nominal dividend payments on each equity asset decreases proportionally and thus, the price of each equity asset decreases proportionally

[15] To determine dividend payments within a portfolio model, an equivalent approach is applied by Tille (2008).

[16] An increase in n^B is considered given the ceteris paribus assumption. Consequently, it is implied that the demand for domestic bonds is completely elastic; this is generally not the case, but is assumed for this gedankenexperiment.

given an unchanged discount rate (i^E). In sum, the aggregated value of domestic equity (E) remains unchanged.

The structure of ownership rights is another difference between domestic bonds and equity assets. Merton (1974) maintains that each equity asset is considered to contain a call option on producers' assets, i. e., producers' real capital goods. By exercising this option, they receive real goods to the value of the current equity price (see equation 15). In the following analysis, the opposite relationship is also assumed, i. e., real goods contain call options on equity assets. Thus, private households have the ability to redeem a proportion of their equity assets in return for real goods on the one hand or exchange a part of their real income for equity assets on the other. While this assumption seems unfamiliar at first, it becomes clear when bringing to mind how different mechanisms can be used to redeem or generate equity assets in practice, given a fixed amount of liabilities.

The first possibility is a change in the stocks of produced goods. If stocks are reduced, equity capital is released, whereas if stocks are increased, additional equity capital is bounded given an unchanged amount of liabilities. The second possibility is the depreciation channel. If depreciations on real capital are not entirely replaced, equity capital is released and the cash flow from investing increases. If producers' cash flow is used for additional investment on the other hand, additional equity is bounded. The third possibility is a direct exchange of equity with the producers. Although owners of small private companies are able to personally draw or contribute equity capital relatively easily, the more coordination that is required, the higher the likelihood that partners will be present. For instance, shareholders of corporations have to decide at general meetings whether stocks should be repurchased or issued.

Since all three procedures are time consuming, it is reasonable to assume that private households are only gradually able to redeem or contribute equity over the long term. Therefore, the amount of equity assets is considered constant in the short term and may change over time.

Below, it needs to be discussed what incentives private households have to exchange equity assets for real goods, and vice versa. Generally, it is reasonable to assume that private households consume in an efficient way insofar that they maximise the real amount of consumption ($\frac{C_D}{p} + \frac{C_F}{\widehat{p^{\star}} \cdot s}$) given their budget constraint. At any time, their budget constraint is expressed by their income balance restriction (equation 12). Taking equations 11, 18, 19, and 20 into account, it follows that private households' budget constraint can be expressed by:

$$Y + s \cdot \overline{q^F} \cdot n^F = C_D + C_F \tag{39}$$

To maximise real consumption, private households compare the price level of domestic goods with the price level of foreign goods in domestic currency. If the price levels are different, private households accordingly shift their consumption to the relatively cheaper good. Consequently, the composition of consumption depends on the real exchange rate

(s^{real}), which is the quotient of the foreign price level in domestic currency ($\widehat{p^*} \cdot s$) and the domestic price level (p):

$$s^{real} = \frac{\widehat{p^*} \cdot s}{p} \tag{40}$$

If $s^{real} = 1$, the *law of one price* holds in terms of purchasing power parity, and private households are indifferent to the consumption of either domestic or foreign goods. If private households were to consume more domestic goods than are domestically produced ($C_D > Y$), they would respectively consume less foreign goods than foreign interest payments ($C_F < s \cdot \overline{q^F} \cdot n^F$) according to income balance restriction 39. The domestic economy would experience a current account surplus[17], which would be associated with an excess supply of foreign currency, leading to an appreciation of the domestic currency (decrease in s). Thus, domestic goods would become relatively expensive (s^{real} would decrease), and private households would adjust the composition of their consumption until purchasing power parity were again to hold in conjunction with an equilibrium on the foreign exchange market (balanced current account). Consequently, long term equilibrium is inevitably associated with purchasing power parity and a balanced current account, insofar that private households consume domestic goods to the value of domestic production (Y), and foreign goods to the value of foreign interest payments ($s \cdot \overline{q^F} \cdot n^F$).

If $s^{real} > 1$ in a situation without long term equilibrium, domestic goods are relatively cheaper, and private households tend to substitute foreign goods for domestic goods in order to maximise real consumption. However, if they do so, the result is that they require more domestic goods than are domestically produced (in accordance with income balance restriction 39). This can be overcome in two ways; on the one hand, domestic goods can be released in the long term if domestic producers reduce their amount of debt liabilities (see equation 15); on the other hand, private households have the possibility to carry out additional domestic consumption themselves, since in the long term they are able to redeem equity assets in return for domestic real goods from the producers.

If domestic goods are relatively expensive compared to foreign goods ($s^{real} < 1$), domestic private households tend to consume less domestic goods than are domestically produced, exchanging the surplus in return for equity assets. During the transition process towards a long term equilibrium with purchasing power parity and a balanced current account, the following relationship holds accordingly:

$$\begin{gathered} C_D = Y - d\widehat{K} - dn^B \cdot p^B - dn^E \cdot p^E \\ dn^E \begin{cases} < 0 & \text{if } s^{real} > 1 \\ > 0 & \text{if } s^{real} < 1 \\ = 0 & \text{else} \end{cases} \end{gathered} \tag{41}$$

[17]The current account consists of the trade account plus the account of international interest payments.

E. Balance of Payments and Foreign Asset Supply

Balance of Payments

Through the consumption behaviour of private households, it follows that in long term equilibrium, the current account is balanced. Since in long term equilibrium the domestic amount of foreign assets does not change, the capital account is also balanced, with the result being a balanced balance of payments:

$$0 = C_D - Y = -C_F + s \cdot \overline{q^F} \cdot n^F \tag{42}$$

Equation 42 also holds under the occurrence of an exogenous shock. This is because the total amount of credit, domestic bonds, and equity is constant in the short term, given the economic reasons in section D.

During the transition process towards long term equilibrium, the current account may be positive or negative. Since the balance of payments is constantly balanced (Meade, 1951), it is a necessary condition that a positive current account is accompanied by a negative capital account corresponding to the same amount. A positive current account arises if domestic goods are relatively cheaper compared to foreign goods ($s^{real} > 1$), in accordance with private households' consumption behaviour (see equation 41). Following private households' budget constraint 39, less than the total amount of foreign interest income is utilised for the consumption of foreign goods. The residual foreign interest income is then used to acquire foreign assets, causing a capital account deficit equal to the current account surplus. The opposite holds, if $s^{real} < 1$. During the transition process towards long term equilibrium, the balance of payments restriction is consequently expressed by:

$$0 = C_D - Y + d\widehat{K} + dn^B \cdot p^B + dn^E \cdot p^E = -C_F + s \cdot \overline{q^F} \cdot n^F - dn^F \cdot s \cdot p^F \tag{43}$$

While the value of the current account during the transition process is explained by private households' consumption behaviour, the value of the capital account has yet to be explained. What are the incentives for private households to use positive or negative residual foreign interest income to acquire or sell foreign assets?

A current account surplus brings about an excess supply of foreign currency, which subsequently causes an appreciation of the domestic currency (decrease in s). Consequently, the amount of foreign assets held in private households' portfolio loses value in domestic currency. Hence, the foreign asset portion of the portfolio would become too small to maintain an optimal portfolio composition. Private households compensate for this loss in value through increasing the amount of foreign assets they hold. The opposite occurs if a current account deficit exists.

These relationships result through private households' portfolio selection. They will be described in detail upon specification of the supply of foreign assets in the coming section.

Foreign Asset Supply

Overall, the supply of foreign assets vis-à-vis the private households consists of three parts. First, there is the initial amount of foreign assets held domestically ($\overline{n^F}$). The second part is the holdings of the domestic central bank ($\widehat{n^F_{CB}}$), and the third, the changes in the amount of foreign assets due to fluctuations in the balance of payments (dn^F). From private households' budget constraint 39 and the balance of payments restriction 43, it follows for dn^F that:

$$dn^F = -\frac{d\widehat{K} + dn^B \cdot p^B + dn^E \cdot p^E}{s \cdot p^F} \tag{44}$$

As discussed before, the amounts of domestic assets are constant in the short term, and therefore, $dn^F = 0$ according to equation 44. Consequently, the short term supply of foreign bonds vis-à-vis the private households is:

$$(n^F_P)^s = \overline{n^F} - \widehat{n^F_{CB}} \tag{45}$$

Since the amount of domestic assets may adjust over time, dn^F may be positive or negative in the long term. Consequently, the long term supply of foreign bonds vis-à-vis the private households is:

$$(n^F_P)^s = \overline{n^F} - \widehat{n^F_{CB}} + dn^F \tag{46}$$

F. Portfolio Selection and Money Demand

By assumption, private households are risk averse and optimise their individual asset portfolios following the *portfolio selection* of Markowitz (1952). With respect to its personal preferences, each household chooses a portfolio which delivers its preferred risk-return relationship. It is assumed that private households' preferences are constant over time, i. e., not changing with the level of wealth. In addition, transaction costs are not considered. The sum of individual asset holdings corresponds to private households' aggregated portfolio ($M + B_P + E + sF_P$), which represents private households' wealth (W) according to the balance equation 10. The assets within private households' portfolio are gross substitutes and the portfolio proportions corresponding to each asset class (m, b,

e, f) are:

$$m = \frac{M}{W} \qquad b = \frac{B_P}{W} \qquad e = \frac{E}{W} \qquad f = \frac{sF_P}{W} \tag{47}$$
$$m + b + e + f = 1$$

Given the assets' risk structure[18], private households tend to hold higher proportions invested in assets with higher expected returns and lower opportunity costs, i. e., the expected return on alternative assets. For the sake of simplicity, it is assumed that private households form static expectations about future asset prices and the future exchange rate under uncertainty. Accordingly, their expectations do not differ, on average, from current market values. This implies that at no point in time are changes in asset prices or in the exchange rate expected (on average) by private households. Consequently, the expected return on each asset is equal to the corresponding current market level of interest rates (i^B, i^E, $\widehat{i^F}$).

Given the structure of returns, private households tend to increase the fraction they hold of a specific asset the less it contributes to the total risk of the portfolio, and vice versa. Besides the individual risk of each asset class, which is at least partly diversifiable in the portfolio selection process, it is assumed that domestic and foreign assets are exposed to systemic risk, which is related to serious disturbances in the corresponding financial systems. Since systemic risk is considered to affect the entirety of assets in a particular economy, it is termed macroeconomic risk in this paper. This macroeconomic risk may be driven by financial instability, e. g., caused by regulation procedures allowing for a lack of transparency and information asymmetries, by political instability, e. g., caused by national unrest, or even by the risk of natural disasters, e. g., caused by changes in the environment. Since these are factors which lie beyond the scope of this model, it is reasonable to assume that the extent of macroeconomic risk is exogenously given. Here, $\widehat{\sigma}$ is defined as the difference between domestic and foreign macroeconomic risk. Consequently, an exogenous increase in $\widehat{\sigma}$ indicates a relative increase in domestic macroeconomic risk, whereby all domestic assets become relatively riskier compared to foreign assets, and vice versa.[19]

Domestic money is notably different compared to other assets since it is not only part of the portfolio selection process, but is also used for transaction purposes. Consequently, private households' demand for money needs to be consistent with the relations of Quantity Equation 24.[20] Accordingly, private households demand more money the higher the price of one goods transaction (p) is, the more transactions they tend to perform (approx-

[18] The variance-covariance matrix of asset returns.

[19] For example, after the collapse of Lehman Brothers in 2008, it was unclear how the financial systems of the US and closely connected countries may withstand this shock due to the complex and abstruse position of Lehman Brothers within their financial industries. This increase in uncertainty compared to less affected countries would be captured by an increase in $\widehat{\sigma}$ within the model.

