



Working Paper

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# Arbeitspapiere/ Working Papers

Caroline Schmidt

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in Response to Monetary Policy Shocks:  
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# Savings and Investment Correlations in Response to Monetary Policy Shocks: New Insights into the Feldstein-Horioka Puzzle?

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## Abstract

In this paper, it is argued that the observed high positive correlation between national savings and investment which is found in the data can in part be explained by shocks to monetary policy. This hypothesis, which is established by reviewing some empirical findings, is tested in a two-country DSGE-model framework in the tradition of the New Open Economy Macroeconomics. The simulation results obtained support the idea that shocks to monetary policy might contribute to the explanation of the Feldstein-Horioka puzzle.

*Keywords:* Savings Investment Correlations, Monetary Policy Shocks, Feldstein-Horioka Puzzle, Local-currency pricing

*JEL Classification:* E2; E52; F32

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# 1 Introduction

In their seminal contribution, Feldstein and Horioka (1980) investigated the degree of capital mobility by running cross-sectional regressions of gross investment rates on gross savings rates. For the 16 OECD countries considered, the estimated saving-retention coefficient - interpreted as the share of an exogenous increase in savings that will remain in the domestic country - was 0.887 for 15-year averages from 1960 to 74. With high capital mobility this finding is difficult to explain in classical models, since for given investment opportunities, an increase in one countries saving should lead to a proportionate increase in investment in all countries. However, the results found by Feldstein and Horioka suggested that about 90% of an increase in one country's savings is invested in the domestic economy. As a result, Feldstein and Horioka concluded that world capital mobility was still low. Yet, as international financial integration has increased further - at an increasing speed - a number of authors have updated the estimations by Feldstein and Horioka with more recent data and different estimation procedures. Rather surprisingly, the high correlations between domestic investment and domestic saving has been reproduced in most studies.<sup>1</sup> In subsequent cross-sectional studies Linda L. Tesar (1991) estimated saving-retention coefficients varying between 0.79 to 0.95 for domestic saving and investment data from 1960 to 1984. Obstfeld and Rogoff (1995) found a coefficient of 0.622 for a sample of 22 OECD countries over the decade 1982-91. Using data from 1974 to 1990, Obstfeld (1995) estimated both time-series and cross-sectional correlation coefficients for savings and investment ratios for OECD countries in order to capture both long- and short-run relations. In the cross-sectional estimation spanning the whole period, the coefficient is 0.715. If different sub-samples are considered, the coefficient is decreasing over time. In the time-series analysis the coefficients vary. Yet, for most countries, domestic

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<sup>1</sup>For a broader survey see e.g. Coakley et al. (1998).

savings and investment are positively linked and the relationship is rather strong.<sup>2</sup>

The high correlations between domestic savings and investment ratios found in the data, however, do not need to imply a low degree of capital mobility. Instead, as shown by e.g. Baxter and Crucini (1993), but also Cardia (1991), Finn (1990) and Mendoza (1991), time-series correlations of savings and investment in the range of the data are obtained in dynamic stochastic general equilibrium (DSGE) models featuring perfect capital mobility if shocks to productivity are the major source of variability. Baxter and Crucini derive a two-country real business cycle model and show that the correlation induced by shocks to productivity is higher, the larger the size of the country. Finn as well as Mendoza consider the effects of shocks to productivity in a small open economy, where Mendoza compares the resulting variations to historical data of Canada. Cardia investigates a combination of productivity, fiscal and monetary shocks in a small open economy DSGE model, where she finds that shocks to productivity cause high time-series correlations of savings and investment in the model, while shocks to fiscal and monetary policy seem to add little to the correlation.

Yet, shocks to productivity alone are not sufficient to explain the correlations found in the data. S.H. Kim (2001) uses annual panel data for 19 OECD countries to test the significance of cyclical shocks in explaining the high saving-investment correlations. He estimates the saving-retention coefficient where he controls for productivity, fiscal and terms of trade shocks in order to exclude business cycle fluctuations. Although controlling for a combination of all three shocks reduces the saving-retention coefficient from 0.69 to 0.42, it still remains at a significant level above zero. Kim also shows that controlling for productivity shocks only, the saving-retention coefficient merely falls from 0.69 to 0.64. These results suggest that shocks

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<sup>2</sup>Interestingly, countries with high current account surpluses like Switzerland and Japan even feature saving-retention coefficients greater than unity. But also the correlation for traditional current account deficit countries like New Zealand, Australia and Portugal are rather high. For the US, the time series correlation coefficient based on annual data from 1974 to 1990 was 0.773.

other than to productivity also play an important role for the correlations of savings and investment found in the data.

One alternative source of shocks to be considered are shocks to monetary policy. Although monetary policy is not likely to affect savings and investment decisions in the long run, it might well account for short-run variations in these variables. S. Kim (2001) studies the effects of US monetary policy shocks by estimating vector autoregressions. In his extensive investigation, he also analyzes the effects on US investment and savings. In response to both expansionary monetary policy shocks considered, US savings and investment rise significantly for a number of periods. The impulse responses of the two variables are both similarly hump shaped. Kim's results indicate - at least for the US - that in the short run monetary policy will affect savings and investment in a similar way, and might therefore explain in part the correlations found in the data.

In this paper, I analyze whether a positive correlation of domestic savings and investment in response to a monetary policy shock can also be obtained in a theoretical two-country DSGE-model with capital mobility in the tradition of the New Open Economy Macroeconomics (NOEM), a branch of research initiated by Obstfeld and Rogoff (1995).<sup>3,4</sup> It will be shown that this type of model is able to reproduce a correlation close to unity for domestic savings and investment, both for an exogenous process of money supply as well as for a single permanent shift in money supply. In response to such a single permanent increase in the home money supply, both savings and investment in the home economy rise in the short run. As the increase in home savings dominates the effect on investment, the domestic country runs a current account surplus. The similarity of the savings and investment responses is higher, the

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<sup>3</sup>For an excellent survey of the research in this area see Lane (2001), but also Sarno (2001), Fendel (2002).

<sup>4</sup>Although Cardia (1991) includes monetary shocks in her analysis of the Feldstein-Horioka puzzle in a small open economy model, she does not consider the effects of monetary shocks on savings and investment separately. Besides, she does not include price rigidities, and she only considers a small open economy.

bigger the relative size of the home economy. This effect is de facto independent of the price setting behavior of firms, which can either be producer currency pricing (PCP) or local currency pricing (LCP). This does not apply to the foreign country. For the assumption of PCP, both investment and savings in the foreign country rise as well in response to the home monetary expansion and thus exhibit a high degree of correlation. Yet, with LCP, foreign investment initially falls, while savings in the foreign country still increase. When a whole sequence of shocks to home and foreign money supply is simulated, the resulting correlation of savings and investment are close to unity, independent of the price-setting behavior of firms. For a small country, the correlation is somewhat reduced, but only to a small extent, and are still higher than the estimated coefficient of 0.796 for quarterly US data ranging from 1970 to 2005. Overall, the simulation results suggest that shocks to monetary policy might in part account for the time series correlation of domestic savings and investment.

The structure of the paper is as follows. In the next section, the model is derived, including the definition of savings. Besides, the parameter values of the model are calibrated and the properties of the assumed money supply and technology processes are discussed. Section 3 and 4 then present the results. In a first part, the resulting impulse response functions for the relevant home and foreign variables in response to a single permanent 1% increase in home money supply are presented and discussed for illustrational purpose. Impulse responses were computed for different relative sizes of the home economy, and for alternative price setting behavior of firms. In a second part, simulations for sequences of monetary and technology processes are conducted and the resulting outcomes are analyzed. In particular, the correlation coefficients for savings and investment responses but also for the international correlation of a number of variables are computed and then compared to the stylized facts obtained for the US and an aggregate of the remaining G7 countries. Section 4 then concludes.



## 2 The Model

In the following, a two-country dynamic general equilibrium model with nominal price rigidities in the tradition of the *Redux* model by Obstfeld and Rogoff (1995), henceforth OR, is derived. There are two countries, home and foreign. World population is normalized to 1. Share  $n$  of the world population resides in the home country and share  $1 - n$  in the foreign country. Agents consume consumption goods, supply labor and invest in their capital stock which they rent out to firms. A continuum of individual monopolistic firms resides in the home and the foreign country, which are respectively indexed by  $z^h \in [0, n]$  and  $z^f \in [n, 1]$ . Each firm produces a single differentiated good, whereas labor and capital are assumed to be homogenous and can be substituted across firms without any cost. To distinguish foreign from home agents, the foreign variables will be identified with an asterisk.

### 2.1 Consumers

#### 2.1.1 Preferences

Preferences of the representative agent residing in the home country have the following explicit form:

$$U = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[ \frac{C_s^{1-\sigma}}{1-\sigma} + \frac{\chi}{1-\epsilon} \left( \frac{M_s}{P_s} \right)^{1-\epsilon} + \eta \ln(1 - H_s) \right]$$

Direct utility is derived from consumption of a basket of differentiated goods  $C_t$ , from real money balances  $\frac{M_t}{P_t}$ , and from leisure  $(1 - H_t)$ . The parameter  $\beta$  denotes the representative home agent's subjective discount factor. The intertemporal elasticity of substitution is given by  $\frac{1}{\sigma}$ , while  $\epsilon$  is crucial for money demand elasticities.

