Dollar Pricing, the Euro and Monetary Policy Transmission

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Abstract

This paper deals with the international transmission of European and U.S. monetary shocks. First, we study how monetary shocks are transmitted in the case where all export prices are set in U.S. dollars. It is shown that U.S. shocks generate positive comovements of output across regions. On the other hand, European shocks generate negative comovements. Second, we study how the emergence of the euro as an international currency may change the international transmission of monetary shocks. If the role of the euro in international trade increases, this has significant implications for the international transmission of monetary shocks. For example, the stimulate effects of monetary shocks on the region's own output are reinforced and the positive effect of U.S. monetary shocks on European output reverses to negative.

Keywords: New open economy macroeconomics, monetary policy, international policy transmission

JEL classification: F41, F42, F30

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1 Introduction

The purpose of this paper is twofold. First, we study the international transmission of European and U.S. monetary policy shocks in the case where all export prices are set in U.S. dollars. Second, we study how the emergence of the euro as an international currency may change the international transmission of monetary shocks.

One issue that has received considerable attention in open economy macroeconomics is the international transmission of monetary policy. The recent "new open economy macroeconomics" (NOEM) literature[1] has shown that the transmission of monetary shocks across countries is predicated by the pass-through of exchange rate changes to import prices. The degree of exchange rate pass-through and the elasticity of substitution between domestic and foreign goods determine the strength of the expenditure switching effect. The smaller the effect of exchange rate changes on relative prices, the smaller the expenditure switching effect.[2]

Most of the contributions that address the international transmission of monetary shocks, including the seminal Redux model of Obstfeld and Rogoff (1995), assume that export prices are set in the producer's currency. The literature often refers to this case as "producer currency pricing" (PCP). In this case, there is a complete pass-through of exchange rate changes to import prices. On the other hand, among others Betts and Devereux (1996, 2000, 2001) have assumed that export prices can be set in the consumers' currency. This case is often referred as "local currency pricing" (LCP). In this case, exchange rate pass-through to import prices is zero. In Betts and Devereux (2000), the authors incorporate LCP into the Obstfeld-Rogoff (1995) model. They show that the degree of short-run exchange rate pass-through is crucial for the international transmission of monetary shocks.

One limitation of the recent literature is that it has focused primarily on the case where exchange rate pass-through is symmetric, i.e. the same for both countries. A third possibility, that all export prices are set in one currency, has received notable less attention despite it being "probably the most relevant from an empirical viewpoint" (Corsetti – Pesenti 2005, 22). We refer to this case as "dollar pricing" (DP). In the dollar pricing case, exchange rate pass-through is asymmetric. If all firms set export prices in U.S. dollars, exchange rate pass-through is zero in the U.S. and one in Europe. How are monetary shocks transmitted under DP? One purpose of this paper to analyze the international transmission of monetary shocks in

[1] Lane (2001) provides an extensive survey of the NOEM literature. Lane and Ganelli (2003) focus on the pass-though debate and the role of the current account and net foreign assets in adjustment dynamics.

[2] Engel (2002), Obstfeld (2002) and Obstfeld and Rogoff (2000) discuss how low pass-through of exchange rate changes to consumer prices affect the expenditure switching effect.

the DP case.

The single European currency was – and is – a fundamental economic change. As mentioned by Devereux et al. (2003, 223), the academic literature has abundantly discussed the question of whether Europe is an optimal currency area. No doubt a major effect of the euro was to permanently fix exchange rates in Europe. The single European currency can also be a different change: the euro may become an international currency.[3]

In this paper, we concentrate on one question that has attracted surprisingly little attention in the literature. If the euro becomes an international currency, how will this affect the international transmission of European (the euro zone's, to be precise) and U.S. monetary policies? The emergence of the euro is likely to alter international price setting. For example, Devereux et al. (2003, 223) emphasize, that: "While at present world trade and financial flows are carried out predominantly in U.S. dollars, the relative importance of the dollar may diminish as the euro becomes more widely acceptable in international transactions." The emergence of the euro can alter the pricing behavior of both European and U.S. firms. Our conjecture is that the emergence of the euro leads to a situation where more European exports are invoiced in euros, but it does not alter the pricing behavior of U.S. firms. Therefore, we study how the transition from DP to PCP affects the international transmission of European and U.S. monetary policies.

As mentioned, this paper has two main purposes. The first is to study the international transmission of European and U.S. monetary shocks in the DP case. The second is to study how the emergence of the euro affects the international transmission of monetary shocks. To address these research questions, this paper develops a model based on Betts and Devereux (2000). As indicated above, Betts and Devereux build a version of the Obstfeld-Rogoff (1995) model in which a fraction of firms set export prices in the consumers' currency. We make two modifications to their model. The first is the use of staggered price setting.[4] The second is that only a fraction of foreign/European firms set prices separately for two markets.

There is a substantial literature on the international effects of monetary shocks, including innovative papers by Obstfeld and Rogoff (1995) and Betts and Devereux (2000). In this context, other relevant papers include Sutherland (1996) that introduces staggered price setting into the Obstfeld-Rogoff model. The model that is developed in this paper is in one case, where all export prices are set in the producer's currency, rather identical to the model by Sutherland. The models by Senay (1998) and Betts and Devereux (2001) are also relevant. Both papers develop a model that allows for staggered price setting and market segmentation. The authors additionally assume

[3] See e.g. Portes and Rey (1998).

[4] "The use of a staggered price setting structure allows for richer dynamic effects of monetary policy than those found in the models with one-period advanced price-setting that are common in the literature" Gali and Monacelli (2005, 707).

that exchange rate pass-though is symmetric.

Analyses of the international transmission of monetary shocks in the case where exchange rate pass-through is asymmetric include Corsetti and Pesenti (2005) and Schmidt (2005). The analysis of Corsetti and Pesenti (2005) is elegant but somewhat restricted due to the fact that the elasticity of substitution between home and foreign goods is set to unity. Schmidt (2005) develops a model that uses staggered price setting and allows for asymmetric exchange rate pass-through.[5] A limitation of these papers is that only the effects of domestic (U.S. – in this case) monetary shocks are analyzed. The assumption of dollar pricing is also used in the paper by Devereux et al. (2003). Interestingly, they explore the relationship between the euro and the international transmission of monetary shocks. However, the focus of their paper is different from ours, they focus on the question of how the euro may change the sensitivity of consumer prices in Europe to exchange rate changes. In addition, they conjecture that the influence of the euro is to change the pricing behavior of U.S. firms.