[20] See the relationships of the *real-balance effect* and the *net-real-financial-asset effect* in Patinkin (1966).

imated by Y^r), and the fewer transactions that are technically possible to carry out in a certain period of time ($\overline{v}$). Altogether, private households tend to hold a higher fraction of money in their portfolio and decrease the proportions held of remaining assets if $\frac{p \cdot Y^r}{\overline{v}}$ increases, and vice versa.

In sum, the demand for values according to the different asset classes is given by:

$$M^d = m(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \tag{48}$$

$$\frac{\partial m}{\partial i^B} < 0,\ \frac{\partial m}{\partial i^E} < 0,\ \frac{\partial m}{\partial \widehat{i^F}} < 0,\ \frac{\partial m}{\partial \widehat{\sigma}} < 0,\ \frac{\partial m}{\partial (\frac{p \cdot Y^r}{\overline{v}})} > 0$$

$$B_P^d = b(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \tag{49}$$

$$\frac{\partial b}{\partial i^B} > 0,\ \frac{\partial b}{\partial i^E} < 0,\ \frac{\partial b}{\partial \widehat{i^F}} < 0,\ \frac{\partial b}{\partial \widehat{\sigma}} < 0,\ \frac{\partial b}{\partial (\frac{p \cdot Y^r}{\overline{v}})} < 0$$

$$E^d = e(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \tag{50}$$

$$\frac{\partial e}{\partial i^B} < 0,\ \frac{\partial e}{\partial i^E} > 0,\ \frac{\partial e}{\partial \widehat{i^F}} < 0,\ \frac{\partial e}{\partial \widehat{\sigma}} < 0,\ \frac{\partial e}{\partial (\frac{p \cdot Y^r}{\overline{v}})} < 0$$

$$sF_P^d = f(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \tag{51}$$

$$\frac{\partial f}{\partial i^B} < 0,\ \frac{\partial f}{\partial i^E} < 0,\ \frac{\partial f}{\partial \widehat{i^F}} > 0,\ \frac{\partial f}{\partial \widehat{\sigma}} > 0,\ \frac{\partial f}{\partial (\frac{p \cdot Y^r}{\overline{v}})} < 0$$

The private households' demand concerning the quantity of domestic bonds ($(n_P^B)^d$) is derived through dividing B_P^d by the price of one domestic bond (see equation 22). Multiplying E^d by the equity discount rate, one gets the demand for domestic dividend payments (Div^d). Through dividing sF_P^d by the foreign asset price (see equation 23) in domestic currency, the demand for the quantity of foreign bonds ($(n_P^F)^d$) is obtained:

$$(n_P^B)^d = b(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot \frac{i^B}{\overline{\overline{q^B}}} \tag{52}$$

$$Div^d = e(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot i^E \tag{53}$$

$$(n_P^F)^d = f(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot \frac{\widehat{i^F}}{\overline{\overline{s \cdot q^F}}} \tag{54}$$

G. Equilibrium Conditions

Short Term

In the short term, the model shows four equilibrium conditions. Looking at the money market first, it is necessary under the condition of the Quantity Equation 24 that the domestic money amount (M) is equal to money demand (see equation 48) and money supply (see equation 6[21]):

$$M = \frac{p \cdot Y^r}{\overline{v}} = m(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W = \overline{M} + d\widehat{n_{CB}^B} \cdot p^B + d\widehat{n_{CB}^F} \cdot s \cdot p^F \tag{55}$$

Secondly, in reference to the domestic bond market, it is necessary that private households' amount of domestic bonds (n_P^B) is equal to demand (see equation 52) and short term supply (see equation 27):

$$n_P^B = b(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot \frac{i^B}{\overline{\overline{q^B}}} = n^B - \widehat{n_{CB}^B} \tag{56}$$

Thirdly, in the dividend market, it is necessary that private households' claim for dividend payments (Div) is equal to their demand (see equation 53), as well as the amount of dividend payments available in the short term (see equation 37):

$$Div = e(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot i^E = M \cdot \overline{v} - i^K \cdot \widehat{K} - \overline{q^B} \cdot n^B \tag{57}$$

Finally, in the foreign asset market, the amount of private households' foreign assets (n_P^F) must be equal to demand (see equation 54), as well as short term supply (see equation 45):

$$n_P^F = f(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot \frac{\widehat{i^F}}{s \cdot \overline{q^F}} = \overline{n^F} - \widehat{n_{CB}^F} \tag{58}$$

In the short term, the credit amount ($\widehat{K}$) and the amounts of domestic assets (n^B, n^E) are considered constant (see rationale in section D). In relation to equation 44, the total amount of foreign assets consequently remains at the initial level ($\overline{n^F}$).

The remaining endogenous variables are the domestic bond interest rate (i^B), the equity discount rate (i^E), and the exchange rate (s). Through total differentiation of the equilibrium conditions 56, 57, and 58, and the following system of linear equations, the changes in i^B, i^E, and s can be simultaneously determined. Due to Walras' Law, money market condition 55 does not need to be considered. The result is that changes in

[21] In the short term, $d\widehat{K} = 0$ (see *credit view* in section D). Consequently, short term money supply is $\overline{M} + d\widehat{n_{CB}^B} \cdot p^B + d\widehat{n_{CB}^F} \cdot s \cdot p^F$.

(short term) exogenous variables like the interest rate on foreign assets ($\widehat{i^F}$), the relative macroeconomic risk ($\widehat{\sigma}$), the credit interest rate (i^K), and the central bank holdings of domestic bonds ($\widehat{n^B_{CB}}$) and foreign assets ($\widehat{n^F_{CB}}$) affect the endogenous variables and private households' wealth (W) in the short term.

Long Term

In the long term, the money market condition changes slightly compared to the short term as the central bank is able to adjust credit supply:

$$M = m(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W = \frac{p \cdot Y^r}{\overline{v}} = \overline{M} + d\widehat{K} + d\widehat{n^B_{CB}} \cdot p^B + d\widehat{n^F_{CB}} \cdot s \cdot p^F \tag{59}$$

Moreover, the domestic bond market condition changes as the total supply of domestic bonds adjusts in the long term (see equation 33):

$$n^B_P = b(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot \frac{i^B}{\overline{\overline{q^B}}} = \frac{\overline{dc} \cdot M \cdot \overline{v} - i^B \cdot \widehat{K}}{\overline{\overline{q^B}}} - \widehat{n^B_{CB}} \tag{60}$$

The amount of domestic dividend payments adjusts in the long term as well (see equation 38). Therefore, the equilibrium condition concerning domestic dividend payments is:

$$Div = e(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot i^E = M \cdot \overline{v} \cdot (1 - \overline{dc}) \tag{61}$$

In addition, the foreign asset market condition 58 adjusts seeing as the long term supply of foreign assets is required (see equation 46):

$$n^F_P = f(i^B, i^E, \widehat{i^F}, \widehat{\sigma}, \frac{p \cdot Y^r}{\overline{v}}) \cdot W \cdot \frac{\widehat{i^F}}{s \cdot \overline{\overline{q^F}}} = \overline{n^F} - \widehat{n^F_{CB}} + dn^F \tag{62}$$

A stable, long term general equilibrium must be associated with purchasing power parity due to private households' maximising of real consumption (see page 16 et seq.). A necessary condition for long term equilibrium (in addition to the market conditions) is therefore:

$$s = \frac{p}{\widehat{p^*}} \tag{63}$$

With regard to the Quantity Equation (equation 24) and the production function (equation 17), equation 63 can be expressed by:

$$s = \frac{M \cdot \overline{v}}{\overline{a} \cdot n^{CG} \cdot \widehat{p^*}} \tag{64}$$

In the long term, changes in n^E are derived if changes in n^B and n^F are determined, and exogenous changes in $\widehat{K}$ are given (see equation 44). Changes in n_P^B and n_P^F consist of exogenous changes in $\widehat{n_{CB}^B}$ and $\widehat{n_{CB}^F}$, and endogenous changes in n^B and n^F (see equations 19 and 20).

To solve for all endogenous variables, it is therefore sufficient to simultaneously derive the changes in i^B, i^E, s, n^B, and n^F by using the equilibrium conditions 60, 61, and 62, as well as the purchasing power parity condition 64. This results in changes in most of the exogenous variables, which also have an impact in the short term ($\widehat{i^F}$, $\widehat{\sigma}$, $\widehat{n_{CB}^B}$, $\widehat{n_{CB}^F}$), as well as the credit amount ($\widehat{K}$) and the foreign price level ($\widehat{p^*}$) affecting the endogenous variables in the long term. Since the domestic asset amounts and therefore the amount of domestic real capital (n^{CG}) vary in the long term (see equation 15), not only may private households' wealth (W) adjust to changes in the exogenous variables, but also real domestic production (Y^r).

II. Model Solution

A. Fundamental Effects

The impact of changes in exogenous and endogenous variables can be differentiated by four effects. Three effects are related to the demand side. In the following, these are termed the *allocation effect*, *wealth effect*, and *value compensation effect*.

The *allocation effect* captures the fraction of changes in asset demand attributed to private households' portfolio adjustments. Portfolio adjustments take place if private households alter the proportions of the assets held in their aggregate portfolio (m, b, e, and f). For example, if the foreign interest rate ($\widehat{i^F}$) increases exogenously, a higher proportion of their portfolio tends to be in foreign assets (f), with a lower proportion of the remaining assets (m, b, and e), respectively. Consequently, the demand for foreign assets increases, and the demand for the remaining assets decreases. This relationship is analogous if an exogenous shock leads, for example, to an endogenous increase in the domestic bond interest rate (i^B). Private households tend to increase b at the cost of m, e, and f. Since the portfolio proportions depend on i^B, i^E, $\widehat{i^F}$, $\widehat{\sigma}$, and $\frac{p \cdot Y^r}{\overline{v}}$ (see equations 48, 49, 50, and 51), the *allocation effect* results if changes in these variables occur.

The *wealth effect* captures the fraction of changes in asset demand that occur due to changes in the total level of private households' wealth (W). If W decreases (e. g., from an exogenous increase in $\widehat{i^F}$ or an endogenous decrease in n_P^B), private households' demand for quantities of all asset types decreases proportionally, and vice versa (see equations 48, 52, 53, and 54). Since W depends on M, i^B, i^E, $\widehat{i^F}$, s, n_P^B, Div, and n_P^F,[22] the *wealth effect* results if changes in these variables take place.

The *value compensation effect* captures the fraction of changes in asset demand that take place due to changes in the value of one asset type relative to the others. For example,

[22] Equation 10 can be written as $W = M + \frac{n_P^B \cdot \overline{q^B}}{i^B} + \frac{Div}{i^E} + \frac{n_P^F \cdot s \cdot \overline{q^F}}{\widehat{i^F}}$.

if the foreign interest rate ($\widehat{i^F}$) increases exogenously, the value of foreign assets decreases by a higher fraction than the total level of private households' wealth. Consequently, the proportion of foreign assets (f) decreases relative to the others. To compensate for this to the extent that the initial portfolio composition is maintained, private households' demand for foreign assets increases and the demand for the remaining assets decreases, respectively. In sum, the *value compensation effect* occurs if changes in i^B, i^E, $\widehat{i^F}$, or s take place.

Besides the three demand effects, there is also a *supply effect* capturing changes in the amount of assets. For example, the supply of domestic bonds decreases vis-à-vis the private households if the central bank increases its amount of domestic bonds (see equations 27 and 33). All in all, the *supply effect* is present if changes in M, n_P^B, Div, and n_P^F take place.

