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25 June 2011

Center for European, Governance and Economic Development Research
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Discussion Papers

Number 127– June 2011

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ISSN: 1439-2305

Monetary Policy Trade-Offs in a Portfolio Model with Endogenous Asset Supply

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25 June 2011

This paper develops an open economy portfolio balance model with endogenous asset supply. Domestic producers finance capital goods through credit and bonds in accordance with debt capital costs as well as through 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 real exchange rate.

Within this general equilibrium model, it can be shown that expansive monetary interventions, being applied throughout the course of economic crises, stabilise the real amount of domestic investments at the cost of inflation, currency devaluation, distortions of interest rates, and risk clusters on the central bank's balance sheet. Furthermore, through exchange rate stabilising interventions, the central bank is able to stabilise the real amount of domestic investments and in turn the main goal of exchange rate stabilisation is also achieved. However, either risk clusters on central bank's balance sheet or changes in the domestic price level emerge. This consequently results in both types of central bank interventions promoting an inefficient international allocation of real capital investments.

JEL: E10, E44, E52
Keywords: portfolio balance, monetary policy, macroeconomic risk, exchange rate, real capital investments

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), 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.

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

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required as to date there is “no integrative general-equilibrium monetary model of international portfolio choice, although we need one”. Recent research analyses 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 places particular emphasis on trying to explain the home bias in asset holdings (Heathcote and Perri, 2009, and references cited therein).

This paper considers the origination of financial assets and the implications this has for monetary policy transmission. To date, the amount of bonds and equity assets have not been treated as endogenous in the portfolio balance literature, with the exception of Devereux and Saito (2006), who assume that the supply of bonds depends negatively on the bond interest rate. Despite this, neither the possibility to substitute bonds for loans, 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 choose an optimal capital structure according to 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). 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”. Through this approach, it is revealed that portfolio adjustments have an impact on the amount of real domestic investments, which subsequently affect real domestic production. Since the central bank is able to influence the portfolio composition of private households through monetary interventions, it 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 results of the model indicate that the real amount of domestic investments adjusts in reaction to external shocks in exogenous variables. This is evident in investors’ behaviour, seeing as changes in the foreign interest rate, the relative macroeconomic risk, and the foreign price level affect the relative attractiveness of domestic investments compared to foreign investments.

A relative increase in the domestic macroeconomic risk level, seemingly prevalent in times of economic crises, would be followed by real domestic disinvestments in the long term. However, if the central bank reacts with open market purchases of domestic bonds, or with an increase in the supply of credit, it takes over domestic risk on its balance sheet. Through expansive monetary interventions, it reduces the domestic risk premium and consequently averts real domestic disinvestments. There are some related side effects however, such as domestic inflation, currency devaluation, distortions in domestic interest rates, and risk clusters on the central bank's balance sheet.

Furthermore, the central bank is able to stabilise the exchange rate in reaction to external shocks through interventions on credit, domestic bond and foreign asset markets. However, it is essential to choose the right intervention strategy due to the different reasons for exchange rate changes. Sterilised interventions are required and only sustainably effective if changes in the foreign interest rate, or in the relative macroeconomic risk, are the reasons for exchange rate changes. Non-sterilised interventions only work in the case of changes in the foreign price level. Nevertheless, both types of interventions stabilise the real amount of domestic investments, as well as the exchange rate. However, sterilised interventions promote risk clusters on the central bank's balance sheet, whereas non-sterilised interventions are connected with changes in the domestic price level.

Both expansive monetary interventions, being applied during economic crises, and exchange rate stabilising interventions thus avert appropriate adjustments in the real amount of domestic investments, which comes at the cost of foreign investments. These interventions by central banks consequently cause an inefficient international allocation of real capital goods.

The paper is structured as follows; the first section 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. The extent to which expansive monetary interventions are able to neutralise the impact of an increase in the domestic macroeconomic risk is subsequently analysed. Following on from here, the possibilities the central bank has to avert changes in the exchange rate are presented, also illustrating how interventions affect interest rates, as well as the real economy. Vector autoregressive estimations for three different countries in periods when pegged exchange rates existed are then performed.[1] The empirical results highlight that the theoretical implications of exchange rate stabilising interventions also occur in practice. Reasons as to why simplifications do not reduce the general validity of the model are subsequently discussed and the results are then summarised in the conclusion to the paper.

I. Model Structure

A. General Framework

The considered open economy has three different actors, those being the central bank, private households and producers. Each actor 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. Domestic actors are not able to influence variables of the foreign country, while foreign actors neither hold domestic

[1] Austria (1989M06 - 1998M12), Belgium (1989M10 - 1998M12), and Denmark (1999M02 - 2011M3).

assets nor consume domestic goods. The model considers one single and homogenous good, which is produced at home as well as abroad. This good may either be consumed by private households or used as a factor of production. Capital is considered as the only factor of production.

The prices of goods and financial assets are flexible. Domestic bonds and foreign assets are fixed interest bearing assets, whereas domestic equity assets pay out varying dividends. While the domestic asset amounts are considered constant in the short term, in the long term the amount of domestic bonds and equity assets may vary. This is due to producers' maximising firm value and private households' maximising real consumption given their budget constraints. The aggregate portfolio of private households consists of several gross substitutes, these being domestic money, domestic bonds, domestic equity, and foreign assets, and has an optimal composition with respect to private households' risk-return objectives.

Through these assumptions, we obtain a set of general equilibrium conditions for the short term and the long term respectively. In the following sections, the assumptions are specified in detail.[2]

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 also 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:

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

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

[2]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.

[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 since 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. Thereby, it is implied that the central bank can be interpreted as the economy's aggregated banking sector within the model.

