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Total Factor Productivity and the Real Exchange Rate in a Small Open Economy: The Relative Importance of Permanent and Transitory Shocks

Göran Hjelm*

November 16, 2001

Abstract

Recent theoretical research suggest that monetary shocks might play an important role in explaining movements in the real exchange rate in the short and medium run. Empirically, the contribution of transitory (monetary) disturbances in explaining the variance decomposition of real exchange rates has varied substantially in the recent literature. In this paper, we construct new quarterly series of total factor productivity for Sweden and Japan. We find that these series and the real exchange rate are cointegrated and estimate a so called common trends model. The two permanent shocks are identified as being productivity shocks of Japan and Sweden, respectively, and it is shown that the transitory shock can be interpreted as being of monetary origin. Contrary to the predictions of recent theoretical models, the transitory shocks explains only a minor part of the movements in the real exchange rate (7.2% after two quarters at most) which implies that productivity shocks clearly dominate the picture.

Keywords: Real exchange rates; Total factor productivity; Common trends.

JEL Classification: C32; F31; O47.

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1 Introduction

If the nominal exchange rate and the relative price levels of two countries are cointegrated (i.e., the real exchange rate is stationary), no shocks have permanent effects on the real exchange rate. Indeed, this is the corner stone of the famous Purchasing Power Parity (PPP) theory. If, instead, the real exchange rate is not stationary, permanent (real) shocks have permanent effects. That is, such real shocks can explain permanent deviations of the observed real exchange rate from the rate predicted by the simple PPP theory. In the short and medium run, however, transitory shocks may still explain an important part of the movements in the real exchange rate. In this paper, we estimate the relative importance of permanent and transitory shocks on the forecast error variance decomposition (FEVD) of the real exchange rate.

Recently, several theoretical papers have focused on the importance of monetary shocks for the movements in real exchange rates (see, among others, Beaudry and Devereux, 1995, Chari et al., 2001, and Obstfeld and Rogoff, 1995). By incorporating imperfect competition and price stickiness, these models predict an important role for monetary shocks in explaining persistent deviations of the real exchange rate from value predicted by PPP. For example, in Beaudry and Devereux (1995) model, a money shock of 1 percent implies a real depreciation of 0.2 percent still after seven years. The greatest effect is after six quarters (depreciation of 1.3 percent) while the long run effect is constrained to be zero.

Recent empirical articles focusing on the relative importance of permanent and transitory shocks for the FEVD of real exchange rates include, among others, Astley and Garratt (2000), Bergman et al. (2000), Bjørnland (1998), Clarida and Gali (1994), Eichenbaum and Evans (1995), Enders and Lee (1997), Lastrapes (1992), and Rogers (1999). The presented evidence is mixed concerning the importance of transitory shocks. For example, Clarida and Gali (1994) and Enders and Lee (1997) estimate very low share explained by transitory shocks for some bilateral rates while Eichenbaum and Evans (1995) and Rogers (1999) predict a greater role for transitory disturbances. We return to the results and methods applied of previous papers in more detail when our results are presented.

In this paper, we find that the real exchange rate we study (Sweden and Japan) is non-stationary and that the cause of non-stationarity is country differences in Total Factor Productivity (TFP). The models presented by Balassa (1964) and Samuelson (1964) are the most famous contributions in this area. According to these models, permanent deviations from PPP can be explained by productivity differentials. In short, the real exchange rate of a country experiencing faster growth in TFP appreciates. The implication is that PPP is not stationary in general and that relative movements in TFP explain persistent deviations from PPP. Note, however, that other (nominal) factors might explain a significant part of the movements of the real exchange rate in the short and medium run. The econometric model applied in this paper takes such short and medium run movements into account as well.

We estimate a so called common trends (CT) model including three variables: the real exchange rate and the TFP of the two countries in question. According to the theory mentioned above, these variables are potentially cointegrated. This is confirmed in the paper and, hence, the common trends model is driven by two permanent shocks and one temporary shock. We identify the two permanent shocks as being productivity shocks of Sweden and Japan, respectively, while the temporary shock is of nominal nature. Using this information, we calculate the response of the real exchange rate to the three mentioned shocks and, most importantly, the relative importance of the transitory shock in explaining the FEVD of the real exchange rate.

Methodologically, the Blanchard and Quah (1989) type of identification clearly dominates the literature although there are examples using Choleski decomposition.¹ There are few articles that estimate CT models when evaluating movements in real exchange rates; Alexius (2001) estimate CT models of GDP, real exchange rate, and prices of three Nordic countries against Germany but do not consider the relative importance of nominal shocks; Bergman et al. (2000) find that PPP holds and estimate CT models including nominal exchange rates and relative prices. As we find, using different bilateral relationships, that PPP does not hold and include TFP in our analysis, there are great differences in our approaches.

As mentioned, we focus on real exchange rate movements in a small open economy: Sweden against Japan. The choice of Sweden and Japan is arguably interesting for several reasons.² It is well known that Japan's productivity development has been remarkable during the second half of the last century. According to Balassa (1964) and Samuelson (1964), this fact should be reflected in the development of the real exchange rate. This is tested and confirmed in the paper. Including Sweden enables us to investigate the sources of real exchange rate movements of a small open economy. Moreover, we make use of the small country assumption when identifying (and thereby interpreting) the structural shocks.

Unlike previous studies focusing on the relationship between productivity and real exchange rates, we construct (using quarterly data from the OECD:s Business Sector Data Base) a new series of TFP. Previous studies estimating cointegrating relationships between real exchange rates and productivity differentials (not focusing of effects of structural shocks though) have used labor productivity (see, e.g., Strauss, 1996, and Begum, 2000).

¹See, e.g., Astley and Garrat (2000), Clarida and Gali (1994), Enders and Lee (1997), Evans and Lothian (1993), Lastrapes (1992), and Rogers (1999) for applications of the Blanchard and Quah (1989) identification and Dibooglu (1996) and Evans and Eichenbaum (1995) for application of Choleski decomposition.

²The reason for not using the bilateral relationship of Sweden and U.S. is the well known erratic behavior of the U.S. nominal and real exchange rate in (foremost) the 1980s (see Branson, 1985, and Strauss, 1996). Meaningful cointegrating relationships are therefore hard to find. Note, however, that many of the studies that are discussed in the paper (see section 4.3) actually use US as the benchmark. They estimate models in first differences, however, i.e. not including any cointegrating restrictions.

We believe that it is important to construct and use TFP as this is the variable implied by theory derived in the paper.