The home agent faces the following intertemporal budget constraint:

$$P_t C_t + P_t V_t + M_t + B_{t+1}^h + e_t B_{t+1}^f + P_t \tau_t = (1 + i_t) B_t^h + (1 + i_t^*) e_t B_t^f + \Pi_t + W_t H_t + r_t^K P_t K_t + M_{t-1} \quad (1)$$

Nominal expenditures on consumption  $P_t C_t$ , investment  $P_t V_t$ , money balances  $M_t$ , two internationally traded riskless bonds  $B_{t+1}^h$  and  $e_t B_{t+1}^f$  and the payment of nominal lump-sum taxes amounting to  $P_t \tau_t$  may not exceed the sum of nominal returns from last period's bonds in terms of the home currency, i.e.  $(1 + i_t) B_t^h$  and  $(1 + i_t^*) e_t B_t^f$ , nominal profits  $\Pi_t$  from the shares of home firms, nominal wage income  $W_t H_t$ , nominal rental payments received on the capital stock  $r_t^K P_t K_t$ , plus last period's money balances  $M_{t-1}$ . Agents can trade only two internationally traded bonds  $B_t^h$  and  $B_t^f$ , where the former is denominated in the home and the latter in the foreign currency. The bonds yield the nominal riskless interest rate  $i_t$  and  $i_t^*$  between period  $t - 1$  and  $t$ , respectively, and are assumed to be perfect substitutes. This implies perfect capital mobility in the sense of Mundell.<sup>5</sup> For the distribution of profits, I assume that all agents within one country hold equal shares of all firms residing in this country, and home (foreign) firms profits are distributed equally among all home (foreign) agents.

The explicit form of the law of motion for capital is:

$$K_{t+1} = (1 - \delta) K_t + V_t - \frac{\phi \{K_{t+1} - K_t\}^2}{2 K_t} \quad (2)$$

Capital depreciates at the constant rate  $\delta$  and increases with investment  $V_t$  but at a decreasing rate because of non-linear capital adjustment costs, which are governed by  $\phi$ . Capital adjustment costs are incorporated in order to mitigate the response of

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<sup>5</sup>Mundell (1963, p. 475) states that "the assumption of perfect capital mobility can be taken to mean that all securities in the system are perfect substitutes". Note, however, that the *physical* capital stock per se is internationally immobile, as is labor.

investment to country-specific shocks. For the absence of adjustment costs, capital will be transferred immediately in vast amounts from one country to the other as soon as the returns differ in the two countries – even though home agents cannot explicitly invest in the foreign capital stock. This is possible as investment is implicitly assumed to be reversible, i.e. investment can become negative. This implies that home agents can reduce the home capital stock to increase the amount of goods available in the home economy, which can then be exported to the foreign country and integrated in the buildup of the foreign capital stock. Due to the implied trade balance surplus, home agents acquire net foreign assets, i.e. claims on the foreign production, which yield a higher return than home capital. Hence, to avoid excessive immediate investment responses, capital adjustment costs are included in the model.

The agent maximizes her expected lifetime utility  $U$  with respect to  $C_t$ ,  $M_t$ ,  $H_t$ ,  $K_{t+1}$ ,  $B_{t+1}^h$  and  $B_{t+1}^f$  subject to her intertemporal budget constraint and to the law of motion for the capital stock. The resulting first order conditions of the domestic representative agent are:

$$C_t^{-\sigma} = \beta E_t \left[ (1 + i_{t+1}) \left( \frac{P_t}{P_{t+1}} \right) C_{t+1}^{-\sigma} \right] \quad (3)$$

$$\frac{M_t}{P_t} = \left[ \chi C_t^\sigma E_t \left[ \frac{1 + i_{t+1}}{i_{t+1}} \right] \right]^{\frac{1}{\epsilon}} \quad (4)$$

$$\eta \frac{1}{(1 - H_t)} = C_t^{-\sigma} \frac{W_t}{P_t} \quad (5)$$

$$\left( 1 + \phi \frac{K_{t+1} - K_t}{K_t} \right) C_t^{-\sigma} = \beta E_t \left[ \left( 1 + r_{t+1}^K - \delta + \frac{\phi}{2} \frac{K_{t+2}^2 - K_{t+1}^2}{K_{t+1}^2} \right) C_{t+1}^{-\sigma} \right] \quad (6)$$

$$(1 + i_{t+1}) E_t \left[ \frac{C_{t+1}^{-\sigma}}{P_{t+1}} \right] = (1 + i_{t+1}^*) E_t \left[ \frac{C_{t+1}^{-\sigma}}{P_{t+1}} \left( \frac{e_{t+1}}{e_t} \right) \right] \quad (7)$$

The first optimality condition, equation (3), is the Euler equation which determines the optimal intertemporal consumption path. Equation (4) characterizes the money market equilibrium. The third optimality condition, equation (5), determines optimal labor supply. For the assumption of certainty equivalence used for the linear approximation of the model below, the last optimality condition, equation (7), reduces to the uncovered interest parity.

The agent's aggregate investment decision is determined by equation (6). For the agent to be indifferent between additional investment in capital stock and more consumption, the cost borne in terms of foregone utility of consumption in order to increase today's capital stock by one unit has to be equal to the marginal utility derived from this investment. While the adherent cost of an additional unit of capital is augmented by the marginal capital adjustment costs,  $\phi \frac{K_{t+1} - K_t}{K_t}$ , the revenue associated with this investment is measured in terms of the increase in expected consumption possibilities and the resulting expected increase in utility tomorrow. The rise in consumption possibilities consists of the increase in the capital stock itself, the expected real interest payment of the firm minus depreciation,  $r_{t+1}^K - \delta$ , plus the expected decrease in capital adjustment costs tomorrow,  $\frac{\phi}{2} \frac{K_{t+2}^2 - K_{t+1}^2}{K_{t+1}^2}$ .<sup>6</sup> The latter outcome is due to the fact that capital adjustment costs are declining in the actual size of the capital stock.

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<sup>6</sup>Note, however, that the expected real return on the capital stock  $E_t [r_{t+1}^K]$  still depends on other determinants like expected demand, expected marginal costs and the expected overall capital stock. But for now I will take the expected rental rate as given.

### 2.1.2 Consumption

The household's consumption basket is defined as an aggregate of the consumption of home and foreign goods, which takes the explicit form of a CES-function:

$$C_t = \left( n^{\frac{1}{\mu}} (C_t^h)^{\frac{\mu-1}{\mu}} + (1-n)^{\frac{1}{\mu}} (C_t^f)^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}} \quad (8)$$

$C_t^h$  and  $C_t^f$  are the representative home agent's consumption baskets that consist of domestically produced goods and imported foreign goods respectively.<sup>7</sup> In the following we assume that the consumption baskets of agents in both countries are identical and that the share of home goods consumed depends on the relative size of the home country  $n$ . This assumption implies purchasing power parity as long as the law of one price holds for all goods. The parameter  $\mu$  denotes the elasticity of substitution between domestically produced goods  $C_t^h$  and imported foreign goods  $C_t^f$ .

Both  $C_t^h$  and  $C_t^f$  consist of a weighted average of home and foreign differentiated goods each of which is produced by an individual monopolistic firm. The composition of the commodity basket of home goods consumed by agents in the home country is defined as:

$$C_t^h = \left( n^{-\frac{1}{\theta}} \int_0^n c_t^h (z^h)^{\frac{\theta-1}{\theta}} dz^h \right)^{\frac{\theta}{\theta-1}}$$

Consumption of foreign goods is allocated analogously:

$$C_t^f = \left( (1-n)^{-\frac{1}{\theta}} \int_n^1 c_t^f (z^f)^{\frac{\theta-1}{\theta}} dz^f \right)^{\frac{\theta}{\theta-1}}$$

The parameter  $\theta$  denotes the elasticity of substitution between different goods

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<sup>7</sup>A notational remark: The superscript  $h$  denotes goods and prices of home producers, whereas  $f$  denotes goods and prices of foreign producers. As goods are traded, we also differentiate between prices and goods that are valid for respective markets: Variables marked with an asterisk identify goods that are sold in the foreign market and prices that are charged in the foreign currency.

produced within one country, but also governs the magnitude of the markup. Via expenditure minimization we obtain the consumption demand of the representative home agent for the representative home good  $h$  and the representative foreign good  $f$ ,  $c_t^h(h)$  and  $c_t^f(f)$ , as:

$$c_t^h(h) = \left( \frac{p_t^h(h)}{P_t^h} \right)^{-\theta} \left( \frac{P_t^h}{P_t} \right)^{-\mu} C_t \quad (9)$$

$$c_t^f(f) = \left( \frac{p_t^f(f)}{P_t^f} \right)^{-\theta} \left( \frac{P_t^f}{P_t} \right)^{-\mu} C_t \quad (10)$$

### 2.1.3 Investment

For simplicity, I assume that investment features the same composition as consumption. Hence, aggregate investment demand of the representative home agent is defined as follows:

$$V_t = \left( n^{\frac{1}{\mu}} (V_t^h)^{\frac{\mu-1}{\mu}} + (1-n)^{\frac{1}{\mu}} (V_t^f)^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}} \quad (11)$$

Investment demand for home and foreign goods are - in correspondence to consumption demand - defined as:

$$V_t^h = \left( n^{-\frac{1}{\theta}} \int_0^n v_t^h(z^h)^{\frac{\theta-1}{\theta}} dz^h \right)^{\frac{\theta}{\theta-1}}$$

$$V_t^f = \left( (1-n)^{-\frac{1}{\theta}} \int_n^1 v_t^f(z^f)^{\frac{\theta-1}{\theta}} dz^f \right)^{\frac{\theta}{\theta-1}}$$

