The Real-Interest-Differential Model after Twenty Years

Alan G. Isaac*
Department of Economics
American University
Washington, DC 20016

Suresh de Mel
Office of the Resident Representative
International Monetary Fund
c/o Central Bank of Sri Lanka
Janadhipathi Mawatha, Colombo 1
Sri Lanka

Abstract

Two decades ago, Frankel (1979) reported empirical results favoring the Dornbusch (1976) overshooting model. Despite an important theoretical and empirical critique by Driskill and Sheffrin (1981), Frankel's classic empirical results spawned a huge literature. We attempt to replicate the Frankel and the Driskill and Sheffrin results. We also offer an update and an extended critique of their work. While specialists in international finance generally accept that the initial promise of Frankel's real-interest-differential model has not been realized, we believe that many will be surprised nevertheless by our bleak findings.
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*Corresponding author. Tel: +1-202-885-3770; fax: +1-202-885-3790.
E-mail addresses: aisaac@american.edu (A.G. Isaac), suresh.imf@cbsl.lk (S. de Mel).

1   Introduction

The simple monetary approach to the determination of flexible exchange rates scored some early empirical successes (Frenkel, 1976; Bilson, 1978), but its performance declined as experience with the generalized float accumulated. Suspicion fell on the monetary approach's assumption of continuous purchasing power parity. Dornbusch (1976) provides the key theoretical response: he shows that price inertia can be an important source of large real-exchange-rate movements. The seminal empirical paper is Frankel (1979), which applies the Dornbusch overshooting model to the USD/DEM exchange rate. Frankel estimates a single equation "real-interest-differential" (RID) model, which is a partially reduced form of the Dornbusch (1976) model. He finds striking support for the Dornbusch model against the simple monetary approach model.

Unfortunately, Driskill and Sheffrin (1981) find that Frankel's estimation procedure produces inconsistent coefficient estimates. They develop an explicit rational-expectations version of the RID model, which allows the derivation and estimation of a true reduced-form equation for the exchange rate, and they firmly reject the model.

In this paper, we update and attempt to replicate the Frankel and the Driskill and Sheffrin results. In doing so, we have several goals. First, we believe that attempted replications of classic pieces of empirical work are scientifically valuable, whether successful or not, and we wish to contribute to such work. Related to this first goal, careful expositions of past theoretical and empirical modeling efforts indicate what can be salvaged and what must be discarded. As it turns out, we uncover some past mistakes in econometric and economic thinking about the RID model, and we explore how these have contributed to its evaluation. We also wish to reassess this classic literature in the light of the great increase in available data. Finally, we find this an interesting case study of the extent to which historical contingencies can mislead empirical researchers, especially in light of the continuing influence of these papers on pedagogy and research strategy in applied exchange rate economics.

Section 2 presents the RID model and our replication of Frankel (1979). Section 3 presents the model under rational expectations and discusses our efforts to replicate Driskill and Sheffrin (1981). We also explain why the empirical model estimated by Driskill and Sheffrin cannot underpin a critique of the RID model—a point which is not generally recognized. We then estimate their theoretical model, which we call the RIDRE model, and our results prove somewhat more favorable than theirs. Finally, in section 4 we offer additional perspective on the RID and RIDRE models by reestimating them over an updated sample.

More than twenty years have passed since Frankel (1979) offered his exciting support for a simple empirical version of the Dornbusch (1976) overshooting model. His RID model remains, with the simple monetary approach model, a pedagogic staple in the field of international monetary economics. Although specialists

in international finance generally accept that the initial promise of Frankel's research has not been realized, many will be surprised nevertheless by our bleak findings.

2 The "Real Interest Differential" Model

We characterize Frankel's RID model in terms of four structural equations plus two simplifying auxiliary assumptions. The structural equations characterize uncovered interest parity, regressive expectations, long-run purchasing power parity, and a classical model of long-run price determination.