The results show that the bilateral real exchange rate of Sweden and Japan is non-stationary the real exchange rate and the TFPs of Sweden and Japan are cointegrated. The FEVD shows that the real exchange rate of Sweden and Japan is almost entirely driven by permanent productivity shocks. Nominal (transitory) shocks play a very minor role even at short horizons. This is contrary to recent theoretical contributions which emphasize the importance of monetary (transitory) shocks in the short and medium run. Our results are explained by the close relationship between the real exchange rate and the relative TFP growth of Sweden and Japan.

The rest of the paper is structured as follows. Section 2 derive the theoretical relationship between TFP and real exchange rates using a model presented in Obstfeld and Rogoff (1996). In section 3 we describe how we construct the TFP series. Using the TFP data and data on nominal and real exchange rates and relative price levels, we test for unit roots and cointegration. In section 4, we first derive and identify the common trends model applied. Impulse response and variance decomposition analysis is then carried out and, finally, we compare our results with those of previous studies. Section 5 concludes.

2 TFP and the Real Exchange Rate

In this section we derive the relationship between the real exchange rate and the TFP of two countries. Let e denote the natural logarithm of the nominal exchange rate (price of one unit of foreign currency in terms of domestic currency, foreign is denoted by * in the following) and p, p^* denote the natural logarithm of the general price levels. The natural logarithm of the real exchange rate can then be expressed as:

$$q = e + p^* - p. \quad (1)$$

If PPP holds, q is stationary. There is a whole literature (way to large to survey here!) on testing if q is stationary or not.³ We only note here that we reject the stationarity of q in this paper. Moreover, we find that q corrected for TFP differentials is stationary which is in line with the theory outlined below.

We follow Obstfeld and Rogoff's (1996) derivation of the relationship between the real exchange rate and TFP differentials. Production of tradeables (subscript $_T$) and non-tradeables (subscript $_{NT}$) is given by constant returns to scale (CRTS) production functions in both the home and foreign country (we consider only the home country

³For some recent contributions, see, among others, Begum (2000), Dibooğlu (2000), Eichenbaum and Evans (1995), Enders and Lee (1997), Engle (2000), Rogers (1999), and Strauss (1996) for studies rejecting PPP. See, among others, Bergman et al. (2000), Cheung and Lai (1998), Culver and Papell (1999), Frankel and Rose (1996), and Taylor and Sarno (1998) for some recent studies supporting PPP.

explicitly at first):

$$Y_T = A_T F(K_T, L_T), \quad Y_{NT} = A_{NT} G(K_{NT}, L_{NT}), \quad (2)$$

where A, K, L are TFP, capital and labor, respectively. Capital is assumed to be internationally mobile while labor is mobile only between a country's two sectors. Hence, the capital return (r) is determined on the world market. Wages (w) can differ between countries while being equalized within each country. Profit maximization implies that the marginal products of capital and labor are equal to the real interest rate (r) and the current wage (w), respectively. More formally, the well known first order conditions of CRTS production functions are:

$$\begin{aligned} (i) & : r = A_T f'(k_T) \\ (ii) & : w = A_T f(k_T) - A_T f'(k_T) k_T \\ (iii) & : r = p A_{NT} g'(k_{NT}) \\ (iv) & : w = p A_{NT} g(k_{NT}) - p A_{NT} g'(k_{NT}) k_{NT}, \end{aligned} \quad (3)$$

where $A_i f(k_i)$, k_i are production and capital per labor input, respectively ($i = T, NT$). p is the price of non-tradeables in terms of tradeables. The price of tradeables is unity for simplicity and the same in both countries due to perfect competition in the tradable goods market. Conditions (ii) and (iv) imply that workers get what is left of the value of production ($A_T f(k_T)$ and $p A_{NT} g(k_{NT})$, respectively) when total capital income ($A_T f'(k_T) k_T$ and $p A_{NT} g'(k_{NT}) k_{NT}$, respectively) has been withdrawn. Hence, we have the following zero profit conditions (L is normalized to one):

$$A_T f(k_T) = r k_T + w, \quad p A_{NT} g(k_{NT}) = r k_{NT} + w. \quad (4)$$

Recognizing that r (the world interest rate) is constant and taking (i) in (3) into account, log differentiation of the two conditions in (4) yields:

$$\hat{A}_T = \frac{w L_T}{Y_T} \hat{w}, \quad \hat{p} + \hat{A}_{NT} = \frac{w L_{NT}}{p Y_{NT}} \hat{w}, \quad (5)$$

where $\hat{\cdot}$ denote percentage change. If we combine the two expressions in (5) and let $\mu_{LT} = \frac{w L_T}{Y_T}$ and $\mu_{LNT} = \frac{w L_{NT}}{p Y_{NT}}$, we can solve for the price level in the non-tradable sector:

$$\hat{p} = \frac{\mu_{LNT}}{\mu_{LT}} \hat{A}_T - \hat{A}_{NT}. \quad (6)$$

As it is reasonable to assume that the labor share is greater in the non-traded sector ($\frac{\mu_{LNT}}{\mu_{LT}} > 1$), faster TFP growth in the traded sector increase the price of non-tradeables. The reason for this is straightforward. If $\hat{A}_T - \hat{A}_{NT} > 0$, the non-tradable sector has to increase its' price as wages are equalized in the two sectors and the wage increase is determined by the increase in A_T .

In order to evaluate the effect of TFP growth on the real exchange rate, we assume that the above analysis holds for the foreign country as well (we only add an '*' to the variables below). The price level of the two countries is a geometric average of the price levels of tradeables and non-tradeables. For simplicity, we continue to assume that the price level of tradable goods is unity in both countries. The aggregate price levels can therefore be expressed as:

$$P = (1)^\gamma p^{1-\gamma} \quad P^* = (1)^{\gamma^*} (p^*)^{1-\gamma^*},$$

where γ, γ^* is the share represented by the tradeable sector. Note, as the price levels of tradeable goods are equalized in the two countries (normalized to one), the real exchange rate depends *only* on the relative price of non-traded goods:

$$Q = \frac{P^*}{P} = \frac{(p^*)^{1-\gamma^*}}{(p)^{1-\gamma}}. \quad (7)$$

P^*/P is hence the real exchange rate - an increase in P (non-tradeables) implies a real appreciation of the home country (i.e., q falls in terms of (1)). By log-differencing (7) and substitute \hat{p} using the expression in (6) and doing the same operation for \hat{p}^* (using the foreign counterpart of (6)), we get the following relationship between the percentage change of the real exchange rate (\hat{q}) and relative percentage change of TFP in the two countries:

$$\begin{aligned} \hat{q} &= (1 - \gamma^*)\hat{p}^* - (1 - \gamma)\hat{p} \\ &= (1 - \gamma^*) \left[\frac{\mu_{LNT}^*}{\mu_{LT}^*} \hat{A}_T^* - \hat{A}_{NT}^* \right] - (1 - \gamma) \left[\frac{\mu_{LNT}}{\mu_{LT}} \hat{A}_T - \hat{A}_{NT} \right]. \end{aligned} \quad (8)$$

