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Banks' balance sheets and the international transmission of shocks*

Johanna Krenz†

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Abstract

I propose a framework to think about the global comovement in macroeconomic variables during the recent financial crisis. The framework is used to address one question in particular: what is the role of banks' balance sheet exposure to foreign assets for the international transmission of country-specific shocks? It is shown that this role depends on the nature of the shock: balance sheet exposure is essential for global comovement in the case of capital quality shocks. Conditional on technology shocks and shocks to the net worth of bankers, however, the share of foreign assets in banks' portfolios does not play a decisive role for cross-country correlations. This implies that an evaluation of the risks arising from financial integration needs to take into account the nature of the shocks which are likely to hit the economy. An additional result of the model is that if financial institutions undertake the international portfolio choice decision instead of households, they do not necessarily choose the portfolio which yields the highest degree of consumption risk sharing. Given that a large part of international portfolio holdings are managed by financial intermediaries, this provides a possible explanation for the well-known empirical finding of modest international risk sharing despite open financial markets.

JEL classification: E44, F30, F44
Keywords: international transmission, financial frictions, capital quality shocks, risk sharing, portfolio choice

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1 Introduction

The recent economic crisis with its origin in the U.S. financial sector has been characterized by an unprecedented global comovement in real as well as financial variables. Given the substantial increase in cross-border holdings of financial assets and liabilities since the early 1990s (see, e.g., Lane and Milesi-Ferretti, 2007), a common explanation of the global scale of the crisis is centered around *international balance sheet exposure* of highly leveraged financial institutions: A drop in the value of some assets related to the U.S. subprime mortgage market forced balance sheet constrained investors around the globe – holding similar portfolios – to deleverage by selling assets across the board. This caused a general decline in asset prices, aggravating the initial events and spreading the crisis to other sectors and other countries.

This paper assesses the role of banks' balance sheet exposure for global comovement in real and financial variables. To this end, I set up a two-country real DSGE model featuring leverage-constrained financial intermediaries as modeled in Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) who hold risky claims on home and foreign capital as in Dedola et al. (2013) and Carniti (2012). I use this framework to analyze a type of shock which has recently gained importance in the business cycle literature due to its ability to capture the broad dynamics of the subprime crisis (Gertler and Karadi, 2011, p. 27) – a *shock to the quality of capital*. I find that for capital quality shocks, a sufficiently high share of foreign assets in banks' portfolios leads home and foreign output to move into the same direction. On the contrary, balance sheet exposure only plays a minor role in the transmission of technology shocks and shocks to the net worth of bankers – shocks which have been at centerstage in previous accounts of the role of balance sheet exposure for global comovement (see, e.g., Dedola and Lombardo, 2012; Yao, 2012). The result that balance sheet exposure matters for the transmission of capital quality shocks but not for other shocks is interesting, as it has important implications for an assessment of the risks of financial integration measured in *quantitative* terms: The model implies that the risks arising from high international asset positions depend on the nature of the shocks which are likely to hit the economy.

How is it possible that balance sheet exposure matters for the transmission of capital quality shocks but not for other shocks? A capital quality shock directly reduces the value of the corresponding assets in banks' balance sheets whereas technology shocks and net worth shocks reach the asset side of balance sheets mainly via asset prices, which are equalized through international arbitrage in this kind of model.

Recently, capital quality shocks have been given much attention in the closed economy literature, as they can reproduce a comovement of real and financial variables very close to the one observed since the beginning of the 'Great Recession' of 2008-2009 (see, e.g., Furlanetto and Seneca, 2014; Gertler and Karadi, 2011; Gertler and Kiyotaki, 2010). Furthermore, various empirical studies show that this kind of shock was the most important driver of business cycle fluctuations in recent years (Sanjani, 2014; Liu et al., 2011; Justiniano et al., 2011). In the light of these findings, my results suggest that including capital quality shocks into the research agenda of the international business cycle literature might constitute an important step forward in explaining the global scope of the recent economic crisis.

In addition, the analyses conducted in this paper contribute to the literature on international portfolio choice.[1] In most previous contributions, households undertake the portfolio choice decision. In this case, the optimal portfolio coincides with the portfolio which yields the highest degree of consumption risk sharing. In my model, bankers undertake the portfolio choice decision. The same setup is used in the models by Dedola et al. (2013) and Carniti (2012). However, to the best of my knowledge, this is the first paper to analyze the implications of this feature for international portfolio choice and consumption risk sharing. Bankers are owned by households, hence, they internalize the objective of the household. However, due to an agency problem between bankers and depositors, they have an additional motive, namely the maximization of net wealth which serves as collateral (cf. Gertler and Karadi, 2011). Therefore, the portfolio they choose is different from the portfolio which yields the highest degree of consumption risk sharing. This is an interesting finding with respect to the well known empirical finding that the level of international risk sharing is relatively low despite wide financial market integration (see, e.g., Backus et al., 1992; Obstfeld, 1995; Baxter and Jermann, 1997; Lewis, 1999; Kose et al., 2009).

Similar theoretical accounts of the risks resulting from balance sheet exposure so far have only considered technology shocks and shocks to the net worth of investors. They do not feature a financial intermediation sector. Using a two-country New Keynesian model with leverage-constrained investors, Dedola and Lombardo (2012, p. 319) argue that price equalization in integrated financial markets leads to business cycle comovement "quite independently of the exposure to foreign assets in the balance sheet of leveraged investors". Their model features equity and bond market integration which leads to a perfect equalization of credit spreads. A similar contribution is the model by Yao (2012) which features non-separable preferences. She comes to the conclusion that a higher degree of balance sheet exposure leads to higher international business cycle comovement in the case of technology shocks. However, varying the degree of balance sheets exposure only has quantitative effects. Dedola et al. (2013) and Carniti (2012) have proposed two-country frameworks with banks and integrated financial markets, very similar to the one in the present paper. They also analyze the effects of capital quality shocks under different degrees of balance sheet exposure, however, they are mainly interested in the question how unconventional monetary policy should be conducted in this context.

While much evidence has been brought forward that the balance sheet channel has played an important role in the financial crises of the nineties (see, e.g., Kaminsky and Reinhart, 2000), empirical evidence with respect to the direct role of foreign asset holdings during the 'Great Recession' is mixed. For instance, using a cross-country dataset, Rose and Spiegel (2010) come to the conclusion that exposure to U.S. assets cannot account for the observed cross-country differences in decline in output growth. On the other hand, using a similar methodology but additionally including data on consumption and total domestic demand to measure recessions, Lane and Milesi-Ferretti (2010) find that exposure to foreign assets worked as an important channel of transmission during the recent crisis.