The analysis of this paper predicts that, in the DP case, the impact of U.S. monetary shocks on European output and consumption is positive. On the other hand, European monetary shocks have negative implications for the U.S. economy. The differences in the international transmission of monetary shocks stem from asymmetric exchange rate pass-through. Another finding is that if the role of the euro in international trade increases, the stimulate effects of monetary shocks on the region's own output are reinforced. A sting in the tail is that the increase in the effectiveness of monetary shocks comes at the expense of the other region's output. In particular, the model predicts that the emergence of the euro can reverse the positive effect of U.S. monetary shocks on European output to negative.

The paper is structured as follows. Section 2 discusses how the emergence of the euro as an international currency may change the currency denomination of international trade. Section 3 introduces the model and derives the equilibrium conditions. Section 4 uses the model to study the international transmission of monetary shocks under DP. Section 5 analyzes how the emergence of the euro affects the international transmission of monetary shocks. Section 6 presents conclusions.

[5] The model developed in this paper differs from the model by Schmidt (2005) in many ways. In this paper, in contrast to Schmidt (2005), there is no home bias in consumption, we do not allow for different elasticities of substitution across and within countries, we abstract capital formation and there is only one international traded asset.

2 The Emergence of the Euro as an International Currency

2.1 The Role of the Euro in International Trade

A good question in international macroeconomics is "if output prices are preset in nominal terms, in what currency are they denominated?" (Obstfeld and Rogoff 2000, 118). But let us put aside for a moment the question of what determines the choice of currency of price setting (invoicing currency). Let us briefly look at the evidence. A report by ECU institute (1995, 73) concludes that: "The national currency remains the principal currency used for the denomination of national exports," as cited by Obstfeld and Rogoff (2000). However, the U.S. is an exception, with 92 % of exports and 80 % of imports invoiced in dollars. Thus "there is asymmetry such that U.S. exports to Europe are heavily invoiced in dollars, but European exports to the U.S. are also invoiced in dollars" (Devereux et al. 2003, 224). Hence, it is essential to study the international transmission of monetary shocks in the case where all export prices are set in dollars.

The euro has started to change the invoicing of international trade. In the review of the international role of the euro, the ECB (2005, 29) notes that: "The use of the euro as a currency of the settlement or invoicing of international trade transactions... ...has shown a notable increase in recent years." The ECB's review also points out: "Concerning exports, in 2004 the share of the euro in extra-euro area exports increased for both goods and services." For example, in 2001 49 % of German exports to the extra-euro area were invoiced in euros (or in Deutsche Marks), by 2004 the share had increased to 61.1 %.

2.2 The Euro and the Choice of Invoicing Currency

Returning to the question of what determines the choice of currency in which international trade is be to invoiced. The question is complex and we do not try to give a comprehensive answer to this question. Instead, we highlight the key results of the literature that are relevant to the theme of this paper.

Swoboda (1968, 1969) emphasized the role of transaction costs in trading in different currencies to be an important factor in the choice of invoicing currency. He argued that the dollar in much used in international trade as a vehicle currency because it is highly liquid currency with low transaction costs. The euro is highly liquid currency with low transaction costs and thus the use of the euro in international trade is likely to increase.

The choice of invoicing currency affects the risks arising from exchange rate fluctuations. Partial equilibrium models such as Giovannini (1988), Donnenfeld and Zilcha (1991) and Bacchetta and van Wincoop (2005) show that there is trade-off between demand and price uncertainty that the ex-

porter faces. If PCP is chosen, there is uncertainty about demand because prices abroad move one-to-one with the exchange rate. Exchange rate fluctuations change the quantity demanded. If LCP is chosen, there is no demand uncertainty, but there is uncertainty about the price when converted back to the exporter's currency. Bacchetta and van Wincoop (2005) show that, for a profit-maximizing firm, high product differentiation (a low price elasticity of demand) makes PCP more attractive. The emergence of the euro as an international currency can imply that European firms are able to avoid the exchange rate risk.

Bacchetta and van Wincoop (2005) show that the market share of the exporting country is also crucial for the pricing decision. The higher the market share of an exporting country, the more likely it chooses PCP. If the country is large enough and firms coordinate their choice of invoicing currency, they all prefer PCP. The relative price of the firm's output is less sensitive to the exchange rate, reducing demand uncertainty, the more of its competitors choose the same invoicing currency.

Bacchetta and van Wincoop (2005) also study the effect of a monetary union on the choice of invoicing currency in international trade, providing important insights about the implications of the European Monetary Union (EMU). One of the main results is that: "If a set of countries form a monetary union they are more likely to invoice in their own currency" (Bacchetta and van Wincoop 2005, 306). EMU created a large region, with a larger market share than that of any of single European country. Therefore, EMU is likely to lead more invoicing in euros than in the currencies that were replaced by the euro. In their model, it is possible that before EMU all European exporters invoice in foreign currency while after EMU there is a Nash equilibrium where all exporters invoice in euros. Certainly, the emergence of the euro as an international currency is a long-run issue.

The increase in the use of the euro in international trade is likely to continue. For the reasons discussed above, the share of the euro in the invoicing of European exports is likely to increase. The findings of Bacchetta and van Wincoop (2005) suggest that, after the creation of a monetary union, also imports by the monetary union are more likely to be invoiced in the union's currency. However, we conjecture that U.S. firms will not change - much - their export pricing; the use of the euro in the exports of third countries likely is to increase substantially more. Besides, it is highly unlike that the emergence of the euro as an international currency would be so powerful that both European and U.S. firms start to invoice their exports in euros. It would turn the world upside down.

3 The Model

In this section, we develop a fairly standard NOEM model. As mentioned, the model is based on Betts and Devereux (2000). We extend the Betts-Devereux model by allowing a staggered price setting framework. In addition, we assume that only a fraction of European firms price-discriminate across regions.

3.1 Region Size and Market Structure

The world economy is made up of two regions, the U.S. and Europe (the euro zone). The world economy consists of the governments and a continuum of households and firms. The world size normalized to one, and consider that households and firms over the [0,n) interval are in the U.S., while households and firms over the [n,1] interval are in Europe. Within each region, every household owns an equal share of all domestic firms.

As mentioned, the report by ECU Institute (1995) suggests that both U.S. exports to Europe and European exports to the U.S. are mainly invoiced in dollars. We assume that all U.S. firms set a unified price across the two regions. U.S. firms set prices in U.S. dollars and let prices in Europe move one-to-one with the exchange rate. Our conjecture is that more European firms will set export prices in euros. Hence, we allow for two types of European firms. First, a fraction s of European firms price-discriminate across regions. These firms set prices separately for the U.S. and European market and set prices in the local currency of the customer. Hence, we dub these firms as "European LCP firms". Second, the remaining $1-s$ of European firms, like U.S. firms, set a unified price across the two regions. These firms set prices in euros and let prices in the U.S. move one-to-one with the exchange rate. Because these firms set export prices in the producer's currency, we dub these firms as "European PCP firms".