$$i_t = s_{t+1}^e - s_t \tag{1}$$

$$s_{t+1}^e - s_t = \Delta \bar{s}_{t+1}^e - \theta(s_t - \bar{s}_t) + \varepsilon_t \tag{2}$$

$$\bar{s}_t = \bar{p}_t \tag{3}$$

$$\bar{p}_t = \bar{m}_t - \phi \bar{y}_t + \lambda \pi_t \tag{4}$$

Here s is the logarithm of the spot rate, s_{t+1}^e is the value of s_{t+1} expected at time t, $\bar{s}$ is the full-equilibrium value of s, and i is the nominal interest differential.[1] Additionally, θ is the speed at which the exchange rate is expected to move toward its full-equilibrium level, ε is a random deviation from the deterministic regressive-expectations formulation, and $\Delta \bar{s}^e$ is the rate at which the full-equilibrium exchange rate is expected to change over time. Finally, $\bar{m}$, $\bar{y}$, and $\bar{p}$ are the (logs of) the full-equilibrium levels of the relative money supply, income, and price level (as determined by the simple classical model of price determination), while π is the expected full-equilibrium inflation-rate differential. For convenience in exposition, we set all constants to zero, including the long-run real exchange rate.

If (3) is common knowledge, then $\Delta \bar{s}^e = \pi$. This link between long-run purchasing power parity and expected depreciation is our first auxiliary assumption, which allows us to solve for the exchange rate as

$$s = \bar{m} - \phi \bar{y} + \left(\lambda + \frac{1}{\theta}\right)\pi - \frac{1}{\theta}i + \nu \tag{5}$$

where $\nu = \varepsilon/\theta$. The second auxiliary assumption equates observed exogenous variables to their full-equilibrium levels, which produces the RID model.

2.1 Replication: Frankel (1979)

In this section, we replicate some key results of Frankel (1979). In order to implement (5) empirically, Frankel assumes that observed values of money and income equal their full-equilibrium values. This gives him (6),

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[1]More precisely, $i_t = \ln[(1+I_t)/(1+I_t^*)]$ where I_t and I_t^* are the domestic and foreign nominal interest rates, as an absolute rate of return from t to $t+1$.

which we will refer to as the RID model of the spot rate.

$$s_t = m_t - \phi y_t + \left(\lambda + \frac{1}{\theta}\right)\pi_t - \frac{1}{\theta}i_t + \nu_t \tag{6}$$

Here m is the log of the relative money supply, and y is the log of relative real income. The RID model predicts a money supply coefficient of unity, negative income and interest-rate coefficients, and a positive coefficient on expected inflation. These predictions have been subject to a great deal of empirical scrutiny.

<center>[[[Table 1 About Here]]]</center>

Frankel's ordinary least squares estimates are reported in the OLS:f79 rows of Table 1. His estimated coefficients have the predicted signs, are of plausible size, and (excepting the interest-rate coefficient) appear significantly different from zero. When Frankel restricts the coefficient on the relative money supply to unity, as implied by his theoretical model, the results are little changed.[2] The OLS:78 rows of Table 1 show that we are able to replicate these results exactly.[3]

There is strong evidence of serial correlation in the OLS residuals. To address this problem, Frankel reports iterated Cochrane-Orcutt (CORC) results. The AR1:f79 rows of Table 1 report Frankel's CORC results, which closely resemble the OLS results. The AR1:78 rows of Table 1 show that we are able to replicate these results quite closely.[4] Frankel's results were seen as exciting initial support for the real interest rate differential model, and we find that his results are replicable. (The remainder of Table 1 is discussed below.)

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[2] The t-statistic suggests this restriction will not be rejected. However Frankel suggests that this constraint addresses worries that central banks may vary money supplies in response to exchange rates and may also improve the estimation if money demand shocks are important.

[3] Frankel supplied his data for the Haynes and Stone (1981) comment on his 1979 article. We are extremely grateful to Stephen Haynes for his professionalism in archiving this data and for his courtesy in providing it to us. This data is used in the reported replications.

[4] Our CORC results can be produced with the iterative CORC procedure in the online GAUSS source code archive, setting the convergence criterion to .01 and the initial value of rho to zero. Our results differ noticeably from Frankel's only for a coefficient on the nominal interest differential. We estimate the coefficient as -2.61 while Frankel reports -0.259. Given that we are able to replicate his OLS results *exactly* and his other CORC results quite closely, we presume there is a typographical error in Frankel's table.

Frankel (1979) also "tests" for non-instantaneous adjustment in capital markets by including a lagged interest differential term. Our replication of this equation was also exact for OLS and very close for CORC. The equation is too *ad hoc* to report here, but our results are available upon request. Finally, Frankel finds a significant sign on the interest rate only after turning to an instrumental variable procedure. Since the data set we obtained did not include his instruments, we were unable to replicate these results. The IV results reported in Table 1 are discussed in the next section.