To simplify the discussion, let $\hat{A}_{NT} = \hat{A}_{NT}^*$ as it is reasonable to assume that productivity differences are greatest in the tradable sector (see, e.g., Obstfeld and Rogoff, 1996, for evidence). The standard argument is that it is harder to improve relative productivity in the non-traded sector which, to a great extent, consists of the service sector (the typical example is haircuts). Moreover, assume for the moment that the share of tradeable sector (γ, γ^*) is the same. Then equation (8) implies:

$$\hat{q} = (1 - \gamma) \left[\frac{\mu_{LNT}^*}{\mu_{LT}^*} \hat{A}_T^* - \frac{\mu_{LNT}}{\mu_{LT}} \hat{A}_T \right].$$

An increase in foreign productivity in the tradable sector (\hat{A}_T^*) generate a real appreciation (depreciation) for the foreign (home) country as q increases. The opposite is true if \hat{A}_T goes up. As the capital stock (needed to construct TFP) is not available for the traded and non-traded sectors separately on quarterly basis, we calculate the aggregate TFP in Sweden and Japan (see the next section for details). That is, we calculate A and A^* , respectively. One implication of this procedure is that we do not have theoretical values of the coefficients on A and A^* but the signs of the coefficients are of course straightforward.

3 Data and the Construction of TFP

According to the theoretical outline above, we need data on real exchange rate and TFP of Sweden and Japan. The real exchange rate is constructed according to equation (1) using data on nominal exchange rates and consumer price indices from IFS (June 2001 CD-ROM). The time period for which all relevant variables are available is 1966:1-1996:4. TFP on quarterly basis is not directly available in the OECD data base. However, quarterly data for the *business sector* on GDP, employment, capital stock, and labor compensation is available in the OECD Business Sector Data Base.⁴ Using this data, we are able to construct TFP for the countries we study.

The starting point for calculating TFP is a Cobb-Douglas production function with CRTS:

$$Y_t = A_t K_t^\lambda L_t^{1-\lambda}, \quad (9)$$

where A is the measure of TFP. Taking the natural logarithm of (9) we get the Solow residual:

$$\ln A_t = \ln Y_t - \lambda \ln K_t - (1 - \lambda) \ln L_t. \quad (10)$$

As well known, $\lambda (1 - \lambda)$ is the elasticity of output with respect to capital (labor) input and perfect competition implies that $\lambda (1 - \lambda)$ is equal to the share of capital (labor) income to the value of output: $\frac{rK}{pY} (\frac{wL}{pY})$. As we have data on Y_t , K_t , L_t , w , and λ we can easily calculate A_t in (10).⁵

The data used in the paper is displayed in Figure 1. In order to be able to see the relationships between the three variables more clearly, we have transformed the series into indices (the series in natural logarithms are used in the estimations later on). First we can note that the real exchange rate series in Figure 1 appears to be non-stationary. This is tested and confirmed below (section 3.1). The real depreciation of the Swedish real exchange rate against the Yen is great indeed. According to the theory outlined in section 2, we would then expect that $(\Delta TFP^{Japan} > \Delta TFP^{Sweden})$ which is obviously the case by inspecting the bottom panel of Figure 1.

3.1 Test of Cointegration

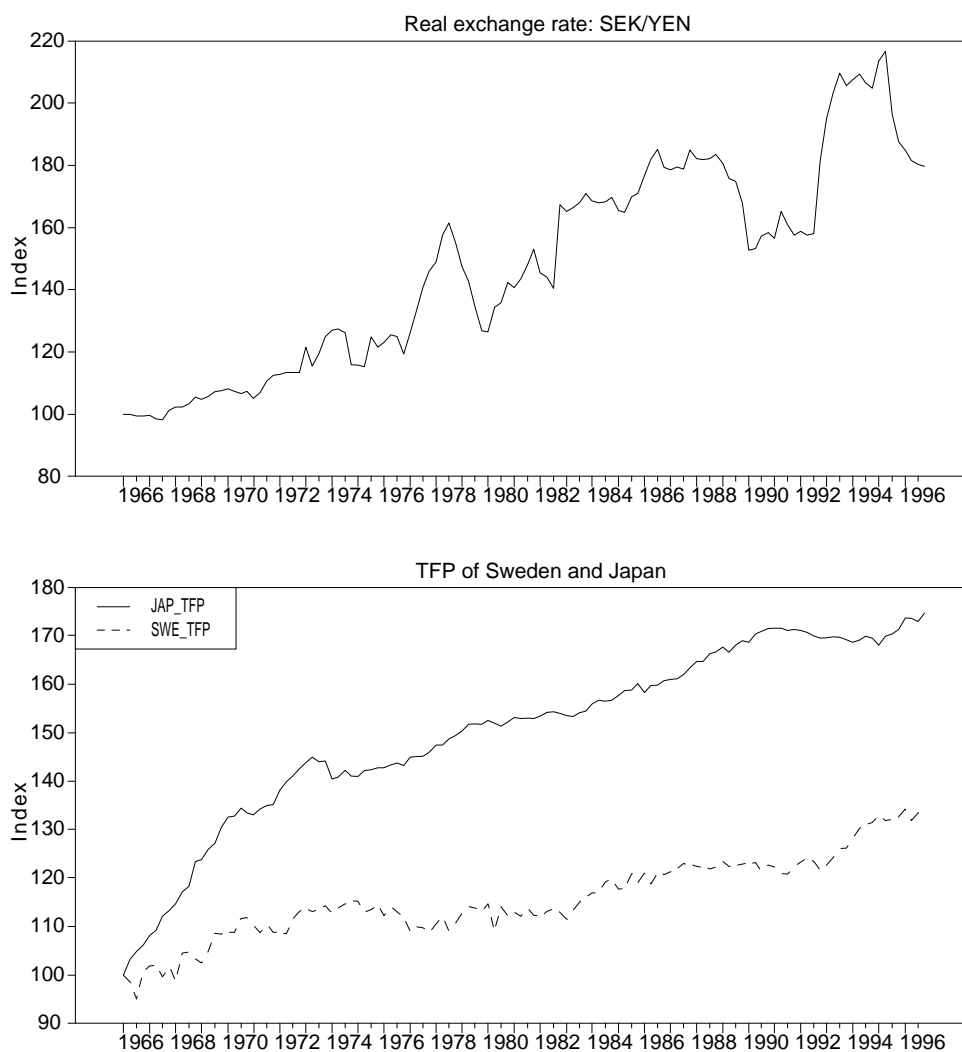
In this section we test if the log of the real exchange rate (q) and the log of TFP of Japan and Sweden are cointegrated as implied by theory above. We estimate with separate coefficients on Japan's and Sweden's TFPs, respectively.⁶ There are several reasons for

⁴Hence, it is not possible to calculate TFP for the whole economy. As we calculate TFP of the business sector for both countries, we believe it is a good approximation for relative movements in TFP for the whole economy of the two countries.