The paper is organized as follows. The next section develops the model. Section 3 provides the calibration. In section 4, I present and discuss the results. The final section concludes and gives an outlook.

[1] There is a fairly large number of contributions building on the method proposed by Devereux and Sutherland (2007; 2008; 2011a), some of which have already been mentioned above. Alternative methods to find international portfolios were proposed by Tille and van Wincoop (2010) and Evans and Hnatkovska (2005), among others.

2 Model

I assume that the world consists of two countries with symmetric structures, each inhabited by a continuum of agents of equal size. Both countries produce the same homogenous final good. Each country features a financial intermediation sector which is modeled as in Gertler and Karadi (2011). The role of intermediaries is to transfer funds between households and final goods producers who use the loans to finance investment into physical capital. Intermediaries face an endogenously determined constraint on their leverage ratio, motivated by a simple agency problem which drives a wedge between saving and borrowing rates. This or slightly modified setups of the banking sector have been used in various accounts of the recent financial crisis. Following this practice ensures comparability with existing literature.

The two-country version of the model developed in this paper features final goods market integration as well as asset market integration, i.e., I allow intermediaries to purchase financial claims on final goods producing firms at home and abroad as in Dedola et al. (2013) and Carniti (2012). Deposit markets remain national which matches empirical facts according to which households prefer to hold deposits nationally, despite large differences in deposit rates. Integration of asset markets introduces an endogenous portfolio choice problem as returns to equity are subject to country-specific risk. I solve this problem using the method proposed by Devereux and Sutherland (2007; 2008; 2011a).

As there are six different sources of risk, home and foreign technology, capital quality and bankers' net wealth shocks and only two types of assets to provide insurance against country-specific risk (financial claims on home and foreign final goods firms), international consumption risk sharing is incomplete.

For simplicity only home country equations will be displayed. Foreign variables will be denoted with an asterisk.

2.1 Households

Within each household, there are two member types, workers and bankers. While the worker supplies work to final goods firms and deposits to banks, the banker manages a financial intermediary and transfers retained earnings back to her household when the lifetime of the bank ends. Within the family, there is perfect consumption risk sharing, which allows to maintain the representative agent framework. As in Gertler and Karadi (2011), it is assumed that a fraction $1-f$ of household members are depositors, while a fraction f are bankers. Between periods there is a random turnover between the two groups: with probability θ_B a banker will stay a banker and with probability $1-\theta_B$ she will become a depositor. The relative proportions are kept fixed. New bankers are provided with some start-up funds from their respective households.

The lifetime utility of a representative home worker, who draws utility from consumption C_t and disutility from labor L_t, is given by

$$E_t \sum_{k=0}^{\infty} \Theta_{t+k} \left(\ln C_{t+k} - \chi \frac{L_{t+k}^{1+\phi}}{1+\phi} \right),$$

with χ, $\phi > 0$. Variable Θ_t is the endogenous discount factor of households chosen to ensure stationarity as explained below.

Households save by depositing funds at competitive intermediaries in their country. Deposits held between $t-1$ and t, denoted by D_{t-1}, are equivalent to one-period riskless real bonds paying the gross real rate of return R_{t-1}. Furthermore, households provide labor to final goods firms and receive the real wage w_t. Hence, the home household's budget constraint is given by

$$C_t + D_t = R_{t-1} D_{t-1} + w_t L_t + \pi_t,$$

where π_t denotes net profits from the ownership of firms (financial and non-financial).

It is well known that market incompleteness in international financial markets implies a unit root in a first-order approximation of the model. To avoid this problem, several stationarity-inducing features have been proposed (see, e.g., Schmitt-Grohé and Uribe, 2003). I use an endogenous discount factor to ensure stationarity in consumption. The discount factor is determined as in Schmitt-Grohé and Uribe (2003):

$$\begin{aligned} \Theta_{t+1} &= \Theta_t \beta(C_{A,t}), \\ \Theta_0 &= 1, \end{aligned}$$

where $C_{A,t}$ is aggregate home consumption. Using aggregate consumption in the endogenous discount factor ensures that the household does not internalize the effect of her consumption decision on the discount factor, which simplifies calculations considerably. As in Devereux and Yetman (2010) the following functional form of the endogenous discount factor is assumed:

$$\beta(C_{A,t}) = \omega_c (1 + C_{A,t})^{-\eta_c}.$$

Parameter η_c drives the elasticity of the discount factor with respect to consumption.

Hence, the household's first-order conditions for the optimal choice of labor and consumption are given by

$$w_t = \chi \frac{L_t^{\phi}}{\lambda_t},$$

and

$$1 = \beta(C_{A,t}) E_t \{\Lambda_{t,t+1}\} R_t,$$

with the household's real stochastic discount factor defined as

$$\Lambda_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t},$$

where λ_t denotes the marginal utility of consumption given by

$$\lambda_t = C_t^{-1}.$$

2.2 Banks

In the model economy, home financial intermediaries channel funds from home households to home and foreign final goods producers, fulfilling the double role of investment as well as commercial banks.

In addition to obtaining funds from households, banks also raise funds internally by accumulating retained earnings. The balance sheet of home bank i is given by

$$Q_t S_{iH,t} + Q_t^* S_{iF,t} = D_{i,t} + N_{i,t},$$

where Q_t (Q_t^*) denotes the price of the home (foreign) capital asset. Deposits at bank i are denoted by $D_{i,t}$. Variable $S_{iH,t}$ ($S_{iF,t}$) denotes state-contingent claims on future returns of a unit of capital used in final goods production in the home (foreign) country one period later, whose gross rate of return is given by $R_{k,t}$ ($R^*_{k,t}$). Intermediary i's net worth is given by $N_{i,t}$. It evolves according to the following equation:

$$N_{it} = R_{k,t} Q_{t-1} S_{iH,t-1} + R^*_{k,t} Q^*_{t-1} S_{iF,t-1} - R_{t-1} D_{i,t-1}.$$

As can be seen from the equation above, any growth in banks' equity capital above the riskless rate depends on the premia $R_{k,t} - R_{t-1}$ and $R^*_{k,t} - R_{t-1}$ and on the quantity of assets. Financial intermediaries cannot fund assets with an expected discounted premium below zero. In a frictionless financial market, risk-adjusted premia would always be zero. In this model due to the presence of a leverage constraint, the spread may be positive. As will be seen later, it covaries negatively with GDP, as banks' inability to obtain funds increases during bad states of the economy.