B. *Impact of Changes in Exogenous Variables*

General Outline

Changes in exogenous variables cause demand or supply effects which lead to excess demand or excess supply on the respective asset markets. Consequently, the endogenous variables adjust in order to produce opposing demand and supply effects that compensate for the imbalances, thus achieving general equilibrium once again. To determine the exogenous impacts, the equilibrium conditions are totally differentiated, and the respective systems of linear equations for the short term and the long term are solved. Table 2 gives an overview of the short term impact of changes in the exogenous variables, while table 3 summarises the impacts with respect to the long term. In relation to the tables, it is important to note that the values of the portfolio fraction elasticities are considered reasonable if, for example, the value of $\frac{\partial b}{\partial i^E}\frac{i^E}{b}$ is similar compared to $\frac{\partial m}{\partial i^E}\frac{i^E}{m}$ and $\frac{\partial f}{\partial i^E}\frac{i^E}{f}$, etc. The values of $\overline{dc}$ and $\overline{v}$ are considered reasonable if $\overline{dc} \cdot \overline{v} > i^B$.[23]

External Influence on Domestic Variables

Subsequently, the impact of changes in variables which are not under the control of the central bank ($\widehat{\sigma}$, $\widehat{i^F}$, and $\widehat{p^*}$) are looked at, with changes in these variables being termed external shocks.[24]

If an increase in domestic macroeconomic risk leads to a relative risk increase ($d\widehat{\sigma} > 0$), the risk averse private households tend to increase their exposure to foreign assets

[23]The solving of the model is described in detail by a supplemental paper available on the IQSS Dataverse http://dvn.iq.harvard.edu/dvn/dv/schueder. Therein, the solutions are available in explicit formulas (e. g., useful for simulating the model results). Likewise, it is proven that the short term system and the long term system are truly dynamically stable, following the approach by Metzler (1945). See also the review of Hands (2010) on stability tests for general equilibrium models.

[24]Exogenous increases in $\widehat{\sigma}$, $\widehat{i^F}$, and $\widehat{p^*}$ are discussed. The conclusions hold vice versa if decreases in $\widehat{\sigma}$, $\widehat{i^F}$, and $\widehat{p^*}$ are considered.

Table 2—Impact of Changes in the Exogenous Variables in the Short Term

	$di^B/$	$di^E/$	$ds/$	$dW/$	$dp/$
$/d\widehat{\sigma}$	$\gtrless 0$	$\gtrless 0$	> 0	$> 0\,^b$	$= 0$
$/d\widehat{i^F}$	$\gtrless 0$	$\gtrless 0$	> 0	$> 0\,^b$	$= 0$
$/di^K$	$\gtrless 0$	< 0	$\gtrless 0$	< 0	$= 0$
$/d\widehat{n^B_{CB}}$	$< 0\,^a$	$> 0\,^a$	$\gtrless 0$	> 0	> 0
$/d\widehat{n^F_{CB}}$	$\gtrless 0$	> 0	$> 0\,^a$	> 0	> 0

[a] Given reasonable values of portfolio fraction elasticities.

[b] Given $\frac{\partial m}{\partial \widehat{\sigma}} \frac{\widehat{\sigma}}{m}$, and respectively $\frac{\partial m}{\partial \widehat{i^F}} \frac{\widehat{i^F}}{m}$, differ sufficiently from 0.

Table 3—Impact of Changes in the Exogenous Variables in the Long Term

	$di^B/$	$di^E/$	$ds/$	$dn^F/$	$dn^B/$	$dW/$	$dY^r/$	$dp/$
$/d\widehat{\sigma}$	$\gtrless 0$	$\gtrless 0$	> 0	> 0	$\gtrless 0$	$> 0\,^c$	< 0	> 0
$/d\widehat{i^F}$	$\gtrless 0$	$\gtrless 0$	> 0	> 0	$\gtrless 0$	$> 0\,^c$	< 0	> 0
$/d\widehat{p^*}$	$= 0$	$= 0$	< 0	> 0	$= 0$	$= 0$	< 0	> 0
$/d\widehat{K}$	$> 0\,^a$	$> 0\,^b$	$> 0\,^b$	$< 0\,^b$	$> 0\,^a$	> 0	$> 0\,^b$	$> 0\,^b$
$/d\widehat{n^B_{CB}}$	$> 0\,^a$	$> 0\,^b$	$> 0\,^b$	$< 0\,^b$	$> 0\,^b$	> 0	$> 0\,^b$	$> 0\,^b$
$/d\widehat{n^F_{CB}}$	$> 0\,^b$	$> 0\,^b$	$> 0\,^b$	$\gtrless 0$	$> 0\,^b$	> 0	$\gtrless 0$	$> 0\,^b$

[a] Given reasonable values of portfolio fraction elasticities, $\overline{dc}$, and $\overline{v}$.

[b] Given reasonable values of portfolio fraction elasticities.

[c] Given $\frac{\partial m}{\partial \widehat{\sigma}} \frac{\widehat{\sigma}}{m}$, and respectively $\frac{\partial m}{\partial \widehat{i^F}} \frac{\widehat{i^F}}{m}$, differ sufficiently from 0.

(increase in f) at the cost of domestic assets (decrease in m, b, and e). This behaviour is based on risk-return considerations. Consequently, the initial disturbance of an increase in $\widehat{\sigma}$ consists of an *allocation effect*. The increasing demand for foreign assets causes an increase in demand for foreign currency, with the exchange rate therefore increasing endogenously. The increase in the exchange rate induces a *wealth effect*, which positively affects the demand for all asset types, and a *value compensation effect*, which negatively affects the demand for foreign assets and positively affects the demand for domestic assets. In the short term, a new equilibrium is obtained through this increase in the exchange rate to the extent that the initial *allocation effect* is entirely compensated for by the endogenous *wealth effect* and the *value compensation effect.* No changes in domestic interest rates emerge if the elasticity of m, with respect to $\widehat{\sigma}$, corresponds to the respective elasticities of b and e. However, the domestic bond interest rate, as well as the equity discount rate, may increase if b and e are, in relative terms, more negatively affected by an increase in $\widehat{\sigma}$ than m, and vice versa. If private households consider money as risk free (or nearly risk free)[25], an increase in $\widehat{\sigma}$ has a positive impact on i^B and i^E, and a less positive impact on s, seeing as the increases in i^B and i^E negatively affect the demand for foreign assets again. In sum, private households' wealth increases in the short term in reaction to $d\widehat{\sigma} > 0$, given that the positive *wealth effect* produced by $ds > 0$ is not exceeded by potential negative *wealth effects* caused by $di^B > 0$ and $di^E > 0$. The domestic price level is not affected since an increase in $\widehat{\sigma}$ neither influences the domestic money amount nor real domestic production in the short term.

When interpreting the long term effects, it is essential to consider that the short term increase in the exchange rate has made the consumption of foreign goods relatively more expensive.[26] Consequently, private households optimise their consumption composition, substituting imports of foreign goods by exchanging equity assets in return for domestic goods from the producers (see equation 41). The current account surpluses realised here cause, on the one hand, an excess supply of foreign currency so that the exchange rate decreases. On the other hand, they are used to acquire additional foreign assets. Over time, the *wealth effect* and the *value compensation effect* caused by the short term increase in the exchange rate convert for the most part into a long term *wealth effect*, as well as a long term *supply effect* through the increase in the amount of foreign assets. However, the exchange rate does not return to its initial value. Since the domestic stock of real capital (n^{CG}) decreases due to the exchange of equity assets (see equation 15)[27], real domestic production (Y^r) also decreases. Thus, the domestic price level increases (see equation 25) to the extent that in the new long term equilibrium, purchasing power parity is obtained with a higher exchange rate than before. All in all, private households' wealth increases due to the positive *wealth effects* resulting from the increase in the amount of foreign assets and the increase in the exchange rate. However, this is only the case if the effects are not overcompensated for by negative *wealth effects* related to an increase in i^B, an associated decrease in n_P^B, and an increase in i^E.[28]

In sum, the resulting reduction in the domestic stock of real capital, in reaction to the increase in $\widehat{\sigma}$, is a logical consequence of private households' investment behaviour. If

[25] $\frac{\partial m}{\partial \widehat{\sigma}} \frac{\widehat{\sigma}}{m}$ would be zero or close to zero.

[26] An increase in the real exchange rate (s^{real}) results, see equation 40.

[27] Furthermore, the supply of domestic bonds is negatively affected in the long term if the domestic bond interest rate increases in the short term (if $\frac{\partial m}{\partial \widehat{\sigma}} \frac{\widehat{\sigma}}{m}$ is zero or close to zero). In this case, additional domestic disinvestment takes place due to the long term decrease in n^B (see equations 15 and 32).

[28] Overcompensation would occur if private households consider money to be risk free or nearly risk free (see footnote 25).

domestic investment becomes relatively riskier, risk averse investors will relocate capital through disinvesting domestically and investing in relatively less risky projects abroad until their investment portfolio is balanced once again.

An increase in the foreign interest rate ($\widehat{i^F}$) has a similar impact on the endogenous variables as does an increase in $\widehat{\sigma}$. The difference is that the initial disturbance of $d\widehat{i^F} > 0$ consists of a *wealth effect* and a *value compensation effect* in addition to the *allocation effect*. In the short term, the exchange rate also increases, which balances out demand and supply. Likewise, the amount of domestic real capital decreases in the long term since foreign investment becomes relatively more attractive. However, the reason for the reduction in the domestic stock of real capital is not based on changes in the relative risk, but on changes in the relative return on investment projects.

An increase in the foreign price level ($\widehat{p^*}$) has no short term effect within the model. However, foreign goods become relatively more expensive compared to domestic goods. Consequently, private households adjust their consumption composition over the long term. They exchange equity assets in return for domestic goods to allow for the substitution of foreign imports (see equation 41). A current account surplus is obtained, causing the exchange rate to decrease. The private households thus acquire additional foreign assets to compensate for the relative loss in the value of foreign assets.[29] Overall, the negative *wealth effect* connected to $ds < 0$ compensates for the positive *wealth effect* connected to $dn_P^F > 0$, with the result being that private households' wealth remains unchanged. That being said, the domestic stock of real capital decreases, which also causes real domestic production to decrease. Finally, the new long term general equilibrium is characterised by a lower exchange rate and a higher domestic price level compared to the initial situation.

As was the case before, the real domestic disinvestment caused by the increase in the foreign price level is comprehensible from an investor's perspective because it is reasonable to shift real capital internationally if a relatively higher value added can be realised abroad.

Central Bank's Influence on Domestic Variables

The central bank is able to influence the endogenous variables by changing their policy variables i^K (in the short term), $\widehat{K}$ (in the long term), $\widehat{n_{CB}^B}$, and $\widehat{n_{CB}^F}$.[30]

If the central bank increases the credit interest rate (i^K) in the short term, it reduces the amount of domestic dividend payments (see equation 37).[31] On the one hand, the

[29]The negative *wealth effect* and the *value compensation effect* caused by the decrease in the exchange rate is compensated for by the positive *wealth effect* and the *supply effect* connected to the increase in the amount of foreign assets.

[30]Subsequently, exogenous increases in i^K, $\widehat{K}$, $\widehat{n_{CB}^B}$, and $\widehat{n_{CB}^F}$ are discussed. The conclusions hold vice versa if decreases in these variables are considered.

[31]Bernanke and Kuttner (2005) show empirically that an unexpected 25 basis point decrease in the federal funds rate causes an 1% increase in stock prices, and vice versa. They identify changes in (future) dividend payments being a likely reason for these changes in stock prices, as is the case within this model.

reduction in Div produces a negative *wealth effect*, causing the demand for all asset types to decrease. On the other hand, the negative *supply effect* produces an excess demand for domestic dividend payments and as a consequence, the equity discount rate decreases endogenously. Below, the excess demand for domestic dividend payments is primarily balanced by the resulting *value compensation effect*, whereas the excess supply of the remaining asset types is balanced in particular by the related *wealth* and *allocation effects*.[32] In total, private households' wealth is lower in the short term equilibrium than it was in the initial situation. Finally, the demand for credit becomes elastic over the long term[33], and i^K decreases to its initial value so that the long term equilibrium is equal to the initial situation. Consequently, a sole short term increase in i^K has no long term impact on the endogenous variables.