2.2 Consistent Single Equation Estimation

Is (6) a valid regression equation? Frankel turns to instrumental variables to rectify possible defects (presumably measurement error) in his expected inflation variable. He also constrains the money supply coefficient to unity as a response to possible money supply endogeneity. However, Driskill and Sheffrin (1981) argue correctly that Frankel's entire theoretical framework suggests that the interest rate is endogenous, raising concerns that all of his estimated coefficients are biased and inconsistent.[5]

We will illustrate the problem by turning to the rest of the Dornbusch (1976) model, following the discrete-time exposition of Driskill and Sheffrin. Begin by considering money market equilibrium, as represented by (7).[6]

$$i_t = -\frac{1}{\lambda}m_t + \frac{1}{\lambda}\phi y_t + \frac{1}{\lambda}p_t + \frac{1}{\lambda}v_{m,t} \tag{7}$$

Here $v_{m,t}$ is an error term representing money demand shocks, which is discussed in more detail in section 3. Equation (7) suggests that we might approach the estimation of (6) in two stages, with m, y, and p as instruments for i.

The basic Dornbusch overshooting model treats m, y, π as fixed, which motivates their exogeneity in Frankel's empirical implementation. The proper treatment of p is perhaps less evident. For example, let us follow Driskill and Sheffrin in representing the dynamic adjustment in the Dornbusch overshooting model by (8).[7]

$$p_t - p_{t-1} = \delta(s_{t-1} - p_{t-1}) + \pi_{t-1} + v_{p,t} \tag{8}$$

In this case p is a suitable instrument for i only if there is no correlation between the error in the price equation (v_p) and the error in the interest rate equation (v_m). In the absence of such a restriction, we might use (8) to substitute for p in (7), yielding (9).

$$i_t = -\frac{1}{\lambda}m_t + \frac{1}{\lambda}\phi y_t + \frac{1}{\lambda}[(1-\delta)p_{t-1} + \delta s_{t-1} + \pi_{t-1}] + \frac{1}{\lambda}(v_{m,t} + v_{p,t}) \tag{9}$$

This suggests m_t, y_t, p_{t-1}, s_{t-1}, and π_{t-1} as instruments for i_t. Table 1 reports the implied instrumental variables estimates: the IV0:78 rows are IV estimates of the basic RID model, and purely for the purpose

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[5]Recall that Frankel assumes that the observed relative money supply is equal to its full-equilibrium level. This assumption can be justified (see Driskill and Sheffrin), but not if we treat the interest rate as exogenous.

[6]Once we have equation (7), the RID model can be summarized as relating the *real* exchange rate to the same real interest differential: $s_t - p_t = -(\lambda + 1/\theta)(i - \pi_t) + \text{noise}$, which compares to Frankel (1979, eq. A3).

[7]This is a standard discrete time version of the price dynamics in the Dornbusch (1976) overshooting model, modified to include Frankel's secular inflation term. This price adjustment formulation is particularly tractable because the price level is predetermined. In the Dornbusch model, the relative price level adjusts in response to relative excess demand in the goods market. The particularly simple formulation in (8) arises, after suppressing constants, when one realizes that relative excess demand can be indexed by the real exchange rate in the Dornbusch model.

of comparison, the IV1:78 rows report the results with an AR(1) correction. In brief, the results look much the same as before.[8]

3 The RID Model with Rational Expectations

In this section we present the Driskill and Sheffrin (1981) version of the real-interest-differential model under rational expectations (RIDRE), and we attempt to replicate their empirical results. The Driskill and Sheffrin study is well known for two primary reasons: it offers a coherent, detailed attack on Frankel's classic RID model, and it contains an early attempt to test the parameter restrictions implied by the rational expectations hypothesis.

The structural model is just a discrete-time version of the Dornbusch (1976) model, with equations (1), (7), and (8) representing uncovered interest parity, money market equilibrium, and price dynamics. Driskill and Sheffrin explicitly characterize the two random shocks: v_p is assumed to be white noise but v_m is allowed to be serially correlated.

$$v_{m,t} = \rho_m v_{m,t-1} + \eta_t \tag{10}$$

where η_t is white noise. In addition, they assume that expectations formation is rational in the sense of Lucas (1972).

$$s^e_{t+1} = \mathcal{E}_t s_{t+1} \tag{11}$$

Here $\mathcal{E}_t$ is the expectations operator conditional on the information available at time t, which includes the current and past values of all variables plus the structure of the model.