As it is assumed that each period a fraction 1-θ_B of bankers exits the business with i.i.d. probability and pays out accumulated earnings to their respective households,[2] a banker maximizes the terminal value of her net worth given by

$$V_t = \max\ E_t \sum_{k=0}^{\infty} (1-\theta_B)\theta_B^k \Theta_{t+k} \Lambda_{t,t+k+1} N_{i,t+k+1}.$$

To motivate the requirement to build up net worth, the following moral hazard problem is assumed: At the beginning of each period, before the shocks realize and any other transactions take place, the banker can choose to divert the fraction λ of available funds back to the household. The cost associated with this fraud is that the depositors recover the remaining fraction $1-\lambda$ and force the banker into bankruptcy. Therefore, for households to be willing to deposit funds with the bank, the following incentive constraint must hold

$$V_{i,t} \geq \lambda B_{i,t},$$

with $B_{i,t} \equiv Q_t S_{iH,t} + Q_t^* S_{iF,t}$ denoting total bank assets. To solve the banker's maximization problem define the objective of the bank recursively as

$$V_{i,t} = \max\ E_t \beta(C_{A,t}) \Lambda_{t,t+1} [(1-\theta_B) N_{i,t+1} + \theta_B V_{i,t+1}],$$

and conjecture that the value function is linear in assets and net worth:

$$V_{i,t} = \nu_{iH,t} Q_t S_{iH,t} + \nu_{iF,t} Q_t^* S_{iF,t} + \eta_{i,t} N_{i,t}.$$

The banker's problem consists in choosing the amount of home assets, $S_{iH,t}$, foreign assets, $S_{iF,t}$ and deposits $D_{i,t}$ such that terminal net worth is maximized and the incentive constraint holds. It can be solved using the Lagrange method.

[2]This arrangement precludes bankers from aggregating so much net worth that the incentive constraint becomes irrelevant for them.

The solutions for the coefficients are given by

$$\nu_{H,t} = E_t\left\{\Omega_{t+1}(R_{k,t+1} - R_t)\right\}$$
$$\nu_{F,t} = E_t\left\{\Omega_{t+1}(R^*_{kt+1} - R_t)\right\}$$
$$\eta_t = E_t\left\{\Omega_{t+1}\right\}R_t,$$

where

$$\Omega_{t+1} = \beta(C_{A,t})\Lambda_{t,t+1}\left[(1-\theta_B) + \theta_B\left(\eta_{t+1} + \nu_{t+1}\phi_{t+1}\right)\right],$$

which can be interpreted as the stochastic discount factor of the banker. It differs from the household's stochastic discount factor due to the presence of financial frictions. The discount factor is a key variable for the determination of international portfolio positions. The difference between the two agents' discount factors drives one of the results of this paper: The fact that in this model the portfolio decision is made by the banker instead of the household leads to inefficiently low insurance of country-specific consumption risk (cf. section 4.1). The reason is that bankers have a motive in addition to the maximization of lifetime utility, namely, the maximization of terminal net wealth. Note that the subscript i was dropped as the coefficients exclusively depend on aggregate variables.

A further first-order condition is given by

$$\nu_{H,t} = \nu_{F,t} \equiv \nu_t \quad \Leftrightarrow \quad E_t\left\{\Omega_{t+1}R_{k,t+1}\right\} = E_t\left\{\Omega_{t+1}R^*_{k,t+1}\right\}.$$

It is the first-order condition relevant for optimal portfolio choice as will be explained further in section 2.6.

Assuming that the incentive constraint binds,[3] it can be expressed in terms of the coefficients of the value function

$$B_t = \frac{\eta_t}{\lambda - \nu_t}N_t = \phi_t N_t,$$

where ϕ_t is the ratio of intermediated assets to net worth, which can be referred to as the leverage ratio. Note that it is determined endogenously in this model.

Finally, the law of motion for aggregate net worth can be derived as

$$N_t = (N_{n,t} + N_{e,t})\,\varepsilon_{N,t}$$
$$N_{e,t} = \theta_B\left[\left((R_{k,t} - R_{t-1}) - \frac{Q^*_{t-1}S_{F,t-1}}{B_{t-1}}(R_{k,t} - R^*_{k,t})\right)\phi_{t-1} + R_{t-1}\right]N_{t-1}$$
$$N_{n,t} = \omega[Q_{t-1}S_{H,t-1} + Q^*_{t-1}S_{F,t-1}],$$

where $N_{e,t}$ denotes existing bankers' net worth, $N_{n,t}$ denotes new bankers' net worth and ω is the fraction of the assets given to new bankers by their households. Variable $\varepsilon_{N,t}$ denotes an exogenous disturbance to bankers' net wealth.

2.3 Final goods firms

Final goods producing firms can sell their products to home and foreign consumers in a perfectly competitive market.

[3] Parameters and steady state values are chosen such that the incentive constraint binds in the steady state. Holding the variance of shocks small enough guarantees that the incentive constraint also binds in a stochastic environment.

The Cobb-Douglas production function of the representative final goods firm is given by:

$$Y_t \quad = \quad A_t(\Psi_t K_{t-1})^{\alpha} L_t^{1-\alpha},$$

where Y_t denotes output, A_t technology and Ψ_t capital quality. Labor L_t is provided by households in the same country only. Capital K_{t-1} was bought from capital goods producers in the same country in the previous period at price Q_{t-1}. To obtain funds to finance capital purchases, the firm issues state-contingent securities to home and foreign intermediaries at the same price. Each period, after being productive, the firm has to pay back capital returns on the securities issued in the previous period. As in Gertler and Karadi (2011) I assume a shock to the quality of capital to provide a source for exogenous variations in the price of capital. It can be interpreted as the sudden realization that much of the capital installed is of lower quality than previously thought. As capital provides collateral to banks, banks' balance sheets will be contracted in response to a negative capital quality shock. The law of motion for capital is given by

$$K_t = I_t + (1-\delta)\Psi_t K_{t-1},$$

where I_t is aggregate investment and δ denotes physical depreciation.

The first-order conditions of the final goods producer's profit maximization problem are, therefore, given by

$$R_{k,t+1} = \frac{\alpha \frac{Y_{t+1}}{K_t} + (1-\delta)\Psi_{t+1} Q_{t+1}}{Q_t},$$

and

$$w_t = (1-\alpha)\frac{Y_t}{L_t}.$$

The firm earns zero profits state-by-state, hence, it simply pays out the ex post return to capital, $R_{k,t}$, to the financial intermediary.