If the central bank increases the credit amount in the long term[34], it directly increases the money supply and thus the amount of money held in private households' portfolio (see equation 4 and equilibrium condition 59). The increase in the money supply produces a *wealth effect* and a *supply effect*. Since the domestic price level increases proportionally (see equation 25), the increase in $\frac{p \cdot Y^r}{\overline{v}}$ produces a balancing *allocation effect*. When considered on its own, it consequently follows that increases in the money supply have a neutral effect on the endogenous variables i^B, i^E, s, n_P^F, and n_P^B, while increasing W and p. However, increases in the money supply also increase the amount of dividend payments (see equation 38) and the supply of domestic bonds[35]. The excess supply of domestic dividend payments causes an increase in the equity discount rate. In addition, the excess supply of domestic bonds causes the domestic bond interest rate to increase. Furthermore, the private households optimise their consumption composition in reaction to the increase in the domestic price level by increasing their demand for foreign imports. Through the related increase in demand for foreign currency, the exchange rate increases and foreign assets are sold. The exchange of domestically produced goods for equity assets goes hand in hand with this. In sum, the increase in the amount of credit, domestic bonds, and domestic equity assets causes an increase in the domestic stock of real capital (n^{CG}, see equation 15) at the cost of foreign investment (n^F, see equation 44). In the new long term equilibrium, private households are satisfied with a lower amount of foreign assets in their portfolio for two reasons: firstly, because of the increase in domestic interest rates, and secondly, due to the increase in the exchange rate. Furthermore, private households' wealth increases because of the net positive wealth effects, and finally, real domestic production increases due to the increase in n^{CG}.

[32] Thereby, no changes in the domestic bond interest rate or in the exchange rate are required. The domestic bond interest rate only decreases if the demand for domestic bonds is more positively affected by a decrease in i^E than the demand for foreign assets, and vice versa. Concerning the exchange rate, the relationship applies analogically in the case of the demand for foreign assets.

[33] By assumption, the *money view* holds in the long term.

[34] A short term increase in $\widehat{K}$ is not feasible since in the short term, the demand for loans is inelastic according to the *credit view*.

[35] The increase in the bond supply is definite if the reasonable proposition $\overline{dc} \cdot \overline{v} > i^B$ is implied (see equation 33).

A purchase of domestic bonds by the central bank ($d\widehat{n^B_{CB}} > 0$) increases the money supply in the short term. By again considering the partial impact, the resulting increase in the money supply has a neutral effect on the endogenous variables i^B, i^E, and s, while increasing W and p. However, through acquiring domestic bonds, the central bank decreases the domestic bond supply vis-à-vis the private households. Furthermore, the increase in the money supply produces an increase in domestic dividend payments. Consequently, the excess demand for domestic bonds is balanced by a decrease in the domestic bond interest rate, while the excess supply of dividend payments is balanced by an increase in the equity discount rate. Thus, short term equilibrium is characterised by an increase in W, p and i^E, and a decrease in i^B, while the reaction of s is ambiguous.[36]

In the long term, private households optimise their consumption composition in reaction to the increase in p. Furthermore, domestic producers increase the bond supply due to the short term decrease in i^B, and the lasting increase in the money supply (see equation 32). Except for n^B, an increase in $\widehat{n^B_{CB}}$ has the same long term impact on the endogenous variables as an increase in $\widehat{K}$.[37] This result is obvious since in the long term, producers consider bonds and loans as perfect substitutes, following the *money view* (see page 11).

If the central bank acquires additional foreign assets ($d\widehat{n^F_{CB}} > 0$), the domestic price level and dividend payments increase in the short term because of the increase in the money supply. In response, the excess supply of dividend payments is balanced by an endogenous increase in the equity discount rate. Furthermore, the increase in $\widehat{n^F_{CB}}$ decreases the short term supply of foreign assets vis-à-vis the private households. The resulting excess demand for foreign assets produces an excess demand for foreign currency, with the exchange rate increasing as result. The exchange rate increases until the decrease in f, produced by the lower amount of foreign assets held by private households, is sufficiently compensated for. In this case, the excess demand for foreign assets is balanced in the short term.[38]

An increase in $\widehat{n^F_{CB}}$ is similar to $d\widehat{K} > 0$ and $d\widehat{n^B_{CB}} > 0$ in that it increases domestic money supply and thereby increases the amount of dividend payments, as well as the domestic price level. However, an increase in $\widehat{n^F_{CB}}$ has only an ambiguous impact on the bond interest rate in the short term. Consequently, producers' incentive to increase the domestic bond supply over time is lower compared to $d\widehat{K} > 0$ and $d\widehat{n^B_{CB}} > 0$. Moreover, $d\widehat{n^F_{CB}} > 0$ has a positive impact on the exchange rate in the short term and thereby increases the relative price of foreign goods. Depending on whether the impact of the increase in the domestic price level or the increase in the exchange rate prevails, private households decrease or increase the consumption of domestic goods over time. Overall,

[36] The exchange rate (s) is only positively affected by the intervention if the positive effect a decrease in i^B has on the demand for foreign assets outweighs the counteracting negative effect caused by the increase in i^E (and vice versa).

[37] Given an identical increase in the money amount associated with both interventions.

[38] There is a chance that the exchange rate may also decrease in the short term, but only if the increase in i^E has an exceptionally strong negative impact on the demand for foreign assets.

the long term reaction of the amount of domestic equity assets and foreign assets, as well as the amount of domestic real capital goods, is ambiguous.

In long term equilibrium, for each money unit created by $d\widehat{n^F_{CB}} > 0$, the increase in the total amount of domestic bonds is lower, and the increase in the domestic bond interest rate is higher compared to $d\widehat{K} > 0$ and $d\widehat{n^B_{CB}} > 0$. Moreover, the reaction of the domestic stock of real capital is ambiguous, as is the reaction of real domestic production. Finally, purchasing power parity is obtained with a higher exchange rate than in the case of $d\widehat{K} > 0$ and $d\widehat{n^B_{CB}} > 0$.

III. Monetary Policy Interventions and Trade-Offs

A. Implementation of Monetary Policy

As demonstrated in the previous section, domestic variables can be influenced by exogenous changes in external variables ($\widehat{\sigma}$, $\widehat{i^F}$, and $\widehat{p^*}$) that are not under the control of the central bank. If the central bank is to maintain a certain target value, e. g., for the exchange rate, the domestic price level, or real domestic production, this target may not be achieved in the short term or in the long term due to external shocks. The central bank is able to react through adjusting its policy variables with the goal of compensating for external impacts. However, an intervention stabilising one variable may have destabilising side effects on other variables. Subsequently, the trade-offs associated with monetary policy interventions are analysed on the basis of two strategies which are applied in practice: expansive interventions in times of economic crises, and exchange rate stabilisation.

B. Expansive Monetary Interventions

Expansive Monetary Policy during Economic Crises

Generally, economies are affected by a high level of risk in times of economic crises (Schwert, 1989; Mishkin, 2001; Angeletos and Werning, 2006). For example, since the start of the financial crisis in 2007, the financial markets of various advanced economies experienced massive distortions. Due to the burst of the US housing bubble and the collapse of Northern Rock and Lehman Brothers, a high amount of systemic risk has become prevalent. Concerning the model used in this paper, it is possible to trace the substantial decline in the British Pound (starting in September 2007) back to the increase in Britain's relative macroeconomic risk ($\widehat{\sigma}$) caused by the bank run on Northern Rock. Taking Europe and the United States into account, the decline in equity indices and the pressure on bond markets, which followed the collapse of Lehman Brothers, would imply that money was less affected by the increase in macroeconomic risk when compared to bonds and equity assets. In sum, it is highly probable that negative *wealth effects* have prevailed, decreasing the wealth of European and US households.

Central banks have often reacted to financial and economic distortions by relaxing banking restrictions and using expansive monetary policy.[39] Over the course of the recent financial crisis, central banks reduced interest rates, expanded the credit supply and, especially as interest rates approached the zero lower bound, carried out open market purchases of domestic assets. The US Federal Reserve and the Bank of England in particular expanded their balance sheets through acquiring a variety of domestic debt securities, mainly in the form of long term government bonds, but also commercial papers and mortgage-backed securities (Klyuev et al., 2009). These interventions are also referred to as 'quantitative easing' (Bernanke and Reinhart, 2004; Bernanke et al., 2004).[40]

The Impact of Expansive Monetary Interventions

In terms of the presented model, expansive monetary interventions are open market purchases of domestic bonds and increases in the credit supply. Subsequently, the paper analyses the extent to which these interventions and the connected liquidity provision help to mitigate the impact of an increase in domestic macroeconomic risk ($\widehat{\sigma}$). Without central bank intervention, the model implies that an increase in $\widehat{\sigma}$ may be associated with a decrease in private households' wealth in the short term.[41] In the long term, a reduction in the domestic stock of real capital takes place, causing a decrease in real domestic production.

In the short term, the impact of an open market purchase of domestic bonds is different compared to that of an expansion in credit lending. Through a purchase of domestic bonds, the central bank decreases the domestic bond supply vis-à-vis the private households, thereby taking on a part of the increased domestic risk on its balance sheet. As a consequence, there is less domestic risk in the market, causing a decline in risk premiums, i. e., a decrease in i^B, and an increase in domestic bond prices.[42] Furthermore, the increase in liquidity produces an increase in dividend payments. Equity prices increase on the one hand, while the excess supply of dividend payments is balanced again by an increase in i^E on the other. Since $di^B < 0$ positively affects the demand for foreign assets, and $di^E > 0$ has a negative impact, the exchange rate is not necessarily affected in the short term. Finally, the negative *wealth effects* connected to the decrease in n_P^B and the increase in i^E, are outweighed by the positive *wealth effects* associated with the decrease in i^B, the increase in Div, and the increase in M. Consequently, possible negative *wealth effects* caused by $d\widehat{\sigma} > 0$ can be compensated for in the short term through an increase in $\widehat{n_{CB}^B}$. However, this is only possible at the cost of an increase in the domestic price

[39] See, for example, Minsky (1986) and Neely (2003), who discuss the reaction of the US Federal Reserve to several crises.

[40] See also the discussion on the term 'quantitative easing' in Klyuev et al. (2009).

[41] This is the case if private households consider money to be risk free or nearly risk free (see footnote 25).

[42] Borio and Zhu (2008) refer to this as the 'risk-taking channel' of monetary policy, which was seen as important during the recent central bank interventions (Klyuev et al., 2009). For example, the negative impact of recent open market purchases on bond interest rates is illustrated by Gagnon et al. (2011) in the case of the US and by Joyce et al. (2011) in the case of Britain.

level, which is produced by the expansion of the money supply (see equations 25 and 6). Furthermore, domestic interest rates and asset prices are distorted, no longer reflecting the changes in the external economic conditions.

Due to the implications of the *money view*, the central bank is not able to increase the amount of credit in the short term. However, if it tends to increase credit lending in the long term, it needs to reduce the credit interest rate in the short term in order to offer incentives for additional borrowing. Through a decrease in the credit interest rate, the amount of dividend payments increases (see equation 37). Consequently, equity prices and the equity discount rate increase, while the bond interest rate and the exchange rate are not necessarily affected. Compared to a purchase of bonds, the wealth effect is less pronounced since no substantial decrease in the domestic bond interest rate is to be expected in the short term.

However, the long term implications of an open market purchase of domestic bonds and an increase in the credit amount are the same. Due to the decrease in either the bond or credit interest rate, as well as the increase in dividend payments, both the domestic bond supply and the demand for credit increase in the long term, in accordance with the *static trade-off theory* and the *credit view* (see equation 32). By increasing the amount of credit, the central bank takes on domestic risk on its balance sheet. In addition, the money supply increases, causing an increase in the domestic price level.

