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

Caroline Schmidt*

Swiss Institute for Business Cycle Research

this Version December 2005
(first Version April 2002)

Abstract

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

Keywords: Savings Investment Correlations, Monetary Policy Shocks, Local-currency pricing, New Open Economy Macroeconomics, Feldstein-Horioka Puzzle

JEL Classification: E2; E52; F32

*Correspondence to: Caroline Schmidt, Konjunkturforschungsstelle der ETH Zürich, ETH Zentrum WEH, CH-8092 Zürich, Switzerland, Phone: ++41-44-632-6899, Fax: ++41-44-632-1218, E-mail: schmidt@kof.ethz.ch.

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 1960-74. 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 - many 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.[1] In subsequent cross-sectional studies Linda L. Tesar (1991) found 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 the long- and the 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 savings and investment are positively linked and the relationship

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[1]For a broader survey see e.g. Coakley et al. (1998).

is rather strong.[2]

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. Baxter and Crucini (1993) show, that the observed high correlation can be explained in a two-country real business cycle model with shocks to productivity as the major source of variability. Yet, shocks to productivity alone are not sufficient to explain the correlations found in the data. S.H. Kim (2001) uses panel data 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 significantly, 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 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 U.S. monetary policy shocks with vector autoregressions. In his extensive investigation, he also analyzes the effects on U.S. investment and savings. In response to both expansionary monetary policy shocks considered, U.S. 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 U.S. - that in the short run monetary policy will affect savings and investment in a similar way, and might therefore explain in part the correlations

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[2]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.

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 model with capital mobility in the tradition of the New Open Economy Macroeconomics (NOEM), a branch of research initiated by Obstfeld and Rogoff (1995).[3] It will be shown that this type of model is able to reproduce a correlation close to unity for domestic savings and investment, at least in the country of origin of the shock. In response to a surprise monetary impulse in the home economy, 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 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. Hence, the resulting correlation of savings and investment in the foreign country is heavily reduced for LCP and can even become negative.

The structure of the paper is as follows. In the next section, the model is derived, including the definition of savings, and the parameter values of the model are calibrated. Section 3 then presents the results. In a first part, the resulting impulse response functions for the relevant home and foreign variables in response to the monetary shock are illustrated and discussed. Impulse responses were computed for different relative sizes of the home economy, and for alternative price setting behav-

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[3]For an excellent survey of the research in this area see Lane (2001), but also Sarno (2001), Fendel (2002).

ior of firms. In a second part, the corresponding correlation coefficients for savings and investment responses but also for the international correlation of consumption and output are given and discussed. 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:

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

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 β denotes the representative home agent's subjective discount factor. The intertemporal elasticity

of substitution is given by $\frac{1}{\sigma}$, while ϵ is crucial for money demand elasticities.

The home agent faces the following intertemporal budget constraint:

$$P_t C_t + P_t V_t + M_t + B_{t+1}^h + e_t B_{t+1}^f + P_t \tau_t = (1 + i_t) B_t^h + (1 + i_t^*) e_t B_t^f + \Pi_t$$

$$+ W_t H_t + r_t^K P_t K_t + M_{t-1} \qquad (1)$$

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 Π_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.[4] 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:

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

Capital depreciates at the constant rate δ and increases with investment V_t but at a decreasing rate because of non-linear capital adjustment costs, which are governed

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[4]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.

by ϕ. Capital adjustment costs are incorporated in order to mitigate the response of 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^h_{t+1} and B^f_{t+1} 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:

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

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

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

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

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

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, $\frac{\phi}{2} \frac{K_{t+2}^2 - K_{t+1}^2}{K_{t+1}^2}$.[5] 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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[5]Note, however, that the expected real return on the capital stock $E_t \left[r_{t+1}^K \right]$ 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:

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

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.[6] 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 longs as the law of one price holds for all goods. The parameter μ 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:

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

Consumption of foreign goods is allocated analogously:

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

The parameter θ denotes the elasticity of substitution between different goods

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[6]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:

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

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

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:

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

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

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

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

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:

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

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

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 $1 - n$:

$$y_t^h(h) = n\left[c_t^h(h) + v_t^h(h)\right] + (1 - n)\left[c_t^f(h) + v_t^f(h)\right] \tag{14}$$

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:

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

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

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

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:

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

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

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

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:

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

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

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

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:

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

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:

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

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.[7] The decision will depend on which asset yields higher returns on interest, Real savings are then defined as:

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

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 γ 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 γ cannot adjust their prices.

