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TECHNICAL TRADING AT THE CURRENCY MARKET INCREASES THE OVERSHOOTING EFFECT*

MIKAEL BASK

Department of Economics, Umeå University
SE-901 87 Umeå, Sweden

It is shown in this letter that the magnitude of exchange rate overshooting is larger than in Dornbusch (1976) when chartists are introduced into the model. Specifically, the extent of overshooting depends inversely on the planning horizon. The latter follows from explicitly modelling the behavior of practitioners: for shorter planning horizons, more weight is placed on technical analysis, while more weight is placed on fundamental analysis for longer planning horizons. (JEL: F31)

1. *Introduction*

The purpose of this letter is to implement theoretically, the observation that the relative importance of fundamental versus technical analysis in the foreign exchange market depends on the planning horizon. For shorter planning horizons, more weight is placed on technical analysis, while more weight is placed on fundamental analysis for longer planning horizons. Taylor and Allen (1992)[1], for example, conducted a questionnaire survey on the use of technical analysis among chief foreign exchange dealers based in London, and they found that at least 90 per cent of the respondents reported placing some weight on technical analysis. Moreover, a skew towards reliance on technical, as opposed to fundamentalist, analysis at shorter planning horizons was found, which became gradually reversed as the length of the planning horizon considered was increased.

In the model developed below, the chartists use moving averages when forming their expectations since it is the most common model used by practitioners (e.g., Taylor and Allen, 1992, and the references in footnote 1). Being restricted to the use of technical analysis, however, is not a shortcoming for the chartists since a primary assumption behind technical analysis is that all relevant information about the future development of the exchange rate is contained in past exchange rates. Further on, the fundamentalists base their expectations about the future development of the exchange rate according to a model that consists of macroeconomic fundamentals only. Specifically, they use (a simplified version of) the Dornbusch (1976) overshooting model. Now, the question in fo-

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[1] *Other related studies are Lui and Mole (1998), Cheung and Wong (2000), and Cheung and Chinn (2001).*

cus in this letter is: hos is the magnitude of exchange rate overshooting affected when chartists are introduced into the Dornbusch (1976) model?

The remainder of this letter is organized as follows. The benchmark model and the expectations formations are presented in Section 2. The formal analysis of the model is carried out in Section 3, and Section 4 contains some concluding remarks.

2. *Theoretical framework*

2.1 Benchmark model

The model consists of a real sector and a monetary sector, where the Phillips curve and aggregate demand for goods constitute the real sector, and the money and the international asset markets constitute the monetary sector. All variables, except the interest rates, are in natural logarithms, and Greek letters denote positive structural parameters.

The Phillips curve is

$$(1) \quad \frac{dp}{dt} = \alpha \left(y^d - y \right),$$

where $\frac{dp}{dt}$, y^d and y denote the inflation rate, aggregate demand for goods and aggregate supply of goods, respectively. Goods prices respond to market disequilibria, but not fast enough to eliminate the disequilibria instantly. Two extremes are obtained by letting $\alpha \to \infty$, which is the case of perfectly flexible prices, and by setting $\alpha = 0$, which is the case of completely rigid prices. A permanent and fully employed work force is assumed, which implies that fluctuations in demand for goods result only in price movements and not in output movements.

Aggregate demand for goods is

$$(2) \quad y^d = \beta (s - p) + \gamma y,$$

where s and p denote the spot exchange rate and the price level, respectively. The exchange rate is defined as the amount of the domestic currency one has to pay for one unit of the foreign currency. The first term on the righ-hand side of the equation represents net exports, which depend on the real exchange rate, $s-p$. The second term represents income-dependent demand for goods. Contrary to the Dornbusch (1976) model, the dependence of aggregate demand on the interest rate is not considered here. This renders the complete model more transparent without qualitatively changing its major implications.

