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# Exchange Rate Disconnect in a Standard Open-Economy Macro Model

BERND KEMPA bernd.kempa@uni-essen.de
Department of Economics, University of Essen, 45117 Essen, Germany

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*Abstract*

This paper demonstrates that the well-documented exchange rate disconnect can be explained within traditional exchange rate models. It is shown that even if the underlying fundamentals are invariant across exchange rate regimes, equilibrium real exchange rates are more volatile under flexible nominal exchange rates than under fixed rates. In particular, fixed rates reduce the requisite adjustments of the real exchange rate in response to both nominal and real shocks relative to a floating-rate scenario.

The non-neutrality of nominal exchange rate regimes with respect to real variables, especially the real exchange rate, is by now a well-established fact. The substantial increase in the level of real exchange rate variability after the demise of the Bretton-Woods system of fixed exchange rates in favor of floating rates in the early 1970s may be the most prominent and well-documented example (e.g. Stockman, 1983; Mussa, 1986). Traditional open-economy macro models such as the monetary model of exchange rate determination (Frenkel, 1976; Mussa, 1976) or the sticky-price model of overshooting exchange rates (Dornbusch, 1976; Mussa, 1982) do not account for this non-neutrality proposition. These models identify a set of fundamental determinants of exchange rates, mainly money, output and interest rates, which remain essentially unchanged across exchange rate regimes empirically. So it seems that traditional exchange rate models are unable to account for the patterns of exchange rate volatility encountered in the data (Baxter and Stockman, 1989; Flood and Rose, 1995).

One way of addressing what has been termed by Obstfeld and Rogoff (2000) as the exchange rate disconnect puzzle is to allow for imperfections in financial markets. Flood and Rose (1999) argue that the structure of the foreign exchange market is likely to be influenced by the particular choice of an exchange rate regime. They consider a portfolio balance equation that links the exchange rate to expectations about the future level and volatility of the exchange rate. Under flexible rates, the foreign exchange market becomes more attractive to noise traders who in turn create volatility, whereas with exchange rates credibly fixed, there are no deals to be made from exchange rate speculation, and exchange rate volatility simply disappears. This line of reasoning has been further elaborated and formalized by Jeanne and Rose (2002), who model the noise component as being endogenously determined by the decision of noise traders of whether or not to enter the currency markets. Their model gives rise to multiple equilibria, where in a high volatility equilibrium, noise traders are attracted to the currency market by the high risk premium that they themselves generate by entering the market.

Another line of research into the exchange rate disconnect investigates the implications of alternative pricing assumptions for exchange rate behavior within fully articulated general-equilibrium open-economy macro models of the Obstfeld and Rogoff (1995) variety. Betts and Devereux (2000) and Devereux and Engel (2002) show within such a framework that pricing-to-market, in which firms preset prices in buyers' currencies in internationally segmented markets, magnifies the response of exchange rates to shocks in fundamentals. Using similar frameworks, Dedola and Leduc (2001) and Duarte (2003) demonstrate that local-currency pricing increases the volatility of the real exchange rate under a float while only marginally affecting the volatility of fundamentals across exchange rate regimes.

Using a different approach, Hairault, Patureau, and Sopraseuth (2004) introduce adjustment costs on money holdings within a limited participation model to assess the relevance of nominal exchange rate overshooting. They show that overshooting indeed plays a key role in accounting for the excessive degree of exchange rate volatility, thus rationalizing the disconnect between exchange rates and their fundamental determinants. As overshooting is also a characteristic phenomenon in almost all canonical exchange rate models incorporating some form of short-term price rigidities, their finding suggests that the exchange rate disconnect may be compatible with traditional sticky-price macro models of the open economy after all. In fact, traditional exchange rate models have recently been shown to be able to forecast a statistically significant portion of the variation in exchange rates, even at short horizons [MacDonald and Marsh (1997), MacDonald (1999), Mark and Sul (2001), and Rapach and Wohar (2004)].