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[7]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 firms 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: [8]

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

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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[8] 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, $\widetilde{P}_t^{h,PCP}(h)$, is then derived as a markup over a weighted average of expected future nominal marginal costs:

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

$D_{t,t+i}^{h,PCP}$ 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 $\widetilde{P}_t^{h,PCP}(h)$.

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

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

where $\Lambda_{t,t+i}$ is defined as above. $\widetilde{P}_t^{h,LCP,*}(h)$ 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 $\widetilde{P}_t^{h,LCP}(h)$ and $\widetilde{P}_t^{h,LCP,*}(h)$ set at time t.

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

derived as:

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

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:

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

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*}:

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

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:

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

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:

$$P_t^h = P_t^{h,PCP} \tag{29}$$

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

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

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:

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

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

country can be simplified to:

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

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:

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

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

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:

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

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:

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

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:

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

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:

$$Y_t^h = s^h Y_t^{h,LCP} + \left(1 - s^h\right) Y_t^{h,PCP} \qquad (37)$$

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

the home country can be written as:

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

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. 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 thirty-nine variables, given by X_t

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

The model is solved by linearizing around the symmetric steady state, where neither country owns net foreign assets.[9] I abstract from real growth due to technological progress and from growth in the monetary base. Hence, in equilibrium all nominal and real variables are constant.

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[9]For the solution of the model, the MATLAB code provided by Schmitt-Grohé and Uribe (2004) is employed.

2.5 Calibration

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).[10] For the benchmark calibration, I choose -0.39. The benchmark values for money demand elasticities imply that σ is about 2.5. The parameter θ 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 U.S., I assume $\theta = 10$. The capital share α 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 δ is set to 0.021, which implies an annual depreciation rate of about 10%, corresponding to the typical estimates for U.S. data. The steady state share of labour, $\overline{H}_0$, is set to 0.3. For simplicity, the relative preference parameter for real balances, χ, is assumed to be 1. The last two assumptions further determine η, 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 ϕ 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 μ is set equal to 1.5 as found by Hooper and Marquez (1995, Table 4.1) for the U.S. The degree of pricing

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[10]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.

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

σ	2.5	χ	1	θ	10
ϵ	2.5	δ	0.021	μ	1.5
ϕ	8	β	$\frac{1}{1.01}$	s	0/1
η	2.8	α	$\frac{1}{3}$	γ	0.75

3 Results

In this section, the impulse responses obtained for a 1% 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