Minimizing expenditures on investment, the following demand schedules for investment demand of the representative home agent for the representative home good

$h$  and the representative foreign good  $f$ ,  $v_t^h(h)$  and  $v_t^f(f)$  are derived as:

$$v_t^h(h) = \left( \frac{p_t^h(h)}{P_t^h} \right)^{-\theta} \left( \frac{P_t^h}{P_t} \right)^{-\mu} V_t \quad (12)$$

$$v_t^f(f) = \left( \frac{p_t^f(f)}{P_t^f} \right)^{-\theta} \left( \frac{P_t^f}{P_t} \right)^{-\mu} V_t \quad (13)$$

#### 2.1.4 Aggregate Demand

Preferences are assumed to be identical across agents. Since all agents residing in one country face the same restrictions in form of their budget constraints, they will all reach the same demand decisions for consumption and investment. Hence, total demand for the representative home good  $h$  consists of the demand of the representative home and foreign agent for consumption and investment, weighted with the relative country size  $n$  and  $1 - n$ :

$$y_t^h(h) = n [c_t^h(h) + v_t^h(h)] + (1 - n) [c_t^f(h) + v_t^f(h)] \quad (14)$$

Substituting for  $c_t^h(h)$ ,  $c_t^f(f)$ ,  $v_t^h(h)$  and  $v_t^f(f)$  with equations (9), (10), (12) and (13), total demand for the representative home good  $h$  can be written as:

$$\begin{aligned} y_t^h(h) &= n \left( \frac{p_t^h(h)}{P_t^h} \right)^{-\theta} \left( \frac{P_t^h}{P_t} \right)^{-\mu} [C_t + V_t] \\ &\quad + (1 - n) \left( \frac{p_t^{h*}(h)}{P_t^{h*}} \right)^{-\theta} \left( \frac{P_t^{h*}}{P_t^*} \right)^{-\mu} [C_t^* + V_t^*] \end{aligned} \quad (15)$$

Thus, total demand for good  $h$  depends on its relative price and the substitutability between goods as well as on the aggregate level of expenditures for consumption and investment in both countries. Similarly, the representative foreign firm faces the

following demand for its good  $f$

$$y_t^f(f) = n \left( \frac{p_t^f(f)}{P_t^f} \right)^{-\theta} \left( \frac{P_t^f}{P_t} \right)^{-\mu} [C_t + V_t] + (1-n) \left( \frac{p_t^{f*}(f)}{P_t^{f*}} \right)^{-\theta} \left( \frac{P_t^{f*}}{P_t^*} \right)^{-\mu} [C_t^* + V_t^*] \quad (16)$$

### 2.1.5 Prices

The individual price of the representative home good  $h$  is  $p_t^h(h)$ .  $P_t^h$  denotes the price level for the basket of domestically produced goods, which is defined as:

$$P_t^h = \left[ \frac{1}{n} \int_0^n (p_t^h(z^h))^{1-\theta} dz^h \right]^{\frac{1}{1-\theta}} \quad (17)$$

Correspondingly, the home price index for imported goods from the foreign country  $P_t^f$ , is defined as:

$$P_t^f = \left[ \frac{1}{1-n} \int_n^{1^f} (p_t^f(z^f))^{1-\theta} dz^f \right]^{\frac{1}{1-\theta}} \quad (18)$$

Recall that  $p^f(z)$  denotes the *home* currency price of the foreign good  $z$ . The home consumer price index is then a weighted average of individual home and import goods prices, defined as:

$$P = \left[ n (P^h)^{1-\mu} + (1-n) (P^f)^{1-\mu} \right]^{\frac{1}{1-\mu}}. \quad (19)$$

As the intermediate price indices  $P^h$  and  $P^f$  are *both* denominated in the home currency, the exchange rate does not appear in the aggregation of prices for home and foreign goods directly. Nevertheless, the home country price level might be affected by exchange rate changes via changes in the import price index  $P^f$ .



Accordingly, in equation (15)  $p_t^{h*}$  ( $h$ ) is the foreign currency price of the representative home good  $h$ ,  $P_t^{h*}$  denotes the foreign currency price level of goods imported from the home country and  $P_t^*$  is the absolute consumer price level in the foreign country. The corresponding foreign price level is

$$P^* = \left[ n (P^{h*})^{1-\mu} + (1-n) (P^{f*})^{1-\mu} \right]^{\frac{1}{1-\mu}}. \quad (20)$$

### 2.1.6 Budget Constraint

As Ricardian equivalence holds in this type of models, assuming a balanced budget has no consequence on the results of the following analysis. For simplicity it is assumed that all seigniorage revenue accruing to the central bank is redistributed to agents in form of a lump-sum transfer:

$$M_t - M_{t-1} = -P_t \tau_t$$

This assumption reduces the home economy's budget constraint to:

$$P_t C_t + P_t V_t + B_{t+1}^h + B_{t+1}^f e_t = (1 + i_t) B_t^h + (1 + i_t^*) B_t^f e_t + \Pi_t + W_t H_t + P_t r_t^K K_t \quad (21)$$

### 2.1.7 Savings

Nominal savings  $P_t S_t$  are then defined as nominal income - resulting from factor income, profits and returns on interest - less expenditures on consumption. Nominal savings can then be written as:

$$P_t S_t = \left[ i_t B_t^h + i_t^* B_t^f e_t + \Pi_t + W_t H_t + P_t r_t^K K_t \right] - P_t C_t$$

Rearranging equation (21), we obtain:

$$P_t S_t = P_t V_t + \underbrace{(B_{t+1}^h - B_t^h) + (B_{t+1}^f - B_t^f)}_{=B_{t+1}-B_t} e_t \quad (22)$$

From equation (22) it becomes evident that domestic savings are either used to build up the capital stock at home or to increase the stock of net foreign assets via a current account surplus.<sup>8</sup> The decision will depend on which asset yields higher returns on interest, Real savings are then defined as:

$$S_t = \frac{B_{t+1} - B_t}{P_t} + V_t \quad (23)$$

In the steady state both the nominal and the real current account need to be balanced, i.e.  $B_{t+1} - B_t = 0$ . Thus, the definition in equation (23) implies that home agent's steady-state expenditures on investment need to coincide with the home economy's real savings as defined above. Yet, in response to a shock, home savings and investment might be affected quite differently.

## 2.2 Firms

### 2.2.1 Pricing

Each firm will set its price so as to maximize expected profits, taking its individual demand schedule, equation (15), into account. Yet, firms are assumed to set nominal prices in advance as in Calvo (1983). Each firm faces the same constant probability  $(1 - \gamma)$  every period to change its price next period and  $\gamma$  to keep the price constant, independent of its history of price changes. By the law of large numbers, a constant fraction  $(1 - \gamma)$  of firms will actually change their prices each period, while the remaining fraction  $\gamma$  cannot adjust their prices.

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<sup>8</sup>Note that government bonds as an alternative investment possibility are not available for agents.

Betts and Devereux (2001, 2000, 1996), Engel (2000) and Schmidt (2006) have shown that the international transmission effects of monetary policy shocks are crucially affected by the way firms set their prices. Two alternative price-setting strategies are considered in this literature: producer-currency-pricing (henceforth PCP) and local-currency-pricing (henceforth LCP). Whereas a PCP firm sets the price for its good in the domestic currency of the producer, independent of the market where the good is sold, the LCP firm is assumed to set two different prices, one for the home market and one for the foreign market, each in the local currency of the market. In the presence of short-run price rigidities import prices of PCP goods exhibit a complete exchange-rate pass-through while import prices of LCP goods are not affected by a change in the exchange rate. In the following, I will consider the existence of both types of firms, in order to analyze whether the effects on savings and investment correlations in response to a monetary shock are sensitive to the different price-setting strategies. The share  $s$  of LCP firms in both countries is allowed to vary between 0 and 1.

### 2.2.2 Profit Maximization

**Profit maximization of the representative home PCP firm** In the presence of price rigidities à la Calvo, firms set prices so as to maximize their expected discounted future profits, which are given by:<sup>9</sup>

$$E_t \left[ \sum_{i=0}^{\infty} (\gamma\beta)^i \Lambda_{t,t+i} \left( \frac{\tilde{P}_t^{h,PCP}(h)}{P_{t+i}} - \frac{MC_{t+i}}{P_{t+i}} \right) y_{t,t+i}^{h,PCP}(h) \right]$$

with:

$$\Lambda_{t,t+i} = \left( \frac{C_{t+i}}{C_t} \right)^{-\sigma}$$

$y_{t,t+i}^{h,PCP}(h)$  denotes the expected total demand of the representative home PCP

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<sup>9</sup>A notational remark: The superscript *PCP* identifies goods produced and prices charged by PCP firms, the superscript *LCP* marks the respective variables for LCP firms.

firm at time  $t + i$  provided that the price set at time  $t$  is still effective. The optimal price of the representative home PCP firm at time  $t$ ,  $\tilde{P}_t^{h,PCP}(h)$ , is then derived as a markup over a weighted average of expected future nominal marginal costs:

$$\tilde{P}_t^{h,PCP}(h) = \frac{\theta}{\theta - 1} \frac{E_t \left[ \sum_{i=0}^{\infty} (\gamma\beta)^i \Lambda_{t,t+i} D_{t,t+i}^{h,PCP} MC_{t+i} \right]}{E_t \left[ \sum_{i=0}^{\infty} (\gamma\beta)^i \Lambda_{t,t+i} D_{t,t+i}^{h,PCP} \right]} \quad (24)$$

$D_{t,t+i}^{h,PCP}$  denotes total expected future real sales revenues of the PCP firm, given that the optimal price chosen at time  $t$  is still effective. Since all PCP firms in the home country face the same constraints, each firm that can adjust its price in period  $t$  will choose the same price  $\tilde{P}_t^{h,PCP}(h)$ .