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

$$(3) \qquad \widehat{K} + B_{CB} + sF_{CB} = M + NetA$$

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

$$(4) \qquad dM = d\widehat{K} + d\widehat{n^B_{CB}} \cdot p^B + d\widehat{n^F_{CB}} \cdot s \cdot p^F$$

$$(5) \qquad dNetA = dp^B \cdot \widehat{n^B_{CB}} + dp^F \cdot s \cdot \widehat{n^F_{CB}} + ds \cdot p^F \cdot \widehat{n^F_{CB}}$$

The 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:

$$(6) \qquad M^s = \overline{M} + d\widehat{K} + d\widehat{n^B_{CB}} \cdot p^B + d\widehat{n^F_{CB}} \cdot s \cdot p^F$$

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^B_P, n^E, n^F_P) 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, if the value of assets (measured in domestic currency) changes, the residual position of net assets $NetA$ adjusts to this in the case of the central bank.

[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 $n^E = n^E_P$.

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:

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

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

The nominal income of the private households is the sum of interest payments and central bank distribution:

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

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, private households' balance of income is always 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 rationale here is substantiated 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 investments, and vice versa. The consequence is that in the long term, producers' real amount of domestic 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:

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

Consequently, producers' balance of income is always balanced.

[9] In the case of producers, 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 $dY^r = 0$ as well. 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 as well. The rationale for these relationships is substantiated in section D.

Given the balance equations of the open economy's three actors (3, 10, and 13), as well as the following relations,

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

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

we find 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 ($W + NetA$):

$$CG + sF = W + NetA \tag{21}$$

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

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

[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).

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 through 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 investments 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 therefore 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 portion ($\overline{dc}$) of producers' income (Y):

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

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 ($\widehat{n^B_{CB}}$):

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

Regarding the credit market, the central bank consequently 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, and can therefore be considered as exogenously determined by the central bank's monetary policy interventions in the short term. As a result, producers' target capital structure is not necessarily matched in the short term, since deviations from equation 26 are possible due to the resulting implications of the *credit view*.[12]

Hence, over time credit demand and bond supply become more and more elastic, 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

[12]Since $\widehat{K}$ and n^B are constant in the short term, 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.

rationale of the *static trade-off theory*.[13] Thereby, it is implied that over the long term producers will 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 ($(n^B)^s$) depend negatively 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 depends positively, 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 which occurs when choosing the desired amount of debt capital. 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 optimal amount of debt capital, the following equations hold:

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

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

Due to the *money view*, 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 (see equation 30), and bond and credit interest rate being equal (see equation 31).

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

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

[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.

Solving the 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:

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

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.[15] By transposing equation 18 under consideration of equation 16, it follows in general that:

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

Following this, it will firstly be discussed which variables Div is determined by in the short term. Taking the equations 19, 22, and Quantity Equation 24, it follows 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):

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

[15]For determining dividend payments, an equivalent approach is applied by Tille (2008).

Secondly, 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, we obtain the following:

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

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 domestic 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 given an unchanged discount rate (i^E). In sum, the aggregated value of domestic equity (E) remains unchanged.[17]

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

[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.

[17]The same conclusion can be drawn by analysing the approach by Tille (2008).

private companies are able to personally draw or contribute equity capital relatively easily, the more coordination that is required, the more is 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.

It also 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 ($\frac{C_D}{p} + \frac{C_F}{\widehat{p^*} \cdot s}$) given their budget constraint. At any time, their budget constraint is expressed by their income balance restriction (equation 12). Taking the 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 domestic price level (p) and the foreign price level in domestic currency ($\widehat{p^*} \cdot s$):

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

Here, it is initially discussed how private households consume if purchasing power parity holds ($s^{real} = 1$) – given long term equilibriums in all other markets. If $s^{real} = 1$, private households are indifferent regarding the consumption of either domestic or foreign goods. If in such a situation 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[18], which would be connected 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 increase) 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). Conse-

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

quently, long term equilibrium is inevitably connected 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 allow for 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. On the other side of the coin, 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:

$$C_D = Y - d\widehat{K} - dn^B \cdot p^B - dn^E \cdot p^E \tag{41}$$

$$dn^E \begin{cases} > 0 & \text{if } s^{real} > 1 \\ < 0 & \text{if } s^{real} < 1 \\ = 0 & \text{else} \end{cases}$$

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 balanced as well, 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.

Hence, 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). In such a case, private households tend to consume more domestic goods than are domestically produced. Consequently, 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. Thus, private households compensate for this loss in value caused by the exchange rate by 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:

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

Since the domestic asset amounts 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:

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

F. *Portfolio Selection and Money Demand*

By assumption, private households are risk averse and maintain their individual asset portfolios following the optimal portfolio rule 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, 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[19], private households tend to hold a higher proportion invested in an asset the higher its expected return and the lower its opportunity costs (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 of 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

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

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 range of the model, it is reasonable to assume, for the sake of simplicity, that the extent of macroeconomic risk is exogenously given. Here, we define $\widehat{\sigma}$ 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.[20]

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. Accordingly, private households will demand more money the higher the price of one goods transaction (p) is, the more transactions they tend to perform (approximated by Y^r), and the less transactions are technically possible to proceed 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:

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

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

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

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

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

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

[20]E. g., 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.