⁵We follow the OECD and use average λ during the estimation period.

⁶Alexius (2001) who also considers a CT model, estimates with separate coefficients for some bilateral relationships while using common coefficients for others depending on the economic content of the

Figure 1: Real exchange rate and total factor productivity indices for Sweden and Japan (1966:1-1996:4)



this. First, as outlined in section 2, the coefficients are most likely different due to country specific sizes of the tradeable sector as well as country specific relative labor shares in the traded and non-traded sectors. Second, by keeping them separate, we are able to identify permanent productivity shocks of both Japan and Sweden - this is discussed in detail in section 4.1 below. Third, and most important, we let the data decide and can reject that the coefficients on Swedish and Japanese TFP are equal.

It is clear from the displayed Trace test in Table 1 that the real exchange rate and the TFP of Sweden and Japan indeed are cointegrated.⁷ It turns out that the sign of the coefficients in the estimated cointegrating vector are in line with the theory outlined above. More specifically, the implied cointegrating relationship is:

$$q^{swe_jap} = 2.63 * TFP^{jap} - 0.54 * TFP^{swe}. \quad (11)$$

Equation (11) implies that an increase in Japan's TFP increase q , i.e. appreciating Japan's real exchange rate. The opposite is true for an increase in Sweden's TFP as q then decreases, i.e. an appreciation of Sweden's real exchange rate. We can also note that the magnitude of the coefficients in the two cointegrating vectors shown in (11) is rather different and we can reject that they are equal (p-value: 0.03).⁸

In Table 1 we test also for stationarity and trend stationarity.⁹ We can reject stationarity/trend stationarity in all cases but one - the p-value for the null of trend stationarity of Japanese TFP is 0.21. We treat all three variables symmetrically, though, being integrated of order one.¹⁰

4 The Common Trends Model

In the above section we found the existence of one cointegrating relationship for the variable vector $x' = [TFP^{jap} \quad TFP^{swe} \quad q^{swe_jap}]$. Hence, as we have three variables and one cointegrating vector, the system is driven by two common trends including two

estimated impulse responses and cointegration vectors.

⁷We choose the most parsimonious model (beginning with 8 lags) in which the null of no autocorrelation can not be rejected. 6 lags is chosen and the conclusion from the Trace test is not sensitive to the use of different lag lengths. Lagrange multiplier tests of autocorrelation are applied (see Johansen, 1995).

⁸We can note from Alexius (2001), whose analysis is somewhat close to ours, that the (common) cointegration coefficient on $(GDP - GDP^*)$ ranges from 0.42 to 4.41 depending on the bilateral relationship considered.

⁹These tests are described in Johansen (1995) and Hansen and Juselius (1995).

¹⁰With eight lags, no autocorrelation can not be rejected and then we *can* reject that Japanese TFP is trend stationary (p-value: 0.03). Moreover, when using the Pantula (1989) principle to choose model specification (see also Johansen, 1992), the model with an unrestricted constant is chosen instead of a model including a deterministic trend in the cointegration space. Parallel results using eight lags show no important differences compared to six lags and we choose to present the latter due to fewer lags.

Table 1: Test of cointegration using Johansen's Trace test

H_0	Trace	Critical value
$r=0$	40.37*	29.38
$r \leq 1$	12.35	15.34
$r \leq 2$	1.07	3.84

Test of:		
	Stationarity	Trend stationarity
TFP^{jap}	0.00	0.21
TFP^{swe}	0.00	0.00
RE^{swe_jap}	0.00	0.00

Note: All variables are in natural logarithms. Time period: 1966:1-1996:1. First, we test if the real exchange rate and TFP of the two countries are cointegrated. 'Critical value' shows the asymptotic 95 percent critical values of the Trace test (Johansen, 1995). '**' denotes significance at the 5 percent level. Stationarity/trend stationarity is the null in the tests shown.

permanent shocks, and one temporary shock. In section 4.1, we derive and identify the common trends model to be estimated. After having identified the shocks, we carry out impulse response analysis in section 4.2. In section 4.3, we compare the estimated FEVD of the real exchange rate explained by the transitory shocks with previous studies.

4.1 Identification

Following Warne (1993), the structural CT model can be described as:

$$x_t = x_0 + \Upsilon \tau_t + \Phi(L)\nu_t, \quad (12)$$

where $x'_t = [TFP^{jap} \quad TFP^{swe} \quad q^{swe_jap}]$, $\Phi(\lambda) = \sum_{i=0}^{\infty} \Phi_i \lambda^i$ is finite for $|\lambda| \leq 1$ which implies that $\Phi(L)\nu_t$ is stationary. Hence, the 3×1 vector of structural shocks, ν_t ($E[\nu_t] = 0$), have only temporary effects on x_t . As we have three variables and one cointegrating vector, there are two common trends (τ_t is 2×1):

$$\tau_t = \mu + \tau_{t-1} + \varphi_t, \quad (13)$$

where $\varphi'_t = [\varphi_t^{jap} \quad \varphi_t^{swe}]$ is a 2×1 vector of structural shocks having permanent effect on the variables in the model ($E[\varphi_t] = 0$). We label these shocks as productivity (supply) shocks of Japan, φ_t^{jap} , and Sweden, φ_t^{swe} , respectively. We allow the two shocks having permanent effects on x_t also to have temporary effects on x_t as well so that the vector of

structural shocks having temporary effects on x_t is: $\nu_t' = \left[\varphi_t^{jap} \quad \varphi_t^{swe} \quad \psi_t \right]$, where ψ_t is the temporary shock. Solving (12) with respect to (13) we get:

$$x_t = x_0 + \Upsilon \left[\tau_0 + \mu t + \sum_{j=1}^t \varphi_j \right] + \Phi(L)\nu_t. \quad (14)$$