Eq. (3) constitutes the money market:

$$(3) \quad m = p + \delta y - \zeta i,$$

where m and i denote the money supply and the interest rate, respectively. Thus, the real money demand, $m-p$, depends on aggregate income and the interest rate. The money market is assumed to be in permanent equilibrium, i.e., disturbances are immediately intercepted by a perfectly flexible interest rate.

Eq. (4) constitutes the international asset market:

$$(4) \quad i = i^* + E\left(\frac{ds}{dt}\right),$$

where i^* and $E\left(\frac{ds}{dt}\right)$ denote the foreign interest rate and the expected rate of change of the exchange rate, respectively. This asset market equilibrium condition, also known as uncovered interest rate parity, is based on the assumption that domestic and foreign assets are perfect substitutes. The equilibrium condition is maintained by the assumption of a perfectly flexible exchange rate.

2.2 Expectations formations

We model the behavior of practitioners in the following way:

$$(5) \quad E\left(\frac{ds}{dt}\right) = E_c\left(\frac{ds}{dt}\right)\exp(-\tau) + E_f\left(\frac{ds}{dt}\right)(1-\exp(-\tau)),$$

where $E(\cdot)$, $E_c(\cdot)$ and $E_f(\cdot)$ denote market expectations and the expectations of chartists and fundamentalists, respectively. $E(\cdot)$ is a weighted average of chartists' and fundamentalists' expectations, where τ, the planning horizon, determines the weights.

The most common model used by chartists is the moving average model (e.g., Taylor and Allen, 1992, and the references in footnote 1). In this model, buying and selling signals are generated by two moving averages; a short-period and a long-period moving average, where a buy (sell) signal is generated when the short-period moving average rises above (falls below) the long-period moving average. In its simplest form, the short-period moving average is the current exchange rate and the long-period moving average is an exponential moving average of past exchange rates (Bishop and Dixon, 1992).

Thus, chartists expect an increase (a decrease) in the exchange rate when the current exchange rate is above (below) an exponential moving average of past exchange rates:

$$(6) \qquad E_c\left(\frac{ds}{dt}\right) = \eta\left(s - MA\right),$$

where *MA* denotes the long-period moving average. Moreover, we model this long-period moving average as[2]

$$(7) \qquad MA(t) = \int_{-\infty}^{t} \omega(\mu)\, s(\mu)\, d\mu,$$

where

$$(8) \qquad \int_{-\infty}^{t} \omega(\mu)\, d\mu = \int_{-\infty}^{t} \exp(\mu - t)\, d\mu = 1.$$

Finally, following Dornbusch (1976), the expectations of fundamentalists are

$$(9) \qquad E_f\left(\frac{ds}{dt}\right) = \theta\left(\bar{s} - s\right),$$

where $\bar{s}$ is the exchange rate in long-run equilibrium.

[2] *Note that MA also includes the current exchange rate, which is important in the derivation of eq. (22).*

3. Formal analysis of the model

3.1 Long-run equilibrium

Since the long-period moving average in long-run equilibrium, $\overline{MA}$, is equal to the exchange rate in long-run equilibrium,

$$(10) \qquad \overline{MA} = \int_{-\infty}^{t} \omega(\mu)\, \bar{s}\, d\mu = \bar{s} \int_{-\infty}^{t} \omega(\mu)\, d\mu = \bar{s},$$

the chartists expect a constant exchange rate in long-run equilibrium:

$$(11) \qquad E_c\left(\frac{ds}{dt}\right) = \eta\left(\bar{s} - \overline{MA}\right) = \eta\left(\bar{s} - \bar{s}\right) = 0.$$

Moreover, the fundamentalists also expect a constant exchange rate in long-run equilibrium since

$$(12) \qquad E_f\left(\frac{ds}{dt}\right) = \theta\left(\bar{s} - \bar{s}\right) = 0.$$

Then, substitution of eqs. (11)–(12) into the expectations formation in eq. (5) yields

$$(13) \qquad E\left(\frac{ds}{dt}\right) = 0 \cdot \exp(-\tau) + 0 \cdot (1 - \exp(-\tau)) = 0,$$

which means that the market as a whole expect a constant exchange rate in long-run equilibrium.