**Profit maximization of the representative LCP firm** The representative LCP firm faces essentially the same optimization problem as the PCP firm, but maximizes profits arising from the home and the foreign market, choosing two different prices. Expected profits then are

$$E_t \left[ \sum_{i=0}^{\infty} (\gamma\beta)^i \Lambda_{t,t+i} \left( \frac{\tilde{P}_t^{h,LCP}(h)}{P_{t+i}} - \frac{MC_{t+i}}{P_{t+i}} \right) y_{t,t+i}^{h,LCP}(h) + (\gamma\beta)^i \Lambda_{t,t+i} \left( \frac{e_{t+i} \tilde{P}_t^{h,LCP,*}(h)}{P_{t+i}} - \frac{MC_{t+i}}{P_{t+i}} \right) y_{t,t+i}^{h,LCP,*}(h) \right]$$

where  $\Lambda_{t,t+i}$  is defined as above.  $\tilde{P}_t^{h,LCP,*}(h)$  denotes the optimal export price of the representative *home* LCP firm set in the *foreign* currency, which is converted to the home currency via the exchange rate  $e_{t+i}$ . The quantities  $y_{t,t+i}^{h,LCP}$  and  $y_{t,t+i}^{h,LCP,*}$  denote home and foreign agents' demand for the representative home LCP good at  $t + i$  given the prices  $\tilde{P}_t^{h,LCP}(h)$  and  $\tilde{P}_t^{h,LCP,*}(h)$  set at time  $t$ .

The optimal export price  $\tilde{P}_t^{h,LCP,*}(h)$  of the representative home LCP firm is

derived as:

$$\tilde{P}_t^{h,LCP,*}(h) = \frac{\theta}{\theta - 1} \frac{E_t \left[ \sum_{i=0}^{\infty} (\gamma\beta)^i \Lambda_{t,t+i} D_{t,t+i}^{h*,LCP} \frac{MC_{t+i}}{e_{t+i}} \right]}{E_t \left[ \sum_{i=0}^{\infty} (\gamma\beta)^i \Lambda_{t,t+i} D_{t,t+i}^{h*,LCP} \right]} \quad (25)$$

Correspondingly,  $D_{t,t+i}^{h*,LCP}$  is defined as expected future real sales revenues of the LCP firm - albeit only in the export market. As the LCP price for the foreign market is set in the *foreign* currency, the optimal newly set price also depends on the expected future path of the nominal exchange rate, as the LCP firm takes into account the increase in markup resulting from a devaluation of the home currency.

### 2.2.3 Price indices

In the presence of both PCP and LCP firms, the import price index in the foreign and the home economy (derived in equation (18)) can be expressed more explicitly.  $P_t^f$ , the home price index for imported goods from the foreign country, is then defined as:

$$P_t^f = \left[ \frac{1}{1-n} \left( \int_n^{n+(1-n)s} (p_t^f(z^f))^{1-\theta} dz^f + \int_{n+(1-n)s}^1 (e_t p_t^{f*}(z^f))^{1-\theta} dz^f \right) \right]^{\frac{1}{1-\theta}} \quad (26)$$

Recall that  $p^f(z)$  denotes the *home* currency price of the foreign good  $z$ , whereas  $p^{f*}(z)$  denotes the foreign currency price of foreign goods. Hence,  $P^f$  refers to the price index of home agents' import goods in the home currency which is altered by a change in the exchange rate, depending on the degree of local-currency pricing. The analogous reasoning applies to the foreign import price index  $P^{h*}$ :

$$P^{h*} = \left[ \frac{1}{n} \left( \int_0^{ns} (p^{h*}(z))^{1-\theta} dz + \int_{ns}^n \left( \frac{1}{e_t} p^h(z) \right)^{1-\theta} dz \right) \right]^{\frac{1}{1-\theta}}. \quad (27)$$

Again,  $p^{f*}(z)$  is the foreign currency price of the foreign good, while  $p^{h*}(z)$

denotes the foreign currency price of the home good.

Although individual prices of each type of firm residing in one country differ, it is possible to define an average price for each type of firm in each country. The home country price index for home PCP goods  $P^{h,PCP}$  is then a weighted average of last period's price index and the optimal price at time  $t$ :

$$P_t^{h,PCP} = \left[ \gamma \left( P_{t-1}^{h,PCP} \right)^{1-\theta} + (1-\gamma) \left( \tilde{P}_t^{h,PCP}(h) \right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad (28)$$

In the log-linearized version of the model, the optimal price in the domestic market of the LCP firm is identical to the PCP firm's price. Therefore, the home price index for domestically produced goods, defined in equation (17) above, is simply written as:

$$P_t^h = P_t^{h,PCP} \quad (29)$$

And the price index for domestic goods produced by LCP firms evolves analogously:

$$P_t^{h,LCP,*} = \left[ \gamma \left( P_{t-1}^{h,LCP,*} \right)^{1-\theta} + (1-\gamma) \left( \tilde{P}_t^{h,LCP,*}(h) \right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad (30)$$

Hence, the price index of imported goods in the home economy can be written as a weighted average of the average prices of foreign LCP and PCP goods  $P_t^{f,LCP}$  and  $P_t^{f,PCP,*}$  targeted at the home market. The respective weights are determined by the share  $s$  of LCP firms. Therefore, the home price index of imported foreign goods, defined in equation (26) above, simplifies to:

$$P_t^f = \left[ s \left( P_t^{f,LCP} \right)^{1-\theta} + (1-s) \left( e_t P_t^{f,PCP,*} \right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad (31)$$

For analogous reasons, the foreign price index of goods imported from the home

country can be simplified to:

$$P_t^{h*} = \left[ s \left( P_t^{h,LCP,*} \right)^{1-\theta} + (1-s) \left( \frac{P_t^{h,PCP}}{e_t} \right)^{1-\theta} \right]^{\frac{1}{1-\theta}}$$

#### 2.2.4 Production

Firms at home and abroad produce under constant-returns-to-scale, employing the following Cobb-Douglas production function, displayed for the example of the representative home firm  $h$ :

$$y_t(h) = A_t K_t(h)^\alpha H_t(h)^{1-\alpha}$$

$A_t$  represents the common level of technology in the home country, while  $K_t(h)$  and  $H_t(h)$  denote the individual capital and labor inputs of the representative home firm  $h$ . Cost minimization implies that firms will demand factor inputs to satisfy:

$$W_t = MC_t (1 - \alpha) \frac{y_t^h(h)}{H_t(h)} = MC_t (1 - \alpha) \frac{y_t^h}{H_t} \quad (32)$$

$$P_t r_t^K = MC_t \alpha \frac{y_t^h(h)}{K_t(h)} = MC_t \alpha \frac{y_t^h}{K_t} \quad (33)$$

$MC_t$  denotes the nominal marginal costs of production. Since all firms in one country have to pay the same wage and face the same rental rate for capital, marginal costs are the same across all firms residing in one country.

#### 2.2.5 Real income

Since all agents residing in one country are assumed to hold identical shares of all domestic firms, it is possible to rewrite the home economy's real income in terms of production. Hence, home country's real income in terms of purchasing power,  $Y_t^{RI,h}$ ,

is defined as:

$$Y_t^{RI,h} = \frac{P_t^h}{P_t} \left[ y_t^{h,PCP} + (1-s)y_t^{h,PCP,*} \right] + s \frac{e_t P_t^{h,LCP,*}}{P_t} y_t^{h,LCP,*} + \frac{i_t B_t}{P_t}. \quad (34)$$

Real income of home agents increases with higher sales - both in the home and the foreign market -, with improving terms of trade and with higher real return on their net foreign assets.

By analogous reasoning, real savings in terms of purchasing power can be defined as:

$$S_t = Y_t^{IR,h} - C_t \quad (35)$$

As is obvious from equation (35), the evolution of real income is crucial for real domestic savings. With current consumption being mainly determined by the real interest rate, real savings evolves as the residual of real income and consumption.

Finally, the real current account is defined relative to home output, defined as the real change in net foreign assets, is the surplus of real income over real expenditures on consumption and investment and can be thus written as:

$$\frac{B_{t+1} - B_t}{P_t} = Y_t^{IR,h} - C_t - V_t. \quad (36)$$

## 2.3 Market Clearing

In equilibrium, all goods, factor and asset markets need to clear in the home and the foreign economy. In the home goods market, aggregated demand consists of demand for LCP and PCP goods:

$$Y_t^h = s y_t^{h,LCP} + (1-s) y_t^{h,PCP} \quad (37)$$

Since all home firms produce with the same capital-labor ratio, total supply in



the home country can be written as:

$$Y_t^h = \int_0^n A_t K_t^\alpha (z^h) H_t^{1-\alpha} (z^h) dz^h = A_t K_t^\alpha H_t^{1-\alpha} \quad (38)$$

The foreign goods market clears analogously. The home (foreign) money market is in equilibrium if national money demand corresponds to the exogenous supply of home (foreign) currency provided by the national central bank. The explicit form of the money supply processes will be defined below. Bond markets clear in equilibrium if aggregate *world* assets, i.e. the joint net assets of home and foreign agents, are equal to zero in all periods.