This paper demonstrates that the exchange rate disconnect can in fact be identified even within the class of traditional rational-expectations macro models of the open economy. To this end, a simple variant of the well-known two-country open-economy Obstfeld (1985) model is analyzed. The model is a discrete-time two-period model allowing to study dynamics (first period) and steady states (second period) in the simplest possible form. Moreover, the model incorporates a very straightforward element of stickiness by assuming that wages are determined on the basis of price expectations formed one period in advance. The major advantage of this model relative to most other standard exchange rate models is the explicit incorporation of two countries, allowing to analyze exchange rate behavior in a general equilibrium of an integrated world economy.

In its original version, the model is solved for the long-run steady state under flexible exchange rates. Here the corresponding short-run solutions are derived and compared across fixed and flexible rate regimes. It turns out that the model delivers a crucial difference in levels of exchange rate variability for any given level of variability in fundamentals. In particular, exchange rates are more volatile under flexible exchange rates compared with a system of fixed exchange rates, even if the levels of fundamentals variability remain unchanged across regimes. Interestingly, the results go through whether or not exchange rate overshooting is present or absent.

The remainder of the paper is structured as follows. Section 2 presents the model and displays its steady state solution. Section 3 derives the instantaneous adjustments of the endogenous variables and demonstrates the exchange rate disconnect. Finally, Section 4 sums up the results.

## 1. The Obstfeld exchange rate model

The Obstfeld model consists of the following log-linear equations:

$$m_t - p_t = \phi y_t - \lambda i_t, \tag{1}$$
$$m_t^* - p_t^* = \phi^* y_t^* - \lambda^* i_t^*, \tag{2}$$
$$y_t^d = \delta q_t - \sigma r_t + \gamma y_t^* + g_t, \tag{3}$$
$$y_t^{*d} = -\delta^* q_t - \sigma^* r_t^* + \gamma^* y_t + g_t^*, \tag{4}$$
$$q_t = e_t + p_t^* - p_t, \tag{5}$$
$$y_t^s = \theta(p_t - w_t), \tag{6}$$
$$y_t^{*s} = \theta^*(p_t^* - w_t^*), \tag{7}$$
$$w_t = {}_{t-1}p_t, \tag{8}$$
$$w_t^* = {}_{t-1}p_t^*, \tag{9}$$
$$y_t^s = y_t^d, \tag{10}$$
$$y_t^{*s} = y_t^{*d}, \tag{11}$$
$$i_t = i_t^* + {}_t e_{t+1} - e_t, \tag{12}$$
$$r_t = r_t^* + {}_t q_{t+1} - q_t. \tag{13}$$

Equations (1) and (2) are the money market equilibrium conditions for the domestic and foreign economies, where all variables concerning the latter are denoted by asterisks. Money supplies and price levels are denoted by $m$ and $p$, respectively. The money demand functions are standard and depend positively on aggregate income $y$ and negatively on the interest rate $i$. Equations (3) and (4) express aggregate demand as functions of output, the real interest rate $r$, the real exchange rate $q$ and a demand shift term $g$. Equation (5) defines the real exchange rate as the nominal exchange rate $e$, interpreted as the domestic currency price of foreign exchange, adjusted for the price level of foreign output $p^*$ relative to the price level of domestic output $p$. Equations (6) and (7) are aggregate supply functions which depend negatively on current levels of the real wage rate. The domestic and foreign nominal wage rates $w$ and $w^*$ are in turn defined in Equations (8) and (9) as depending on (rational) expectations as of time period $t-1$ of the domestic and foreign price levels prevailing in time period $t$. The output market equilibria are stated in Equations (10) and (11). Finally, Equations (12) and (13) are the nominal and real versions of the uncovered interest parity condition. Here the time index $t$ denotes the interest rate prevailing between periods $t$ and $t+1$, such that any differential between domestic and foreign nominal or real interest rates be exactly compensated by corresponding expectations of adjustments in the nominal or real exchange rates between periods $t$ and $t+1$.