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

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

The private households' demand concerning the quantity of domestic bonds $((n_P^B)^d)$ is derived by dividing B_P^d by the price of one domestic bond (see equation 22). Multiplying E^d by the equity discount rate, we then get the demand for domestic dividend payments (Div^d). Finally, by 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:

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

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

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

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

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

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). Consequently, in connection with equation 44, the total amount of foreign assets 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, the money market condition 55 does not need to be considered. The result is that changes in (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 central bank holdings of domestic bonds ($\widehat{n_{CB}^B}$) and foreign assets ($\widehat{n_{CB}^F}$) affect the endogenous variables and consequently 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:

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

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

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

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):

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

A stable, long term general equilibrium must be connected with purchasing power parity due to private households' maximising real consumption (see rationale in section D on page 14). 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 (see equation 24) and the production function (see 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^B and n^F consist, in turn, of exogenous changes in $\widehat{n_{CB}^B}$ and $\widehat{n_{CB}^F}$, and endogenous changes in n_P^B and n_P^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_P^B, and n_P^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 investments, vary in the long term (see equation 15), not only private households' wealth (W), but also the real domestic production (Y^r) may adjust to changes in the exogenous variables.

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* respectively.

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). Consequently, 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 based on 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 based on changes in the value of one asset type relative to the others. For example, 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) held in the portfolio decreases relative to the others. To compensate for the relative loss in value so 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.

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

Table 1—Impact of Changes in the Exogenous Variables in the Short Term

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

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 1 gives an overview of the short term impact of changes in the exogenous variables, while table 2 summarises the impacts with respect to the long term. In relation to the tables, it is also 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]

[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.

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

	$di^B/$	$di^E/$	$ds/$	$dn_P^F/$	$dn_P^B/$	$dW/$	$dY^r/$	$dp/$
$/d\widehat{\sigma}$	$\gtreqless 0$	$\gtreqless 0$	> 0	> 0	$\gtreqless 0$	$> 0\,^b$	< 0	> 0
$/d\widehat{i^F}$	$\gtreqless 0$	$\gtreqless 0$	> 0	> 0	$\gtreqless 0$	$> 0\,^b$	< 0	> 0
$/d\widehat{p^*}$	$= 0$	$= 0$	< 0	> 0	$= 0$	$= 0$	< 0	> 0
$/d\widehat{K}$	$> 0\,^a$	$> 0\,^a$	$> 0\,^a$	$< 0\,^a$	$> 0\,^a$	> 0	$> 0\,^a$	$> 0\,^a$
$/d\widehat{n_{CB}^B}$	$> 0\,^a$	$> 0\,^a$	$> 0\,^a$	$< 0\,^a$	$> 0\,^a$	> 0	$> 0\,^a$	$> 0\,^a$
$/d\widehat{n_{CB}^F}$	$> 0\,^a$	$> 0\,^a$	$> 0\,^a$	$< 0\,^a$	$> 0\,^a$	> 0	$> 0\,^a$	$> 0\,^a$

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

[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.

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 now 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 (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, through this exchange rate increase a new equilibrium is obtained to the extent that the initial *allocation effect* is entirely compensated by the endogenous *wealth effect* and the *value compensation effect*. Thereby, 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 more negatively affected by an increase in $\widehat{\sigma}$ than m (in relative terms), and vice versa. Subsequently, if private households consider

[24]Subsequently, 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.

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, since 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 $d\widehat{\sigma} > 0$, assuming 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 which are realised 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. Consequently, 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 retrieve its initial value. Since the amount of real domestic investments (n^{CG}) decreases due to the exchange of equity assets (see equation 15)[27], real domestic production (Y^r) also decreases. Consequently, 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 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 disinvestment in domestic real capital goods in reaction to the increase in $\widehat{\sigma}$ is a logical consequence of private households' investment behaviour. If domestic investments become relatively riskier, risk averse investors will relocate capital by investing in relatively less risky projects abroad until their investment portfolio is balanced again.

An increase in the foreign interest rate ($\widehat{i^F}$) has a similar impact on the endogenous variables, much like 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

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

[26] A decrease 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 (this is the case if $\frac{\partial m}{\partial \widehat{\sigma}} \frac{\widehat{\sigma}}{m}$ is zero or close to zero). In this case, additional domestic disinvestments take place due to the long term decrease in n^B (see equation 32).

[28] Overcompensation would occur if private households consider money to be risk free or nearly risk free ($\frac{\partial m}{\partial \widehat{\sigma}} \frac{\widehat{\sigma}}{m}$ would be zero or close to zero).

allocation effect. However, the exchange rate also increases in the short term, which balances out demand and supply. Likewise, the amount of real domestic investments decreases in the long term since foreign investments become relatively more attractive. However, the reason for real domestic disinvestment 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 therefore being that private households' wealth remains unchanged. That being said, the real amount of domestic capital investments decreases, also causing 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 are comprehensible from an investor's perspective. It is reasonable to shift real investments 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 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 so that the excess demand for domestic dividend payments is primarily balanced by the resulting *value compensation effect*. Besides the *value compensation effect*, the excess supply of the remaining asset types is primarily balanced by the related

[29]The negative *wealth effect* and the *value compensation effect* caused by the decrease in the exchange rate is compensated 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 identified changes in (future) dividend payments being a likely reason for these changes in stock prices, as is the case within the current model.

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, credit demand 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 money amount 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 connected increase in demand for foreign currency, the exchange rate increases and foreign assets are sold. Going hand in hand with this is the exchange of domestically produced goods for equity assets from the producers. In sum, the increase in the amount of credit, domestic bonds and domestic equity assets causes an increase in real domestic investment (see equation 15) at the cost of foreign investment (see equation 44). In the new long term equilibrium, private households hold a lower amount of foreign assets 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}.

A purchase of domestic bonds by the central bank ($\widehat{dn_{CB}^B} > 0$) 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, in 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,

[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).

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, 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). Considering all effects together, 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*.