The RIDRE model specification is completed by an atheoretical characterization of the exogenous variables y, m, and π. (Driskill and Sheffrin choose these to match Frankel's discussion.) Relative income is assumed to follow a random walk. The relative money supply is assumed to follow a random walk around a trend, π_t, which in turn follows a random walk. Equations (12), (13), and (14) characterize these stochastic

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[8]The Durbin-Watson statistic suggests that the AR(1) correction has not been adequate to remove the serial correlation. The Breusch-Godfrey LM test for serial correlation confirms this. While we can get acceptable results from the Breusch-Godfrey LM test for serial correlation (and of course from the DW test as well) if we add an AR(2) correction, this does not improve the RID model's performance. When we extend the sample in section 4, this remains the case even if we break the sample in two to accommodate the German unification.

processes, where $\eta_{y,t}$, $\eta_{m,t}$, and $\eta_{\pi,t}$ represent white noise.

$$y_t = y_{t-1} + \eta_{y,t} \tag{12}$$

$$m_t = m_{t-1} + \pi_t + \eta_{m,t} \tag{13}$$

$$\pi_t = \pi_{t-1} + \eta_{\pi,t} \tag{14}$$

Putting it all together leads to the rational expectations solution for the spot rate:

$$s_t = (1 - c_2)m_t + c_2 p_t - (1 - c_2)\phi y_t + (1 - c_2)\lambda \pi_t$$
$$- [1/\lambda(1 - c_2\delta - \rho_m)]v_{m,t} \tag{15}$$

where $c_2 = (1 - \sqrt{1 + 4/\lambda\delta})/2 < 0$. While Frankel (1979) focuses only on the determination of s, Driskill and Sheffrin consider the model's implied solutions for i and p as well. Their restricted model therefore consists of equations (15), (7), and (8), and their corresponding unrestricted model is (16), (17), and (18).

$$s_t = c_1 m_t + c_2 p_t + c_3 y_t + c_4 \pi_t + \epsilon_{s,t} \tag{16}$$

$$i_t = b_1 m_t + b_2 p_t + b_3 y_t + \epsilon_{i,t} \tag{17}$$

$$p_t = a_1 s_{t-1} + a_2 p_{t-1} + a_3 \pi_{t-1} + \epsilon_{p,t} \tag{18}$$

Note that to move from the RID model to (16), we must drop the interest rate differential and add the relative price level to the regressors. The negative coefficient that the RID model predicts for the interest differential is now found on the price level. (We will return to this.)

The rational expectations solution of the model implies eight within-equation and cross-equation parameter constraints. These constraints are reasonably intuitive. By inspection, we need $a_1 + a_2 = 1$ and $a_3 = 1$ in order to satisfy the price adjustment equation. We need $b_1 + b_2 = 0$ because of the absence of money illusion in the assets markets. We need $c_1 + c_2 = 1$ for a similar reason: it ensures that the real exchange rate is related to the real but not the nominal money supply. From the money market equation we can see directly that it must be the case that $b_3/b_2 = \phi$, and since we also need $\phi = -c_3/(1 - c_2)$, it must be true that $-c_3/(1 - c_2) = b_3/b_2$. Similarly, from the money market equation we can see directly that it must be the case that $1/b_2 = \lambda$, and since we also need $\lambda = c_4/(1 - c_2)$, it must be true that $c_4/(1 - c_2) = 1/b_2$. So far we have stated these restrictions so that they apply equally to the RID model. However under rational expectations c_2 is not a free parameter, since the expected and actual speeds of adjustment must be the same. Furthermore, since the autoregressive error structure in the exchange rate equation is due to the money market shock, the rational expectations solution must imply that $\rho_s = \rho_m$.[9]

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[9]Algebraic details are given in a supplement to this paper, available from the authors. Note two small divergences between our theoretical presentation and that of Driskill and Sheffrin (1981). First, they treat the monetary shock, v_m, as serially

3.1 Replication: Driskill and Sheffrin (1981)

In this section we attempt to replicate key empirical results from the Driskill and Sheffrin (1981) study. The original study appears flawed. Correcting these flaws offers a modest improvement over their results.