For the purpose of this paper, it is convenient and without loss of generality to assume identical elasticities for the domestic and foreign economies so that the asterisks may be dropped from all foreign parameters. Suppressing the time index $t$ for convenience, the resulting steady-state of the model under flexible exchange rates is then a simplified version of the solution presented in Obstfeld (1985, p. 391):[1]

$$r = r^* = \frac{1}{2\sigma}(g + g^*), \tag{14}$$

$$q = \frac{1}{2\delta}(g^* - g), \tag{15}$$

$$p = m + \frac{\lambda}{2\sigma}(g + g^*), \tag{16}$$

$$p^* = m^* + \frac{\lambda}{2\sigma}(g + g^*), \tag{17}$$

$$e = m - m^* + \frac{1}{2\delta}(g^* - g). \tag{18}$$

The solution of the flexible exchange rate scenario reveals some of the characteristic properties of the model. The fundamental variables are the shift terms $m, m^*, g$ and $g^*$, where changes in $m$ and $m^*$ may comprise any shock in the domestic and foreign money markets, either to money supply or to money demand. The parameters $g$ and $g^*$ can be broadly defined as any shock to domestic or foreign aggregate demand such as autonomous shifts in consumption, investment or fiscal policy. Money is neutral in the long run as $m$ and $m^*$ do not enter the equations for the real interest rate or the real exchange rate. All that a shock in the money market does is shift the nominal variables $p$, $p^*$ and $e$ by identical amounts. In contrast, any increase in aggregate demand in either the home or the foreign economies raises all equilibrium real interest rates and price levels, but exerts differential impacts on the nominal and real exchange rates. In particular, a home expansion of aggregate demand results in a reduction of both $e$ and $q$, implying nominal and real appreciations relative to the foreign economy.

The model can also be solved for fixed exchange rates in the same way as in Obstfeld (1985). In the fixed-rate steady state, the log-level of the nominal exchange rate is constant and can be assumed to equal zero. Then Equation (18) implies:

$$m^* = m + \frac{1}{2\delta}(g^* - g). \tag{19}$$

With the assumption that the foreign country is obliged to intervene in the foreign exchange market to maintain the exchange rate parity, Equation (19) can be substituted for $m^*$ in Equation (17), resulting in:

$$p^* = m + \frac{1}{2\delta}(g^* - g) + \frac{\lambda}{2\sigma}(g + g^*). \tag{20}$$

The fixed-rate steady state is thus represented by Equations (14)–(16), (19) and (20).

## 2. The disconnect

The assumption that wage rates in the current period depend on price expectations of the previous period introduces an element of stickiness into the model and accounts for differences in the responses of the endogenous variables in the short and long runs. The instantaneous effects can be identified by equating aggregate demand and aggregate supply in the domestic and foreign economies, displayed below for the identical elasticity scenario under flexible exchange rates:[2]

$$\begin{aligned}\left(\theta + \frac{(\sigma+\delta)(1+\lambda+\phi\theta)}{\lambda}\right) p_t - \left(\gamma\theta + \frac{\delta(1+\lambda+\phi\theta)}{\lambda}\right) p_t^* = \delta\, {}_t e_{t+1} + \sigma_t\, p_{t+1} \\ + \theta\left(1 + \frac{(\sigma+\delta)\phi}{\lambda}\right) {}_{t-1}p_t - \theta\left(\gamma + \frac{\delta\phi}{\lambda}\right) {}_{t-1}p_t^* + g_t + \frac{\sigma+\delta}{\lambda} m_t - \frac{\delta}{\lambda} m_t^*,\end{aligned} \tag{21}$$

$$\begin{aligned}&\left(\theta + \frac{(\sigma+\delta)(1+\lambda+\phi\theta)}{\lambda}\right) p_t^* - \left(\gamma\theta + \frac{\delta(1+\lambda+\phi\theta)}{\lambda}\right) \\ &\times p_t = -\delta\, {}_t e_{t+1} + \sigma_t\, p_{t+1}^* + \theta\left(1 + \frac{(\sigma+\delta)\phi}{\lambda}\right) {}_{t-1}p_t^* - \theta\left(\gamma + \frac{\delta\phi}{\lambda}\right) {}_{t-1}p_t \\ &+ g_t^* + \frac{\sigma+\delta}{\lambda} m_t^* - \frac{\delta}{\lambda} m_t.\end{aligned} \tag{22}$$