Consequently, both types of expansive monetary interventions increase the debt liabilities of producers, resulting in an increase in the domestic stock of real capital goods (see equation 15). The domestic bond interest rate increases in reaction to the resulting excess supply of domestic bonds, eventually causing bond and credit interest rates to exceed the initial value which existed before the expansive monetary interventions (see table 3). Through private households' adjustment in consumption behaviour, both a current account deficit and an increase in the exchange rate occur. Furthermore, an additional increase in the domestic stock of real capital follows, witnessed through the increasing amount of domestic equity assets. The final result is that the imminent decline in the domestic stock of real capital caused by $d\widehat{\sigma} > 0$ can be averted in the long term through expansive monetary interventions.

The Trade-Offs of Expansive Monetary Interventions

Through an open market purchase of domestic bonds or an increase in the credit supply, central banks are able to avert two crucial consequences of an increase in domestic macroeconomic risk. First, a negative wealth effect caused by a decline in bond and equity indices can be alleviated in the short term, primarily through open market purchases of domestic bonds. Second, impending real domestic disinvestment can be avoided since expansive monetary interventions produce an increase in the domestic stock of real capital (attributed to increases in the amount of debt and equity assets). The long term impacts of both types of expansive monetary interventions are theoretically the same. However, open market purchases of domestic bonds may be more effective in practice if the short term possibilities to decrease credit interest rates are limited to near the zero lower bound. The reason for this is that a higher amount of credit will only be swiftly accepted by producers if borrowing becomes noticeably more attractive in the short term through a substantial decrease in the credit interest rate, which may be close to impossible near the zero lower bound.

However, side effects arise which lead one to question whether aggregate welfare is positively affected overall by expansive monetary interventions. For example, the price level of domestic goods rises due to the increase in the money supply. The welfare impact of increases in the price level is generally considered to be negative in the literature, particularly if they are persistent (Lucas, 2000; Lagos and Rocheteau, 2005; Burstein and Hellwig, 2008). In addition, the increase in the domestic price level is the underlying reason for a long term devaluation of the domestic currency. Consequently, additional exchange rate volatility occurs, which may cause increasing costs of currency hedging. Fluctuations in the interest rates on debt capital may also bear long term risks for (highly) indebted institutions. If, for example, the government considers the short term decrease in bond interest rates after an open market purchase to be persistent, subsequently financing investment and social projects with a relatively low return through the issue of bonds, they may run into problems with a long term increase in bond interest rates. More precisely, it is possible that the liquidity of indebted institutions will become severely endangered from a long term perspective, given low budgetary foresight. Regarding the central bank, it takes on domestic risk on its balance sheet by purchasing domestic bonds and expanding the credit amount. Since the central bank can be considered as a crucial institution within a state, it may itself become a source of macroeconomic risk. However, to date it is unclear what level of intervention can lead to an inadequately diversified cluster of domestic risk on its balance sheet. Finally, expansive monetary interventions cause an inefficient international allocation of real capital. If domestic macroeconomic risk increases, domestic investment becomes less attractive compared to foreign investment. Consequently, it would be suitable to reduce the amount of domestic investment. If the central bank takes on the increase in domestic risk through expansive monetary interventions, it stabilises the domestic stock of real capital at the cost of foreign investment.

In a nutshell, the impact of expansive monetary interventions on domestic welfare is ambiguous in times of economic crises. A definite assessment of their impact is only possible on a case-by-case basis. However, it is reasonable to conclude that world welfare is negatively affected due to the resulting inefficient international allocation of real capital.

C. Exchange Rate Stabilisation

General Remarks

It is commonly observed that many countries do not float their currencies, intervening in order to stabilise the exchange rate. The extent to which a country stabilises its currency in relation to foreign currencies is defined by its exchange rate regime. Even though there is much debate about how exchange rate regimes of countries should be classified (Reinhart and Rogoff, 2004; Levy Yeyati and Sturzenegger, 2005), it is clear that exchange rate stabilisation continues to this day (Levy Yeyati et al., 2010). A recent example is Switzerland. To interrupt the continuous appreciation of the Swiss Franc, the Swiss National Bank decided to enforce a minimum exchange rate of 1.20 Swiss Franc per Euro "with the utmost determination" starting from the 6^{th} of September 2011 (Swiss National Bank, 2011).

An advantage of stabilised exchange rates is the lower transaction costs in regards to currency hedging. Consequently, low exchange rate volatility tends to foster international trade (Ozturk, 2006). Through enforcing a certain exchange rate target, the central bank is also able to influence the competitiveness of domestic producers on international markets (Rodrik, 2008). On the other hand, the central bank has to maintain the exchange rate target, thereby losing monetary policy autonomy (Shambaugh, 2004; Obstfeld et al., 2005). Despite this, a new dimension in the discussion regarding exchange rate regimes emerges within the current model. The following shows that exchange rate stabilisation can be related to the stabilisation of the domestic stock of real capital.

The Impact of Exchange Rate Stabilisation

In the short term, the exchange rate increases ($ds > 0$) if there is a relative increase in domestic macroeconomic risk ($d\widehat{\sigma} > 0$) or through an increase in the foreign interest rate ($d\widehat{i^F} > 0$). The reason for this is that domestic private households tend to hold a higher proportion of foreign assets in their portfolio, therefore demanding foreign currency to allow for the purchase of foreign assets. To avoid a short term increase in the exchange rate, the central bank has to avert these foreign asset purchases through the capital account. This is possible by satisfying demand, i. e., supplying their own stocks of foreign assets ($\widehat{dn_{CB}^F} < 0$). However, with $\widehat{dn_{CB}^F} < 0$, the domestic amount of money (M) would be negatively affected. The domestic price level (p), the amount of dividend payments (Div), and the equity discount rate (i^E) would decrease as a consequence (see equations 4, 25 and 37, and table 2). Furthermore, a decrease in the domestic price level would produce an appreciation of the domestic currency since purchasing power parity holds in the long term. To avoid these side effects, the central bank needs to purchase domestic bonds. Through a so called sterilised intervention, the impact on the money supply is completely neutralised.[43] However, through the purchase of domestic bonds, the central bank negatively affects the domestic bond interest rate. The result here is that the impact on the domestic money amount cannot be neutralised by the central bank without also having a short term influence on the domestic bond interest rate.

[43]This is the case if $dM < 0$, caused by $\widehat{dn_{CB}^F} < 0$, corresponds to $dM > 0$, caused by $\widehat{dn_{CB}^B} > 0$. Therefore, it must hold that $\widehat{dn_{CB}^F} \cdot s \cdot \frac{\overline{q^F}}{\overline{i^F}} + \widehat{dn_{CB}^B} \cdot \frac{\overline{q^B}}{\overline{i^B}} = 0$.

In the long term, the amount of domestic real capital would decrease following a relative increase in domestic macroeconomic risk ($d\widehat{\sigma} > 0$) or an increase in the foreign interest rate ($d\widehat{i^F} > 0$). The reason for this is that private households adjust their consumption composition due to the short term increase in the exchange rate, whereby the amount of domestic equity assets is reduced (see equation 41). The domestic stock of real capital (n^{CG}) therefore decreases (see equation 15). If the central bank averts the short term increase in the exchange rate without affecting the money supply, no incentive remains to reduce the domestic stock of real capital with the amount of equity assets. Only minor changes in n^{CG} may result in the long term due to decreases or increases in the amount of domestic bonds.[44]

In the long term, changes in the foreign price level ($\widehat{p^*}$) have an impact on the exchange rate (s) as well. If the foreign price level increases, domestic private households adjust their consumption composition according to the real exchange rate (see equation 41). They substitute the relatively expensive foreign imports for domestic goods, thereby reducing the amount of equity assets and the domestic stock of real capital. The resulting surplus on the current account produces a decrease in s. The central bank is able to avert an appreciation of the domestic currency by increasing the domestic price level (p) through reflationary monetary interventions, such as $\widehat{K} > 0$, $\widehat{n^B_{CB}} > 0$, or $\widehat{n^F_{CB}} > 0$.

By increasing p through $\widehat{K} > 0$ or $\widehat{n^B_{CB}} > 0$, no incentive remains for private households to adjust their consumption composition. Consequently, the amount of domestic real capital goods (n^{CG}) is sustained since the number of equity assets does not change. The result is that n^{CG} even increases overall due to the positive reaction of the supply of domestic bonds. An increase in $\widehat{n^F_{CB}}$, on the contrary, has an ambiguous impact on n^{CG}. Therefore, a combination of $\widehat{K} > 0$ or $\widehat{n^B_{CB}} > 0$ with $\widehat{n^F_{CB}} > 0$ can stabilise both n^{CG} and the exchange rate. In addition, such combined interventions avert risk clusters on the central bank's balance sheet.

The Trade-Offs of Exchange Rate Stabilisation

In sum, sterilised interventions are required to avert exchange rate deviations, which are caused by changes in $\widehat{\sigma}$ and $\widehat{i^F}$. The domestic money supply needs to be adjusted to sustainably neutralise exchange rate deviations caused by changes in $\widehat{p^*}$. Both types

[44] If i^B increases following the external shock, and this increase is higher than the decrease following central bank intervention, the supply of domestic bonds decreases in the long term. Consequently, real domestic disinvestment takes place ($n^{CG} < 0$), real domestic production decreases and the domestic price level increases. The increase in the domestic price level would positively affect the exchange rate since purchasing power parity holds in the long term. Hence, this impact on the exchange rate can be neutralised by adequately decreasing the domestic money amount to the extent that the domestic price level remains constant in the long term. This can be realised by decreasing the credit amount ($\widehat{K}$) or the central bank's amount of domestic bonds ($\widehat{n^B_{CB}}$). However, the decrease in n^{CG} cannot be totally averted. From the opposite perspective, if an increase in i^B is lower than the decrease following the central bank interventions or i^B remains constant/decreases in reaction to the external shock, the central bank has to sufficiently increase the domestic money supply over time in order to stabilise the exchange rate in the long term. Still, an increase in n^{CG} would remain.

of intervention not only stabilise the exchange rate, but can also avert changes in the domestic stock of real capital, which would otherwise be caused by external shocks.[45] Nonetheless, both types of intervention are associated with trade-offs possibly affecting aggregate welfare.

Sterilised interventions represent asset swaps by the central bank. As a precondition for sterilised interventions, it is necessary for the central bank to possess a sufficient amount of domestic bonds or foreign assets so that the necessary transaction amount can be carried out. By selling foreign assets and buying domestic bonds to avoid a devaluation of the domestic currency, the central bank accumulates domestic risk on its balance sheet. Consequently, the central bank may itself become a source of macroeconomic risk if it builds up an inadequate cluster of domestic risks.[46] By taking over domestic risk, the central bank reduces the risk premium on domestic assets relative to foreign assets. The result here is the stabilisation of the amount of domestic equity assets, as well as lowering the interest rate on domestic bonds, promoting an increase in bond supply. The domestic stock of real capital is stabilised or even increased if the amount of domestic assets increases overall. As a consequence, these sterilised interventions cause an inefficient international allocation of real capital. If $\widehat{\sigma}$ or $\widehat{i^F}$ increase, domestic investment becomes less attractive compared to foreign investment. If the central bank takes on domestic risk through sterilised interventions, it averts adjustments in the domestic stock of real capital at the cost of foreign investment.

Reflationary monetary interventions avert exchange rate changes caused by increases in the foreign price level ($\widehat{p^*}$). However, this comes at a cost, i. e., increases in the domestic price level (p). In addition, these non-sterilised interventions may hinder adequate adjustments in the amount of real capital goods. If the price level of foreign goods increases, foreign investments produce a higher value added than before, therefore becoming relatively more attractive than domestic investments. As a consequence, domestic disinvestment and foreign investment take place. Reflationary interventions that focus on domestic markets ($\widehat{K} > 0$, $\widehat{n^B_{CB}} > 0$) avert domestic disinvestment and even increase the domestic stock of real capital, both at the cost of foreign investment. Reflationary interventions that focus on the foreign asset market ($\widehat{n^B_{CB}} > 0$) cannot, on average, avert domestic disinvestment. However, non-sterilised interventions that focus on either domestic or foreign markets would again produce risk clusters on the central bank's balance sheet. Through a combination of both types of non-sterilised interventions, the central bank firstly avoids risk clusters and secondly prevents changes in the domestic stock of real capital.[47]

[45] Only minor changes in n^{CG} may be expected because of changes in the domestic bond supply.