## 2.4 Equilibrium

Equilibrium is characterized by equations (2), (3), (4), (5), (6), (19), (24), (28), (29), (25), (30), (31), (32), (33), (37), (38), and their foreign counterparts, demand equation (15) for both LCP and PCP firms in the home and the foreign economy, as well as equations (7), (21), the bonds market equilibrium and home and foreign savings, which gives 41 equations. This is a dynamic system in the following 41 variables, given by  $X_t$

$$\begin{aligned} X_t = \{ & C_t, C_t^*, H_t, H_t^*, V_t, V_t^*, K_t, K_t^*, W_t, W_t^*, r_t^k, r_t^{k*}, i_t, i_t^*, MC_t, MC_t^*, e_t, B_t^h, B_t^f \\ & P_t, P_t^*, P_t^h, P_t^f, P_t^{h*}, P_t^{f*}, \tilde{P}_t^{h,PCP}, \tilde{P}_t^{h,LCP,*}, \tilde{P}_t^{f,PCP}, \tilde{P}_t^{f,LCP}, P_t^{h,PCP}, \\ & P_t^{h,LCP}, P_t^{f,PCP}, P_t^{f,LCP}, Y_t^h, Y_t^f, y_t^{h,PCP}, y_t^{h,LCP}, y_t^{f,PCP}, y_t^{f,LCP}, S_t, S_t^* \} \end{aligned}$$

The model is solved by linearizing around the symmetric steady state, where neither country owns net foreign assets.<sup>10</sup>

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<sup>10</sup>For the solution of the model, the MATLAB code provided by Schmitt-Grohé and Uribe (2004) is employed.

## 2.5 Parameter values

### 2.5.1 Preferences

The calibrated parameters are presented in table 1. The quarterly real interest rate is set to 1% in the steady state. The consumption elasticity of money demand ( $\frac{\sigma}{\epsilon}$  in the model) is commonly estimated to be about unity, see, e.g., Mankiw and Summer (1986), which is the value I adopt. For the interest elasticity of money demand ( $-\frac{\beta}{\epsilon}$  in the model), the estimates vary from  $-0.39$  in Chari et al. (2002) to  $-0.051$  in Mankiw and Summers (1986).<sup>11</sup> For the benchmark calibration, I choose  $-0.39$ . The benchmark values for money demand elasticities imply that  $\sigma$  is about 2.5. The parameter  $\theta$  determines the markup of prices over marginal costs. Consistent with the findings of Basu and Kimball (1997), which suggest a markup of about 10% in the US, I assume  $\theta = 10$ . The capital share  $\alpha$  is set to  $\frac{1}{3}$ . This value is in line with empirical evidence on the labor share provided by Bentolila and Saint-Paul (2003), which is found to range from 62% to 68% for the G-7 countries in the 1990s. The rate of depreciation  $\delta$  is set to 0.021, which implies an annual depreciation rate of about 10%, corresponding to the typical estimates for US data. The steady state share of labour,  $\bar{H}_0$ , is set to 0.3. For simplicity, the relative preference parameter for real balances,  $\chi$ , is assumed to be 1. The last two assumptions further determine  $\eta$ , the preference parameter for leisure, to be 2.8. The price adjustment parameter is set such that the average time between price adjustment for a firm is one year. This implies  $\gamma = 0.75$ . The value for capital adjustment costs  $\phi$  is set to 8, which induces an investment response to an unanticipated increase in home money supply for the baseline calibration of about 3 times the size of the corresponding output response in the home country, and thus corresponds to the findings of the VAR analysis. Finally, the elasticity of substitution between home and foreign goods  $\mu$  is set equal to 1.5

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<sup>11</sup>Both Chari et al. and Mankiw and Summers use consumption as the relevant quantity variable for the estimation of money demand elasticities, which corresponds to the setup in the model. Chari et al. (2002) also implicitly assume a unity consumption elasticity of money demand in their regression.

as found by Hooper and Marquez (1995, Table 4.1) for the US The degree of pricing to market is either set to 0 or 1. The relative country size in the benchmark is set to 0.5 which implies that both countries are of equal size. Yet, also a relative size of 0.1 (small country case) and 0.9 (large country case) will be analyzed.

Table 1: Calibrated parameters

$\sigma$	2.5	$\chi$	1	$\theta$	10
$\epsilon$	2.5	$\delta$	0.021	$\mu$	1.5
$\phi$	8	$\beta$	$\frac{1}{1.01}$	$s$	0/1
$\eta$	2.8	$\alpha$	$\frac{1}{3}$	$\gamma$	0.75

### 2.5.2 Exogenous variables

In order to determine the properties of the exogenous money supply processes in the home and the foreign country, logged narrow money supply (M1) for both the US and the remaining G7 countries was HP-filtered and a first order vector autoregression (VAR) was estimated for the period 1970:Q2-2005:Q4.<sup>12</sup> The estimation output is presented below:

$$\begin{bmatrix} m_{t+1}^{US} \\ m_{t+1}^{G6} \end{bmatrix} = \begin{bmatrix} 0.9378 & 0.021704 \\ (0.03036) & (0.02436) \\ -0.082545 & 0.835035 \\ (0.05763) & (0.00127) \end{bmatrix} \cdot \begin{bmatrix} m_t^{US} \\ m_t^{G6} \end{bmatrix} + \begin{bmatrix} \epsilon_t^{US} \\ \epsilon_t^{G6} \end{bmatrix}$$

with  $m_t^{US}$  and  $m_t^{G6}$  as the HP-filtered logged narrow money supply in the US and the G6 countries, respectively, and  $\text{Var } \epsilon_t^{US} = 0.0000883$ ,  $\text{Var } \epsilon_t^{G6} = 0.0000568$ ,  $\text{Cov}(\epsilon_t^{US}, \epsilon_t^{G6}) = 0.00000254$ . Standard errors are reported in parenthesis.

While the estimates of the diagonal elements are highly significant, this is not true for the off-diagonal elements. This result is in line with Kollmann (2001), who also finds that money supply in one country has no effect on money supply in the other country in subsequent periods. For the simulations, I assume the following

<sup>12</sup>US and G7 data obtained from the OECD (Main Economic indicators). A more detailed description of the data can be found in the appendix.

process for money supply:

$$\begin{bmatrix} m_{t+1} \\ m_{t+1}^* \end{bmatrix} = \begin{bmatrix} 0.89 & 0 \\ 0 & 0.89 \end{bmatrix} \cdot \begin{bmatrix} m_t \\ m_t^* \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \epsilon_t^* \end{bmatrix}$$

with  $\epsilon_t$  and  $\epsilon_t^*$  joint normally distributed with mean zero, variance 0.00007225 and covariance 0.00000254.

For the exogenous process of technology in both countries, I rely on the assumptions employed in Kollmann (2001):

$$\begin{bmatrix} \ln(A_t) \\ \ln(A_t^*) \end{bmatrix} = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix} \cdot \begin{bmatrix} \ln(A_{t-1}) \\ \ln(A_{t-1}^*) \end{bmatrix} + \begin{bmatrix} \xi_t \\ \xi_t^* \end{bmatrix}$$

where  $\xi_t$  and  $\xi_t^*$  are normal white noises with variance 0.00007225 and covariance 0.00001864.

In the following, two different types of simulations are investigated. For illustrational purposes, I will first present and discuss the impulse responses obtained for a 1% permanent increase in home money supply for alternative assumptions on price-setting behavior of firms and different country sizes. This procedure helps to analyze the propagation mechanism in the model. In a subsequent section, the results obtained from multiperiod simulations of the model for both separate and combined shocks to money supply and productivity will be compared to stylized facts of historical business cycle data for the US and the remaining G7 countries.

### 3 Results I: Impulse responses

In this section, the impulse responses obtained for a 1% permanent increase in the home nominal money supply are presented. Results for three different relative sizes of the home economy are shown. For each size, I will show both results arising for

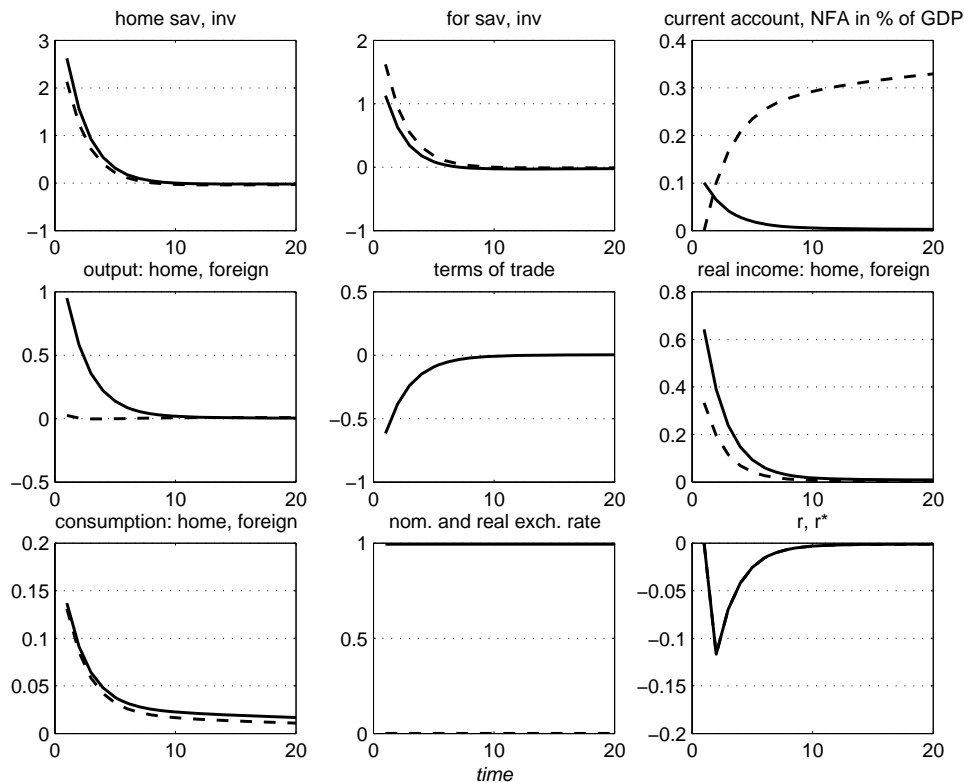
complete PCP and complete LCP. The plotted impulse responses are percentage deviations from respective steady-state values, except for the interest rates and the current account. For the interest rates, the deviations depicted are in percentage-points, while the current account balance is defined relative to steady-state home nominal income. Solid lines show the responses of home variables, dashed lines the corresponding responses of foreign variables. The horizontal axes depict the number of quarters.