Two special cases are worth observing. When $s = 0$, all export prices are set in dollars. When $s = 1$, export prices are set in the producer's currency. As was mentioned, we suppose that the emergence of the euro as an international currency implies that more European firms set export prices in euros. For simplicity, we assume that this implies a transition from DP to PCP.

3.2 Households

3.2.1 Preferences

Preferences are identical across regions. The lifetime utility of a representative U.S. household, indexed by z, is given by

$$U_t(z) = \sum_{s=t}^{\infty} \beta^{s-t} \left[\log C_s + \frac{\chi}{1-\varepsilon} \left(\frac{M_s}{P_s} \right)^{1-\varepsilon} - \frac{\ell_s(z)^2}{2} \right]. \tag{1}$$

Here β is the discount rate, C is a consumption index (defined below), ε and χ are positive parameters, M is the nominal balances and P is the consumer price index (defined below). The variable ℓ is the amount of labour supplied by a representative U.S. households. The consumption index is

$$C = \left[\int_0^1 c(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}},$$

where $c(z)$ is consumption of good z and $\theta > 1$ measures the elasticity of substitution between differentiated goods (and the price elasticity of demand). Let p_t represent dollar prices, while prices denoted by q_t represent euro prices. The consumer price index is

$$P_t = \left[\int_0^n p_t(z)^{1-\theta} dz + \int_n^{n+(1-n)s} p_t(z^*)^{1-\theta} dz + \int_{n+(1-n)s}^1 (E_t q_t(z^*))^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

Here $p(z)$ is the dollar price of U.S. good z, $p(z^*)$, is the dollar price of European good z^* and $q(z^*)$ is the euro price of a European good. The variable E is the exchange rate, the dollar price of the euro. Similarly, the European price index is

$$P_t^* = \left[\int_0^n (p_t(z)/E_t)^{1-\theta} dz + \int_n^1 q_t(z^*)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

3.2.2 Budget Constraints and First-Order Conditions

Households receive a wage income, dividends from domestic firms, nominal transfers from the government and purchase consumption goods. Households can hold two assets, domestic money and international assets. We assume that the only internationally traded asset is a riskless nominal bond, denominated in the dollar. A representative U.S. household maximizes the utility function (1) subject to the budget constraint

$$M_t + \delta_t D_t = D_{t-1} + M_{t-1} + w_t \ell_t - P_t C_t + \pi_t + P_t \tau_t. \tag{2}$$

Here δ_t is the nominal price of the bond ($\delta_t = (1+i_t)^{-1}$, where i_t is the nominal U.S. interest rate) that pays one dollar in period $t+1$ and D_t is the bond holdings at the beginning of period t, w is the nominal wage and π denotes the nominal profits (dividends) of U.S. firms. The government repays all seignorage revenues to households in the form of lump sum transfers. These transfer are denoted by τ.

In Europe, the budget constraint is

$$M_t^* + \delta_t^* \frac{D_t^*}{E_t} = \frac{D_{t-1}^*}{E_t} + M_{t-1}^* + w_t^* \ell_t^* - P_t^* C_t^* + \pi_t^* + P_t^* \tau_t^*, \tag{3}$$

This implies that the realized return in euros on the international bond at the beginning of period t is $(1+i_t) E_{t-1}/E_t$. The global asset-market-clearing condition requires $nD_t + (1-n) D_t^* = 0$.

The first-order conditions for the maximization problems for U.S. and European households are[6]

$$\delta_t P_{t+1} C_{t+1} = \beta P_t C_t, \tag{4}$$

$$\delta_t^* P_{t+1}^* C_{t+1}^* E_{t+1} = \beta P_t^* C_t^* E_t, \tag{5}$$

$$\ell_t = \frac{w_t}{C_t P_t}, \tag{6}$$

$$\ell_t^* = \frac{w_t^*}{C_t^* P_t^*}, \tag{7}$$

$$\frac{M_t}{P_t} = \left(\frac{\chi C_t}{1-\delta_t} \right)^{\frac{1}{\varepsilon}}, \tag{8}$$

$$\frac{M_t^*}{P_t^*} = \left(\frac{\chi C_t^*}{1 - \frac{\delta_t^* E_{t+1}}{E_t}} \right)^{\frac{1}{\varepsilon}}. \tag{9}$$

Equations (4) and (5) are the Euler equations for the intertemporal allocation of consumption. Equations (6) and (7) govern the optimal labour supply, it depends on the real wage and the level of real consumption. Equations (8) and (9) show that the demand for money is a positive function of consumption and a negative function of the interest rate.

3.3 Monetary Policy

We abstract from government spending so the transfers to households are given by

$$\tau_t = \frac{M_t - M_{t-1}}{P_t}. \tag{10}$$

[6] The usual transversality condition applies. Since the model hitherto is identical to that of Betts and Devereux (2000), the first order conditions are the same as in their model.

The money supply is assumed to follow a first-order autoregressive process

$$\hat{M}_t = \rho \hat{M}_{t-1} + \epsilon_{M,t},$$

where percentage changes from the baseline are denoted by hats and $\epsilon_{M,t}$ is an unpredictable shift in the money supply. As usual, we consider the Dornbusch (1976) experiment of an unanticipated permanent rise in the money supply, thus we assume $\rho = 1$. In Europe, the transfers to households and monetary policy are completely analogous to those of the U.S.

3.4 The Terms of Trade and the Real Exchange Rate

For future reference, we define the terms of trade and the real exchange rate. The U.S. export price index is given by

$$\Gamma_t(z) = \left[\int_0^n p_t(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

In the same way, the European export price index (the U.S. import price index) is given by

$$\Gamma_t^*(z^*) = \left[\int_n^{n+(1-n)s} \left(p_t(z^*)/E_t\right)^{1-\theta} dz + \int_{n+(1-n)s}^{1} q_t(z^*)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

Thus the U.S. terms of trade, the relative price of U.S. exports in terms of U.S. imports, can be written as

$$TOT_t = \frac{\Gamma_t(z)}{E_t \Gamma_T^*(z^*)}.$$

The real exchange rate is defined as

$$\text{Real exchange rate} = \frac{E_t P_t^*}{P_t}.$$

3.5 Firms

3.5.1 Technology and Profits

Each firm produces a differentiated good. The production function is linear in labour input

$$y_t(z) = \ell_t(z),$$

where $y(z)$ is the total output of firm z and $\ell(z)$ is labour input used by firm z. The total output of a European LCP firm is divided between output sold in the U.S. denoted by $v^*(z^*)$, and output sold in Europe, denoted by