Figure 1: Impulse responses to a permanent increase in home money supply for n = 0.5 and complete PCP
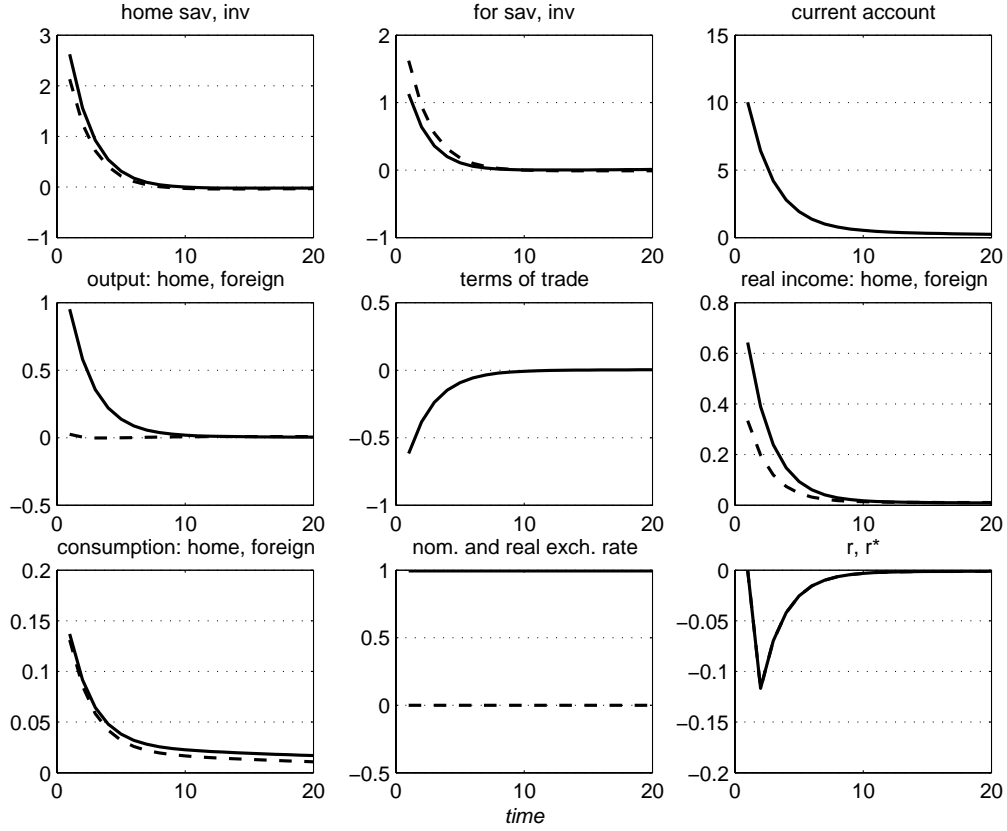
surplus measured in terms of steady-state income.

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

Figure 2: Impulse responses to a permanent increase in home money supply for n=0.5 and complete LCP
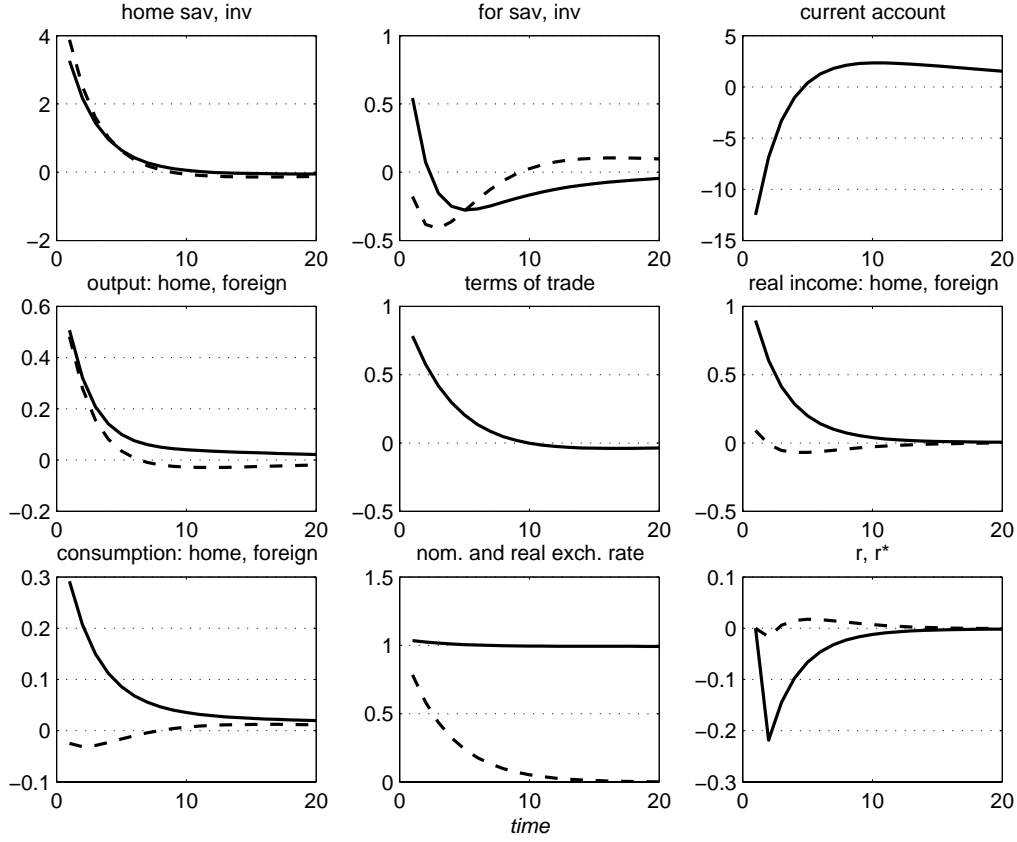
as, with prices pre-set in the producer's currency, home country's import prices rise in terms of the home currency. The increase in real income allows foreign agents to raise their savings even for the higher level of consumption. Yet, savings in the home economy rise by more than investment, and home 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 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 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 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