Now, the equations that describe the money and the international asset markets, i.e., eqs. (3)–(4), can be solved to yield the price level in long-run equilibrium, $\bar{p}$:

$$(14) \qquad \bar{p} = m - \delta y + \zeta i^*,$$

where eq. (13) is utilized in the derivation. Thus, the quantity theory of money holds in the long-run since

$$(15) \qquad \frac{d\,\bar{p}}{dm} = 1.$$

Furthermore, if we evaluate the equations that describe the goods market, i.e. eqs. (1)–(2), in long-run equilibrium and note that the price level is constant, i.e., $\frac{dp}{dt}=0$, the exchange rate in long-run equilibrium can be solved to yield

$$(16)\quad \bar{s}=\bar{p}+\frac{1-\gamma}{\beta}y.$$

Thus, purchasing-power parity holds in the long-run since

$$(17)\quad \frac{d\,\bar{s}}{d\,\bar{p}}=1.$$

Finally, the quantity theory of money and purchasing-power parity, i.e., eq. (15) and eq. (17), implies that

$$(18)\quad \frac{d\,\bar{s}}{dm}=\frac{d\,\bar{s}}{d\,\bar{p}}\frac{d\,\bar{p}}{dm}=1,$$

which will be utilized later on.

3.2 The overshooting phenomenon

Substitution of the expectations of chartists and fundamentalists, i.e., eq. (6) and eq. (9), into the expectations formation in eq. (5) yields

$$(19)\quad E\left(\frac{ds}{dt}\right)=\eta\left(s-MA\right)\exp\left(-\tau\right)+\theta\left(\bar{s}-s\right)\left(1-\exp\left(-\tau\right)\right).$$

Then, substitution of the equations that describe the money and the international asset markets, i.e., eqs. (3)–(4), into eq. (19) implies that

$$(20)\quad \frac{p+\delta y-m}{\zeta}-i^{*}=\eta\left(s-MA\right)\exp\left(-\tau\right)+\theta\left(\bar{s}-s\right)\left(1-\exp\left(-\tau\right)\right).$$

Differentiating eq. (20) with respect to *s*, $\bar{s}$, *m* and *MA*, keeping the price level constant, gives

$$(21)\quad \frac{ds}{dm}=\frac{1+\zeta\theta-\zeta\left(\eta\frac{dMA}{dm}+\theta\right)\exp\left(-\tau\right)}{\zeta\theta-\zeta\left(\eta+\theta\right)\exp\left(-\tau\right)},\quad \tau\neq\log\left(1+\frac{\eta}{\theta}\right),$$

where $d\bar{s}=dm$ is utilized. Now, since[3]

$$(22)\quad \begin{aligned}\frac{dMA\left(t\right)}{dm} &= \frac{dMA\left(t\right)}{ds\left(t\right)}\frac{ds\left(t\right)}{dm}\\ &=\frac{d}{ds\left(t\right)}\int_{-\infty}^{t}\omega\left(\mu\right)s\left(\mu\right)d\mu\cdot\frac{ds\left(t\right)}{dm}\\ &= \omega\left(t\right)\frac{ds\left(t\right)}{ds\left(t\right)}\frac{ds\left(t\right)}{dm}\\ &=\exp\left(t-t\right)\frac{ds\left(t\right)}{dm}=\frac{ds\left(t\right)}{dm},\end{aligned}$$

eq. (21) can be solved to yield

$$(23)\quad \frac{ds}{dm}=1+\frac{1}{\zeta\theta\left(1-\exp\left(-\tau\right)\right)}>\frac{d\,\bar{s}}{dm},\quad \tau>0.$$

Thus, in the short-run, before goods prices have time to react, the exchange rate will rise more than the money supply, and, thus, more than is necessary to bring the exchange rate to long-run equilibrium.