$x^*(z^*)$. The profits of a European LCP firm, a European PCP firm and a U.S. firm, respectively, are given by

$$\pi_t^{LCP}(z^*) = \left(p_t(z^*) v_t^*(z^*)\right)/E_t + q_t(z^*) x_t^*(z^*) - w_t^* \ell_t^*(z^*),$$

$$\pi_t^{PCP}(z^*) = q_t(z^*) y_t^*(z^*) - w_t^* \ell_t^*(z^*),$$

$$\pi_t(z) = p_t(z) y_t(z) - w_t \ell_t(z).$$

The demand functions are

$$v_t(z^*) = \left(\frac{p_t(z^*)}{P_t}\right)^{-\theta} nC_t, \tag{11}$$

$$x_t(z^*) = \left(\frac{q_t(z^*)}{P_t^*}\right)^{-\theta} (1-n) C_t^*, \tag{12}$$

$$y_t^*(z^*) = \left(\frac{E_t q_t(z^*)}{P_t}\right)^{-\theta} nC_t + \left(\frac{q_t(z^*)}{P_t^*}\right)^{-\theta} (1-n) C_t^*, \tag{13}$$

$$y_t(z) = \left(\frac{p_t(z)}{P_t}\right)^{-\theta} nC_t + \left(\frac{p_t(z)}{E_t P_t^*}\right)^{-\theta} (1-n) C_t^*. \tag{14}$$

Equations (11) and (12) represent the demand functions for a European LCP firm in the U.S. and Europe, respectively. Equations (13) and (14) represent the demand function for a European PCP firm and a U.S. firm, respectively. Making use of the demand functions and the fact that the nominal marginal cost equals the nominal wage, the profits of the firms can be written as

$$\begin{aligned} \pi_t^{LCP}(z^*) &= \left[\left(\frac{q_t(z^*)}{P_t^*}\right)^{-\theta} (1-n) C_t^*\right] \left(q_t(z^*) - w_t^*\right) \\ &\quad + \left[\left(\frac{p_t(z^*)}{P_t}\right)^{-\theta} nC_t\right] \left(\frac{p_t(z^*)}{E_t} - w_t^*\right), \end{aligned} \tag{15}$$

$$\pi_t^{PCP}(z^*) = \left[\left(\frac{q_t(z^*)}{P_t^*}\right)^{-\theta} (1-n) C_t^*\right] \left(q_t(z^*) - w_t^*\right) + \left[\left(\frac{E_t q_t(z^*)}{P_t}\right)^{-\theta} nC_t\right] \left(q_t(z^*) - w_t^*\right),$$

$$\pi_t(z) = \left[\left(\frac{p_t(z)}{P_t}\right)^{-\theta} nC_t\right] \left(p_t(z) - w_t\right) + \left[\left(\frac{p_t(z)}{E_t P_t^*}\right)^{-\theta} nC_t\right] \left(p_t(z) - w_t\right).$$

3.5.2 International Price Setting

In the absence of nominal rigidities, a European LCP firm maximizes (15) with respect to $q_t(z^*)$ and $p_t(z^*)$. The pricing rule is given by

$$p_t(z^*) = E_t q_t(z^*) = \frac{\theta}{\theta - 1} w_t^*.$$

The optimal price is just a constant markup over marginal costs. Since the price elasticity of demand is the same in both markets, the law of one price (LOOP) holds.

We now turn to staggered price adjustment. We consider a discrete-time version of Calvo (1983). Each period t, there is a probability γ that a firm has no opportunity to change its price. Firms set prices to maximize expected discounted profits taking into account the expected time until they will be able to change their prices. For example, the objective of a European LCP firm is

$$\max_{p_t(z^*),q_t(z^*)} V_t(z^*) = \sum_{s=t}^{\infty} \gamma^{s-t} \zeta^*_{t,s} \pi_t^{LCP}(z^*), \tag{16}$$

where $\zeta^*_{s,t} = \Pi_{j=s}^{t} \left(1 + i_j^*\right)^{-1}$ is the discount factor between time t and time s. The first-order conditions are

$$p_t(z^*) = \left(\frac{\theta}{\theta - 1}\right) \frac{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta^*_{t,s} C_s \left(\frac{1}{P_s}\right)^{-\theta} w_s^*}{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta^*_{t,s} C_s \left(\frac{1}{P_s}\right)^{-\theta} / E_t}.$$

$$q_t(z^*) = \left(\frac{\theta}{\theta - 1}\right) \frac{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta^*_{t,s} C_s^* \left(\frac{1}{P_s^*}\right)^{-\theta} w_s^*}{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta^*_{t,s} C_s^* \left(\frac{1}{P_s^*}\right)^{-\theta}}.$$

These equations are a bit uninformative. We can use these equations to obtain difference equations to describe the price setting strategy:

$$\hat{p}_t(z^*) = \beta\gamma \hat{p}_{t+1}(z^*) + (1 - \beta\gamma)\left(\hat{w}_t^* + \hat{E}_t\right),$$

$$\hat{q}_t(z^*) = \beta\gamma \hat{q}_{t+1}^*(z) + (1 - \beta\gamma)\hat{w}_t^*. \tag{17}$$

The price setting strategy is forward-looking. A LCP firm sets price, for the good sold in Europe, as a markup over a weighted average of current and expected nominal marginal costs. The price of the same good in the U.S. depends also on the exchange rate. The price setting problem facing a European PCP firm is almost identical to that of a LCP firm, albeit it sets only one price. However, the price setting strategy of a PCP firm is identical to (17). By the same token, the price setting strategy of a U.S. firm is to set price that a markup over a weighted average of current and expected nominal marginal costs

$$\hat{p}_t(z) = \beta\gamma \hat{p}_{t+1}(z) + (1 - \beta\gamma)\hat{w}_t.$$

3.6 A Symmetric Steady State and Equilibrium

All firms within a region are symmetric, which implies that every firm which alter its price in period t sets the same price and produces the same output. The law of large number implies that a fraction γ of goods prices remain unchanged, while the remaining $1-\gamma$ of firms get to set new prices. Thus the price indexes can be written as

$$P_t = \left[\begin{array}{c} n(1-\gamma)\sum_{s=0}^{\infty}\gamma^s p_{t-s}(z)^{1-\theta} + [(n+(1-n)s)-n](1-\gamma)\sum_{s=0}^{\infty}\gamma^s p_{t-s}(z^*)^{1-\theta} + \\ [1-(n+(1-n)s)](1-\gamma)\sum_{s=0}^{\infty}\gamma^{s-t}(E_{t-s}q_{t-s}(z^*))^{1-\theta} \end{array} \right]^{\frac{1}{1-\theta}},$$

$$P_t^* = \left[n(1-\gamma)\sum_{s=0}^{\infty}\gamma^s (p_{t-s}(z)/E_{t-s})^{1-\theta} + (1-n)(1-\gamma)\sum_{s=0}^{\infty}\gamma^s q_{t-s}^*(z^*)^{1-\theta} \right]^{\frac{1}{1-\theta}}.$$

In a steady state, all exogenous variables are constant. Because consumption is constant, the steady-state world interest rate $\bar{\imath}$ (steady state values are marked by overbars) is tied down by the consumption Euler equations (4) and (5): $\beta = \bar{\delta} = (1+\bar{\imath})^{-1}$.