Driskill and Sheffrin do not discuss their data in any detail, simply noting that it is from Frankel. Unfortunately, the original Frankel (1979) data set does not allow an exact replication of their results. Nevertheless our attempted replication of some of their simplest regressions yields very similar results. For example, they offer a collection of "data diagnostics," comparable to the Dickey-Fuller tests considered in more modern work, which suggest that the levels of these variables contain a unit root and that the random walk assumption is reasonable. We were able to reproduce those results fairly closely, and augmented Dickey-Fuller tests agree.[10] We also considered the RIDRE assumptions that relative money supply follows a random walk around a trend and that this trend in turn follows a random walk, and we found some support for these as well.

3.1.1 Estimating the DS81 Empirical Model

Recall that Driskill and Sheffrin offer (16), (17), and (18) as their three unrestricted regression equations for s, i, and p. They initially estimate these using ordinary least squares. Since their Durbin-Watson statistic suggests the presence of serial correlation in the residuals of the exchange rate and interest rate equations, they reestimate these with an AR(1) adjustment.[11] Our replication results, presented in Table 2, are in general agreement with theirs.

[[[Table 2 About Here]]]

In Table 2, results are ordered by equation, estimation procedure, and data sample. First consider the exchange rate equation. We report Driskill and Sheffrin's OLS results in row OLS:DS81, followed by our replication in row OLS:78. We report Driskill and Sheffrin's results with an AR(1) correction in row AR1:DS81, followed by our replication in row AR1:78. The replications show general qualitative agreement

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correlated in their empirical discussion, while for "expository ease" (p.1069) it is white noise in their algebra. This apparently led them to overlook the restriction $\rho_s = \rho_m$. Second, they ignore the constraint in the price equation on the expected inflation variable coefficient ($a_3 = 1$), while we include it. (Since they drop π in their final estimations, this omission might be considered irrelevant to their empirics.) In section 3.2, we deal with these issues in greater detail. Absent the shocks, our restricted model compares to equations 10, 11, and 12 in Driskill and Sheffrin (1981): just set $\rho_m = 0$ in (15), and note that they state the solution for p_t in terms of π_t by invoking (14).

[10]As with our replication of Frankel (1979), we are here working with the data supplied by Frankel to Haynes and Stone (1981). Our results are tabulated and discussed in a supplement to this paper, which is available from the authors.

[11]They discover that the core inflation differential (π_t) is insignificant in both the exchange rate and price equations. On this basis, they drop π_t and reestimate both equations. This has little effect on their results, so we report only the results based on the RIDRE model (which includes π where appropriate).

with the Driskill and Sheffrin results, but there are differences in the details. (We argue in section 3.2 that some of the differences trace to errors in the original study.) Our coefficients have the predicted signs, but only the relative price level has a coefficient that is significant at the 5% level. At the 10% level the money supply coefficient is also significant but is also much smaller than predicted. Driskill and Sheffrin, on the other hand, find only relative income to be significant. Our point estimate of the relative money supply coefficient is comparable to theirs, which is significantly less that predicted by the overshooting theory. Similarly, the sum of the coefficients on the relative money supply and the relative price level is much smaller than the predicted value of unity. Note that the Durbin-Watson statistic still suggests serial correlation.

Next consider the interest rate equation in Table 2. We report Driskill and Sheffrin's OLS results in row OLS:DS81, followed by our replication in row OLS:78. (We believe the differences in coefficient magnitude trace to a failure to scale the interest rate in the original study; see section 3.2.) We report Driskill and Sheffrin's results with an AR(1) correction in row AR1:DS81, followed by our replication in row AR1:78, which confirms their finding that only the relative money supply is significant at the 10% level.

Finally, consider the price equation in Table 2. We report Driskill and Sheffrin's OLS results in row OLS:DS81, followed by our replication in row OLS:78. Like Driskill and Sheffrin, we find a highly significant coefficient on the lagged relative price variable. We find the other variables to be insignificant even at the 10% level, while Driskill and Sheffrin report the lagged-exchange-rate coefficient to be statistically significant. The theory predicts that the sum of the coefficients on the lagged relative price level and lagged exchange rate should be 1. Our estimates sum to 0.954, which is less than one standard deviation away from 1. The Driskill and Sheffrin estimates sum to 0.84, which is significantly less than 1. In this modest respect, our price-equation results are an improvement over theirs.