2.4 Capital goods firms

Competitive capital goods firms produce capital only for the domestic market using national final output as input facing investment adjustment costs (in consumption units). Adjustment costs are assumed to be proportional to the aggregate past capital stock as in Chari et al. (2002).[4] Their functional form is given by

$$f(\cdot) = \frac{\eta_I}{2}\left(\frac{I_t}{\delta K_{t-1}} - 1\right)^2 \frac{\delta K_{t-1}}{I_t},$$

with $0 < \eta_I$. The capital goods producer chooses I_t to maximize lifetime profits given by

$$E_t \sum_{k=0}^{\infty} \Theta_{t+k}\Lambda_{t,t+k}\left\{Q_{t+k}I_{t+k} - \left[1+f(\cdot)\right]I_{t+k}\right\}.$$

[4]Note that in Chari et al. (2002) capital adjustment costs are on gross investment. In that case, the capital decision depends on the price of capital. I follow the approach used by Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) and assume that adjustment costs are on net investment so that the capital decision is independent of the market price of capital.

From the first order conditions, I obtain the real price of one unit of capital

$$Q_t = 1 + \eta_I \left(\frac{I_t}{\delta K_{t-1}} - 1 \right).$$

Due to flow investment costs, capital goods firms can earn profits outside the steady state. These profits are distributed lump-sum to the households.

2.5 Further equilibrium conditions

The model equilibrium is further characterized by the international capital market clearing condition, an international goods market clearing condition and the home and foreign aggregate resource constraints.

The capital market clearing condition states that the current value of total capital installed in both countries has to be equal to the total value of state contingent claims on future returns of capital held by home and foreign banks

$$Q_t K_t + Q_t^* K_t^* = Q_t (S_{h,t} + S_{h,t}^*) + Q_t^* (S_{f,t} + S_{f,t}^*).$$

Final goods market clearing is given by

$$Y_t + Y_t^* = C_t + C_t^* + [1 + f(\cdot)] I_t + [1 + f^*(\cdot)] I_t^*.$$

The home aggregate resource constraint is derived from the aggregation of the budget constraint over home households, considering profits from the ownership of non-financial firms, retained earnings from exiting bankers and the transfer to new bankers

$$\begin{aligned} &Y_t + Q_{t-1}^* S_{F,t-1} R_{k,t-1}^* - Q_{t-1} S_{H,t-1}^* R_{k,t-1} \\ &\quad = C_t + [1 + f(\cdot)] I_t + Q_t^* S_{F,t} - Q_t S_{H,t}^*. \end{aligned}$$

2.6 Portfolio indeterminacy and solution method

Recall home banks' first-order condition $\nu_{H,t} = \nu_{F,t}$ which can be rewritten as

$$E_t \left\{ \Omega_{t+1} R_{k,t+1} \right\} = E_t \left\{ \Omega_{t+1} R_{kt+1}^* \right\}.$$

Evaluated in the non-stochastic steady state, this equation becomes

$$R_k = R_k^*,$$

and, approximated up to first order,

$$E_t R_{k,t+1} \approx E_t R_{k,t+1}^*.$$

Hence, in the steady state and evaluated up to first-order, both assets pay the same return. This implies that all possible compositions of banks' portfolios, given by $B_t = Q_t S_{H,t} + Q_t^* S_{F,t}$, pay the same return in the non-stochastic steady state and in expectations, evaluated up to a first order. Therefore, international portfolio choice is indeterminate up to first-order accuracy. The economic intuition behind this indeterminacy problem is that the two capital assets are only distinguishable in terms of their risk characteristics which can only be captured with an approximation of second-order or higher (Devereux and Sutherland, 2008).

Parameter	Description	Value
Households		
χ	utility weight of labor	5.6
ϕ	inverse of Frisch elasticity of labor supply	0.276
η_c	parameter from endogenous discount factor	0.01
ω_c	parameter from endogenous discount factor	0.996
Capital goods firms		
η_I	inverse elasticity of investment with respect to price of capital	1.728
Final goods firms		
α	capital share	0.33
δ	depreciation rate	0.025
Financial intermediaries		
λ	fraction of divertable assets	0.383
ω	transfer to entering banks	0.003
θ_B	quarterly survival rate of banks	0.972
Exogenous processes		
ρ_ψ	persistence of capital quality shock	0.66
ρ_A	persistence of technology schock	0.95
σ_ψ	standard deviation of capital quality shock	0.01
σ_A	standard deviation of technology shock	0.01
σ_N	standard deviation of net wealth shock	0.01

Table 1: *Parameters*

It can be shown that only steady state portfolio shares matter for the (first-order) dynamics of the remaining variables. To find the steady state portfolio shares, I use the method proposed by Devereux and Sutherland (2007; 2008; 2011a). It is based on a second-order approximation of the portfolio equations and a first-order approximation of the non-portfolio parts of the model. Recently, other local and global methods have been proposed by other authors[5], however, the method developed by Devereux and Sutherland is particularly appealing as it uses well-known perturbation techniques and can be quite easily incorporated into otherwise standard programs used to solve DSGE models, e.g., Dynare.

3 Calibration

Table 1 reports the benchmark calibration. Most parameters are quite standard and do not need to be discussed. The parameters of the banking system, λ, the divertable fraction of assets, θ_B, the average lifetime of banks and ω, the transfer to entering bankers are taken from Gertler and Karadi (2011). They choose these values to hit three targets: a steady state interest rate spread of 100 basis points, a steady state leverage ratio of four and an average lifetime of a bank of 10 years. For parameter χ, the same value as in Dedola et al. (2013) is used. The inverse elasticity of investment with respect to the price of capital was also taken from Gertler and Karadi (2011). Parameter ω_c in the endogenous discount factor was chosen as to guarantee an annual

[5]The methods proposed by Tille and van Wincoop (2010) and Evans and Hnatkovska (2005) also employ perturbation around a non-stochastic steady state to find international portfolios while Coeurdacier et al. (2011) and Juillard (2011) propose to find international portfolios by approximating DSGE models around the risky steady state. Brunnermeier and Sannikov (2015) are able to solve a model featuring an international portfolio choice problem globally by using continuous time.

steady state interest rate of 4%, i.e., a steady state value of $\beta(C_A)$ of 0.99. The persistence of the capital quality shock is also the same as in Gertler and Karadi (2011).

4 Model analysis

4.1 Steady state portfolio holdings and implications for risk sharing

Steady state portfolio holdings in this model are defined as

$$\alpha^P \equiv \frac{Q^* S_f}{Q^* S_f + Q S_h} = \frac{Q S_h^*}{Q^* S_f^* + Q S_h^*},$$

i.e., the share of foreign capital holdings in home banks' portfolios, which – due to symmetry – is equal to the share of home capital holdings in foreign banks' portfolios.