### 3.1 Equal country size

Figure 1 displays the impulse responses for complete PCP in both countries, when both countries are of equal size. In response to the surprise increase in home money supply in period 1, home savings as well as home investment increase. At the same time, savings and investment in the foreign country rise as well. Whereas in the home economy, the increase in savings dominates the rise in investment, the opposite holds true for the foreign economy. As a result, the home country runs a current account surplus measured in terms of steady-state income.

Why are the savings and investment responses to a home monetary expansion in both countries so similar? As PPP holds with complete PCP, the real exchange rate is unaffected by the shock, which leaves no room for a real interest rate differential between the home and the foreign country. Hence, the decline in real interest rates is identical in both countries, stimulating consumption and investment demand in the two economies alike. As import prices exhibit complete exchange-rate pass-through, the increase in world demand is directed towards goods produced in the home country. At the same time, both home and foreign real income increase, although only home output is affected by the shock. The rise of foreign real income is a result of the deterioration of the home economy's terms of trade. The terms of trade deteriorate as, with prices pre-set in the producer's currency, home country's import prices rise in terms of the home currency. The increase in real income allows foreign agents

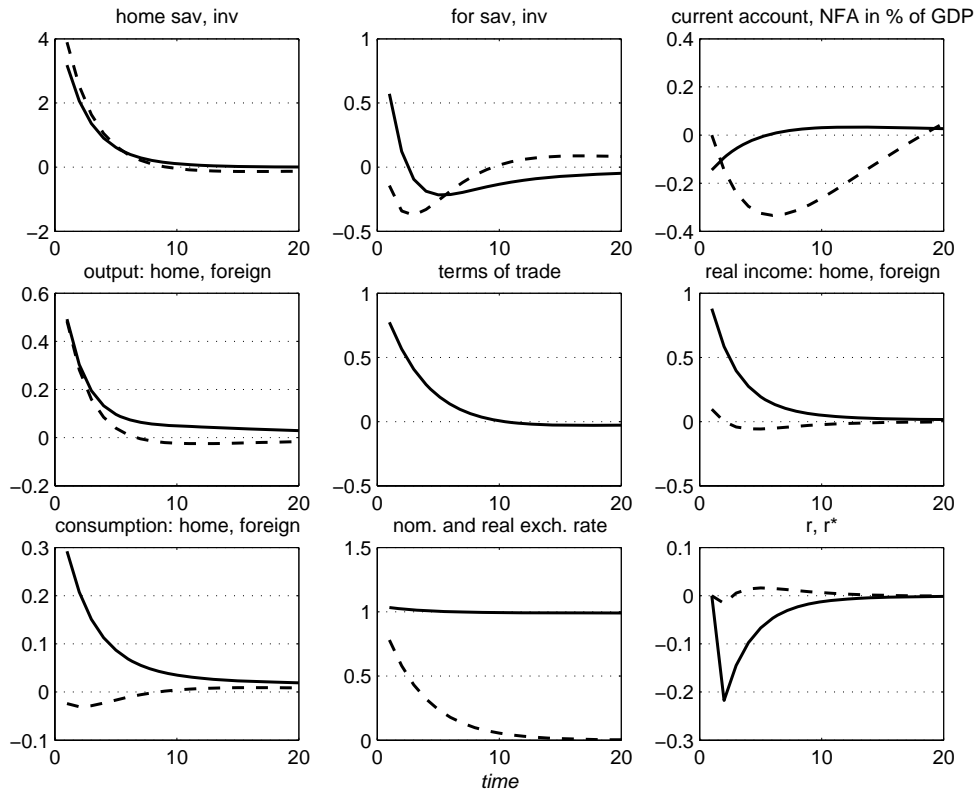
Figure 1: Impulse responses to a permanent increase in home money supply for  $n = 0.5$  and complete PCP



to raise their savings even for the higher level of consumption. Yet, savings in the home economy rise by more than investment, and home agents build up their stock of foreign assets.

The corresponding impulse responses for complete LCP are shown in Figure 2. As before, an unanticipated increase in home money supply raises home savings as well as home investment in the short run. Yet, for complete LCP the increase in home investment outweighs the increase in domestic savings. On the contrary, foreign economy's savings rise, whereas investment falls in the short run. As a result, the home economy runs a current account deficit. When all producers set their export prices in the local currency of the export market, there is no exchange-rate pass-through to import prices. As import prices are unaffected by the nominal depreciation

Figure 2: Impulse responses to a permanent increase in home money supply for  $n=0.5$  and complete LCP



of the home currency, PPP no longer holds and home and foreign real interest rates can diverge. As a result there is no decline in the foreign consumer price level, which prevents a reduction in foreign nominal and real interest rates, as depicted in Figure 2. Instead, with a number of firms already adjusting prices in the short run, the foreign consumer price level is even higher than before, which raises the foreign real interest rate. Therefore, foreign consumption and investment fall. The increase in foreign savings, on the other hand, is stimulated by the decline in foreign consumption together with the temporary rise in foreign real income. Although foreign output increases because of the deterioration of the foreign country's terms of trade, the rise in foreign real income is negligible. Foreign output rises for complete LCP since the expenditure-switching effect is repressed and the increase in home agents' demand is

directed to *both* home and foreign goods. The resulting impulse response functions for foreign savings and investment suggest a low degree of correlation, which is confirmed below.

### 3.2 Small country

Figure 3: Impulse responses to a permanent increase in home money supply for  $n=0.1$  and complete PCP

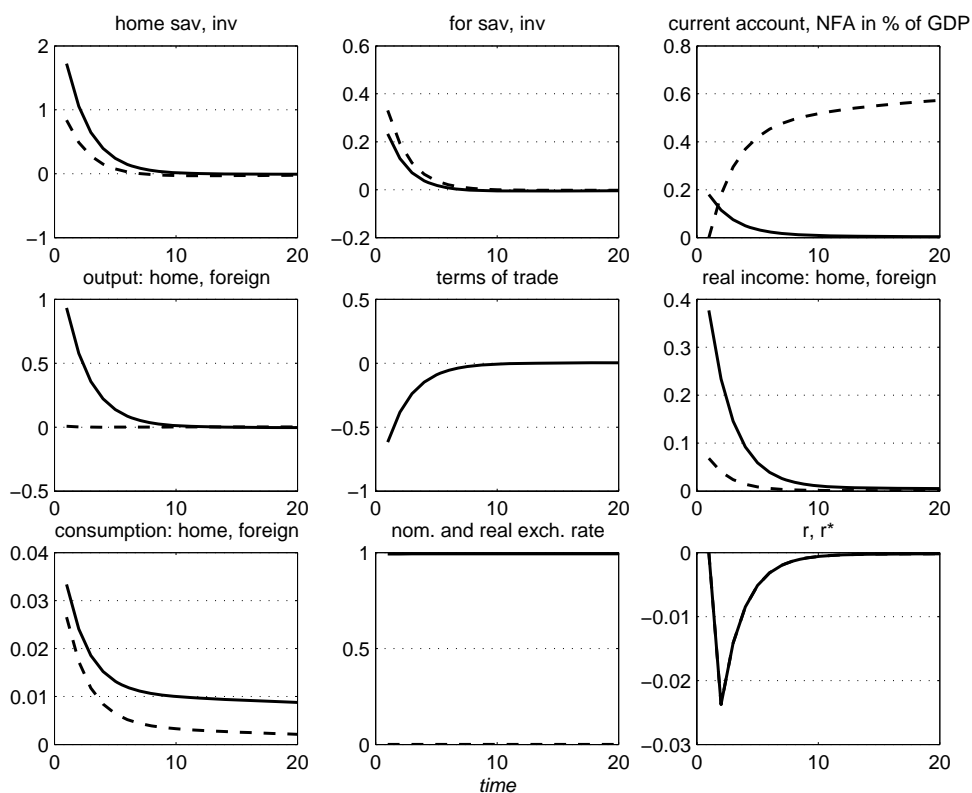
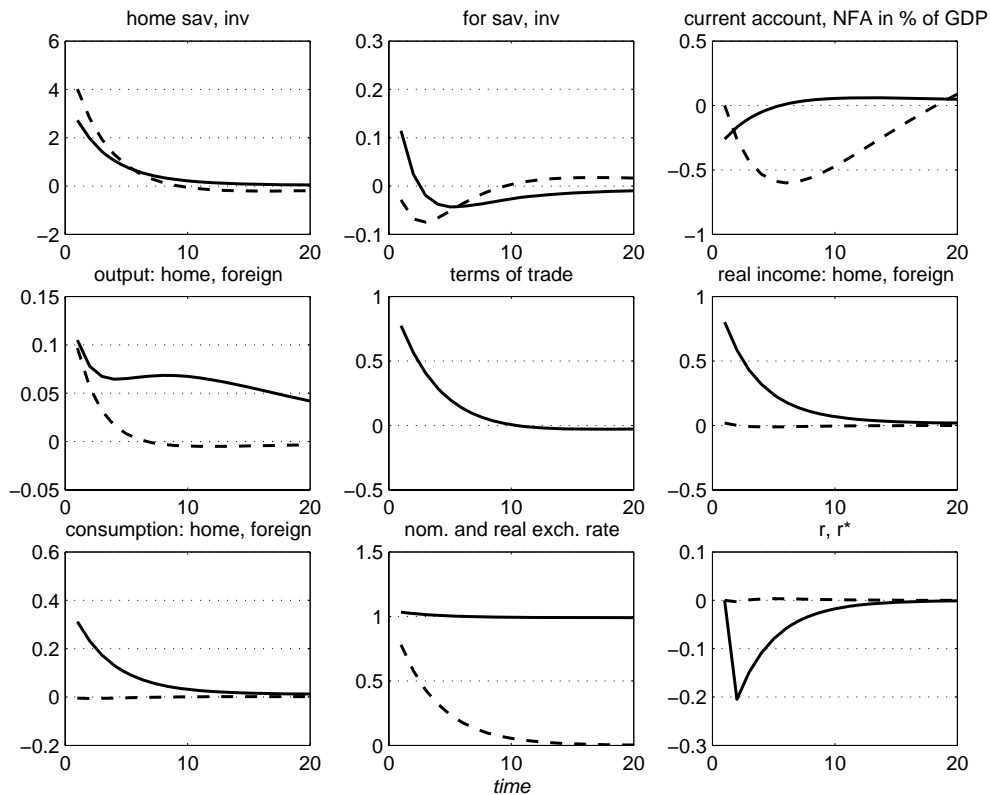