By letting $\tau\rightarrow\infty$, market expectations coincide with the expectations of fundamentalists. Therefore, the equation describing the impact effect of a monetary expansion in Dornbusch (1976) is obtained:

$$(24)\quad \left.\frac{ds}{dm}\right|_{Dornbusch\,(1976)}=1+\frac{1}{\zeta\theta}.$$

Thus, which is an important result in this letter, the magnitude of exchange rate overshooting is larger in this model than in the Dornbusch (1976) model:

$$(25)\quad \frac{ds}{dm}\geq\left.\frac{ds}{dm}\right|_{Dornbusch\,(1976)}.$$

Moreover, the extent of overshooting depends inversely on the planning horizon:

$$(26)\quad \left.\frac{ds}{dm}\right|_{\tau=\tau_0}<\left.\frac{ds}{dm}\right|_{\tau=\tau_1},\quad \tau_0>\tau_1>0.$$

3 Note that $\frac{ds(\mu)}{ds(t)}=0\ \forall\mu<t$.

The latter result means that during periods of time when market expectations are more short-sighted, a given level of monetary disturbances will cause a more volatile exchange rate.

3.3 Saddle-path stability

By using integration by parts repeatedly, the exponential moving average in eqs. (7)–(8) can be rewritten as

$$(27)\quad MA(t) = s(t) - \int_{-\infty}^{t} \exp(\mu - t) \frac{ds(\mu)}{d\mu} d\mu$$

$$= s(t) - \frac{ds(t)}{dt} + \int_{-\infty}^{t} \exp(\mu - t) \frac{d^2 s(\mu)}{d\mu^2} d\mu$$

$$= s(t) - \frac{ds(t)}{dt} + \frac{d^2 s(t)}{dt^2} - \int_{-\infty}^{t} \exp(\mu - t) \frac{d^3 s(\mu)}{d\mu^3} d\mu$$

$$= s(t) - \frac{ds(t)}{dt} + \frac{d^2 s(t)}{dt^2} - \frac{d^3 s(t)}{dt^3} + \int_{-\infty}^{t} \exp(\mu - t) \frac{d^4 s(\mu)}{d\mu^4} d\mu$$

$$= \ldots$$

$$= s(t) + \sum_{i=1}^{\infty} (-1)^i \frac{d^i s(t)}{dt^i}.$$

Then, substitution of eq. (27) into eq. (6) implies that

$$(28)\quad E_c\left(\frac{ds}{dt}\right) = -\eta \sum_{i=1}^{\infty} (-1)^i \frac{d^i s}{dt^i},$$

which can be approximated by

$$(29)\quad E_c\left(\frac{ds}{dt}\right) \approx \eta \left(\frac{ds}{dt} - \frac{d^2 s}{dt^2} + \frac{d^3 s}{dt^3}\right).$$

This approximation[4] makes the complete model more tractable to analyze.

Proposition: The complete model in this letter (i.e., eqs. (1)–(5), eq. (9) and eq. (29)) is characterized by saddle-path stability for all (positive) planning horizons.

Proof: See the Appendix for a proof. ■

4. Concluding remarks

It is shown in this letter that the magnitude of exchange rate overshooting is larger than in Dornbusch (1976) when chartists are introduced into the model. This is an interesting result since the empirical literature demonstrates that there are often large movements in exchange rates that are apparently unexplained by macroeconomic fundamentals. Frankel and Froot (1990, p. 73), for example, writes:

> "[…] the proportion of exchange rate movements that can be explained even after the fact, using contemporaneous macroeconomic variables, is disturbingly low."

Moreover, the extent of exchange rate overshooting depends inversely on the planning horizon. Specifically, the impact effect of a change in current money supply varies negatively with how "long-ranged" the market's planning horizon is.[5] This follows from explicitly modelling the behavior of practitioners: for shorter planning horizons, more weight is placed on technical analysis, while more weight is placed on fundamental analysis for longer planning horizons.