The consolidated budget constraints of the U.S. and European economies, respectively, are given by

$$\delta_t D_t = D_{t-1} + p_t(z)\, y_t(z) - P_t C_t,$$

$$\begin{aligned} -\frac{n}{1-n}\delta_t^* \frac{D_t}{E_t} &= -\frac{n}{1-n}\frac{D_{t-1}}{E_t} + (1-s)\, q_t(z^*)\, y_t^*(z^*) \\ &\quad + s\left(p_t^*(z^*)\, x_t^*(z^*) + \frac{p_t(z^*)\, v_t^*(z^*)}{E_t} \right) - P_t^* C_t^*. \end{aligned}$$

As standard in the literature, we log-linearize the model around the initial symmetric steady state with $\bar{D}_0 = \bar{D}_0^* = 0$. Then the model is analyzed in terms of percentage deviations around this steady state. Equilibrium is sequences of variables that (i) clear the labour, goods and money markets in each region in each period, (ii) satisfy the optimality conditions for consumption evolution, (iii) satisfy the optimal pricing rules and (iv) satisfy the intertemporal budget constraints.

4 The International Transmission of Monetary Shocks under Dollar Pricing

4.1 Calibration

The calibration of the model follows Sutherland (1996), with one exception. The reasoning behind the calibration is as follows. We interpret periods as quarters. Therefore, β is set to $1/1.01$, which implies about 4 percent annual real interest rate.[7] Parameter ε is set to 9, which implicates that the

[7] Sutherland sets $\beta = 1/1.05$. Lowering β causes minor quantative changes.

consumption elasticity of money demand is 1/9 and the interest elasticity of money demand is $-1/9$. The elasticity of substitution between goods θ is set to 6, which means a 20 percent markup in the steady state. Parameter γ is set equal to 0.5, this implies an average delay between price adjustment of six months. Parameter χ is set to 1.

4.2 U.S. Monetary Shocks

In this section we study the international transmission of a U.S. monetary shock in the case where all export prices are set in dollars ($s = 0$). Consider the Dornbusch exercise of an unanticipated permanent rise in the relative U.S. money supply. Figure 1 shows the dynamic responses of key macroeconomic variables to 1 percent rise in the U.S. money supply. In all Figures, the vertical axes show percentage deviations from the initial steady state. Because bond holdings are normalized by initial consumption, the bond holdings of U.S. households show deviation as a percentage of initial consumption level.

Figure 1 demonstrates that a U.S. monetary shock generates not only a positive comovement of output across regions, but also a positive comovement of consumption across regions. This is in contrast to virtually all NOEM models, but consistent with Schmidt (2005). Betts and Devereux (2000, 2001) show that, in the LCP case, monetary shocks tend to generate large negative comovements of consumption across countries, but high positive comovements of output across countries. In the PCP case, the opposite holds true.

Panel (c) in Figure 1 displays that the nominal exchange rate overshoots its new steady state equilibrium level. In the new steady state, the depreciation of the dollar is less than the relative increase in the money supply, as in Obstfeld and Rogoff (1995). As we explain below, a U.S. monetary shock generates a short-run current account surplus which entails a permanent rise in relative U.S. consumption. This mitigates the depreciation of the dollar. In the DP case, as in the LCP case (Betts and Devereux 2000), the exchange rate overshoots if the consumption elasticity of money demand is less than one. Panel (d) demonstrates that the nominal depreciation translates into a real depreciation.

As emphasized by Obstfeld and Rogoff (1995, 645), a monetary shock temporarily lowers the real interest rate and thus raises global consumption demand. In addition, the liquidity effect of a monetary shock lowers nominal interest rates in both regions. Since uncovered interest rate parity is assumed to hold, exchange rate overshooting creates an interest-rate differential that equals the rate of appreciation.

The rise in global demand has different effects on U.S. and European output, because of exchange rate changes. In the DP case, exchange rate pass-through is asymmetric: it is zero in the U.S. and one in Europe. In Eu-

rope, with sticky prices, the depreciation of the dollar implies that European goods become more expensive relative to U.S. goods thus households substitute consumption towards U.S. goods away from European goods. This expenditure-switching effect causes an increase in U.S. income and thus a rise in relative U.S. consumption. As panel (e) shows, to smooth consumption, U.S. households save part of this income by running a current account surplus. Households, however, do not have flat consumption profiles because real interest rates differ from the steady state value.[8]

In the U.S., when prices are sticky, the relative price of U.S. to European goods is left unaffected. The impact of a monetary shock on the output of both regions is influenced by the direct demand increase from U.S. households. This direct demand increase is (almost) identical for both U.S. and European goods. Because European exports increase substantially, European production increases. The depreciation of the dollar does not switch U.S. demand, but it affects the earnings of European firms. When European firms price their exports in dollars, the depreciation of the dollar reduces their earnings measured in euro terms. This reduces European consumption. Some but not all prices are sticky. U.S. firms experience higher marginal costs, due to higher labour demand. Therefore, the U.S. terms of trade improves and U.S. goods become more expensive relative to European goods and some U.S. demand is shifted towards European goods.

As mentioned, a U.S. monetary shock rises European consumption in the short run. A drop in earnings due to the depreciation of the dollar, at given production level, tends to lower European consumption. These effects, however, are offset by positive effects. European exports increase substantially leading to an increase in income. Moreover, the depreciation of the dollar induces a fall in the European CPI allowing for an increase in consumption.

Panel (f) shows that a U.S. monetary shock induces a permanent improvement in the U.S. terms of trade. U.S. households, with higher long-run wealth, choose to work less (the opposite happens in Europe). A fall in the supply of U.S. goods raises the relative price of U.S. goods.