Figure 3 displays the impulse responses for complete PCP in both countries, when the home country is relatively small and represents only 10% of the world population. Again, savings and investment increase in the home economy, although the increase in investment is less than before. The reason is that in the small country case, the 1% increase in home nominal money supply reduces the real world interest rate by less than before, as the monetary impulse is smaller. Thus, the effects on consumption



Figure 4: Impulse responses to a permanent increase in home money supply for  $n=0.1$  and complete LCP



and investment in both countries are reduced. At the same time, the increase in home country's real income is reduced by less, and thus the difference between home savings and investment rises, which is also reflected in the size of the current account surplus. Compared to the benchmark scenario where both countries are of equal size, the larger foreign country is now hardly affected by the home monetary expansion, although savings and investment still comove. Note that real income in the foreign economy hardly increases, as the terms of trade effect for a large country with a low import share is negligible.<sup>13</sup>

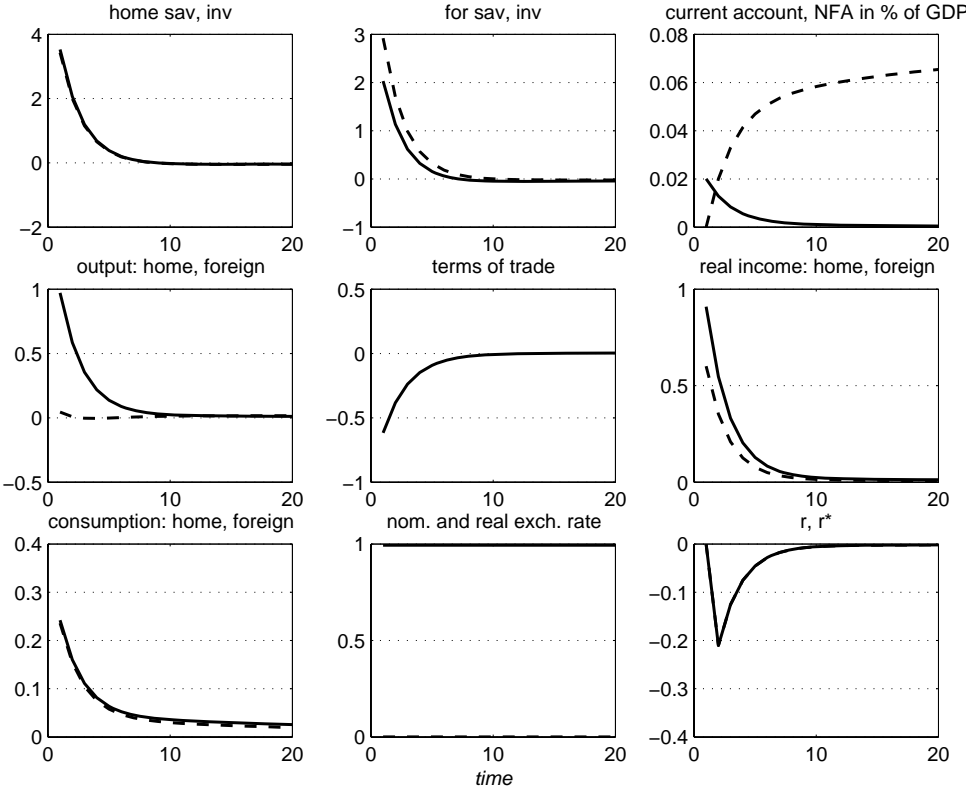
The corresponding impulse responses for complete LCP are shown in Figure 4. As

<sup>13</sup>The import share is determined by the relative country size. I.e. if the foreign country represents 90% of the world economy, its import share is 10% in the steady state.

before, foreign savings and investment are delinked when there is no exchange-rate pass-through to import prices. As for complete PCP in the small country case, the magnitude of the effects on the foreign economy are heavily reduced by the change in relative country size. Foreign real income hardly moves, as the little increase in foreign production is compensated by the deterioration of the terms of trade.

### 3.3 Large country

Figure 5: Impulse responses to a permanent increase in home money supply for  $n=0.9$  and complete PCP

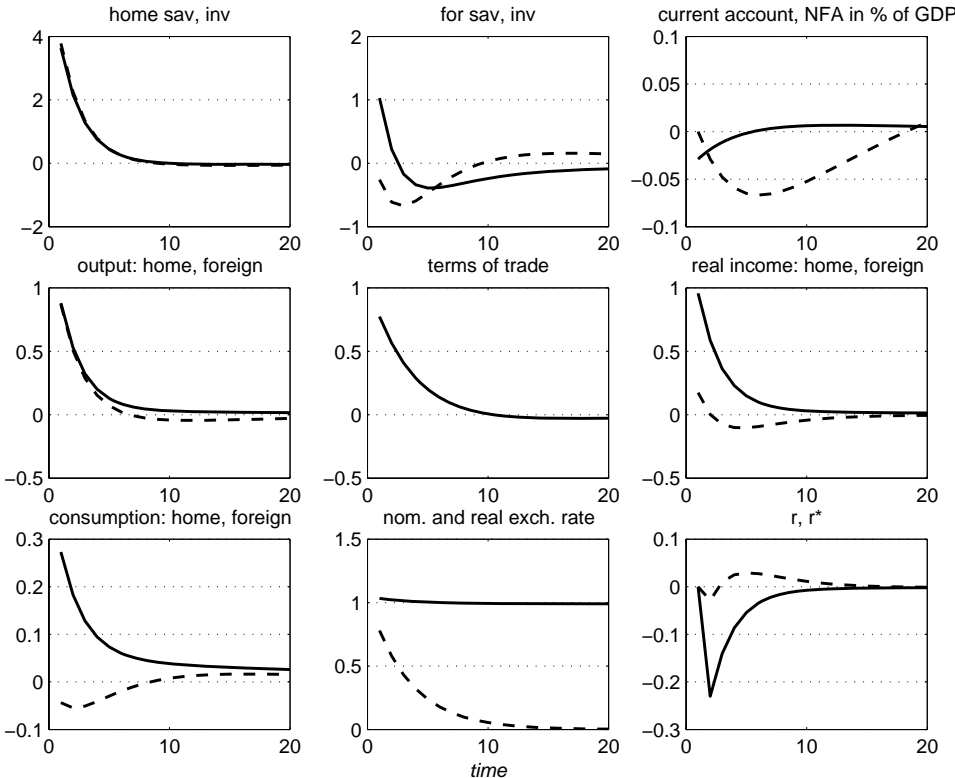


If the home economy accounts for 90% of the world population, an increase in home nominal money supply highly impacts on the home and foreign economy. The corresponding impulse responses for the large country case for complete PCP are shown in Figure 5. Although the home economy still runs a current account surplus,

the impulse responses of home savings and investment almost coincide, reflecting the lack of possibilities to finance investment from or to invest abroad. For the foreign economy, savings and investment responses again exhibit high similarities, which should be reflected in high correlation coefficients. The impact on the foreign economy is heavily increased.

The corresponding impulse responses for complete LCP in the large country case are shown in Figure 6. As for complete PCP, home country's savings and investment basically coincide, whereas the effect on the foreign economy is again dominated by the lack of exchange-rate pass-through, preventing foreign investment to rise. As for complete PCP, the effect on the foreign economy is enlarged.