If the central bank acquires additional foreign assets ($\widehat{dn^F_{CB}} > 0$) in the short term, the domestic price level and dividend payments increase 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. Consequently, 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 now balanced in the short term.[38]

The long term effects of $\widehat{dn^F_{CB}} > 0$ are qualitatively the same as the long term effects of $d\widehat{K} > 0$ and $\widehat{dn^B_{CB}} > 0$. However, the quantitative impact is different. With $d\widehat{K} > 0$ and $\widehat{dn^B_{CB}} > 0$, the central bank increases the demand for domestic debt assets, thereby putting pressure on the interest rates on producers' debt liabilities in the short term. Therefore, domestic producers' motivation to increase the amount of debt liabilities is twofold, with the first reason being connected to the increase in the money supply and the second reason being based on central bank pressure on the interest rates on debt liabilities (see equations 26 and 32). In the case of an increase in $\widehat{n^F_{CB}}$, only the first reason has relevance. For long term equilibrium, the result is that for each money unit created by $\widehat{dn^F_{CB}} > 0$, the increase in the total amount of domestic bonds is less, and the increase in the domestic bond interest rate is higher compared to $d\widehat{K} > 0$ and $\widehat{dn^B_{CB}} > 0$. Therefore, the increase in the real amount of domestic capital goods is less in the case of $\widehat{dn^F_{CB}} > 0$. Consequently, the increase in real domestic production is smaller, and the increase in the domestic price level is higher. Finally, purchasing power parity is obtained with a higher exchange rate than in the case of $d\widehat{K} > 0$ and $\widehat{dn^B_{CB}} > 0$.

[36] The exchange rate (s) is only positively affected by the intervention, if the decrease in i^B effects the demand for foreign assets to this extent positively that the negative effect from the increase in i^E is overcompensated for (and vice versa).

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

[38] Only if the increase in i^E has an exceptionally strongly negative effect on the demand for foreign assets, there is a chance that the exchange rate will decrease (temporarily) in the short term as well.

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 $\widehat{p^*}$) which are not controlled by the central bank. If the central bank is to maintain a certain target value, for example for the exchange rate, the domestic price level, or real domestic production, this target may not be achieved in the short term, or even the long term, due to external shocks. However, the central bank is able to adjust its policy variables with the goal of compensating for their impact. That being said, an intervention stabilising one variable may have destabilising side effects on other variables. Because of this, the trade-offs connected with monetary policy interventions will be 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. Through the burst of the U.S. 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 following the collapse of Lehman Brothers would imply that money was less affected by the increase in macroeconomic risk compared to bonds and equity assets. In sum, it is highly probable that negative *wealth effects* have prevailed, decreasing the wealth of private 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 U.S. 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

[39]See, e. g., Minsky (1986) and Neely (2003) who discuss the reaction of the U.S. Federal Reserve to several crises.

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, it is analysed to what extent 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 connected with a decrease in private households' wealth in the short term.[41] In the long term, real domestic disinvestments take 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 an expansion of credit lending. Through a purchase of domestic bonds, the central bank decreases the domestic bond supply vis-à-vis the private households, thereby taking over 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 while the price of domestic bonds increases.[42] Furthermore, the increase in liquidity produces an increase in dividend payments. As a result, 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 with the decrease in n_P^B and the increase in i^E, are outweighed by the positive *wealth effects* connected 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 by an increase in $\widehat{n_{CB}^B}$ in the short term. However, this is only possible at the cost of an increase in the domestic price level, which is produced by the expansion of the money supply (see equations 25 and 6). Furthermore, domestic interest rates 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

[40] See also the discussion on the term 'quantitative easing' in Klyuev et al., 2009, pg. 9.

[41] If $\frac{\partial m}{\partial \widehat{\sigma}} \frac{\widehat{\sigma}}{m}$ is zero or close to zero, see last chapter.

[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. (2010) in the case of the U.S. and Joyce et al. (2010) in the case of Britain.

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 either in the bond or in the credit interest rate, as well as the increase in dividend payments, the domestic bond supply and the credit demand increases 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 over 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 amount of producers debt liabilities, resulting in an increase in the amount of real domestic investments (see equation 15). However, the domestic bond interest rate also 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 2). Through private households' adjustment in consumption behaviour, current account deficits and an increase in the exchange rate occur. Furthermore, an additional increase in the amount of real domestic investments follows, witnessed through the increasing amount of domestic equity assets. The final result is that the imminent real domestic disinvestments caused by $d\widehat{\sigma} > 0$ can be averted in the long term through expansive monetary interventions.

The Trade-Offs of Expansive Monetary Interventions

As demonstrated, 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 disinvestments can be avoided since expansive monetary interventions produce increases in the amount of real domestic investments (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 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 increased 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, 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 a 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 investments become less attractive compared to foreign investments. Consequently, it would be suitable to reduce the amount of domestic investments. If the central bank takes on the increased in domestic risk through expansive monetary interventions, it averts the domestic disinvestment at the cost of foreign investments.

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

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 expressed 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.

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). 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 has emerged by analysing the trade-offs associated with stabilisation interventions within the current model. The following shows that exchange rate stabilisation is related to the stabilisation of the real amount of domestic investments.

The Impact of Exchange Rate Stabilisation

Within the model, we can analyse how central bank interventions, which are applied in order to avert devaluations of the domestic currency in reaction to external shocks, affect the economy. 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 purchases 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 ($d\widehat{n^F_{CB}} < 0$). However, with $d\widehat{n^F_{CB}} < 0$, the domestic amount of money (M) would be negatively affected, and 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 1). 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 avert these side effects, the central bank needs to purchase domestic bonds. Through a so called sterilised intervention, the impact on the amount of money 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 an influence on the domestic bond interest rate in the short term.