The short-run equilibrium realizations of the endogenous variables can easily be identified by normalizing the initial values of $p$ and $p^*$ at zero such that ${}_{t-1}p_t = {}_{t-1}p_t^* = 0$. Substituting the steady-state solutions for ${}_t e_{t+1}, {}_t\, p_{t+1}$ and

${}_t p^*_{t+1}$ and combining Equations (21) and (22) yields:

$$\begin{aligned} p_t = {} & \frac{(1+\lambda)[a(\sigma+\delta)-b\delta]}{a^2-b^2} m_t + \frac{(1+\lambda)[b(\sigma+\delta)-a\delta]}{a^2-b^2} m_t^* \\ & + \frac{1}{2}\frac{(a+b)\lambda(1+\lambda)}{a^2-b^2}(g_t+g_t^*), \end{aligned} \tag{23}$$

$$\begin{aligned} p_t^* = {} & \frac{(1+\lambda)[a(\sigma+\delta)-b\delta]}{a^2-b^2} m_t^* + \frac{(1+\lambda)[b(\sigma+\delta)-a\delta]}{a^2-b^2} m_t \\ & + \frac{1}{2}\frac{(a+b)\lambda(1+\lambda)}{a^2-b^2}(g_t+g_t^*), \end{aligned} \tag{24}$$

where $a \equiv \theta\lambda + (\sigma+\delta)(1+\lambda+\phi\theta)$ and $b \equiv \gamma\theta\lambda + \delta(1+\lambda+\phi\theta)$.[3]

The short-run aggregate supply effects follow after substituting Equations (23) and (24) into Equations (6) and (7). Combining the resulting expressions with the aggregate demand functions (3) and (4) in the domestic and foreign output market equilibrium conditions (10) and (11), and dropping the time index $t$, the following expressions obtain:

$$\begin{aligned} & \frac{\theta(1+\lambda)[(a-\gamma b)\sigma+\delta(1+\gamma)(a-b)]}{a^2-b^2} m + \frac{1}{2}\frac{\theta\lambda(1-\gamma)(1+\lambda)(a+b)}{a^2-b^2}(g+g^*) \\ & + \frac{\theta(1+\lambda)[(b-\gamma a)\sigma+\delta(1+\gamma)(b-a)]}{a^2-b^2} m^* = \delta q - \sigma r + g, \end{aligned} \tag{25}$$

$$\begin{aligned} & \frac{\theta(1+\lambda)[(a-\gamma b)\sigma+\delta(1+\gamma)(a-b)]}{a^2-b^2} m^* \\ & + \frac{1}{2}\frac{\theta\lambda(1-\gamma)(1+\lambda)(a+b)}{a^2-b^2}(g+g^*) \\ & + \frac{\theta(1+\lambda)[(b-\gamma a)\sigma+\delta(1+\gamma)(b-a)]}{a^2-b^2} m = -\delta q - \sigma r^* + g^*. \end{aligned} \tag{26}$$

Using the real interest parity condition (13) to substitute for $r$ and $r^*$ in Equations (25) and (26), and combining the resulting expressions yields:

$$q = \frac{\theta(1+\lambda)(1+\gamma)(a+b)}{a^2-b^2}(m-m^*) + \frac{1}{2\delta}(g^*-g). \tag{27}$$

Equation (27) implies that the short-run real exchange rate under a float is a function of differential shocks in the money market (nominal shocks) and output markets (real shocks) of the two economies. Comparing this expression with the steady-state response in Equation (15) reveals that the real exchange rate displays overshooting only in the presence of nominal shocks, which moves the short-run real exchange rate temporarily off its long-run equilibrium level.