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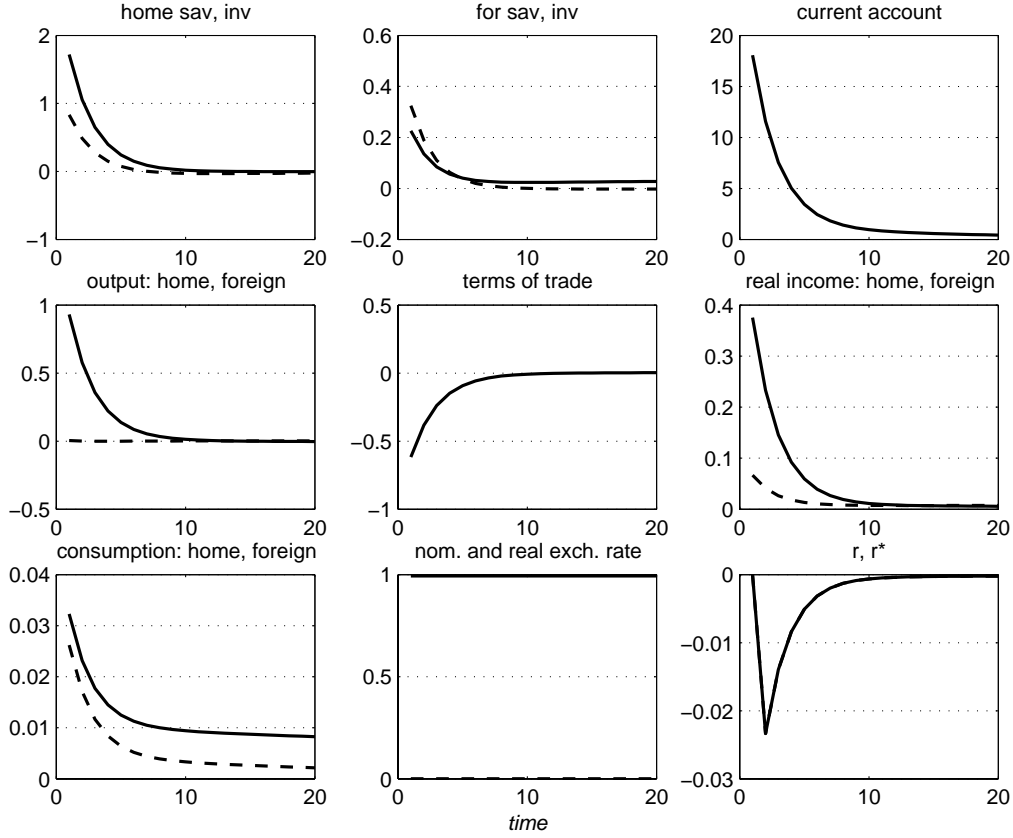

savings and investment rises, which is also reflected in the size of the current account surplus. Compared to the benchmark scenario where both countries are of equal size, the larger foreign country is now hardly affected by the home monetary expansion, although savings and investment still comove. 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.[11]

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

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[11]The import share is determined by the relative country size. I.e. if the foureign country represents 90% of the world economy, its import share is 10% in the steady state.