In the long term, the real amount of domestic capital investments would decrease following a relative increase in the 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 real amount of domestic investment therefore decreases (see equation 15). If the central bank averts the short term increase in the exchange rate without changing the money supply, no incentive remains to reduce the amount of equity assets. Hence, the real amount of domestic investments is not affected by changes in the amount of equity assets either. That being said, the supply of domestic bonds may change if the domestic bond interest rate adjusts overall. Thus, minor decreases or increases in the real amount

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

of domestic investments may result in the long term due to changes 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). Here, they substitute the relatively expensive foreign imports for domestic goods, thereby reducing the amount of equity assets and the real amount of domestic investments. The resulting surplus on the current account produces a decrease in s. The central bank is able to avert the 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, no incentive remains for private households to adjust their consumption composition. Consequently, the real amount of domestic investments (n^{CG}) is not affected by changes in the amount of equity assets. Nevertheless, n^{CG} may increase overall if the supply of domestic bonds is positively affected by the reflationary monetary interventions (see footnote 44).

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 $\widehat{i^F}$. However, the domestic money supply needs to be adjusted to sustainably neutralise exchange rate changes caused by changes in $\widehat{p^*}$. Both types of interventions not only stabilise the exchange rate, but also avert changes in the real amount of domestic investments which would otherwise be caused by external shocks.[45] Nonetheless, both types of interventions are connected 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

[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 disinvestments take place, 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 the real amount of domestic investments cannot be totally averted. From the reverse 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 the real amount of domestic investments would remain.

[45] Only minor changes in the real amount of domestic investments may be expected because of changes in the domestic bond supply.

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 stabilising of the amount of domestic equity assets, as well as the lowering of the interest rate on domestic bonds, promoting increases in the supply of domestic bonds. Therefore, the real amount of domestic capital investments 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 investments become less attractive compared to foreign investments. For this reason, the real amount of domestic investments tends to decrease. If the central bank takes over domestic risk through sterilised interventions, it averts domestic disinvestments at the cost of foreign investments, thereby promoting an inefficient international allocation of real capital.

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 interventions hinder adequate adjustments in the real amount of investments. If the price level of foreign goods increases, real foreign investments produce a higher value added than before, thus become relatively more attractive than domestic investments. As a consequence, domestic disinvestments and foreign investments take place. If the central bank exerts reflationary monetary interventions, it averts domestic disinvestments at the cost of foreign investments. The result here is yet again an inefficient international allocation of real capital.[47]

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 by exchange rate stabilising interventions due to the resulting inefficient international allocation of real capital investments.

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 (namely 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

[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 relations 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.

term deviations of the respective exchange rates, and consequently, 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 the 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, caused by the business cycle in particular. The same is true for *msci*, *reserv*, $M1$, $M3 - M1$, and inf. Concerning $i^K 3m$, the difference between the three month interbank interest rates is taken 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.

Interpretation of Results against the Background of the Model

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 we would expect sterilised interventions if the deviation of the exchange rate is based on changes in $\widehat{\sigma}$ or $\widehat{i^F}$. If it is based on changes in $\widehat{p^*}$, we would expect non-sterilised interventions. However, by solely shocking s within the impulse response estimation, it is implied that the change in s is caused by a change in $\widehat{\sigma}$ with respect to the current model with static expectations.[50] However, expectations may not always be static in practice (Frankel and Froot, 1987).

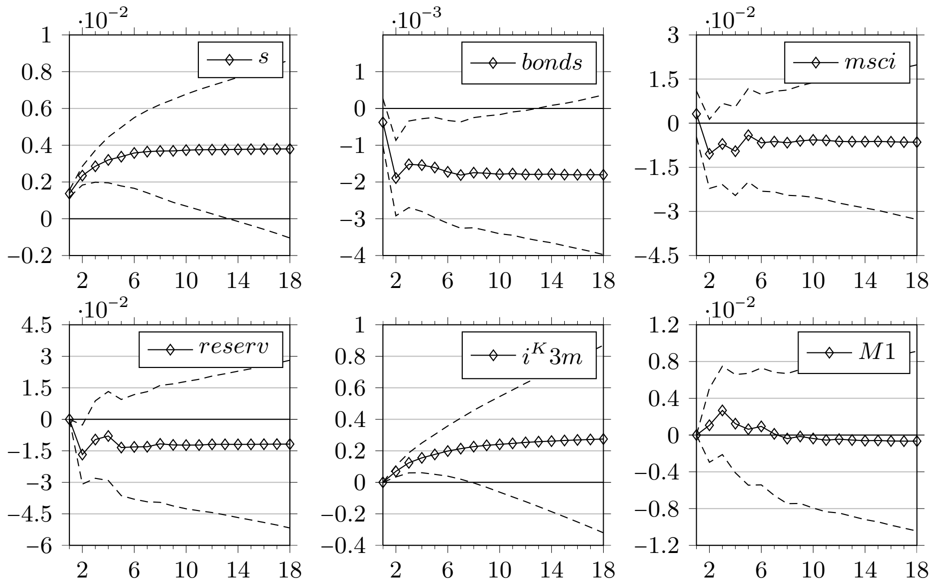
If expectations are not static in particular circumstances, and domestic private households expect a future increase in the exchange rate based on a future increase in $\widehat{\sigma}$ or

[48] See plots of the exchange rates in figure A.1 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 respective EViews workfiles and a detailed description of the data sources are available for download from the IQSS Dataverse http://dvn.iq.harvard.edu/dvn/dv/schueder.

[50] Changes in $\widehat{i^F}$ and $\widehat{p^*}$ must be connected with changes in *bonds*, *msci*, or inf. An increase in $\widehat{i^F}$ would be connected with 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, therefore *bonds* and *msci* would increase. If we only shock the exchange rate within the impulse response estimation without shocking *bonds* and *msci* at the same time, we imply that the exchange rate shock is not caused by a change in $\widehat{i^F}$. The same holds for $\widehat{p^*}$ in connection with inf. Therefore, only changes in $\widehat{\sigma}$ would explain the exchange rate deviation within the current model with static expectations.