[46] By purchasing foreign assets and selling domestic bonds to avert an appreciation of the domestic currency, the central bank is, from the opposite perspective, in danger of accumulating an inadequate cluster of foreign risk on its balance sheet.

[47] Through restrictive monetary interventions, the relationships here hold the other way round if the central bank averts a devaluation of the domestic currency due to a decrease in the foreign price level.

To summarise, it is unclear whether exchange rate stabilisation has a positive impact on domestic welfare. The stabilisation of the exchange rate and the real amount of domestic investment goes hand in hand with either increasing risk clusters on the central bank's balance sheet or with changes in the domestic price level. Nevertheless, it is reasonable to conclude that world welfare is negatively affected because a resulting inefficient international allocation of real capital is to be expected.

D. Empirical Estimation of Exchange Rate Stabilising Interventions

Method and Data

In this section, the exchange rate stabilising interventions of the central banks of three European countries – Austria, Belgium, and Denmark – are analysed. For each country, an impulse response analysis is performed based on an unrestricted vector autoregressive (VAR) estimation. By using this approach, it is possible to simulate short term deviations of the respective exchange rates and to draw conclusions from the reactions of the remaining variables in regards to exchange rate stabilising interventions.

The VAR estimation is based on monthly financial data. For Austria and Belgium, the time period before the Euro introduction is considered, in which the German Mark served as the base currency. For Denmark, it is the time period after the Euro introduction, in which the Euro represents the base currency for the Danish Crone.[48] Each of the three VARs is estimated with time series of eight stationary variables. These reflect the exchange rate in levels (s), governmental bond clean price indices ($bonds$), the MSCI share market indices ($msci$), central banks' amount of currency reserves ($reserv$), the three month interbank interest rates ($i^K 3m$), the monetary aggregates M1 ($M1$), M3 less M1 ($M3 - M1$), and the consumer price indices (inf). The variable $bonds$ represents the growth rate of the domestic bond index, minus the growth rate of the base country bond index in order to exclude common trends, especially those caused by the business cycle. The same is true for $msci$, $reserv$, $M1$, $M3 - M1$, and inf. Concerning $i^K 3m$, it represents the difference between the three month interbank interest rates for the same reason. A constant term, seasonal dummies, and dummies concerning the German monetary union in 1990 are included as exogenous variables.[49] Subsequently, the exchange rate is shocked by one standard deviation and the accumulated responses are determined for a period of 18 months within the impulse response estimation.

[48]See plots of the exchange rates in figure A.2 of the appendix.

[49]See an overview of the VAR estimation settings and respective test statistics in tables A.3 and A.4 of the appendix. The time series are from Datastream and the central banks. The respective EViews workfiles and a detailed description of the data sources, which contains Datastream mnemonics and links to internet resources of central bank time series, are available for download from the IQSS Dataverse http://dvn.iq.harvard.edu/dvn/dv/schueder.

The Impulse Response against the Background of the Model

To choose a consistent ordering in the Choleski decomposition and to interpret the output of the impulse response estimation, one needs to consider the theoretical reasons for the initial exchange rate deviation. This is crucial since one would expect sterilised interventions if the deviation is based on current changes in $\widehat{\sigma}$ or $\widehat{i^F}$. If it is caused by preceding changes in relative good prices ($\widehat{\frac{p}{p^*}}$), non-sterilised interventions would be the likely result. By solely shocking s within the impulse response estimation, it is implied that the change in s is not caused by a contemporaneous change in $\widehat{i^F}$.[50]

Consequently, the initial increase in the exchange rate within the impulse response estimation may be theoretically caused by either a contemporaneous increase in $\widehat{\sigma}$ or a preceding increase in $\widehat{\frac{p}{p^*}}$. Changes in $\widehat{\sigma}$ may also have a contemporaneous impact on bond and equity markets (*bonds* and *msci*) because it may affect i^B and i^E (see table 2). The variables i^K3m, $reserv$, $M1$, $M3 - M1$, and inf are, in contrast, predominantly determined by the central bank in the short term. It is reasonable to assume that changes in these variables only occur with a one-period lag because the central bank requires time to react to changing circumstances. In the following, the applied ordering in the Choleski decomposition i^K3m, $reserv$, $M1$, $M3 - M1$, inf, s, $bonds$, $msci$ consistently reflects these relationships.[51]

Following this, one would expect changes in variables indicating sterilised interventions if an increase in $\widehat{\sigma}$ is the reason for exchange rate changes. If a preceding increase in $\widehat{\frac{p}{p^*}}$ is the reason, one would expect non-sterilised interventions in turn.

Results and Interpretation

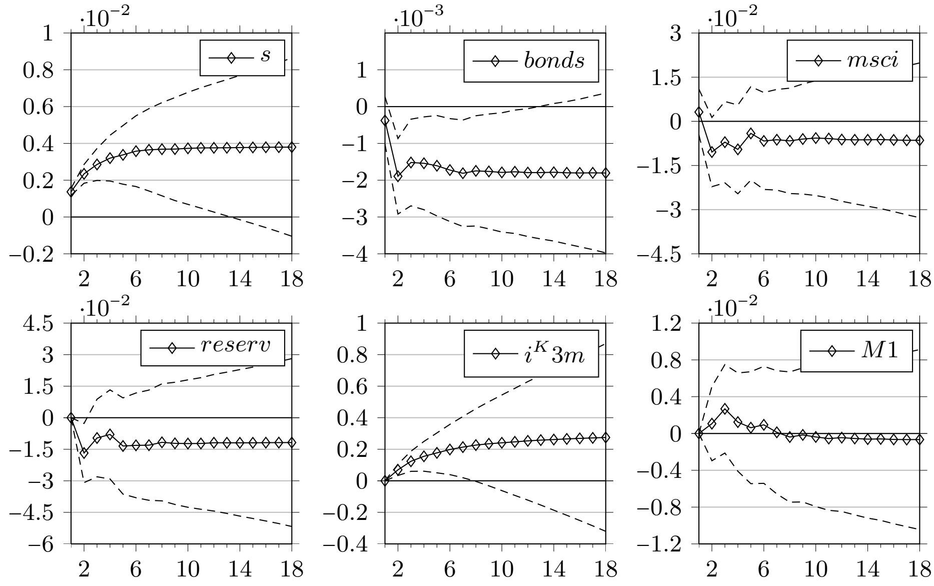
Figures 2 to 4 show the respective responses to a one standard deviation exchange rate shock for Austria, Belgium, and Denmark.[52] Only Austria and Denmark seem to clearly sell currency reserves in reaction to a sudden devaluation of their currencies (decrease

[50]Changes in $\widehat{i^F}$ must be associated with changes in *bonds* and *msci*. An increase in $\widehat{i^F}$ would be followed by a relative decrease in foreign asset prices. Consequently, the bond and stock indices of the foreign base country would decrease relative to the indices of the domestic country whereby *bonds* and *msci* would increase. If one only shocks the exchange rate within the impulse response estimation without shocking *bonds* and *msci* at the same time, the implication is that the exchange rate shock is not caused by a change in $\widehat{i^F}$. Therefore, only current changes in $\widehat{\sigma}$ or preceding changes in $\widehat{\frac{p}{p^*}}$ would explain the current exchange rate deviation.

[51]Variation in the suborder of i^K3m, $reserv$, $M1$, $M3 - M1$, inf or $bonds$, $msci$ has nearly no effect on impulse response estimation results. Variation with reference to the order of s would no longer be consistent with the model relationships anymore. For example, an order of s, i^K3m, $reserv$, $M1$, $M3 - M1$, inf, $bonds$, $msci$ would imply infinitely fast responses by the central bank. With an order of i^K3m, $reserv$, $M1$, $M3 - M1$, inf, $bonds$, $msci$, s, the impact of changes in $\widehat{\sigma}$ on i^B and i^E would fall by the wayside. However, even choosing a 'wrong' ordering has only minor influence because the correlations of residuals are generally low. See EViews workfiles from http://dvn.iq.harvard.edu/dvn/dv/schueder to reproduce results.

[52]For each impulse response estimation holds: accumulated responses, 18 periods, Monte Carlo simulated response standard errors (100000 repetitions), Cholesky type: dof adjusted, see last section and footnote 51 for Cholesky order. The responses of $M3 - M1$ and inf can be found in figure A.3 of the appendix.

Figure 2. : Austria



Responses to a one standard deviation exchange rate shock (± 2 error stdv).

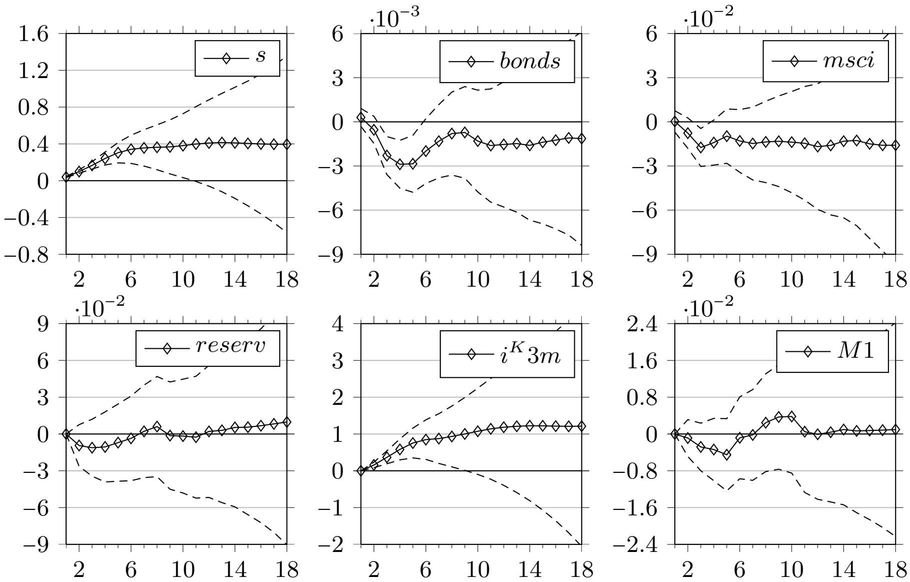
in *reserv*). However, $i^K 3m$ increases in Austria and Belgium, indicating a relatively more restrictive credit supply.[53] For each country, the domestic bond index loses value compared to the base country (decrease in *bonds*), indicating a relative increase in the domestic bond interest rate. This increase might be caused by a sale of domestic bonds by the respective central banks or perhaps by an increase in the domestic bond supply in reaction to the more restrictive credit supply. Furthermore, the relative changes in the domestic share indices have a negative trend (decrease in *msci*); this becomes especially clear in the case of Belgium and Denmark.

In a nutshell, the results imply that the central banks predominantly carry out non-sterilised interventions to stabilise the exchange rate.[54] Consequently, preceding changes in $\frac{p}{p^*}$ are most likely the prevalent reason for exchange rate changes in Austria, Belgium, and Denmark. This result is reasonable since these economies have similar economic structures to their base countries (Helg et al., 1995). Therefore, it seems unlikely that a divergent development in domestic and base country macroeconomic risk has occurred during the considered time periods.

[53]Furthermore, in Belgium $M3 - M1$ reacts positively (see figure A.3). This may indicate that commercial banks substitute increasingly expensive central bank loans through the acquisition of additional savings deposits.