4.3 European Monetary Shocks

We now turn study to the macroeconomic effects of a European monetary shock and consider the same unanticipated permanent rise in the money supply. Figure 2 shows the macroeconomic effects of U.S. and European monetary shocks on output and consumption. Only the effects on output and consumption are shown due to the fact that the responses of other

[8] If the European money supply had been reduced by one percent (at the same time when the U.S. money supply is increased by one percent), households would have maintained a flat consumption profile. Sutherland (1996) considers such an exercise and demonstrates that, in this case, households have a flat consumption profile.

variables are a mirror image of a U.S. shock. The solid lines show the effects of a U.S. monetary shock and the dashes lines show the effects of a European monetary shock. "Domestic output" refers to U.S. (European) output in the case of a U.S. (European) shock.

Figure 2 reveals two noteworthy results. First, while a U.S. monetary expansion increases European output and consumption, a European monetary expansion reduces U.S. output and output. So U.S. monetary shocks generate positive comovements of output across regions. On the other hand, European shocks generate negative comovements. Second, a U.S. monetary expansion increases U.S. output and consumption more than a European expansion increases European output and consumption.

The differences in the international transmission of U.S. and European monetary shocks stem from asymmetric exchange rate pass-through. A European monetary shock, like a U.S. shock, causes an exchange rate depreciation. In the case of a U.S. shock, the direct demand increase coming from U.S. ("domestic") households increases demand for both U.S. ("domestic") and European ("foreign") goods due to the fact that a dollar depreciation does not affect the price of import in the U.S. In the case of a European shock, however, the depreciation of the euro raises the price of imports in Europe and European goods become cheaper relative to U.S. goods. The expenditure switching effect raises European ("domestic") output and consumption, but reduces U.S. ("foreign") output and consumption. Therefore, European shocks, unlike U.S. shocks, generate negative comovements of output across regions.

A European shock raises European output less than a U.S. shock raises U.S. output while the preceding analysis suggests the opposite. The intuition behind this result is as follows. As mentioned, in the case of a U.S. shock, the depreciation of the dollar implies the expenditure-switching effect in Europe. This causes an increase in U.S. output and consumption. On the other hand, in the case of a European shock, due to DP, the depreciation of the euro does not affect the price of imports in the U.S. and there is no expenditure switching effect in the U.S. Asymmetric expenditure switching effects explain the asymmetric transmission of U.S. and European monetary shocks.

5 The Emergence of the Euro and International Monetary Policy Transmission

5.1 U.S. Monetary Shocks

For the reasons discussed in Section 2, our conjecture is that the emergence of the euro as an international currency implies that more European firm invoice their exports in euros. As also mentioned, for simplicity, we suppose

that the emergence of the euro implies a transition to a situation where all export prices are set in the producer's currency. Figure 3 shows the macroeconomic effects of a U.S. monetary shock in two cases. The solid lines depict the effects of a monetary shock in the DP case while the dashed lines depict the PCP case. In the PCP case, the model is rather identical to the Obstfeld-Rogoff model.

As can be seen from Figure 3, the stimulate effects of a monetary shock on U.S. output are reinforced. Moreover, the emergence of the euro induces some interesting qualitative changes. First, a U.S. monetary shock causes a deterioration of the U.S. terms of trade in the short run. Second, the positive impact of a U.S. monetary shock on European output reverses to negative. The intuition behind these changes is apparent: complete exchange rate pass-through.

The U.S. terms-of-trade deterioration is consistent with the conventional presumption that unexpected currency depreciations are associated with deteriorations rather than improvements of the terms of trade [see Obstfeld and Rogoff (2000)]. Thus, in the PCP case, the depreciation of the dollar raises the relative prices of imports, shifting U.S. demand towards U.S. goods away from European goods. This expenditure switching effect increases U.S. output, compared to the DP case. U.S. goods become cheaper relative to European goods also in Europe. Because global, not only European, demand shifts towards U.S. goods, European output decreases. The emergence of the euro, therefore, may reduce the cross country correlations in output. This result is consistent with Betts and Devereux (2000, 2001): the presence of LCP raises the cross country correlations in output.

The emergence of the euro, however, may raise the cross country correlations in consumption. Panel (c) demonstrates that the transition to PCP changes European consumption surprisingly little, notwithstanding the drop in production. The change in the European CPI (DP compared with PCP) is very low. In the PCP case, the improvement of the European terms of trade and the fact the depreciation of the dollar does not reduce the earnings of European firms, at given production level, allow for an increase in European consumption. The fall in income due to the drop in production almost offsets the positive effects, leaving European consumption almost unchanged. The emergence of the euro mitigates the positive impact of a U.S. monetary shock on U.S. consumption. With a greater exchange rate pass-through, the U.S. CPI tends to rise more, inducing a fall in consumption. This and the terms of trade effect dominate leading to a fall in consumption, relative to the DP case, notwithstanding higher production.

Figure 3 illustrates some expected results. First, under PCP, the nominal exchange rate jumps immediately to the steady state level. Second, because preferences are identical across regions and the LOOP holds for all goods, the CPI-based real exchange rate is always constant. These results - of course - are the same as in Obstfeld and Rogoff (1995). The results are based on

costless and free trade, so the LOOP always holds. The degree of exchange rate pass-through is never 1 and instant in practice. For example, deviations for the LOOP can arise from the non-traded component incorporated in the consumer price of the traded good. Local distribution costs such as rents, advertising etc. are likely to cause deviations the LOOP (McCallum and Nelson (2000) and Burstein, Neves and Rebelo (2003)). In any case, we can conclude that the emergence of the euro is likely to reduce the variability of exchange rates that monetary shocks cause.

Finally, panel (g) of Figure 3 shows that the emergence of the euro may reinforce the effect of monetary shocks on the current account. This result is concordant with Betts and Devereux (2000), they show that LCP diminishes the effect on the current account. In the PCP case, ex post real interest rates are equalized across regions, thus the lower U.S. real interest rate encourages European households to borrow more.

5.2 European Monetary Shocks

This section studies how the emergence of the euro may affect the international transmission of European monetary shocks. In the PCP case, the effects of a European monetary shock are exactly the same as those of a U.S. shock. The only asymmetry arises from the international capital market, due to fact that nominal bonds are denominated in the dollar. Free trade in nominal bonds and PPP, however, imply that real interest rates cannot diverge across regions.

It turns out from Figure 4 that the emergence of the euro reinforces the positive effect of a monetary shock on European output. Second, the negative effect of a European monetary shock on U.S. output is reinforced. Third, the emergence of the euro might be good news for U.S. consumers, the negative effect of a European monetary shock on consumption reverses to positive. As in the case of a U.S. shock, the fact that exchange rate pass-through becomes complete in the U.S. explains these changes.