Figure 1. : Austria



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

$\frac{p}{\widehat{p^*}}$, the expected return on foreign assets increases. This consists of foreign interest payments plus the expected exchange rate profit. Due to the increase in the expected return, the demand for foreign assets increases. Thereby, an increase in the exchange rate occurs straightaway.[51] Consequently, the initial increase in the exchange rate within the impulse response estimation may either be theoretically based on an increase in $\widehat{\sigma}$, an expected increase in $\widehat{\sigma}$, or an expected increase in $\frac{p}{\widehat{p^*}}$. If an (expected) increase in $\widehat{\sigma}$ is the reason, we would expect sterilised interventions by central banks in order to stabilise the exchange rate. If an expected increase in $\frac{p}{\widehat{p^*}}$ is the reason, we would expect non-sterilised interventions in turn.

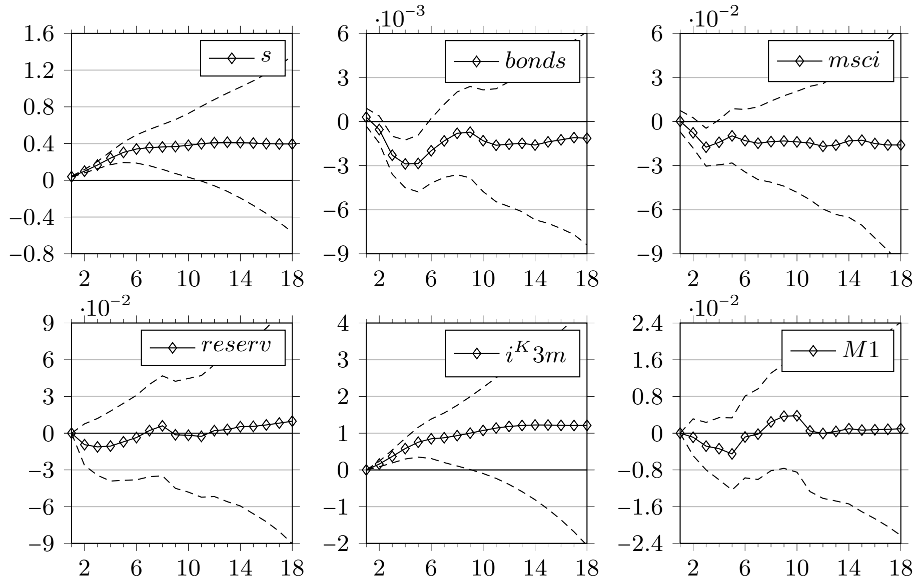
Results and Interpretation

Figures 1 to 3 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

[51] That is not necessarily the case if domestic private households expect a future increase in the exchange rate based on a future increase in $\widehat{i^F}$. The reason for this is that the change in the expected return on foreign assets is indefinite in this case. It consists of foreign interest payments, plus the expected exchange rate profit minus the price loss. Consequently, the demand for foreign assets does not necessarily increase.

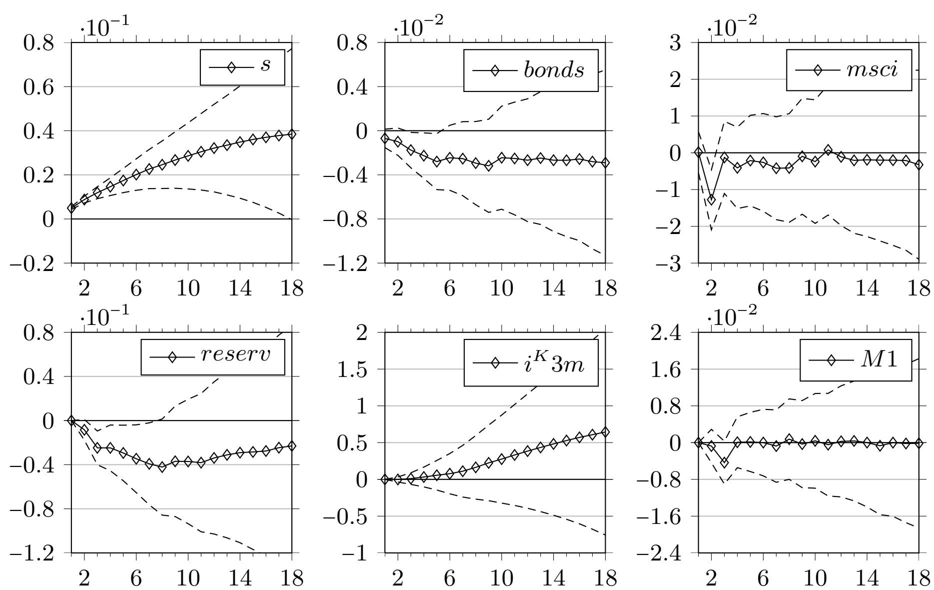
[52] For each impulse response estimation holds: accumulated responses, 18 periods, Monte Carlo simulated response standard errors (100000 repetitions), Cholesky type: dof adjusted, Cholesky order (based on theoretical model): $i^K 3m$, $reserv$, $M1$, $M3 - M1$, inf, s, $bonds$, $msci$, Cholesky order does not drive impulse response estimation results. The responses of $M3 - M1$ and inf can be found in figure A.2 of the appendix.