As the structural CT model and can not be directly observed, we must estimate the reduced form counterpart and impose restrictions in order to identify the structural shocks. We start with the unrestricted vector autoregressive (VAR) model:

$$A(L)x_t = \rho + \varepsilon_t,$$

where $A(\lambda) = I_3 - \sum_{i=1}^p A_i \lambda^i$ satisfies $\det[A(\lambda)] = 0$ if and only if $|\lambda| \geq 1$, λ being the eigenvalues of $A(L)$ (see, e.g., Lütkepohl, 1993). Hence, we allow for unit roots but not explosive roots. Using the Granger Representation Theorem (GRT, see Engle and Granger, 1987) we can rewrite a VAR model as a vector error correction (VEC) model:

$$A^*(L)\Delta x_t = \rho - \gamma z_{t-1} + \varepsilon_t, \quad (15)$$

where $z_{t-1} = \alpha' x_{t-1}$ and $A_i^* = -\sum_{j=i+1}^{p-1} A_j$ for $i = 1, \dots, p-1$. γ is a matrix of parameters that tells us how Δx_t adjusts to last periods equilibrium error. Since Δx_t is stationary, GRT further implies the presence of a vector moving average (VMA) representation of (15):

$$\Delta x_t = \delta + C(L)\varepsilon_t, \quad (16)$$

where $C(\lambda) = I_3 + \sum_{j=1}^{\infty} C_j \lambda^j$. As shown by Stock (1987), $C(\lambda) = C(1) + (1 - \lambda)C^*(\lambda)$ where $C(1) = \sum_{i=0}^{\infty} C_i$, $C_i^* = -\sum_{j=i+1}^{\infty} C_j$, and $C^*(\lambda) = \sum_{i=0}^{\infty} C_i^* \lambda^i$ is absolutely summable. $C(1)$ has rank one in our system and $\alpha' C(1) = 0$. If we substitute the expression for $C(\lambda)$ recursively into (16) we get:

$$x_t = x_0 + C(1)\xi_t + C^*(L)\varepsilon_t, \quad (17)$$

where $\xi_t = \rho + \xi_{t-1} + \varepsilon_t$ and $\delta = C(1)\rho$. Solving (17), we get the *reduced form* CT model:

$$x_t = x_0 + C(1) \left[\xi_0 + \rho t + \sum_{j=1}^t \varepsilon_j \right] + C^*(L)\varepsilon_t,$$

where the relationship with the *structural* CT model in (14) is:

$$\Upsilon \varphi_t = C(1)\varepsilon_t, \quad \Upsilon \Upsilon' = C(1)\Sigma C(1)', \quad \Upsilon \mu = C(1)\rho. \quad (18)$$

Using the first relationship in (18), we can derive an expression for the identified permanent shocks:

$$\varphi_t = (\Upsilon' \Upsilon)^{-1} \Upsilon' C(1)\varepsilon_t. \quad (19)$$

We need to identify the nk parameters in the Υ matrix which, in turn, determines the long run effects of permanent shocks, see (14). First we make use of the fact that $\alpha'\Upsilon = 0$ by definition, i.e. the (empirical) cointegrating vector removes the long run effects of permanent shocks. This implies that rk restrictions are imposed on Υ . Hence, $k(k-1)/2 = 1$ further restriction is needed to identify the permanent shocks in (19). Here we make use of a small country assumption and impose the restriction that Swedish productivity shocks (φ_t^{swe}) have no long run effects on Japan's TFP. That is, in terms of the structural CT model in (12), we have:

$$\begin{bmatrix} TFP_t^{jap} \\ TFP_t^{swe} \\ q_t^{swe-jap} \end{bmatrix} = x_0 + \begin{bmatrix} \Upsilon_{11} & \mathbf{0} \\ \Upsilon_{21} & \Upsilon_{22} \\ \Upsilon_{31} & \Upsilon_{32} \end{bmatrix} \begin{bmatrix} \varphi_t^{jap} \\ \varphi_t^{swe} \end{bmatrix} + \Phi(L)\nu_t. \quad (20)$$

We can note that, as we have $n = 3$ variables, $r = 1$ cointegrating vectors and $k = 2$ common trends, the number of restrictions needed to identify the single transitory shock is $r(r-1)2 = 0$. Hence, there is no identified interpretation of the transitory shock - it is simply identified to have only temporary effects on the variables in the model. Finally, by assuming that the structural shocks are uncorrelated, the system is exactly identified.