The transition to PCP implies that exchange rate movements induce an expenditure switching effects also in the U.S. With nominal prices sticky in the short run, the euro's depreciation switches U.S. demand towards European products away from U.S. products. Under DP, the euro's depreciation switches only European demand towards European products. Under PCP, both U.S. and European households have an incentive to shift to relative less expensive European goods from U.S. goods. Thus world demand shifts towards European products, leading to an increase (fall) in European (U.S.) output and consumption, relative to the DP case. Finally, complete exchange rate pass-through implies that the dollar's appreciation induces a fall in the U.S. CPI. Hence allowing for an increase in U.S. consumption.

6 Conclusions

Monetary policies in the United States and Europe have an important influence on the rest of the world, because of the size of the economies. This paper develops a model for analyzing the international transmission of U.S. and European monetary shocks in the case where all export prices are set in U.S. dollars. We show that asymmetric exchange rate pass-through implies that the international effects of U.S. monetary shocks are different from those of European shocks. For example, U.S. shocks generate positive comovements of output across regions. On the other hand, European shocks generate negative comovements.

After 50 years of the dollar's hegemony in the world economy, the single European currency was brought into play. The introduction of the euro was a fundamental change and the euro may become an international currency. In this paper we attempt to shed light on the question of how the increase in the use of the euro in international trade will affect the international transmission of European and U.S. monetary shocks. It is shown that if the role of the euro in international trade increases, this has significant implications for the international transmission of monetary shocks. More generally, the emergence of the euro as an international currency has significant implications for optimal monetary policy and the conduct of monetary policy.

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Figure 1: Macroeconomic effects of a U.S. monetary shock under dollar pricing

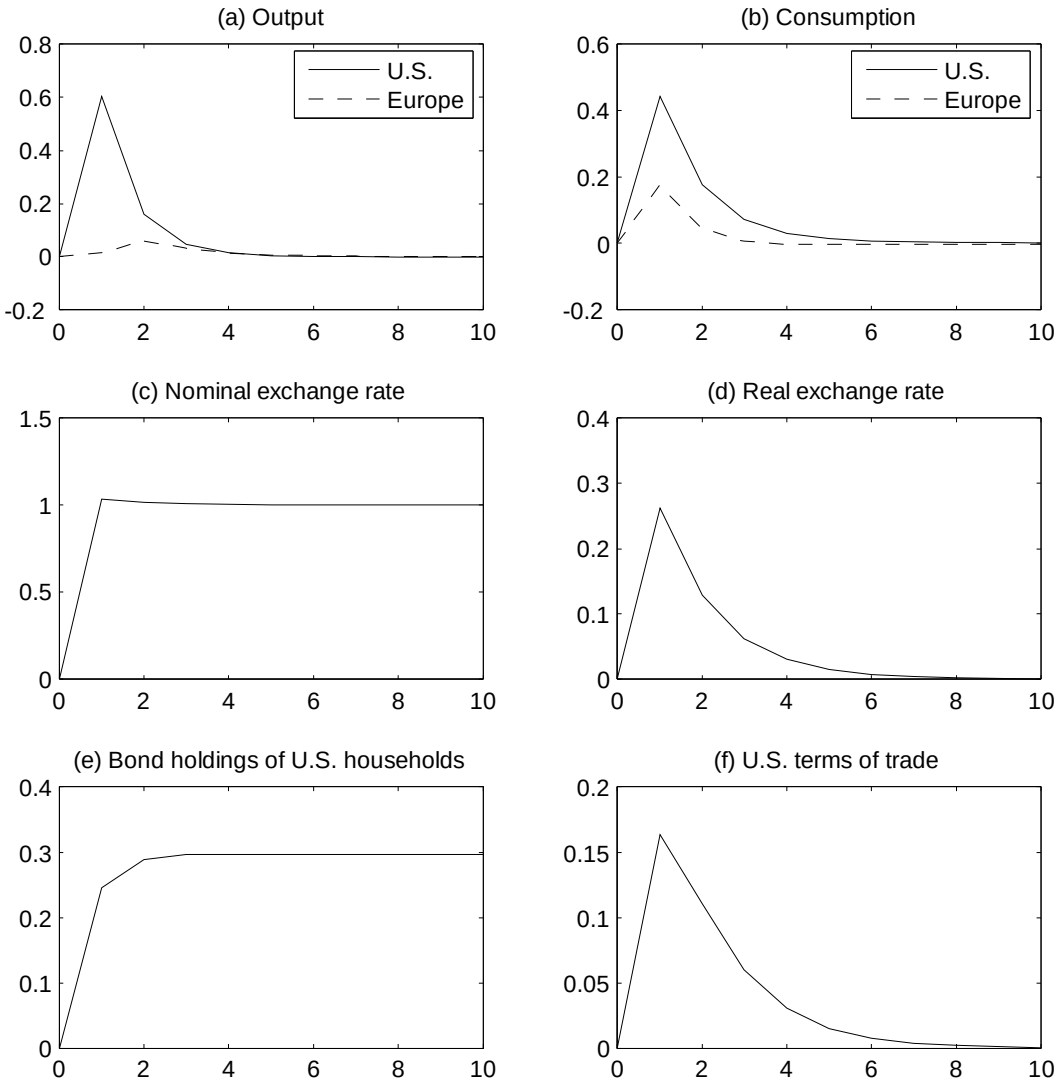

Figure 2: Macroeconomic effects of European and U.S monetary shocks under dollar pricing