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[4] *The approximation can be motivated by the fact that it is a truncated Taylor series, and that the mathematics of catastrophe theory (i.e., the theory that deals with the dynamics when at least one of the variables make discontinuous changes, like the money supply in this letter) encourages us to work with cubic Taylor series without bothering with the remainder.*

[5] *Note that this should not be confused with the delayed overshooting puzzle uncovered by Eichenbaum and Evans (1995), i.e., short-run undershooting and medium-run overshooting of the exchange rate. Gourinchas and Tornell (2001) address this puzzle in an overshooting model combined with learning.*

The characterization of the perfect foresight path, when the exchange rate has been a long time in long-run equilibrium[6] before a monetary disturbance occurs, is investigated in detail in Bask (2003). Therein, it is shown how the planning horizon and the extent of exchange rate overshooting depend on the structural parameters in the model. The characterization of the perfect foresight path for the model in this letter, without the simplification made in Bask (2003), is part of future research.

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[6] *This assumption implies that* $MA \approx \bar{s}$, *which simplifies the analysis considerably.*

Appendix

Proof of Proposition: The dynamic system consisting of eqs. (1)–(5), eq. (9) and eq. (29) (assuming equality in the equation) can be written as a system of four first-order differential equations via the following steps. Firstly, eqs. (1)–(2) and eq. (16) yields

$$\text{(A.1)} \quad \frac{dp}{dt} = -\alpha\beta\left(p - \bar{p}\right) + \alpha\beta\left(s - \bar{s}\right).$$

Secondly, eqs. (3)–(4) and eq. (14) yields

$$\text{(A.2)} \quad E\left(\frac{ds}{dt}\right) = \frac{p - \bar{p}}{\zeta}.$$

Thirdly, eq. (5), eq. (9) and eq. (29) yields

$$\text{(A.3)} \quad E\left(\frac{ds}{dt}\right) = \eta\left(\frac{ds}{dt} - \frac{d^2s}{dt^2} + \frac{d^3s}{dt^3}\right)\exp\left(-\tau\right) + \theta\left(\bar{s} - s\right)\left(1 - \exp\left(-\tau\right)\right).$$

Fourthly, combine eqs. (A.2)–(A.3) and solve for $\frac{d^3s}{dt^3}$:

$$\text{(A.4)} \quad \frac{d^3s}{dt^3} = \frac{\exp\left(\tau\right)}{\zeta\eta}\left(p - \bar{p}\right) + \frac{\theta\left(\exp\left(\tau\right) - 1\right)}{\eta}\left(s - \bar{s}\right) - \frac{ds}{dt} + \frac{d^2s}{dt^2}.$$

Then, the system of first-order differential equations can be written as

$$\text{(A.5)} \quad \begin{cases} \frac{dp}{dt} = -\alpha\beta\left(p - \bar{p}\right) + \alpha\beta\left(s - \bar{s}\right) \\ \frac{ds}{dt} \equiv u \\ \frac{du}{dt} \equiv v \\ \frac{dv}{dt} = \frac{\exp(\tau)}{\zeta\eta}\left(p - \bar{p}\right) + \frac{\theta(\exp(\tau)-1)}{\eta}\left(s - \bar{s}\right) - u + v \end{cases}$$

The Jacobian matrix evaluated at equilibrium, i.e., $\frac{dp}{dt} = \frac{ds}{dt} = \frac{du}{dt} = \frac{dv}{dt} = 0$, is then

$$\text{(A.6)} \quad J = \begin{pmatrix} -\alpha\beta & \alpha\beta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ \frac{\exp(\tau)}{\zeta\eta} & \frac{\theta(\exp(\tau)-1)}{\eta} & -1 & 1 \end{pmatrix},$$

which means that the characteristic equation, det $(J - \lambda I) = 0$, is

$$\text{(A.7)} \quad \lambda^4 + \left(\alpha\beta - 1\right)\lambda^3 - \left(\alpha\beta - 1\right)\lambda^2 + \left(\alpha\beta - \frac{\theta\left(\exp\left(\tau\right) - 1\right)}{\eta}\right)\lambda + \frac{\alpha\beta}{\zeta\eta}\left(\zeta\theta - \exp\left(\tau\right)\left(1 + \zeta\theta\right)\right) = 0,$$

where I is the identity matrix, and λ_1, λ_2, λ_3 and λ_4 are the roots to the dynamic system.