4.2 Impulse Response Analysis¹¹

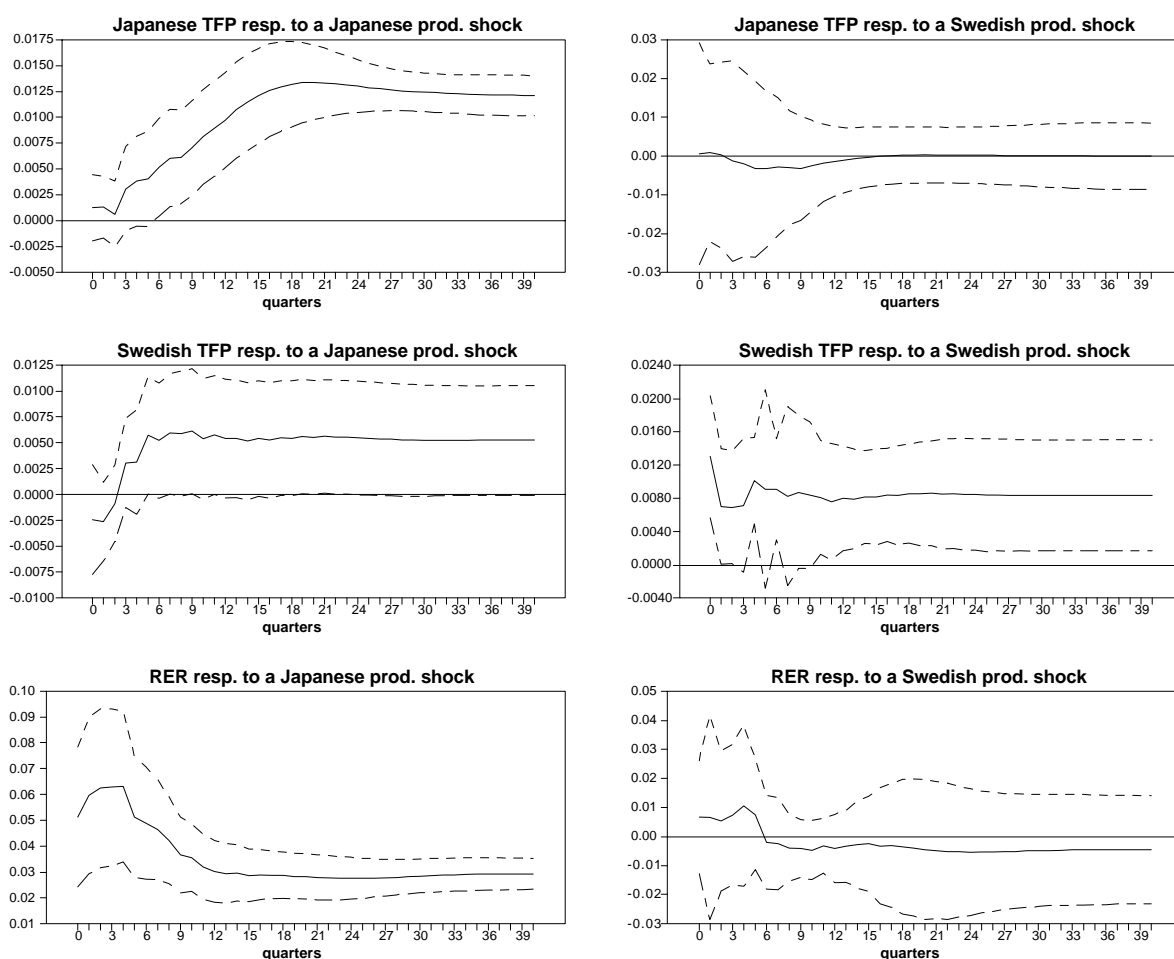
In this section, we evaluate the response of TFP and real exchange rates to the two permanent productivity shocks and to the transitory shock. Although the focus in this paper is on the FEVD of real exchange rates, it is important to investigate whether the interpretation of the two permanent shocks as being induced by productivity shocks of Japan and Sweden, respectively, is supported by data. We will therefore compare the response of these shocks with the theoretical predictions outlined in section 2. Finally, we also show that the transitory shock may be interpreted as being of monetary origin.

4.2.1 The Permanent TFP Shocks

Figure 2 shows the response of the three variables in the system to the two permanent productivity shocks together with 95% confidence bands. The left column of the figure shows the response to Japanese productivity shocks and the TFP of both Japan and Sweden responds positively. The long run Japanese response is significant and over one percentage point (the vertical axis denotes percentage as the series are in natural logs). The Swedish TFP response is close to significant after six quarters and onwards and the long run response is about a half percentage point. Most importantly, the real exchange rate (in terms of SEK/YEN) depreciates (q increases) which should be the case according to the model outlined in section 2.

¹¹The RATS code for the CT program applied is written by Henrik Hansen and Anders Warne.

Figure 2: Impulse responses to the two permanent shocks



Turning to the Swedish productivity shock, it is first important to remember that the long run Japanese TFP response is constrained to be zero while the short and medium run response is unrestricted. It is clear from the right column of Figure 2 that the response of Japanese TFP is very minor indeed. This is what we should expect as Sweden is a small country which can not possibly affect Japan's TFP to any significant extent. The response of Swedish TFP to Swedish productivity shocks is significant at most displacements and the long run response is about 0.8 percentage points. Finally, the real exchange rate appreciate (q falls) in the long run (about 0.5 percentage points) which in line with the theoretical model but the response is not significant.

4.2.2 The Transitory Shock

Contrary to the two permanent shocks examined above, there is, as mentioned, no identified specific source of the transitory shock - it is simply defined to have only temporary effects on the variables in the system. In such a situation, authors sometimes refrain from labelling the transitory shock - it is simply called 'transitory' (see Alexius, 2001, Carstensen and Hansen, 1997, and Mellander et al., 1992). As all our variables are real, economic theory tells us that our transitory shock is of nominal nature. It is therefore tempting to interpret the shock as being induced by monetary shocks. As the transitory shocks in previous studies often is interpreted as being of monetary nature (see section 4.3 below) we show here that this indeed is *possible* in our model as well.

The response of the variables to a transitory shock is displayed in Figure 3. As can be seen in the figure, the shock has most significant effects on Japan's TFP although the magnitude is greater in the response of the real exchange rate. Consider a (relative to Sweden) negative monetary shock in Japan. This causes output growth to slow down (for example, due to the fact that wages are stickier than prices so that the real wage increases) and, as both labor and capital stock are fixed in the short term, TFP in Japan decreases temporarily. Then, when wages adjust so that the real wage return to the level before the shock, output increase again and the effect on TFP goes to zero.