Figure 2. : Belgium



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

Figure 3. : Denmark



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

sell currency reserves in reaction to a sudden devaluation of their currencies (decrease 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 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, changes in expectations concerning $\frac{p}{p^*}$ are most likely the prevalent reason for exchange rate changes in practice. This result is reasonable since the economies analysed have similar economic structures to the base countries (Helg et al., 1995). Therefore, it is unlikely that a divergent development of domestic and base country macroeconomic risk has occurred during the considered time periods.

Nevertheless, differences in stabilising strategies can be observed which have an impact on the effectiveness of interventions. Austria seems to be the only country which 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, which seems to predominantly use currency reserves to stabilise its exchange rate. Its coefficient of variation is 0.16%. Belgium's currency, at 0.90%, has the highest coefficient of variation.[55] Belgium seems to predominantly use adjustments in the credit supply to avert exchange rate deviations. 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 time variation in the exchange rate. However, the increase in *bonds* and $M1$ following the fifth month after the initial exchange rate shock may be due to a central bank purchase of domestic bonds. Consequently, it seems that the Belgian central bank does not completely maintain restrictive policy measures, allowing for a higher variation in the exchange rate than the other central banks.

[53] Furthermore, in Belgium $M3 - M1$ reacts positively (see figure A.2). This may indicate that commercial banks substitute increasingly expensive central bank loans through acquiring 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 no analysed country does *bonds* increase following the initial exchange rate shock. Consequently, sterilised central bank interventions do not seem to be regularly applied in practice.

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

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 qualitatively essential, and may only quantitatively affect the model results.

Assuming rational expectations (instead of static expectations), this would increase the complexity of the model, reducing the extent, but not the direction of the short term reactions of the endogenous variables (with respect to exogenous shocks). In addition, 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. However, by assuming rational expectations, the relations would be qualitatively identical compared to 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. Consequently, the value of equity would exceed the optimal portfolio composition and the demand for dividend payments would decrease in the short term, as is the case within the current model.

Furthermore, it is implied that domestic private households consume all of their income. They may save and invest either domestically or abroad, but domestic investments always correspond to foreign disinvestments, and vice versa (see equation 44). In a nutshell, this implies that aggregate savings are assumed to be zero for the sake of simplicity. However, while to date it is still vague which variables generally determine the amount of savings (Akerlof and Shiller, 2009), it would be expected that the decision of where savings are invested 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 investments would be affected, but not the decision of real investment allocation. Therefore, no qualitative impact on the model results is expected if 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 interest rates and the exchange rate within the current model.

Moreover, additional types of portfolio assets like savings deposits, real estate, or commodities are present in reality. Furthermore, the banking sector does not only consist of the central bank, but also commercial banks. Domestic producers could be grouped in to firms and the state, and they also use labour as a factor of production. In addition, domestic private households generate income through wages, and finally, its 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, the liquidity of commercial banks, the structure of state debt, relative factor prices, or investors' level of confidence within the current model, one would not expect that the introduction of such model extensions could distort, or radically change the present model results.

However, the potential relation of risk clusters on central bank's balance sheet with respect to the domestic macroeconomic risk has yet to be researched. It is possible that the central bank itself would become a source of macroeconomic risk if it builds up extensive risk clusters, with the impacts of additional interventions then being diminished in such a situation. Furthermore, by extending the model with foreign actors or transaction costs, it is possible that expansive or exchange rate stabilising interventions do not promote an inefficient allocation of real capital investments in certain situations. If, for instance, changes in the relative attractiveness of domestic investments are due to monetary interventions by the foreign central bank, expansive monetary interventions by the domestic central bank may avert misallocation of real capital investments. In addition, stabilisation of the exchange rate may have a positive impact on aggregate welfare if real investment procedures are connected to transaction costs, and relative macroeconomic risk ($\widehat{\sigma}$) follows a mean reverting process. In such a case, exchange rate stabilising interventions would avert 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 real capital investments.

V. Conclusion

The presented model extends the existing portfolio balance framework by considering an endogenous asset supply. Furthermore, it accounts for all balance restrictions concerning the analysed economic actors and the balance of payments. Domestic private households maximise real consumption with respect to the real exchange rate, as well as optimise their portfolio composition following Markowitz' portfolio selection. Besides this, 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 investments 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 disinvestments which are caused by a relative increase in domestic macroeconomic risk. However, this can also give rise to risk clusters on the central bank's balance sheet, distortions of domestic interest rates, 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 at the zero lower bound of interest rates.

Concerning exchange rate stabilising interventions, it is essential to exert the appropriate intervention strategy with respect to the underlying reason for the exchange rate change. Sterilised interventions are required to neutralise exchange rate deviations caused by changes in the relative macroeconomic risk and the foreign interest rate level. Non-sterilised interventions are essential for averting exchange rate deviations caused by changes in the foreign price level. However, sterilised interventions promote risk clusters on the central bank's balance sheet, whereas non-sterilised interventions are connected with changes in the domestic price level. Furthermore, from the model we can see that both types of interventions not only stabilise the exchange rate, but also the real amount of domestic investments. Therefore, it becomes traceable why a collapse of a fixed exchange rate regime may be connected with real domestic adjustments. Furthermore, implementing the wrong intervention strategy may avert exchange rate changes in the short term, but in the long term, errors in strategy may be the reason why stabilising interventions sometimes don't succeed (Sarno and Taylor, 2001; Dominguez, 2006). In the case of Austria, Belgium, and Denmark, the paper has empirically shown through VAR impulse response estimations that non-sterilised interventions have predominantly been carried out. This is plausible for these countries if exchange rate deviations can be attributed to changes in relative good price expectations.