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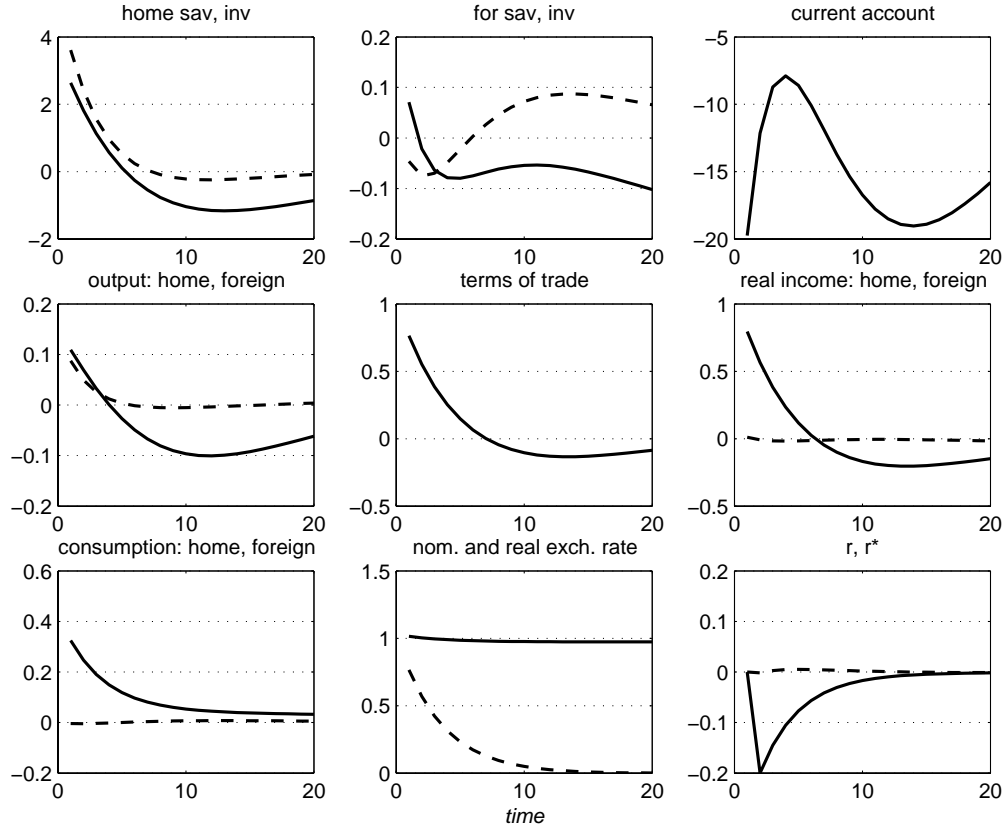

magnitude of the effects on the foreign economy are heavily reduced by the change in relative country size. Foreign real income hardly moves, as the little increase in foreign production is compensated by the deterioration of the terms of trade.