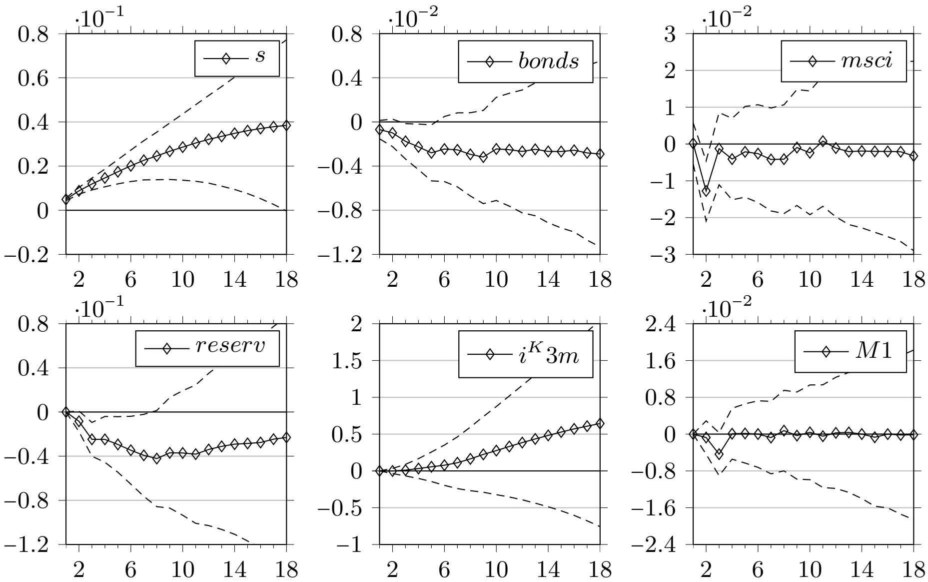
[54]Through sterilised central bank interventions, the domestic bond interest rate would decrease. This would cause a relative increase in the prices of domestic bonds compared to foreign bonds, thus *bonds* would increase. However, in all of the countries analysed *bonds* does not increase following the initial exchange rate shock. Consequently, sterilised central bank interventions do not seem to be regularly applied in practice.

Figure 3. : Belgium



Responses to a one standard deviation exchange rate shock (± 2 error stdv).

Figure 4. : Denmark



Responses to a one standard deviation exchange rate shock (± 2 error stdv).

Nevertheless, differences in stabilising strategies can be observed, which have an impact on the effectiveness of interventions. Austria seems to be the only country whose central bank uses currency reserves and credit supply adjustments to avert exchange rate deviations. The coefficient of variation of its exchange rate is the lowest of the three countries at 0.03%. Second is Denmark with 0.16%, which seems to predominantly use adjustments in currency reserves. Belgium has the highest coefficient at 0.90%[55] and seems to mainly adjust credit supply in order to stabilise the exchange rate. Besides possible differences in the level of interventions, one explanation for the relative high coefficient of variation compared to Austria and Denmark may be that interventions in the foreign asset market are more effective as they have a short term impact on the exchange rate. In contrast, adjustments in the credit supply are more effective in the long term, thus allowing for more short term variation. However, the increase in *bonds* and $M1$ beginning four months after the initial exchange rate shock may be due to a purchase of domestic bonds by the Belgian central bank. Consequently, it seems that it does not completely maintain restrictive policy measures, allowing for a higher variation in the exchange rate than the other central banks.

IV. Remarks on General Validity

Even though the model results become more reliable through the endogenisation of the domestic asset supply, many simplifications remain. However, these simplifications are not expected to be of importance qualitatively, quite possibly only affecting the model results quantitatively.

For instance, it is clear that the banking sector also includes commercial banks. Within the model, an increase in $\widehat{K}$ represents an increase in credit lending by the central bank to the producers. In general, however, the central bank provides the financial means for the commercial banks to increase the credit supply. Thus, an increase in $\widehat{K}$ can also be interpreted as an indirect increase in credit lending. It is obvious that regardless of whether the central bank indirectly supplies the commercial banks with more financial means to increase the credit supply or does this directly through increased credit loans for the producers, the amount of credit available to the producers increases.[56] Consequently, an explicit consideration of the commercial banks does not influence the direction of the model results. It would only increase the complexity without having a qualitative impact. Nevertheless, the quantitative difference of indirect and direct lending, e. g., caused by commercial banks' asset allocation behaviour, could be estimated through the consideration of the commercial banks. For future research, it would certainly be valuable to assess which channel is more advantageous from an efficiency point of view, given various external conditions.

[55] Still, this could be considered small when compared to the USD/DEM coefficient of variation which is 7.59% during the same time period.

[56] The context is illustrated in figure A.1 of the appendix.

The context is similar in the case of the producers, which could be split between government and private companies. Qualitatively, it is not relevant whether bonds are issued or credit is borrowed, by the government or private companies. In both cases, the financial means of the producers used for investment are enhanced.[57] By splitting producers between government and private companies, one could estimate whether public or private investment is more efficient given certain external conditions. For example, Friedman (1978) assesses this issue and discusses both crowding out and in effects under different conditions within a portfolio balance framework. However, more research within these contexts still needs to be carried out.

In addition, expectations may not always be static in practice (Frankel and Froot, 1987). Working under the assumption of rational expectations would only increase the complexity of the model, merely reducing the extent, but not the direction, of the short term reactions of the endogenous variables. Long term results would not be influenced at all. Moreover, the assumption of a constant velocity of money is unrealistic, seeing as it has been commonly observed that changes in the money supply mainly affect the domestic price level in the long term (Christiano et al., 1996; Serletis and Koustas, 1998; Bullard, 1999). Consequently, one would expect that the velocity of money decreases after a monetary expansion, subsequently increasing and reflecting its original range. As a result, increases in the amount of dividend payments would only be effectively realised in the long term. By assuming rational expectations, these relationships would again be qualitatively identical to those of the current model. Domestic private households would expect the future increase in dividend cash flow today, and equity prices would increase instantly due to the discounted cash flow approach. The value of equity would therefore exceed the optimal portfolio composition, and the demand for dividend payments would decrease in the short term, as is the case in the current model.

Furthermore, it is implied that domestic private households consume all of their income. They may invest either domestically or abroad, but domestic investment always corresponds to foreign disinvestment, and vice versa (see equation 44). Thus, the implication here is that aggregate savings are assumed to be zero for the sake of simplicity. However, while it continues to be difficult to comprehend which variables generally determine the amount of savings (Akerlof and Shiller, 2009), it would be expected that the decision of where to invest savings is determined by the same procedures as the investment/disinvestment decision within the current model. Taking savings into consideration, only the aggregate amount of real investment would be affected, but not the decision regarding real capital allocation. Therefore, no qualitative impact on the model results is expected from allowing savings to be different from zero. Nevertheless, for future research it would certainly be valuable to determine how changes in savings behaviour may affect both interest rates and the exchange rate.

[57]It is expected that the government would use their increased financial means for investment in social insurance activities or in public good related industries, like the provision of infrastructure, civil service, or security. Private companies would, accordingly, focus on industries related to the production of private goods.

Moreover, additional portfolio assets such as savings deposits, real estate, or commodities are present in reality. Domestic producers also use labour as a factor of production, and domestic private households generate income through wages. Furthermore, private households' assessment of macroeconomic risk may be driven by psychological factors. Even though it could certainly be enriching to estimate how central bank interventions may affect real estate prices, relative factor prices, or investors' level of confidence, it is unlikely that the introduction of such model extensions would distort or radically change the present model results.

However, the potential relationship between risk clusters on the central bank's balance sheet and domestic macroeconomic risk has yet to be researched. It is possible that the central bank itself could become a source of macroeconomic risk if it builds up extensive risk clusters, thereby diminishing the impact of additional interventions. Furthermore, by extending the model to include foreign actors or transaction costs, it is possible that expansive or exchange rate stabilising interventions will not promote an inefficient allocation of real capital in certain situations. If, for instance, changes in the relative attractiveness of domestic investment are due to monetary interventions by the foreign central bank, expansive monetary interventions by the domestic central bank may avert misallocation of real capital. Stabilisation of the exchange rate may even have a positive impact on aggregate welfare if real investment procedures are connected to transaction costs, and the relative macroeconomic risk ($\widehat{\sigma}$) follows a mean reverting process. In such a case, exchange rate stabilising interventions would avoid the transaction costs connected to real investment procedures caused by stochastic changes in $\widehat{\sigma}$. This would be achieved by sustaining the corresponding mean reverting level of the domestic stock of real capital.

V. Conclusion

The presented model expands upon the existing portfolio balance framework through consideration of an endogenous asset supply. Furthermore, it accounts for all balance restrictions concerning the economic actors analysed and the balance of payments. Domestic private households optimise their portfolio composition following Markowitz's *portfolio selection* and maximise real consumption with respect to the *law of one price*. Domestic producers optimise their capital structure following the *static trade-off theory* and show arbitrage behaviour in the choice of debt capital. Within the model, it becomes clear how asset prices, the exchange rate, and the international allocation of real capital are affected by external variables and monetary policy interventions. Subsequently, the model results are applied by analysing expansive monetary interventions and exchange rate stabilisation interventions in detail.

Expansive monetary interventions may avert real domestic disinvestment, which is caused by a relative increase in domestic macroeconomic risk in times of economic crisis. However, they also give rise to risk clusters on the central bank's balance sheet, distortions of domestic interest rates and asset prices, increases in the domestic price level, and domestic currency devaluation. Even though the impact of open market purchases of domestic bonds and the expansion of credit lending are identical in the long term, bond purchases are expected to be more effective in reducing negative impacts on private households' wealth and more effective at the zero lower bound of interest rates.

Concerning exchange rate stabilising interventions, it is essential to utilise the appropriate intervention strategy with respect to the underlying reason for the exchange rate fluctuation. Sterilised interventions are necessary to neutralise exchange rate deviations caused by changes in relative macroeconomic risk and the foreign interest rate. Non-sterilised interventions are essential for averting exchange rate deviations caused by changes in the relative price level. However, sterilised interventions promote risk clusters on the central bank's balance sheet, whereas non-sterilised interventions are primarily associated with changes in the domestic price level. Additionally, both types of intervention do not only stabilise the exchange rate, but can also stabilise the domestic stock of real capital. One can therefore trace why the collapse of a fixed exchange rate regime may be linked to real domestic adjustments (Eichengreen et al., 1995). Implementing the wrong intervention strategy may avert exchange rate deviations in the short term; in the long term, however, errors in strategy may be the reason why stabilising interventions are sometimes unsuccessful (Sarno and Taylor, 2001; Dominguez, 2006). In the cases of Austria, Belgium, and Denmark, the paper has empirically shown through VAR impulse response estimations that non-sterilised interventions were predominantly carried out. This is plausible for these countries if exchange rate deviations can be attributed to changes in relative good prices.

One of the most important findings of this paper is that central bank interventions may promote an inefficient international allocation of real capital. If external variables change, the relative advantage of domestic investment is altered, and correspondingly, adjustments in the stocks of domestic and foreign real capital become appropriate. Through expansive monetary interventions and exchange rate stabilisation, the central bank can prevent these adequate adjustments from occurring, resulting in an inefficient international allocation of real capital. Overall, this has negative implications for world welfare.

From this point forward, more research is needed to analyse the impact of the central bank's asset structure on domestic macroeconomic risk. Moreover, the central bank's influence on real capital allocation could even be positive in certain situations, especially if the presence of foreign actors or transaction costs is taken into consideration.

In general, monetary policy is associated with trade-offs, both domestically and internationally. Therefore, it is advisable to thoroughly evaluate the welfare impact of central bank interventions through a holistic and internationally coordinated political process. This, in turn, allows for potentially diverse domestic and foreign interests to be equally taken into account.

A supplemental paper referring in detail to the solving of the model and the test for stability, as well as the respective EViews workfiles regarding the VAR estimations, is available for download at the IQSS Dataverse http://dvn.iq.harvard.edu/dvn/dv/schueder.