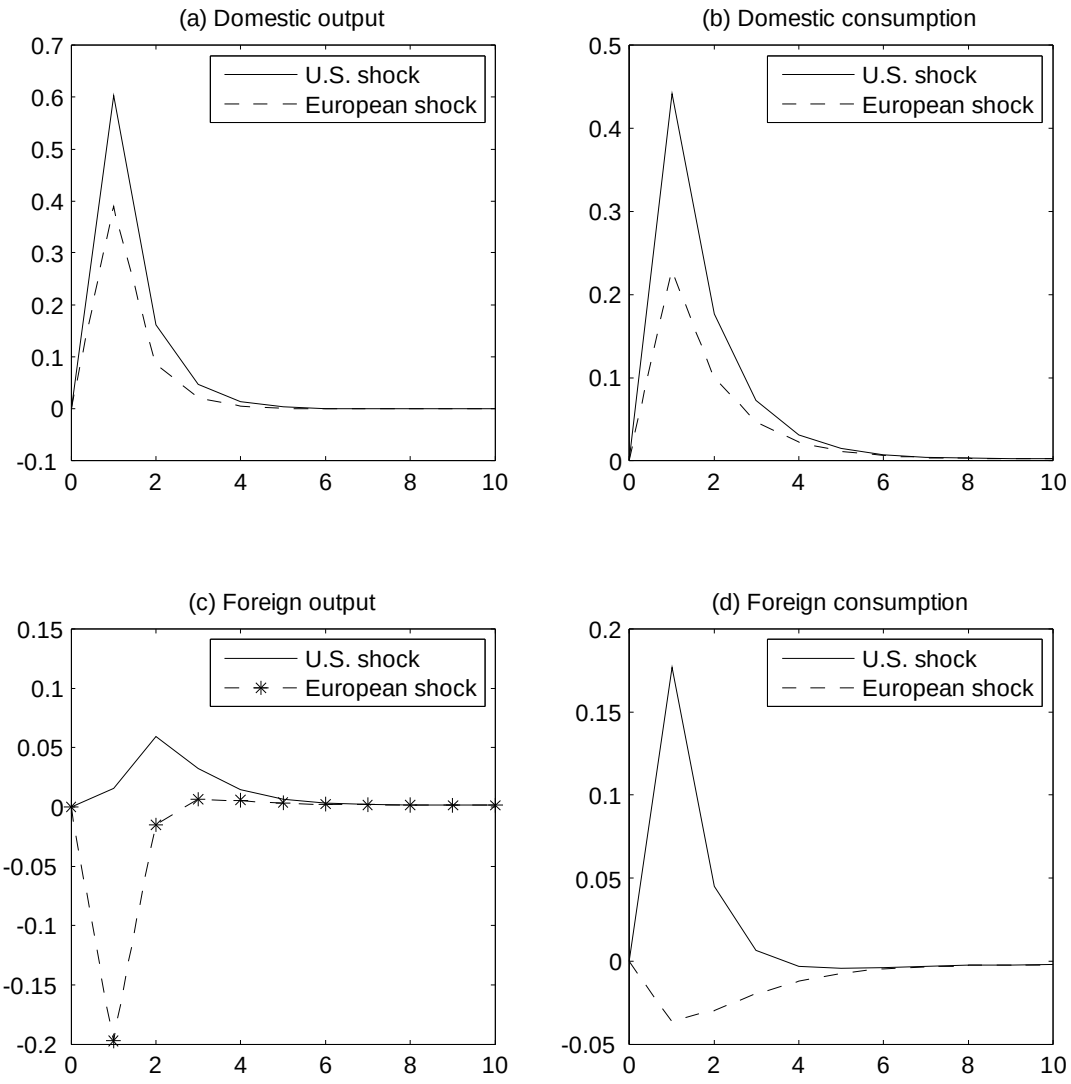

Figure 3: Macroeconomic effects of a U.S. monetary shock - dollar pricing versus producer currency pricing

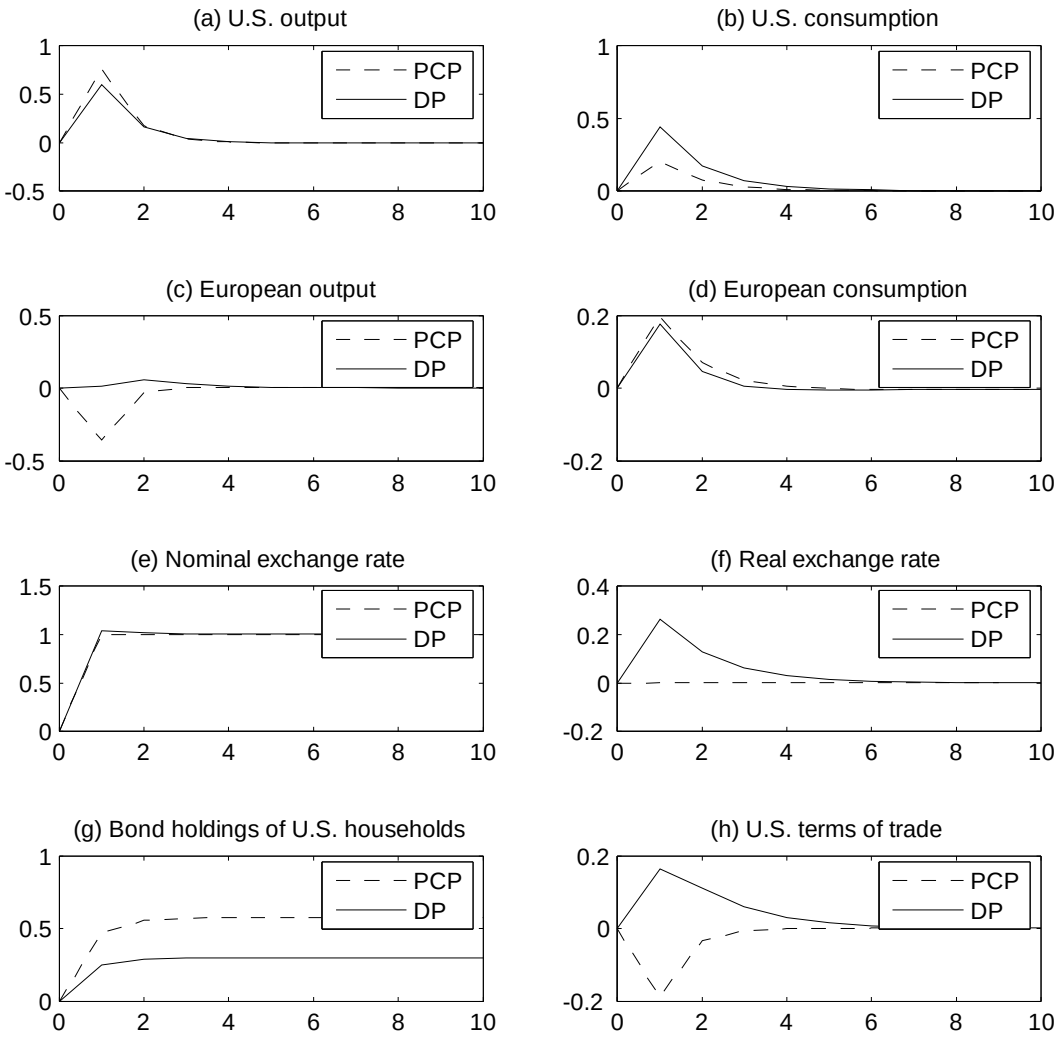

Figure 4: Macroeconomic effects of a European monetary shock - dollar pricing versus producer currency pricing