3.3 Large country

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 econ-

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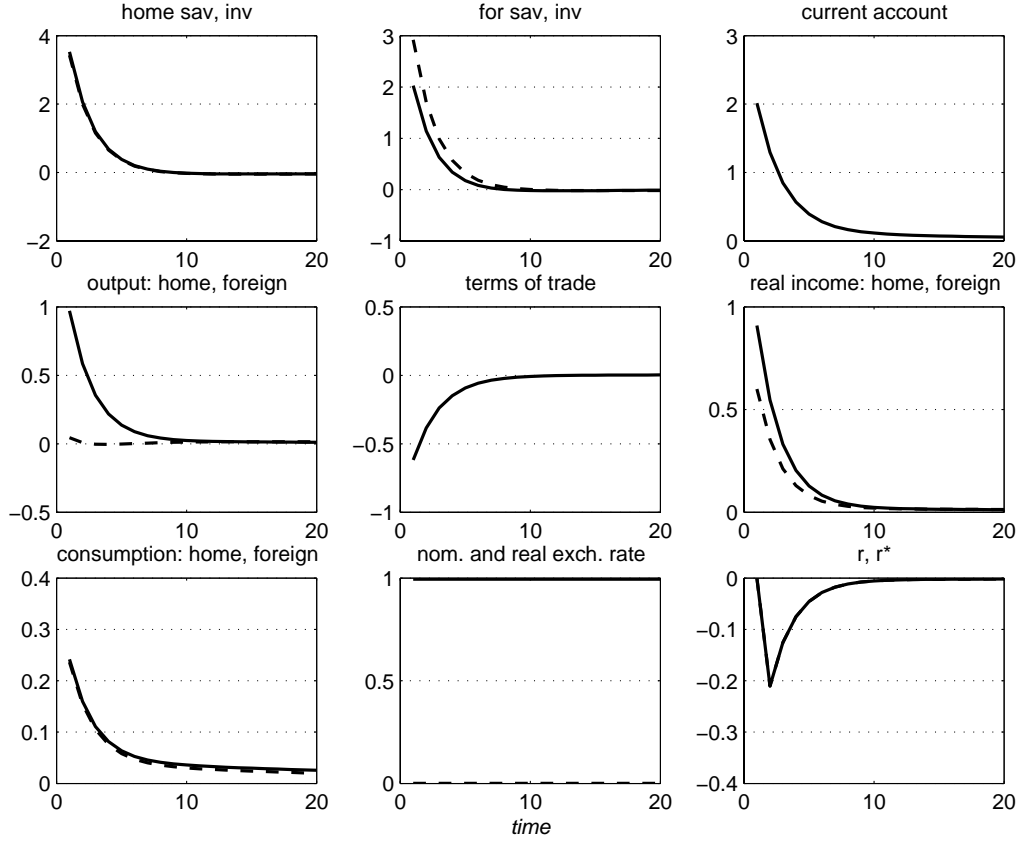

omy, savings and investment responses again exhibit high similarities, which should be reflected in high correlation coefficients. The impact on the foreign economy is heavily increased.

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.

To get a better picture of the simultaneous correlations between domestic savings and investment, the corresponding correlation coefficients are presented below.

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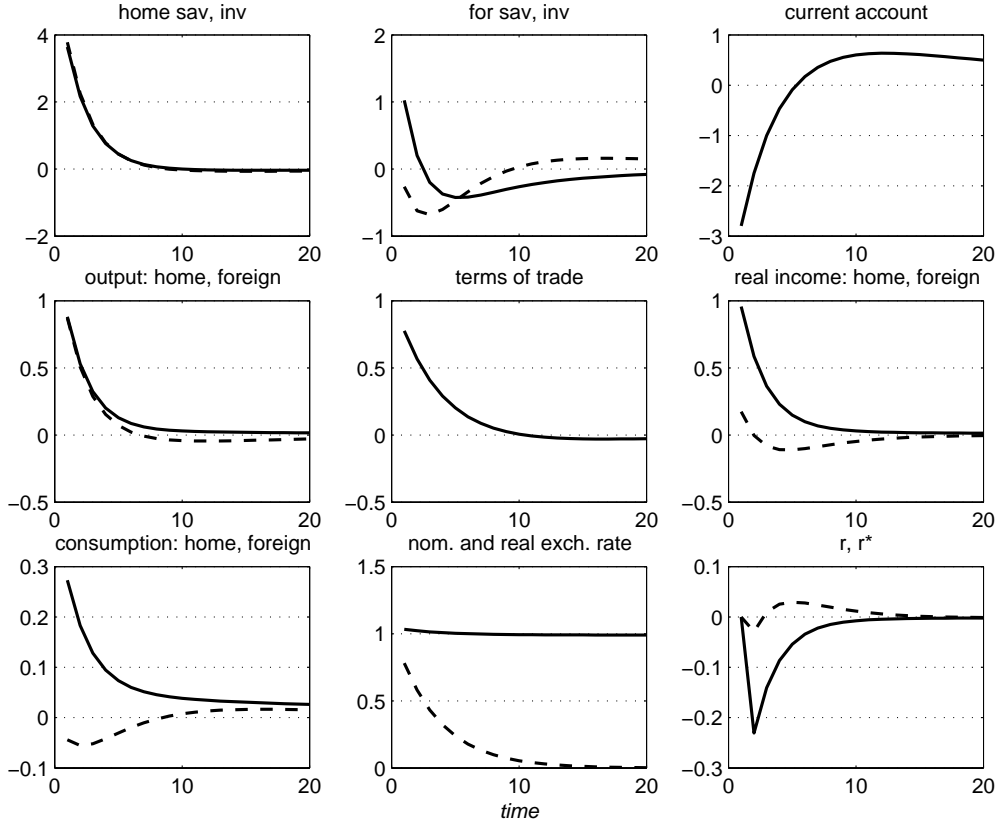
3.4   Correlation coefficients