Using the benchmark calibration, steady state foreign portfolio holdings amount to 0.6, i.e., financial intermediaries hold portfolios with a *foreign bias*. This result is fairly robust to varying parameter values. Data on international portfolio holdings show that developed countries exhibit an equity *home bias* of 60-80%, i.e., an α^P between 0.2 and 0.4 (see, e.g., Coeurdacier and Rey, 2012). The model at hand cannot replicate this characteristic of international financial markets – a weakness shared by many other two-country models with endogenous portfolio choice (see the discussion below). There are also various contributions proposing certain model features which lead to home bias in international portfolios. Coeurdacier and Rey (2012) provide an excellent review of this literature. As the focus of the present paper is different, I refrain from extending the model in a way that it matches data on international portfolio holdings more closely.

In models with international portfolio choice, agents choose portfolio holdings as to optimally insure against country-specific risks. In most of the literature on international portfolio choice, households undertake the portfolio choice decision. Their objective is to choose the portfolio which ensures the best hedging of country-specific consumption risk. A feature of my model is that bankers undertake portfolio decisions instead of households[6] which is a justified assumption given that in the real world a large part of international portfolio holdings is managed by financial intermediaries (Coeurdacier and Rey, 2012). To the best of my knowledge, this paper is the first one to analyze the implications of this feature for international consumption risk sharing. In the present model, banks are owned by households, hence, they internalize the objective of the household which consists in the maximization of lifetime utility. However, they have an additional objective, namely the maximization of terminal net wealth which in the mean time serves as collateral. Therefore, in this setup, the stochastic discount factor relevant for international portfolio choice differs from the households' stochastic discount factor, as long as the incentive constraint is binding, as was already explained in section 2.2.

[6]The models by Dedola et al. (2013) and Carniti (2012) feature the same setup of the banking system as my model, however, they do not analyze the implications of portfolio choice by bankers in detail. In Dedola and Lombardo (2012), Yao (2012) and Devereux and Yetman (2010) so-called 'investors' undertake the portfolio decision, but their objective is also the maximization of lifetime utility, i.e., the stochastic discount factor relevant for international portfolio choice is equivalent to the households' one.

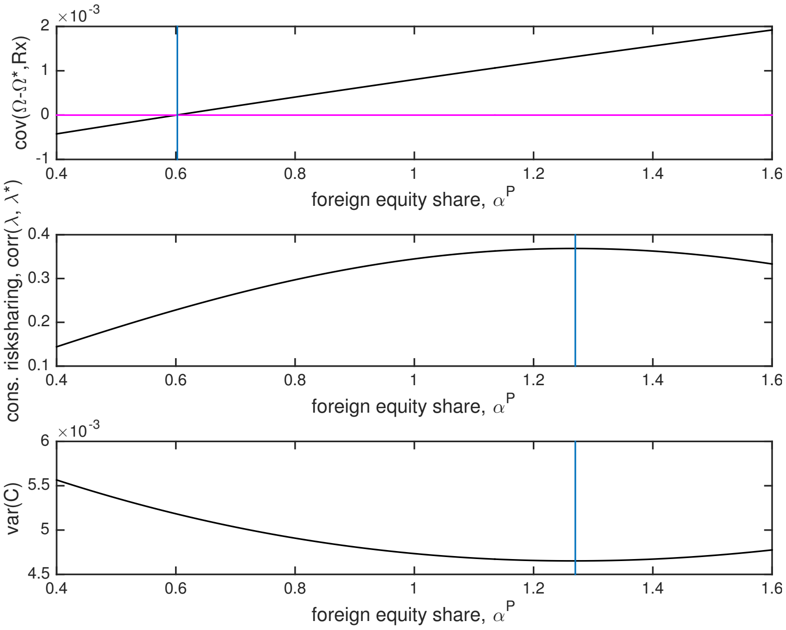

Figure 1: *Some second-order properties of the model*

Figure 1 depicts different second-order properties of the model for varying degrees of balance sheets exposure. The first graph shows the covariance between the difference between stochastic discount factors of bankers, $\Omega_t - \Omega_t^*$, and excess returns on capital, $R_{x,t} \equiv R_{k,t} - R_{k,t}^*$. As explained above, the portfolio allocation chosen optimally by banks is the one which satisfies the equation $E_t(\Omega_{t+1} - \Omega_{t+1}^*)R_{x,t+1} = 0$ up to second-order accuracy. Hence, the first graph intersects the x-axis at point 0.6.

If financial frictions were absent, households would undertake the portfolio decision. They would choose a portfolio which satisfies the equation $E_t(C_{t+1} - C_{t+1}^*)R_{x,t+1} = 0$ up to second-order accuracy (see, e.g., Devereux and Sutherland, 2008). By construction, this portfolio would coincide with the one that maximizes consumption risk sharing. In a two-country RBC model, the correlation between home and foreign marginal utilities can serve as proxy for the degree of consumption risk sharing (see, e.g., Nuntramas, 2011). A correlation coefficient of 1 implies perfect risk sharing. As it can be seen in the second plot of figure 1, the foreign asset share which maximizes risk sharing is given by approximately 1.27. Such a portfolio ($\alpha^P > 1$) reflects the hypothetical case that home banks go short on home assets, i.e., that they channel funds from home firms to foreign firms. This hypothetical portfolio is equal to the portfolio which minimizes consumption volatility, depicted in the third graph. The portfolio chosen by banks yields a lower degree of consumption risk sharing and higher consumption volatility and can therefore be considered as a suboptimal portfolio from the viewpoint of the household.

Why do bankers choose to hold too many home assets relative to what households would prefer? The intuition for this result is as follows: Risk averse households prefer to smooth their consumption streams. This generates a demand for assets which promise a high payoff during bad states of the economy, i.e., in general, states in which labor income is low. In standard open economy models, the class of assets which matches this criterion best are foreign assets. As stated above, various model features have been proposed to uncouple the return to home assets from home labor income[7], such that home agents are inclined to hold a higher share of domestic assets. My model does not include such features, which explains why foreign asset holdings must be high to provide for optimal hedging of labor income risk and, hence, for optimal consumption risk sharing. Bankers inherit the preference for consumption smoothing from households, however, this only explains one part of their motive. Additionally, they care about the growth of their net worth which is generated through excess returns over the risk-free rate. However, expected excess returns from home and foreign asset holdings are equalized in this kind of model. Therefore, bankers cannot hedge their country-specific banking risk by holding a foreign biased portfolio. In addition, bank's balance sheets are subject to multiplier effects. Hence, bankers prefer smaller shocks to their balance sheet which also generates a motive to hold a diversified (i.e., $\alpha^P \approx 0.5$) portfolio.