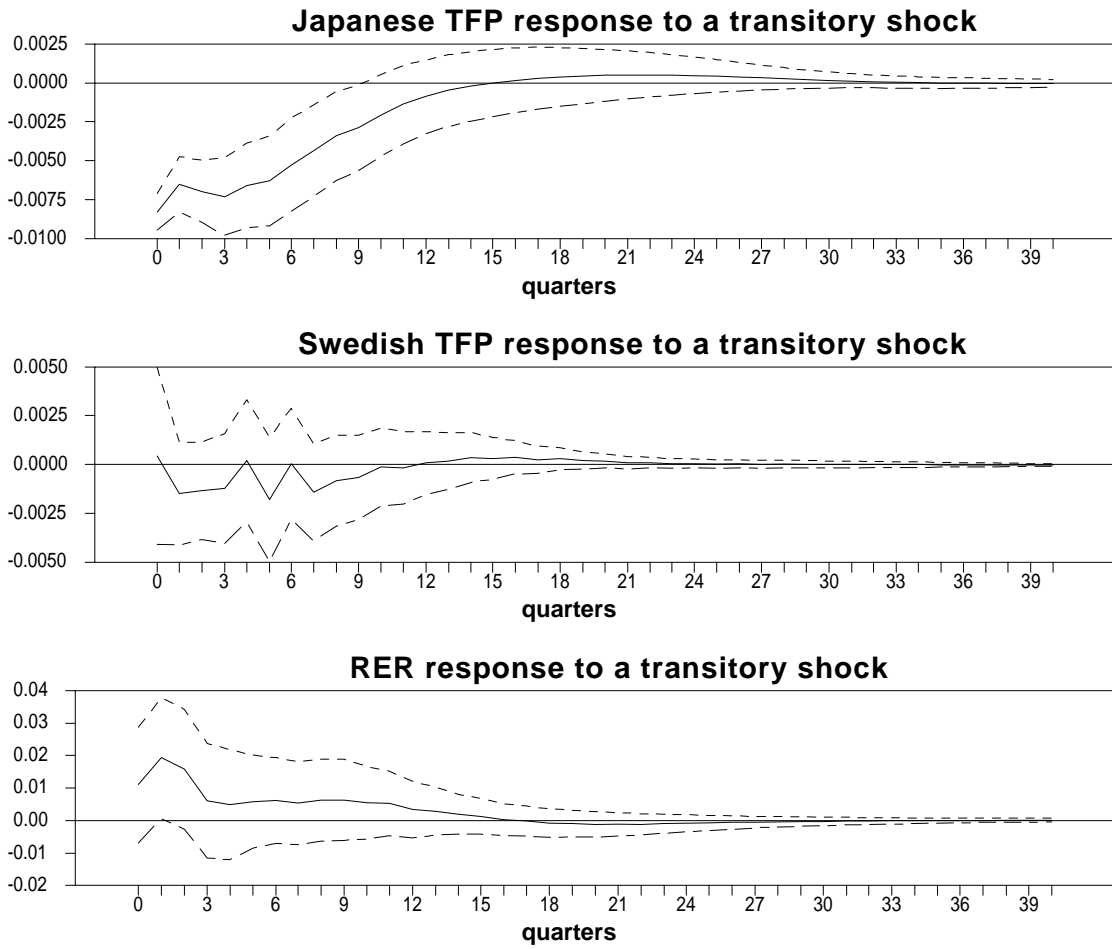
Turning to the response of the real exchange rate (as the response of Swedish TFP is insignificant and very minor indeed), we note that the transitory shock has a positive effect (i.e., a real appreciation of the Yen) in about eight quarters. As prices are more or less sticky in the short run, while the nominal exchange rate is flexible and possibly overshoots (see Dornbusch, 1976), a monetary contraction in Japan implies that the real exchange rate appreciates for Japan in the short run (stemming from the appreciation of the nominal rate). Then, when prices adjust fully, the effect on the real exchange rate goes to zero implying that it is unaffected by nominal (e.g., money) variables in the long run.

To sum up the impulse response analysis, we can note that the interpretation of the permanent shocks and the estimated responses are broadly in line with the theory outlined in section 2 above. A Japanese productivity shock implies a real depreciation of the SEK/YEN rate while a Swedish productivity shock implies a real appreciation. Moreover, a Swedish productivity shock has virtually no effect on Japan's TFP which is what we would expect. We have also shown that it is possible to interpret the transitory shock as being of monetary origin.

4.3 Variance Decomposition

As mentioned in the introduction, the focus of this paper is on the relative importance of transitory shocks in explaining the FEVD of the real exchange rate. There are two reasons for this. First, recent theoretical papers (see, among others, Beaudry and Devereux, 1995,

Figure 3: Impulse responses to the transitory shock



Chari et al., 2001, and Obstfeld and Rogoff, 1995) highlight the importance of monetary shocks when explaining short and medium run movements in the real exchange rate. This research combines general equilibrium models with price stickiness and imperfect competition. Second, a number of recent empirical studies have focused on this issue and a comparison with previous results is therefore given below.

The first row of Table 2 shows the share of the FEVD of the real exchange rate explained by the temporary shock in our application. As can be seen in the table, the transitory shock explains only between 3 – 5% at the horizons shown. The greatest estimated share is 7.2% after two quarters (not shown). Hence, a very low share of the FEVD of the real exchange rate is explained by the transitory shock. This implies that the vast part of the FEVD is explained by productivity shocks. As we shall see below, the estimated share of the FEVD explained by transitory shocks varies greatly in the literature - it ranges from zero to over 50 percent in the short and medium term. Why do *we* get the result that transitory shocks explain only a small share of the FEVD? We believe the answer is rather straightforward. In the bilateral case of Sweden and Japan, we have found a cointegrating relationship between the real exchange rate and the TFPs of the two countries - see Figure 1 and the cointegration test in Table 1. Although there are occasions when the real exchange rate and the TFP differentials go, according to theory, in opposite directions, it is rather clear that the country differences in TFP growth that determine the major part of the movements in the real exchange rate even in the short and medium run.

4.3.1 Comparison with Previous Studies

Methodologically, the Blanchard and Quah, (1989, henceforth: BQ) type of identification of structural shocks clearly dominates the previous literature. BQ's identification implies that long run restrictions (similar to the one used in this paper, without any cointegrating relationships though) are imposed. Typically, the included variables are differenced until stationarity is achieved. For example, Clarida and Gali (1994) include $\Delta(GDP - GDP^*)$, Δq (change in the real exchange rate) and $\pi - \pi^*$ (inflation differential) and interpret the three structural shocks as being (i) supply, (ii) demand, and (iii) money shocks, respectively. By assuming that the last two shocks have no long run effect on the $\Delta(GDP - GDP^*)$ and that the money shock has no long run effect on Δq , exact identification is achieved.¹² A few articles in the literature use short run restrictions á la Choleski in order to identify the structural shocks, see Dibooglu (1996) and Eichenbaum and Evans (1995). That is, they restrict the contemporaneous effects of shocks which is quite the opposite to BQ's method which implies long run restrictions. As the 'BQ-articles', these articles do not include any cointegration relationships/constraints.

¹²Similar examples are Astley and Garratt (2000), Bjørnland (1998), Chardha and Prasad (1997), Enders and Lee (1997), Evans and Lothian (1993), Lastrapes (1992), and Rogers (1999).

Now we turn to comparison of results concerning the share of FEVD explained by transitory shocks. As the labelling of shocks differ in the approaches just mentioned, we refer only to the share of the FEVD explained by shocks *identified* to have only transitory effects on the real exchange rate. The comparison appears in Table 2 and we will briefly comment on the different methodologies, variables, time periods, and countries included:¹³