The correlation coefficients of real domestic savings and investment in both the home and the foreign economy for all six different scenarios are given in Table 2. For the home economy, the correlation coefficient between domestic savings and investment in response to a home monetary expansion is almost unity for all cases considered. This finding seems to support the VAR results by Kim (2001), which indicate a high co-movement in U.S. savings and investment in response to domestic monetary policy shock. In contrast, the correlation between savings and investment in the foreign economy in response to a monetary policy shock in the home economy crucially depends on the way firms set their export prices. If all prices are set in the producer's currency, savings and investment equally exhibit a correlation close

to unity. Yet, if firms set their export prices in the local currency of the market, there is no positive correlation. If the foreign economy is big compared to the home economy, the correlation even becomes negative. These contradictory results ask for empirical evidence regarding the conditional effects of monetary policy on foreign savings and investment. Results in this regard will help to discriminate between the two alternative price-setting assumptions.

Table 2: Savings Investment Correlations

	Equal size		Small country		Large country	
	PCP	LCP	PCP	LCP	PCP	LCP
S/I	0.9999	0.9996	0.9993	0.9851	1.0000	1.0000
S^*/I^*	0.9991	0.0351	0.9971	-0.4037	0.9993	-0.0187

In order to put the results into a different perspective, Table 3 also presents some cross-country correlations for consumption 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 correlated as well, the degree is substantially lower. However, in the data, cross-country correlations of output are substantially higher than the ones 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 perfectly correlated for complete LCP, as the expenditure-switching effect is extenuated. Although these results are somewhat more in line with the empirical evidence regarding the cross-country correlation of output, it is not possible to discriminate between LCP and PCP on this ground. To draw any further conclusions, at least an investigation of the cross-country correlation effects of productivity shocks for both price-setting assumptions would be necessary.

Table 3: Cross Country Correlations for Output and Consumption

	Equal size		Small country		Large country	
	PCP	LCP	PCP	LCP	PCP	LCP
Y/Y^*	0.3750	0.9971	0.3587	0.9268	0.3835	0.9993
C/C^*	1.0000	-0.8690	1.0000	-0.9302	1.0000	-0.8247

4   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 U.S. 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.

To conclude, 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.

It remains open for future research to analyze how the model economies react in response to a sequence of monetary shocks, and how the simultaneous effects of technology shocks impact on the results. In this context, the savings-retention coefficients can be estimated and compared to the estimates of Feldstein and Horioka (1980) and others. Furthermore, these simulations will allow to make more qualified statements on the quantity anomaly regarding the cross-country correlations of output and consumption.

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