To conclude, it is a well-known puzzle in international financial macroeconomics that theoretical models predict a much higher optimal foreign equity share than can be found in the data and – related to this – that actual international risk sharing is relatively low compared to what theoretical models would predict given a high level of international financial market integration (see, e.g., Backus et al., 1992; Obstfeld, 1995; Baxter and Jermann, 1997; Lewis, 1999; Kose et al., 2009). The results provided in this section suggest one possible explanation for this puzzle: In most theoretical models, households choose the portfolio which provides the best hedging of income risk, while in the real world, the largest part of portfolio holdings is intermediated by funds, whose objectives most likely differ from those of households (Coeurdacier and Rey, 2012). My model shows that if banks undertake the portfolio decision in an environment with international financial integration, they do not necessarily choose the portfolio which provides for the highest degree of consumption risk sharing as their main motive is the maximization of net wealth. Hence, my results help reconcile theory on the risk sharing potential of financial markets with empirical evidence of relatively low consumption risk sharing despite wide financial market integration.

4.2 Impulse response analyses

In this section, I analyze the impulse responses to an adverse home capital quality shock and compare them to the impulse responses to shocks which have been considered in previous analyses of the role of balance sheet exposure for the international transmission of shocks, in particular technology shocks and net worth shocks. The aim of the present paper is not to perfectly capture realistic dynamics, but to analyze the role of the financial sector for the global comovement observed in recent years. Hence, I will focus on a discussion of the responses of GDP as the main indicator of real economic activity and of those financial variables which illustrate the international transmission well.

[7] Model features which can uncouple domestic labor income from domestic asset return are, for example, sticky prices (Engel and Matsumoto, 2009) or capital accumulation together with international trade in capital goods (Coeurdacier et al., 2010).

Home banks		*Foreign banks*	
assets	liabilities	assets	liabilities
$Q_t S_{H,t}$	N_t	$Q_t S^*_{H,t}$	N^*_t
$Q^*_t S_{F,t}$	D_t	$Q^*_t S^*_{F,t}$	D^*_t

Figure 2: *Banks' balance sheets under financial market integration*

I begin by explaining the international transmission of the shocks via the financial sector along the balance sheets of home and foreign banks under financial market integration (figure 2). Suppose a negative technology shock hits the production function of the home economy. As a direct effect, the return to home capital and home investment demand are reduced. This exerts downward pressure on the price of home capital, Q_t and thereby affects banks' balance sheets negatively. Hence, this shock transmits from the real to the financial sector primarily via prices. Under financial market integration, capital prices are nearly equalized due to the equalization of expected returns. Therefore, this shock also reaches foreign banks balance sheets mainly via asset price equalization. Now, suppose that a net wealth shock hits home banks' balance sheets, i.e., N_t drops exogenously. The home bank has to deleverage to meet balance sheet constraints. This firesale of assets exerts downward pressure on asset prices, thereby affecting the asset side of banks' balance sheets. As before, foreign banks balance sheets are mainly affected via price equalization. When a capital quality shock hits the home economy, the same price equalization channel as for the previous two shocks comes into effect. However, there is an additional effect on the financial sector. Recall that the capital quality shock not only hits the production function, but also destroys part of the capital stock. As the capital stock is equal to the capital claims issued to banks, the decline in home capital quality causes a devaluation of home capital assets, i.e., of $S_{H,t}$ and $S^*_{H,t}$. The foreign bank suffers from this decline in asset values proportionately to its home asset holdings.

I now turn to the impulse response analysis. I assume three environments in which the shocks hit the home economy: 1) financial market autarky,[8] 2) financial market integration and full home bias, i.e., $\alpha^P = 0$, and 3) financial market integration and an optimal portfolio, i.e., $\alpha^P = 0.6$. The second setting can be seen as a rather hypothetical case in which banks are allowed to trade financial assets – therefore, asset returns are equalized in expectations – however, actual international asset holdings are set to zero. This setting allows me to single out the price equalization channel, as the balance sheet exposure channel is turned off by construction.

4.2.1 Capital quality shocks

Figure 3 shows the impulse responses to a capital quality shock in the home country. The solid blue line and the dashed black line display the impulse responses under financial market integration. The solid blue line gives the impulse responses under full home bias and the dashed black line depicts the impulse responses under optimal diversification.

[8] In the present model, in which both countries produce the same good, financial market autarky implies trade autarky.

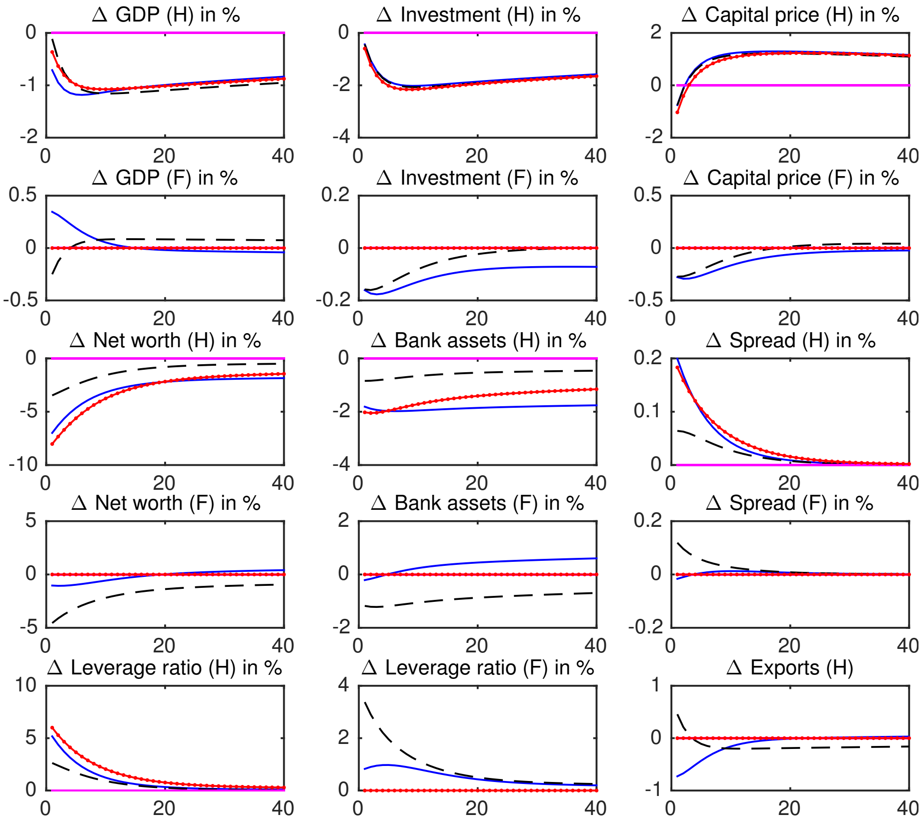

Figure 3: *Impulse responses to a -1% home capital quality shock* (dotted red line: financial market autarky; solid blue line: full home bias, i.e., $\alpha^P = 0$; dashed black line: optimal portfolio, i.e., $\alpha^P = 0.6$)