In order to establish the number of roots with a negative real part, a positive real part, and a real part that is zero, respectively, the Routh-Hurwitz analysis is used. Therefore, the following array of values is created:

(A.8)
$$\begin{array}{ccc}
1 & a_2 & a_4 \\
a_1 & a_3 & 0 \\
-\frac{\begin{vmatrix} 1 & a_2 \\ a_1 & a_3 \end{vmatrix}}{a_1} = a_2 - \frac{a_3}{a_1} & -\frac{\begin{vmatrix} 1 & a_4 \\ a_1 & 0 \end{vmatrix}}{a_1} = a_4 & 0 \\
-\frac{\begin{vmatrix} a_1 & a_3 \\ a_2 - \frac{a_3}{a_1} & a_4 \end{vmatrix}}{a_2 - \frac{a_3}{a_1}} = a_3 - \frac{a_1^2 a_4}{a_1 a_2 - a_3} & -\frac{\begin{vmatrix} a_1 & 0 \\ a_2 - \frac{a_3}{a_1} & 0 \end{vmatrix}}{a_2 - \frac{a_3}{a_1}} = 0 & 0 \\
-\frac{\begin{vmatrix} a_2 - \frac{a_3}{a_1} & a_4 \\ a_3 - \frac{a_1^2 a_4}{a_1 a_2 - a_3} & 0 \end{vmatrix}}{a_3 - \frac{a_1^2 a_4}{a_1 a_2 - a_3}} = a_4 & -\frac{\begin{vmatrix} a_2 - \frac{a_3}{a_1} & 0 \\ a_3 - \frac{a_1^2 a_4}{a_1 a_2 - a_3} & 0 \end{vmatrix}}{a_3 - \frac{a_1^2 a_4}{a_1 a_2 - a_3}} = 0 & 0
\end{array}$$

where a_1, a_2 a_3 and a_4 are coefficients in the following polynomial:

(A.9) $$\lambda^4 + a_1\lambda^3 + a_2\lambda^2 + a_3\lambda + a_4 = 0.$$

Since there are no row of the array with all zeros, there are no roots with a real part that is zero. Then, in order to have four roots with a negative real part, the following conditions must hold:

(A.10) $$\begin{cases} a_1 > 0 \\ a_2 - \frac{a_3}{a_1} > 0 \\ a_3 - \frac{a_1^2 a_4}{a_1 a_2 - a_3} > 0 \\ a_4 > 0 \end{cases},$$

i.e., the number of sign changes in the first column of the array is zero. But $a_4 > 0$ implies that the planning horizon must be negative since

$$\text{(A.11)} \quad \tau < \log \frac{\zeta\theta}{1+\zeta\theta} < 0.$$

Thus, eq. (A.7) does not have four roots with a negative real part. Then, in order to have four roots with a positive real part, the following conditions must hold:

$$\text{(A.12)} \quad \begin{cases} a_1 < 0 \\ a_2 - \frac{a_3}{a_1} > 0 \\ a_3 - \frac{a_1^2 a_4}{a_1 a_2 - a_3} < 0 \\ a_4 > 0 \end{cases},$$

i.e., the number of sign changes in the first column of the array is four. But since $a_4 > 0$ implies that the planning horizon must be negative, eq. (A.7) does not have four roots with a positive real part. Thus, at least one root has a negative real part and at least one root has a positive real part, which means that the dynamic system in eq. (A.5) is characterized by saddle-path stability for all (positive) planning horizons. ■