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Appendix

Tables

Table A.1—Exogenous and Constant Variables

variable	meaning
$\overline{a}$	total factor productivity (constant)
$\widehat{\sigma}$	relative macroeconomic risk (exogenous)
$\overline{q^B}$	coupon payment on one domestic bond (constant)
$\overline{q^F}$	coupon payment on one foreign asset in foreign currency (constant)
$\widehat{i^F}$	interest rate on foreign assets (exogenous)
$\overline{dc}$	fraction of producers' income spent on debt capital costs (constant)
$\widehat{K}$	credit amount (exogenous)
$\overline{M}$	initial amount of domestic money (constant)
$\widehat{n_{CB}^B}$	amount of central bank's domestic bonds (exogenous)
$\overline{n^F}$	initial amount of foreign bonds held domestically (constant)
$\widehat{n_{CB}^F}$	amount of central bank's foreign bonds (exogenous)
$\widehat{p^*}$	price level of foreign goods in foreign currency (exogenous)
$\overline{v}$	velocity of money (constant)

Table A.2—Endogenous Variables

variable	meaning
b	fraction of private households' portfolio held in domestic bonds
B	total value of domestic bonds
B_{CB}	value of central bank's domestic bonds
B_P	value of private households' domestic bonds
B_P^d	private households' demand for domestic bond value
C_D	private households' consumption of domestic goods
C_F	private households' consumption of foreign goods
CG	value of domestic capital goods
div	dividend payment on one domestic equity asset
Div	aggregate dividend payments
Div^d	demand for aggregate dividend payments
e	fraction of private households' portfolio held in domestic equity
E	total value of domestic equity
E^d	private households' demand for domestic equity value
f	fraction of private households' portfolio held in foreign bonds
F	value of foreign bonds held domestically in foreign currency

variable	meaning
F_{CB}	value of central bank's foreign bonds in foreign currency
F_P	value of private households' foreign bonds in foreign currency
F_P^d	private households' demand for foreign bond value in foreign currency
i^B	interest rate on domestic bonds
i^E	interest rate/required rate of return on domestic equity
i^K	credit interest rate
Inc_P	private households' income
K^d	producers' demand for credit
m	fraction of private households' portfolio held in money
M	amount of money
M^d	money demand
M^s	money supply
n^B	total amount of domestic bonds
$(n^B)^s$	total supply of domestic bond quantities
n_P^B	amount of private households' domestic bonds
$(n_P^B)^d$	private households' demand for domestic bond quantities
$(n_P^B)^s$	supply of domestic bond quantities vis-à-vis the private households
n^{CG}	domestic stock of real capital goods
n^E	total amount of domestic equity assets
n^F	total amount of foreign assets held domestically
n_P^F	amount of private households' foreign assets
$(n_P^F)^d$	private households' demand for foreign asset quantities
$(n_P^F)^s$	supply of foreign bond quantities vis-à-vis the private households
$NetA$	central bank's net assets
p	price level of domestic goods
p^B	price of one domestic bond
p^E	price of one domestic equity asset
p^F	price of one foreign bond in foreign currency
s	exchange rate in direct quotation
s^{real}	real exchange rate
val^{CG}	implicit value of one capital good
W	private households' aggregate wealth
Y	nominal domestic production
Y^r	real domestic production

Table A.3—VAR Model Estimation Settings

		Austria	Belgium	Denmark
time period	start	1989M06	1989M10	1999M02
	end	1998M12	1998M12	2011M03
lags		3	5	6
sample period	start	1989M09	1990M03	1999M08
	end	1998M12	1998M12	2011M03
incl. observations (after adj.)		112	106	140
edogenous variables		8	8	8
exogenous variables		14	14	12
constant		1	1	1
seasonal dummies		11	11	11
impulse dummy 1990M06 [a]		1	1	-
shift dummy 1990M06 [a]		1	1	-
total variables		38	54	60
degrees of freedom		74	52	80

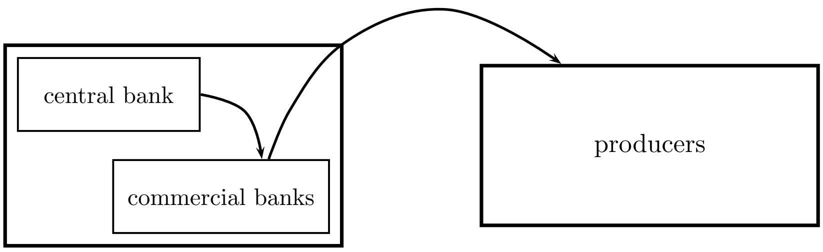
[a] Dummies due to German monetary union.

Table A.4—Test Statistics of VAR Model Estimations

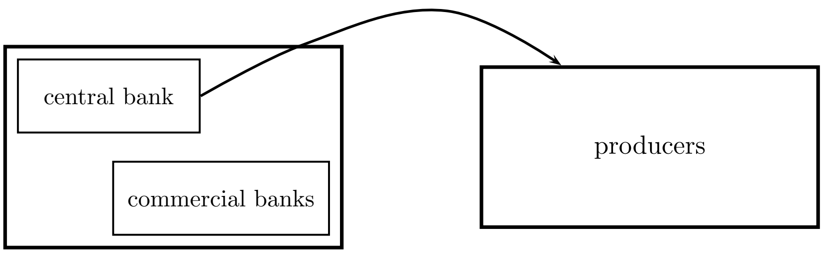
	Austria	Belgium	Denmark
VAR Residual Serial Correlation LM Tests (H_0: no serial correlation at lag order h)			
Lags	Probability		
1	0.342	0.146	0.781
2	0.223	0.428	0.352
3	0.623	0.285	0.688
4	0.598	0.891	0.567
5	0.473	0.310	0.009
6	0.463	0.132	0.029
7	0.826	0.805	0.115
8	0.508	0.207	0.657
9	0.858	0.434	0.975
10	0.379	0.624	0.400
11	0.672	0.760	0.293
12	0.335	0.282	0.650
13	0.594	0.963	0.959
14	0.729	0.784	0.590
15	0.589	0.354	0.576
16	0.337	0.452	0.900
17	0.900	0.682	0.232
18	0.858	0.591	0.652
VAR Residual Heteroskedasticity Test (H_0: no heteroskedasticity)			
	Probability		
Joint test	0.802	0.737	0.137
No Root outside the Unit Circle (Stability Condition)			
	yes	yes	yes

Figure A.1. : Increases in Credit Lending

Indirect



Direct



No qualitative difference between an indirect or direct increase in credit lending is present, only quantitative differences are possible ⇒ commercial banks are not required to be explicitly modelled because they do not affect the direction of model results.

Model implicitly comprises Indirect & Direct

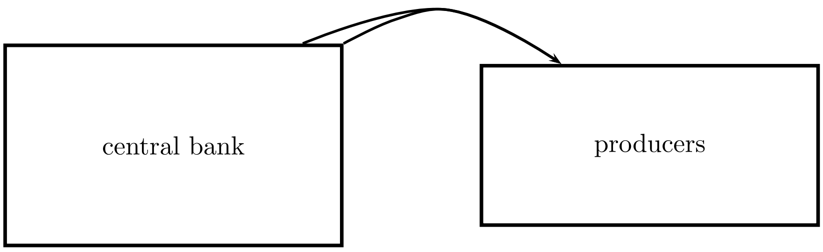
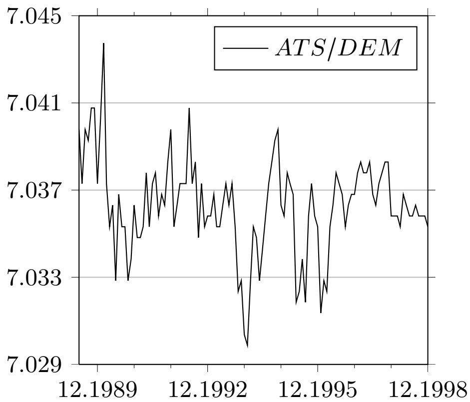


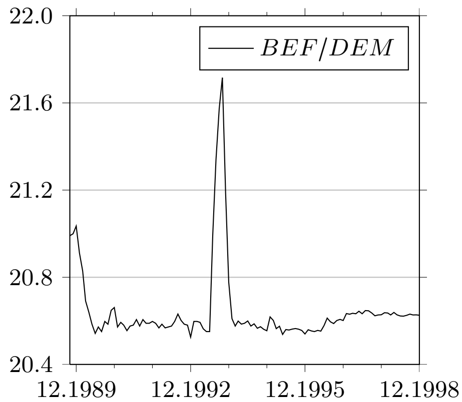
Figure A.2. : Exchange Rates

Austria



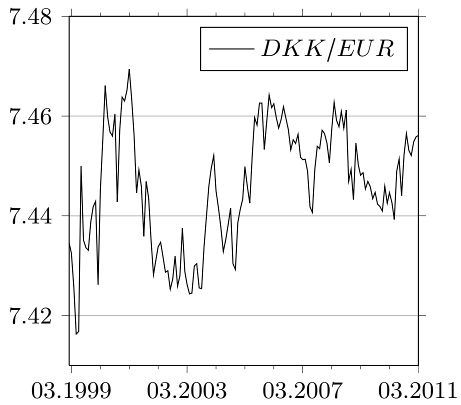
mean = 7.036, stdv = 0.002, stdv/mean = 0.03%

Belgium



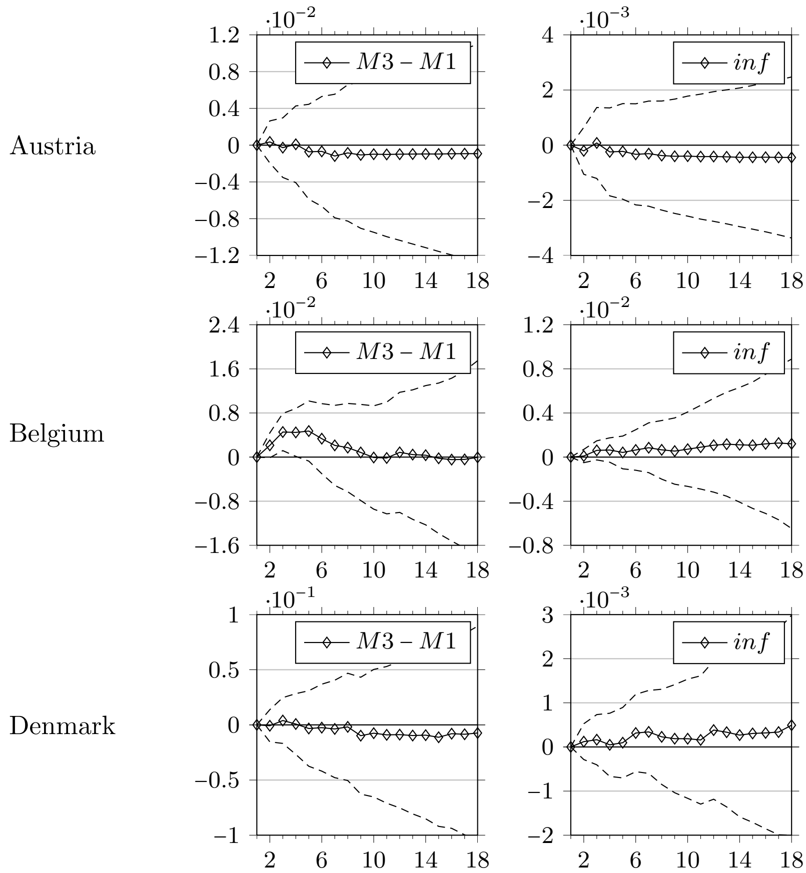
mean = 20.647, stdv = 0.186, stdv/mean = 0.90%

Denmark



mean = 7.446, stdv = 0.012, stdv/mean = 0.16%

Figure A.3. : Responses of $M3 - M1$ and inf



Responses to a one standard deviation exchange rate shock (± 2 error stdv).