In addition to these results, it becomes visible that the stabilisation of the real amount of domestic investments promotes an inefficient international allocation of real capital. If external variables change, the relative advantage of real domestic investments is altered with adjustments in the real amount of domestic and foreign investments therefore being appropriate. Through expansive monetary interventions and exchange rate stabilisation, the central bank stops the adequate adjustments in the international allocation of real capital from occurring. However, more research is needed to analyse the impact of the central bank's asset structure on domestic macroeconomic risk. Furthermore, the central bank's impact on real capital allocation could even be positive in certain situations, especially if the presence of foreign actors or transaction costs are taken into consideration.

In general, the actions of the central bank are connected with trade-offs from both the domestic and the international perspective. Therefore, it is advisable to thoroughly evaluate the welfare impact of central bank actions 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, are 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)
$\widehat{i^F}$	market 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)
$\widehat{n^B_{CB}}$	amount of central bank's domestic bonds (exogenous)
$\overline{n^F}$	initial amount of foreign bonds held domestically (constant)
$\widehat{n^F_{CB}}$	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	market interest rate on domestic bonds
i^E	market 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
$(n_P^B)^d$	demand for domestic bond quantities
$(n_P^B)^s$	supply of domestic bond quantities vis-à-vis the private households
n^{CG}	real amount of domestic 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
$(n_P^F)^d$	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

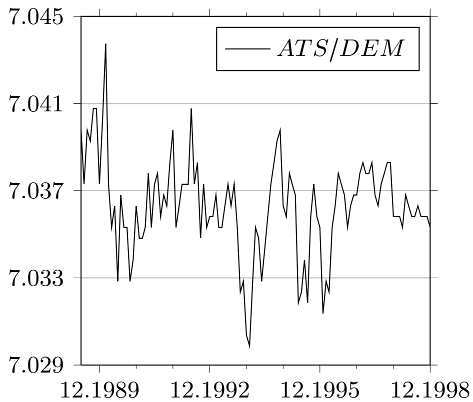
[a] Dummies due to German monetary union.

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

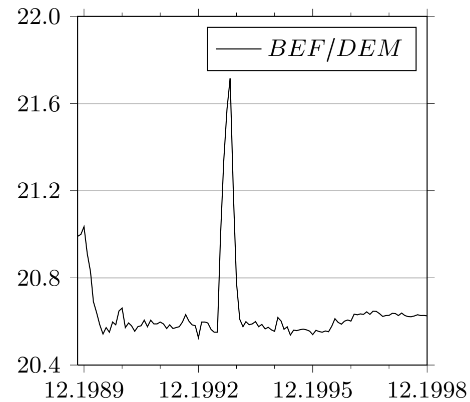
Figure A.1. : Exchange Rates

Austria



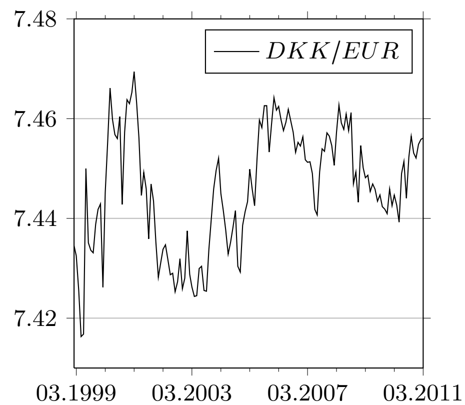
mean = 7.036, stdv = 0.002, stdv/mean = 0.03%

Belgium



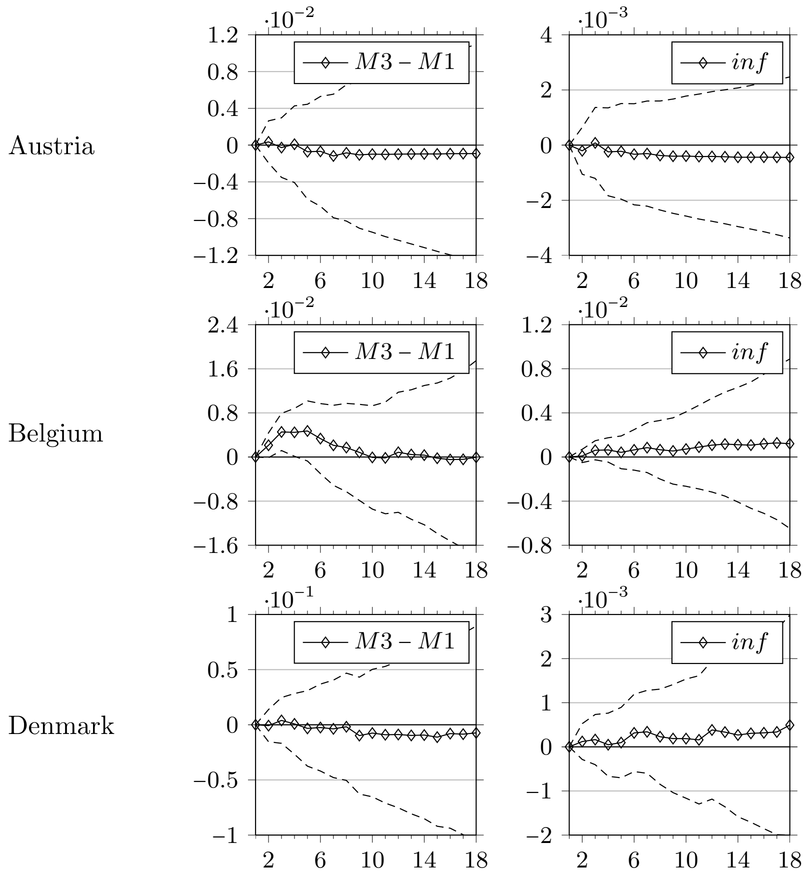
mean = 20.647, stdv = 0.186, stdv/mean = 0.90%

Denmark



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

Figure A.2. : Responses of $M3 - M1$ and inf



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

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