A corresponding expression for the nominal exchange rate can be obtained by using the definition of the nominal rate given in Equation (5) in connection with Equations (23), (24) and (27). The resulting expression reads:

$$e = \frac{(1+\lambda)(a-b)[\theta(1+\gamma)+(\sigma+2\delta)]}{a^2-b^2}(m-m^*)+\frac{1}{2\delta}(g^*-g). \tag{28}$$

Overshooting of the nominal rate occurs whenever the first coefficient on the right-hand side of Equation (28) exceeds unity. As $a^2-b^2=(a+b)(a-b)$, this condition can be stated as:

$$(1+\lambda)\,[\theta\,(1+\gamma)+(\sigma+2\delta)] > a+b. \tag{29}$$

We also know that

$$a+b=(1+\gamma)\theta\lambda+(\sigma+2\delta)(1+\lambda+\phi\theta). \tag{30}$$

Substituting Equation (30) for the right-hand side of (29) and simplifying yields:

$$1+\gamma > \phi\,(\sigma+2\delta) \tag{31}$$

Condition (31) may or may not be satisfied. The Obstfeld (1985) model is thus consistent with over- and undershooting of the nominal rate in response to nominal shocks, where the likelihood of overshooting increases with the degree of openness $\gamma$. This is in contrast to the behavior of the real exchange rate, which always overshoots in response to nominal shocks.

Corresponding results for the fixed-rate scenario can be derived in an analogous fashion. The major difference between the regimes of fixed and flexible exchange rates is the endogeneity of the domestic and/or foreign money supplies. Under the assumption that the foreign central bank alone is obliged to intervene in foreign exchange markets, the domestic money supply remains exogenous whereas the foreign money supply adjusts continuously to keep the foreign exchange market in equilibrium at the fixed nominal exchange rate. Setting $e=0$ in Equation (28) yields the corresponding equation for the foreign money supply:

$$m^* = m+\frac{1}{2\delta}\frac{a^2-b^2}{(a-b)(1+\lambda)[\theta(1+\gamma)+(\sigma+2\delta)]}(g^*-g). \tag{32}$$

Using Equation (32) to substitute for $m^*$ in the price level Equations (23) and (24) results in:

$$p = \frac{(1+\lambda)(a+b)\sigma}{a^2-b^2}m + \frac{1}{2\delta}\frac{b(\sigma+\delta)-a\delta}{(a-b)[\theta(1+\gamma)+(\sigma+2\delta)]}(g^*-g) + \frac{1}{2}\frac{(a+b)\lambda(1+\lambda)}{a^2-b^2}(g+g^*), \tag{33}$$

$$p^* = \frac{(1+\lambda)(a+b)\sigma}{a^2-b^2}m + \frac{1}{2\delta}\frac{a(\sigma+\delta)-b\delta}{(a-b)[\theta(1+\gamma)+(\sigma+2\delta)]}(g^*-g) + \frac{1}{2}\frac{(a+b)\lambda(1+\lambda)}{a^2-b^2}(g+g^*). \tag{34}$$

A comparison of the price level responses under fixed rates of Equations (33) and (34) with those under flexible rates of Equations (23) and (24) reveals that fixing the nominal exchange rate results in an asymmetry of the price level adjustments following aggregate demand shocks. This asymmetry is due to the assumption that the foreign central bank is solely responsible for maintaining the peg. As a consequence, the coefficient of the differential real shock $(g^* - g)$ is unambiguously positive in Equation (34), but can be either positive or negative in Equation (33). As a consequence, the foreign price level reacts stronger to own demand shocks (because of the implied real appreciation) but reacts less strongly in response to demand shocks originating in the rest of the world (because of the implied real depreciation). Whether or not the volatility of the individual price levels is aggravated or dampened thus depends on the incidence of shocks in the system and cannot be determined a priori. However, what can be unambiguously determined is the *global* volatility transfer of fixing the nominal exchange rate as measured by the impact on the price level *differential*. Note that the rate of change of the real exchange rate is given by $\Delta q = \Delta e + \Delta p^* - \Delta p$. Under flexible exchange rates, $\Delta q = \Delta e$ and $\Delta p^* - \Delta p = 0$, whereas under fixed exchange rates, $\Delta e = 0$ and $\Delta q = \Delta p^* - \Delta p \neq 0$. The resulting volatility of the price level differential generates stabilizing supply-side effects in the domestic and foreign output markets. As a consequence, the equilibrium real exchange has to react less under fixed exchange rates than under flexible rates. This result immediately implies an exchange rate disconnect, which can be expressed formally by recalling the definition of the real exchange rate under fixed rates, $q = p^* - p$. Equations (33) and (34) can then be combined to obtain:[4]

$$q = \frac{1}{2\delta}\frac{\sigma+2\delta}{\sigma+2\delta+\theta(1+\gamma)}(g^*-g). \tag{35}$$