Figure 6: Impulse responses to a permanent increase in home money supply for  $n=0.9$  and complete LCP



## 4 Result II: Simulation results and stylized facts

This section aims at an empirical validation of the presented model by comparing simulation results to stylized facts of historical business cycle data for the US and the remaining G6 countries. For this purpose, the model economy was hit by a sequence of shocks to either money supplies, technology inputs or both.<sup>14</sup> The corresponding variations and correlations of the variables are reported in Tables 2 and 3 below and compared to the respective outcome of historical data.<sup>15</sup>

Std. Dev. (in %)	Simulations						Data	
	Shocks to M		Shocks to A		M&A		1970:1-2005:4	
	PCP	LCP	PCP	LCP	PCP	LCP	US	G6
Output	0.198 (0.020)	0.145 (0.014)	1.745 (0.609)	1.747 (0.604)	1.760 (0.603)	1.764 (0.621)	1.567	0.960
Consumption	0.042 (0.005)	0.066 (0.008)	1.350 (0.532)	1.354 (0.532)	1.360 (0.540)	1.365 (0.542)	1.262	0.815
Investment	0.550 (0.053)	0.855 (0.089)	2.862 (0.932)	2.872 (0.932)	2.931 (0.918)	3.014 (0.917)	5.983	3.660
Money	1.658 (0.315)	1.658 (0.310)	0	0	1.667 (0.320)	1.656 (0.310)	2.598	1.365
CPI	0.260 (0.053)	0.195 (0.046)	1.497 (0.650)	1.497 (0.643)	1.538 (0.660)	1.528 (0.660)	1.434	
Nom. exch. rate	0.430 (0.082)	0.437 (0.079)	0.049 (0.019)	0.050 (0.019)	0.433 (0.083)	0.437 (0.082)	5.108	

While the overall variability for the combination of monetary and technology shocks is higher for consumption, investment, output, as well as for prices, and the response of the nominal exchange rate is too low, the variability of both domestic and foreign money supply is in line with the historical data. Also, the relative variability of consumption and investment variability compared to output matches the stylized facts.

The correlation coefficients of real domestic savings and investment for all six different scenarios are given in the first row in Table 3. The correlation coefficient between domestic savings and investment in response to monetary shocks is almost

<sup>14</sup>Each simulation was conducted for 100 periods (quarters). To compute the standard errors, 10.000 simulations were conducted per case.

<sup>15</sup>For the business cycle stylized facts, quarterly data from 1970 to 2005 from the OECD (Main economic indicators) and the IMF (International Financial statistics) were used.

unity, independent of the price-setting behavior of firms. This finding seems to support the VAR results by Kim (2001), which indicate a high co-movement in US savings and investment in response to domestic monetary policy shock.

Table 3: Correlations

Correlations	Shocks to M		Shocks to A		M&A		US	G6
	PCP	LCP	PCP	LCP	PCP	LCP		
$S/I$	0.955 (0.013)	0.967 (0.009)	0.955 (0.029)	0.953 (0.030)	0.954 (0.030)	0.952 (0.30)	0.796	
$Y/Y^*$	0.044 (0.141)	0.944 (0.031)	0.670 (0.220)	0.667 (0.221)	0.657 (0.228)	0.674 (0.218)		
$C/C^*$	0.993 (0.005)	-0.178 (0.158)	0.999 (0.001)	0.999 (0.001)	0.999 (0.001)	0.995 (0.004)	0.509	
$I/I^*$	0.979 (0.006)	-0.183 (0.145)	0.990 (0.006)	0.992 (0.005)	0.990 (0.007)	0.869 (0.076)		
$M/M^*$	0.039 (0.274)	0.035 (0.271)	n.a.	n.a.	0.028 (0.273)	0.035 (0.273)	0.048	
$P/P^*$	-0.349 (0.262)	0.134 (0.345)	0.999 (0.001)	0.999 (0.001)	0.936 (0.049)	0.977 (0.018)		

In order to put the results into a different perspective, Table 3 also presents the cross-country correlations for consumption, investment and output. As PPP holds for the assumption of PCP, there is complete risk sharing and consumption is perfectly correlated internationally, while production at home and abroad are uncorrelated according to these results. However, in the data, the (unconditional) cross-country correlation of output is higher than the one for consumption. This implication of the model is also present in international RBC-models, where this feature is commonly referred to as the ‘quantity anomaly’. For the assumption of complete LCP, however, the positive correlation of home and foreign consumption is lost. Instead, consumption in one country seems to increase at the expense of the other country’s consumption. Yet, production is highly correlated for complete LCP, as the expenditure-switching effect is extenuated. In the presence of technology shocks, the cross-country correlation is close to unity for all variables considered, and there is again no difference for LCP compared to PCP.

Note that the results reported in Tables 2 and 3 refer to the scenario where both countries are of equal size. The overall insights are unaffected when the home

country is small. This holds especially for the variability of the variables, which is hardly affected by the country size, as can be inferred from Table 4 below. Only the variability of investment is higher, probably because the countries reaction to foreign shocks increases.

Table 4: Standard deviations for a small country (n= 0.1)

Std. Dev. (in %)	Simulations small country						Data	
	Shocks to M		Shocks to A		M&A		1970:1-2005:4	
	PCP	LCP	PCP	LCP	PCP	LCP	US	G6
Output	0.200 (0.020)	0.183 (0.018)	1.784 (0.642)	1.770 (0.612)	1.775 (0.612)	1.780 (0.602)	1.567	0.960
Consumption	0.052 (0.006)	0.073 (0.009)	1.380 (0.559)	1.353 (0.536)	1.360 (0.546)	1.366 (0.533)	1.262	0.815
Investment	0.641 (0.061)	0.949 (0.109)	3.144 (0.958)	3.117 (0.917)	3.195 (0.928)	3.292 (0.905)	5.983	3.660
Money	1.661 (0.314)	1.655 (0.316)	0	0	1.654 (0.316)	1.660 (0.321)	2.598	1.365
CPI	0.318 (0.057)	0.192 (0.047)	1.559 (0.669)	1.543 (0.654)	1.570 (0.658)	1.565 (0.646)	1.434	
Nom. exch. rate	0.427 (0.080)	0.437 (0.083)	0.050 (0.019)	0.049 (0.018)	0.433 (0.084)	0.437 (0.082)	5.108	

However, the size of the country influences the resulting correlations of domestic savings and investment, which - for monetary shocks - is noticeably lower for the small country as can be seen in Table 5 below. This result is independent of the price-setting behavior of firms.

Table 5: Correlations for a small country (n=0.1)

Correlations	Shocks to M		Shocks to A		M&A		US	G6
	PCP	LCP	PCP	LCP	PCP	LCP		
$Y/Y^*$	0.045 (0.141)	0.965 (0.020)	0.674 (0.221)	0.666 (0.224)	0.662 (0.224)	0.674 (0.214)	0.655	
$C/C^*$	0.996 (0.003)	-0.147 (0.160)	0.999 (0.001)	0.999 (0.001)	0.999 (0.001)	0.995 (0.004)	0.509	
$I/I^*$	0.989 (0.003)	-0.154 (0.144)	0.994 (0.003)	0.995 (0.003)	0.994 (0.003)	0.899 (0.054)	0.545	
$S/I$	0.869 (0.035)	0.896 (0.026)	0.860 (0.090)	0.854 (0.092)	0.859 (0.088)	0.861 (0.084)	0.796	
$S^*/I^*$	0.999 (0.000)	0.999 (0.000)	0.999 (0.001)	0.999 (0.001)	0.999 (0.001)	0.999 (0.001)	0.796	
$M/M^*$	0.039 (0.272)	-0.039 (0.274)	n.a.	n.a.	0.035 (0.279)	0.041 (0.272)	0.048	
$P/P^*$	-0.261 (0.267)	0.156 (0.343)	0.999 (0.001)	0.999 (0)	0.942 (0.043)	0.980 (0.015)		

## 5 Conclusion

This paper addresses the issue of savings-investment correlations in response to monetary policy shocks. High correlations between domestic savings and investment both for cross-sectional and time-series data are a robust finding for most OECD countries, even for more recent data. As financial markets are more and more internationally integrated, the high correlations found should not conflict with international capital mobility. Therefore, researchers have been engaged in building models assuming perfect capital mobility which generate high correlations for domestic savings and investment in response to exogenous shocks. Baxter and Crucini (1993) present a two-country RBC-model with perfect capital mobility, where savings and investment are highly correlated in response to productivity shocks. However, empirical evidence by S.H. Kim (2001) shows that the unconditional correlations found in the data are not fully explained by shocks to productivity. In this paper, the question is raised whether monetary policy shocks can contribute to the savings-investment correlation and thus help to explain the Feldstein-Horioka puzzle. For this purpose, we investigate if a two-country model in the tradition of the New Open Economy Macroeconomics with capital mobility generates high correlations conditional on monetary policy, even for perfect capital mobility. We find that for the country originating the shock, savings and investment responses are highly correlated, independent of the price-setting behavior of firms. This finding is in line with the evidence from VARs for the US established by S. Kim (2001). The effect on foreign economy's saving and investment, however, highly depends on the price-setting strategy of firms. For producer-currency pricing, foreign savings and investment equally exhibit a high conditional correlation in response to monetary shocks. However, for the assumption of local currency pricing the induced correlation is heavily reduced and can even become negative.

In further simulations, it was also shown that in response to a whole sequence

of monetary shocks, the high correlations between domestic savings and investment persist, independent of the price-setting behavior of firms. Hence, the results presented in this paper support the idea that shocks to monetary policy can contribute to the unconditional correlation of domestic savings and investment found for many industrialized countries, even when capital is perfectly mobile across countries.



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