The size of the effects on the foreign banking system depends very much on the share of home assets in foreign banks' portfolios, α^P. Foreign banks' net worth is only affected very little under the assumption of full home bias and the foreign spread (defined as the difference between the expected return to capital and the foreign deposit rate) even decreases. The effects on the real economy also differ largely. Under full home bias ($\alpha^P = 0$), the adverse shock in the home country actually triggers a small boom in the foreign economy, while under optimal diversification ($\alpha^P = 0.6$) the recession is partly synchronized. The reason for the different transmission of the same shock is that under optimal diversification, foreign banks are affected through a direct devaluation of some of their assets, in particular through a direct devaluation of $S^*_{H,t}$, and through asset price equalization while under full home bias only the latter channel plays a role. The price equalization channel works through an equalization of expected returns on capital due to arbitrage. The equalization of expected returns pushes capital demand and, hence, capital prices into the same direction during the initial periods following the shock. Price equalization attenuates the effects of the shock in the home economy while it is a channel of financial contagion for the foreign economy. If only the price equalization effect is at work, which is the case for $\alpha^P = 0$, the foreign economy initially even profits from the shock in the home country. The reason is that it can increase exports to the home economy where demand did not drop as much as under financial autarky because there the financial accelerator was attenuated. If banks hold diversified portfolios, i.e., $\alpha^P = 0.6$, foreign banks are directly affected by the home shock to a similar extent as home banks. This activates a powerful balance sheet mechanism in the foreign economy: as can be seen in figure 3, foreign banks' net worth drops by a similar amount as in the home economy. Due to the leverage ratio constraint, foreign banks have to further reduce their asset holdings.

The result that home and foreign output are negatively correlated under full home bias but positively correlated under a diversified portfolio is robust to variations of the trade sector of the model. In particular, a version of the model with a home and a foreign good and sticky prices yields qualitatively the same results.

4.2.2 Other shocks

The impulse responses to the net worth shock and the technology shock can be found in the appendix. As before, the solid blue line gives the impulse responses under full home bias ($\alpha^P = 0$) and the dashed black line depicts the impulse responses under optimal diversification ($\alpha^P = 0.6$). The effects of the technology shock on the home economy are similar to those of the capital quality shock. The initial responses are more pronounced and the impulse responses do not display a hump shape as there is only the direct effect on the production function which is, however, larger than for a capital quality shock of the same size. The effects of the net worth shock – a purely financial shock – on the real economy are quite small which has already been observed by Dedola et al. (2013).

With respect to the role of α^P for the international transmission of these shocks, it can be seen that the degree of exposure matters much less and only quantitatively in the case of technology shocks and almost not at all in the case of net worth shocks. As explained above, the reason is that in response to these shocks, financial contagion arises mainly through asset price equalization. In this regard, my results resemble those of previous accounts of the role of balance sheet exposure for the international transmission of shocks (cf. Dedola and Lombardo, 2012; Yao, 2012).

However, my results deviate from those of Dedola and Lombardo (2012) and Yao (2012) in that the correlation of home and foreign GDP for technology and net worth shocks is negative in my model. As their models differ from mine in various respects, I cannot conclusively say which features are responsible for the different cross-country correlations. However, when running some robustness checks, I found that the international comovement of output conditional on technology shocks depends very much on the modeling of the trade sector. For example, introducing a more sophisticated international trade sector with home and foreign goods and sticky prices as in Dedola and Lombardo (2012) into my model yields a positive correlation of output across countries, if the trade elasticity is low enough.

To sum up, whether balance sheet exposure matters for international contagion depends on the type of shock. The reason is that technology and net worth shocks are mainly transmitted via an equalization of asset prices, whereas capital quality shocks are additionally transmitted through direct valuation effects. My results imply that an evaluation of the risks of balance sheet exposure must go beyond an analysis of unconditional cross-country correlations. Instead, we need to find out which shocks are the most important drivers of international business cycles. Furthermore, my results cast some doubt on the finding of previous analyses that technology shocks can be used to explain the synchronization of business cycles if financial frictions are present (e.g., Dedola and Lombardo, 2012; Yao, 2012). I find that the cross-country comovement for these shocks hinges on the setup of the trading sector. On the other hand, a capital quality shock – combined with high balance sheet exposure – seems to be suited well for explaining the international comovement of GDP.

5 Conclusion

By estimating closed economy DSGE models, various authors have recently shown that capital quality shocks are the "key drivers of business cycle fluctuations" (Justiniano et al., 2011; Liu et al., 2011; Sanjani, 2014, p. 23). In an open economy context, – in empirical as well as theoretical studies – these shocks have been given little attention, so far. Considering technology and net worth shocks, previous theoretical accounts of the role of balance sheet exposure for the international transmission of shocks came to the conclusion that the share of foreign assets in investors' portfolios matters very little for the synchronization of business cycles (Dedola and Lombardo, 2012; Yao, 2012). My model extends existing research by studying the international transmission of capital quality shocks and the role of balance sheet exposure of leveraged financial intermediaries therein. I show that conditional on capital quality shocks, balance sheet exposure has an important impact on international business cycle synchronization. In fact, moving from a setting with negligibly low foreign portfolio holdings to a model with completely diversified portfolios changes the sign of the correlation of home and foreign output from negative to positive. This is an important finding as it suggests that an evaluation of the potential risks of cross-country asset holdings must go beyond an analysis of unconditional cross-country correlations. To gain more insights into the question which role price equalization and balance sheet exposure have played during the 'Great Recession' one needs to find out which shocks are the most important drivers of international business cycles.