The disconnect is apparent from Equation (35). The real exchange rate under fixed nominal rates responds solely to shocks in output markets. Whereas shifts in relative money supplies may well continue to occur under fixed nominal rates [comp. Equation (19)], these no longer impact the real exchange rate. As long as money market shocks are important in a float, a switch to fixed rates immediately reduces the variability of real exchange rates. But even if nominal shocks do not account for the bulk of variability of exchange rates under floating, real exchange rates are nevertheless stabilized once fixed rates are implemented. This can easily be seen by comparing the corresponding real exchange rate equations for floating and fixed rates, Equations (27) and (35). It turns out that

$$\frac{\sigma + 2\delta}{\sigma + 2\delta + \theta(1+\gamma)} < 1 \tag{36}$$

so that the response of the real exchange rate is necessarily smaller under fixed rates relative to floating rates.

Equation (36) shows that the exchange rate disconnect comes about because of the endogenous supply responses in the model. Absent these supply effects $(\theta = 0)$, the exchange rate system would be neutral with respect to the transmission of real shocks on the real exchange rate. In such a scenario, any disequilibrium in the output markets would have to be reversed exclusively through the aggregate demand side via appropriate adjustments in the level of the real exchange rate. In contrast, if $\theta > 0$, any increase in aggregate demand in one country drives up its relative price level thus raising aggregate supply. This reduces both the resulting disequilibrium in that country's output market and hence the need for the real exchange rate to contribute to the adjustment in world output markets.

## 3. Conclusion

The exchange rate disconnect puzzle has been raised by Obstfeld and Rogoff (2000) and refers to the empirical observation that nominal and real exchange rates adjust differently to shocks in their fundamental determinants depending on whether fixed or flexible exchange rate systems are in place. The aim of this paper was to demonstrate that the puzzle can be resolved even within traditional exchange rate models. To this end a variant of the Obstfeld (1985) model has been utilized. In particular, it has been shown that under fixed exchange rates, shocks arising in the monetary sector of the model do not impact the real exchange rate. Moreover, fixed rates induce a volatility transfer from the exchange rate to the national price level differentials in the presence of aggregate demand shocks. These price level effects in turn trigger stabilizing aggregate supply responses, which contribute to clear world output markets and ultimately reduce the size of any requisite real exchange rate adjustment under fixed nominal exchange rates.

The exchange rate disconnect working through endogenous supply-side effects is particularly clear-cut in the model because of the assumption that aggregate supply responds to the national price levels, but *not* to the nominal exchange rate. An economy being increasingly integrated with the rest of the world is also likely to experience exchange rate effects on aggregate supply, either through consumers and wage setters looking at the consumer price index including imported consumer goods or by producers using imported intermediate goods. The real exchange rate effect may then depend on the degree of openness on the demand side versus the degree of openness on the supply side.[5] It is left for further research to establish the conditions under which the exchange rate disconnect would continue to arise in such a scenario.

## Notes

1. The steady-state solution presented here only considers one-time permanent shifts in the monetary and fiscal variables. However, the framework can easily be extended to allow for changes in the growth rate of the money stock, as analyzed in Obstfeld (1985).
2. The corresponding expressions for the general case are displayed in Obstfeld (1985, pp. 447–448).
3. It is straightforward to show that both $a - b > 0$ and $a^2 - b^2 > 0$ under the realistic assumption that $0 < \gamma < 1$.
4. Equation (35) can alternatively be derived without recourse to the short-run price level functions by using the output market equilibrium conditions instead.
5. These issues have been raised by an anonymous referee.

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