- Clarida and Gali (1994) study US against Canada, Germany, Japan, and UK using BQ identification and quarterly data over the period 1973:3-1992:4. They include three variables in the study: Δy , GDP differential, US less foreign; Δq , change in the real exchange rate; π , inflation differential, US less foreign. The three structural shocks are labelled supply, demand, and money and the latter shock is identified to have no long run effects on the real exchange rate - the share of the FEVD explained by this shock is shown in Table 2.
- Astley and Garratt (2000) study quarterly data over the time period 1973:1-1994:4 and make use of exactly the same variables and the same method and identification assumptions as Clarida and Gali (1994) described above. The difference is that they use UK as the home country and investigate the bilateral real exchange rates against US, Japan, Germany, and France. The money shock is identified to have no long run effect on the real exchange rate and the share explained of the FEVD of this shock is shown in Table 2.
- Bjørnland (1998) studies the real exchange rate of Norway as an index against several countries using BQ identification. Three further Norwegian variables are included in the study (GDP, real wage, and unemployment) and the time period applied is 1973:2-1994:4. Four structural shocks - productivity, labor supply, fiscal, and velocity - are identified in the model and the latter shock is assumed to have no long run effects on the real exchange rate. The share of the FEVD explained by this shock is shown in Table 2.
- Eichenbaum and Evans (1995) study US against France, Germany, Italy, Japan, and UK using Choleski identification and monthly data over the period 1974:1-1990:5. They consider only monetary shocks in their model by including a 'monetary shock variable' (they test three such variables: the federal funds rate, the ratio of non-borrowed to total reserves, and the Romer and Romer (1989) index, respectively). The first set of variables applied is: US output (Y); US price level (P); a measure of monetary policy shocks (M); short term interest differential ($i^{foreign} - i^{us}$), and the real exchange rate (q). They also test to separate the interest rate variable and

¹³The studies have been selected using one single criteria: they must include estimates of the share of FEVD (in levels) of the real exchange rate explained by shocks identified to have only temporary effects on the real exchange rate. Similar studies, not fulfilling this criteria, include Chadha and Prasad (1997), Dibooglu (2000), Evans and Lothian (1993), and Zhou (1995).

Table 2: Share (in percentage points) of the forecast error variance decomposition of the real exchange rate explained by shocks identified to have only temporary effects on the real exchange rate

Studies	Countries	Horizon					
		1 quar.	1 year	2 years	3 years	4 years	5 years
This paper	JAP/SWE	4	5	3	3	3	3
Clarida/Gali(94)	GER/US	47	50	39	28	21	17
	CAN/US	1	0	0	0	0	0
	JAP/US	36	35	22	15	12	10
	UK/US	2	1	0	0	0	0
Astley/Garratt(00)	FR/UK	0	1	1	1	0	0
	GER/UK	19	8	4	3	2	1
	JAP/UK	2	0	0	0	0	0
	UK/US	1	1	0	0	0	0
Bjørnland(98)	NO/Index	5	4	3	2	—	—
Eich./Evans(95)	JAP/US	—	—	—	23(13)	—	—
	GER/US	—	—	—	43(7)	—	—
	IT/US	—	—	—	38(5)	—	—
	FR/US	—	—	—	38(10)	—	—
	UK/US	—	—	—	26(11)	—	—
Enders/Lee(97)	CAN/US	2	0	0	0	—	—
	GER/US	1	0	0	0	—	—
	JAP/US	4	1	0	0	—	—
Lastrapes(92)	CAN/US	8	10	6	4	3	3
	GER/US	26	27	18	13	11	9
	IT/US	22	11	6	4	3	2
	JAP/US	20	6	3	2	2	1
Rogers(99)	UK/US	—	41	39	—	—	32

Note: See section 4.3.1 for a description of the referred studies.

at the same time include foreign output (Y^*). The share of the FEVD of the real exchange rate explained by monetary shocks is then drastically reduced. The model which measures monetary shocks using the ratio of non-borrowed to total reserves is shown in Table 2. Both the five and seven (in parenthesis) variable specifications are shown and we can note the great differences in the estimated share explained by the monetary shock.

- Enders and Lee (1997) study US against Canada, Germany, and Japan using BQ identification and monthly data during the period 1973:1-1992:4. They include two variables, the first difference of real and nominal exchange rates. The system is identified by assuming that the temporary shock has no long run effect on the real exchange rate. The share of the FEVD explained by this shock is shown in Table 2.
- Lastrapes (1992) studies US against Canada, Germany, Italy, and Japan using BQ identification and monthly data during the period 1973:3-1989:12. He includes the same variables as Enders and Lee (1997) above but finds that the share of the FEVD explained by temporary shocks is much greater, see Table 2.
- Rogers (1999) studies the UK/US relationship using BQ identification and yearly data over the period 1889-1992. The variables in the base line model is: $\Delta(G/Y)$, real government consumption as a share of real GNP, UK less US; Δy , log of real GNP, UK less US; Δq , change in the log of the real exchange rate; $\Delta \ln(M/H)$, log of money multiplier (UK less US), where M is M2 and H is monetary base; $\Delta \ln(H/P_N)$, UK less US, where P_N is the price of non-traded goods. Shocks in the last two variables are identified to have only temporary effects on the real exchange rate and the share of the FEVD of the real exchange rate explained by these shocks is shown in Table 2.

As can be seen in Table 2, the share of the FEVD explained by shocks defined to have only temporary effects on the real exchange rate varies a lot depending on countries considered and methodologies applied. In fact, the share varies from being almost zero at any horizon (e.g., Astley and Garratt, 2000, and Enders and Lee, 1997) to being of substantial magnitude in both the short and medium run (e.g., Clarida and Gali, 1994, and Rogers, 1999).

5 Conclusion

This paper is about how to explain movements in real exchange rates. According to the old (but still alive) PPP theory, the real exchange rate should be stationary. There are, however, theoretical reasons for why PPP may not hold - even in the long run. We put forward one such explanation in this paper - differentials in Total Factor Productivity

(TFP) between countries. In short, a country with higher growth in TFP should experience a real appreciation. Although real factors like productivity may play the dominant role in the long run, recent theoretical articles show that nominal factors might play a role in the short and medium run. In this paper, we try to determine the relative importance of real (permanent) and nominal (transitory) shocks in explaining the forecast error variance decomposition (FEVD) of the real exchange rate in a small open economy.

Analyzing the bilateral rate of Sweden and Japan, we find that the real exchange rate is non-stationary while the real exchange rate and the TFPs are cointegrated. We make use of this fact and estimate a common trends model driven by two permanent shocks and one transitory shock. The model is identified by assuming that Swedish productivity shocks do not have long run effects on Japan's TFP. Focusing on the FEVD analysis, it is clear that the transitory shocks explains a minor part of movements in the real exchange rate - the highest estimated share is 7.2% after two quarters. Hence, productivity (real) shocks explain the vast majority of the FEVD of the real exchange rate. We compare our results with previous literature and find a great variety in the estimated share explained by transitory shocks. Unlike previous studies, we provide an explanation to the observed share of the FEVD explained by transitory shocks. We believe that the main reason for our results is that there *actually is* a rather stable relationship between the real exchange rate of Sweden and Japan and the development of the two countries' TFP. This is shown both graphically (see Figure 1) and econometrically (see the cointegration tests in Table 1).

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