Furthermore, I find that the international transmission of capital quality shocks is quite robust to changes in the model while the cross-country correlation of GDP conditional on technology shocks changes its sign depending on the setup of the trade sector. For example, introducing a more sophisticated international trade sector with home and foreign goods and sticky prices as in Dedola and Lombardo (2012) into my model yields a positive correlation of output across countries if the trade elasticity is low enough. The cross-country correlation of output for net worth shocks is always negative in my model. These results cast some doubt on the explanatory power of technology shocks and net worth shocks with respect to the global scope of the recent financial crisis. Instead, my analysis suggests that incorporating capital quality shocks and international balance sheet exposure into a model with leverage-constrained financial intermediaries can help us to account for the high global comovement in real and financial variables in the recent past.

An important feature of the model developed in this paper is that the portfolio choice decision is undertaken by financial intermediaries instead of households. My paper is not the first to adopt this feature, however, it is the first one to analyze the implications of this feature in more detail. The assumption that financial intermediaries undertake the portfolio choice decision adds realism to the model as in the real world the largest part of portfolio holdings is intermediated by funds (Coeurdacier and Rey, 2012). The analysis conducted in section 4.1 provides evidence that this is also relevant for international portfolio choice and consumption risk sharing. In fact, it might help reconcile theory with empirical evidence on modest degrees of international consumption risk sharing despite open financial markets (see, e.g., Kose et al., 2009).

Appendix

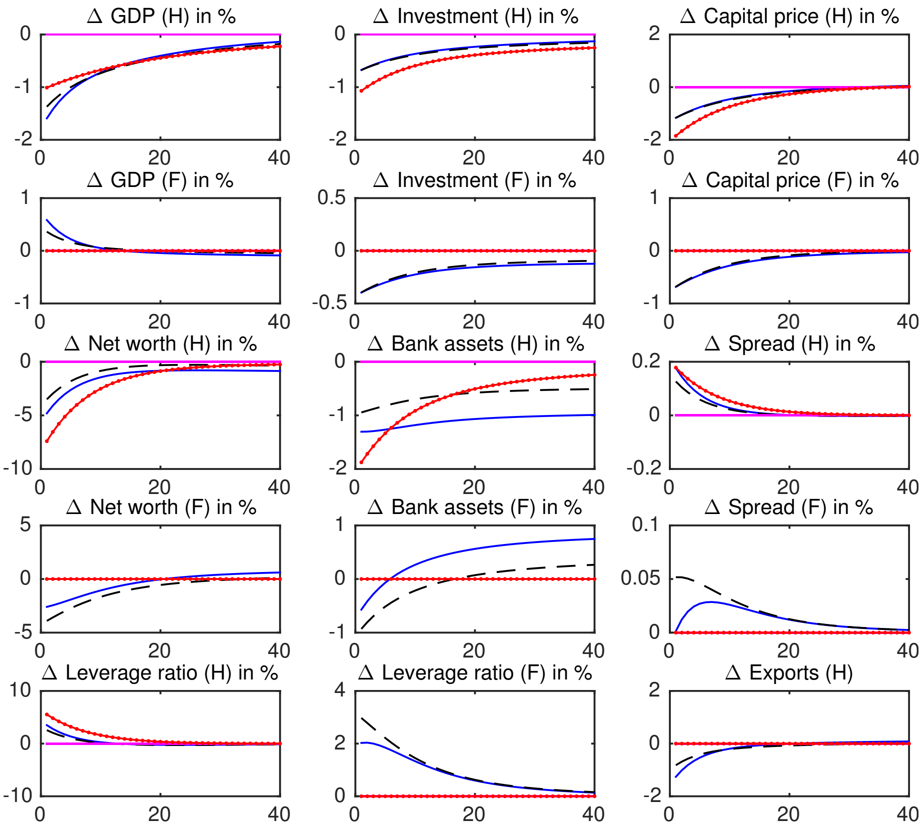

Figure 4: *Impulse responses to a -1% home technology shock* (dotted red line: financial market autarky; solid blue line: full home bias, i.e., $\alpha^P = 0$; dashed black line: optimal portfolio, i.e., $\alpha^P = 0.6$)

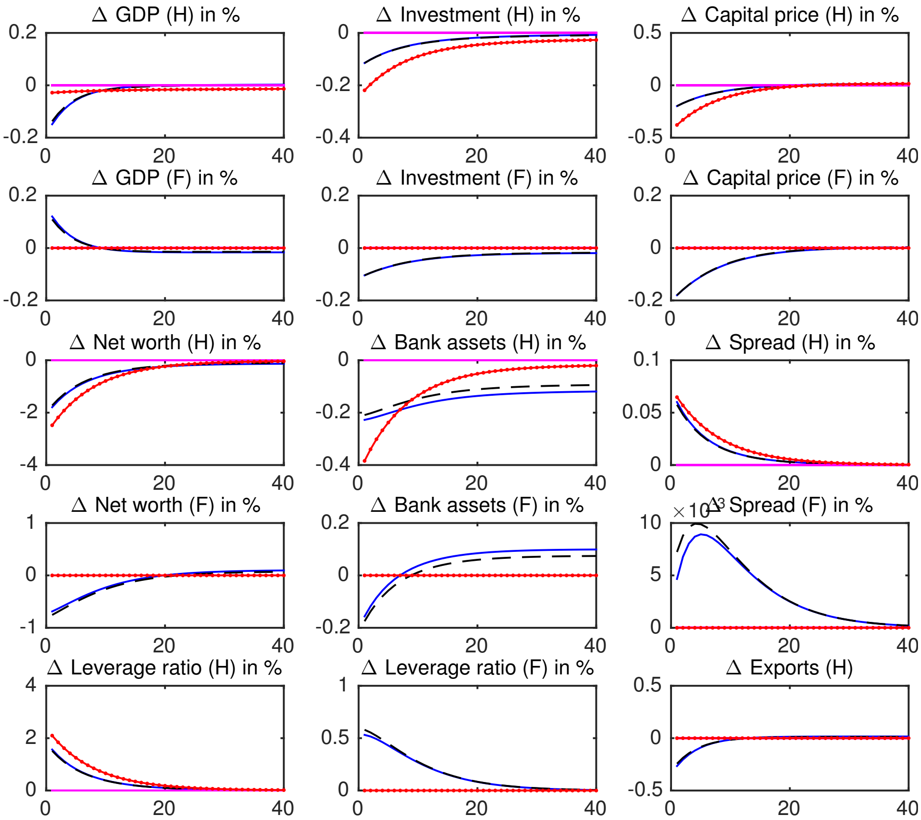

Figure 5: *Impulse responses to a -1% home net wealth shock* (dotted red line: financial market autarky; solid blue line: full home bias, i.e., $\alpha^P = 0$; dashed black line: optimal portfolio, i.e., $\alpha^P = 0.6$)

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