Driskill and Sheffrin also estimate their three restricted equations simultaneously using non-linear least squares. They then report a "likelihood-ratio test" of the validity of the rational-expectations restrictions. Their restricted estimation calculates a total of 8 parameters: three structural parameters (δ, λ, and ϕ), three intercept parameters, and two autoregressive parameters. Their unrestricted model estimates a total of 13 parameters: eight coefficients, three intercepts, and two AR(1) parameters. Table 3 presents the Driskill and Sheffrin results (column DS81) and our attempted replication (column DS81:78).

[[[Table 3 About Here]]]

We initially approach replication by estimating the DS81 model with the Frankel data. Our results in the DS81:78 column of Table 3 are scarcely more encouraging than the original study.[12] Driskill and Sheffrin find only δ to be significant and signed as predicted; ϕ is has the predicted sign but is insignificant, and λ is

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[12]However, it should be noted that these results are very fragile. For example, better looking results can be obtained with an alternative interest rate series.

significant but does not have the predicted sign. While we obtain the predicted signs on all coefficients, we find none of the parameters of interest differ significantly from zero.

The parameter estimates for λ and δ reported in column DS81 of Table 3 imply a complex value for c_2 (the relative price level coefficient in the exchange rate equation). This conflicts with the saddle-path dynamics that are a core constituent of the RIDRE model, but it must be an error (see section 3.2). Our attempted replication is more supportive: in the DS81:78 column of Table 3, we report a negative computed value for c_2. (This is the exchange rate overshooting condition, which is in fact assured by our positive estimates for λ and δ.) In addition, estimated parameters satisfy the condition $0 < 1 + \delta(c_2 - 1) < 1$, which assures the monotonic saddle-path dynamics generally presumed to characterize the overshooting model (Isaac, 1996). (Equivalently, given our positive estimates for λ and δ, we find $\delta < \lambda/(1 + \lambda)$.)

That is the good news for the model. However, like Driskill and Sheffrin, we find that a "likelihood-ratio test" easily rejects the overidentifying restrictions of section 3. So the results reported in column DS81:78 of Table 3, while differing from the Driskill and Sheffrin (1981) results reported in column DS81, still support their basic contention that this model is a poor fit to the data. However, in attempting this replication we encountered problems that require further exploration.

3.2   Estimating the RIDRE Model

In this section, we outline five problems we encountered as we attempted to replicate the Driskill and Sheffrin (1981) study. We fix these problems and report "corrected" empirical results in column RIDRE:78 of Table 3.

Two of our concerns about the Driskill and Sheffrin system estimation are relatively minor. Allowing $v_{m,t}$ to be serially correlated affects the rational expectations solution: there is a cross-equation restriction on first-order autoregressive parameters in exchange rate and interest rate equations.[13] Driskill and Sheffrin neglect this implication. They also report system estimates after excluding π from their model. Since Frankel (1979) places great emphasis on the role of the core-inflation differential, the Driskill and Sheffrin study thereby ceases to be a critique of Frankel's real-interest-differential theory of exchange rate determination. (However, this has little effect on the estimated values of the other coefficients.)

Three additional problems are more serious. Driskill and Sheffrin (1981, Table 3) report a complex value for c_2. This result must be in error: a complex c_2 would imply a complex value for their restricted "likelihood"

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[13]There is a related problem that we finesse in order to stay close to the original RIDRE model. As the model is laid out by Driskill and Sheffrin (1981), there are only two shocks to a three-equation system. Driskill and Sheffrin simply ignore this implication, and we will essentially follow them in this. As a justification, we simply allow for unmodeled white noise to disturb the exchange-rate equation (*after* the AR(1) transformation).

function. Another problem is suggested by the results reported in Table 2: for the exchange rate equation our estimated coefficients on the expected inflation differential (π_t) are much larger than the Driskill and Sheffrin estimates, while for the interest rate equation our estimated coefficients are much *smaller* than theirs. This suggests they failed to scale their interest rate data to absolute one-month rates of return. Finally, recall that Driskill and Sheffrin offer endogeneity of the interest rate as a primary motivation for their reevaluation of the RID model. Their contention that this endogeneity undermines the standard RID estimates has been widely accepted. Ironically, their own formulation suffers from an identical problem: p_t is generally correlated with the error in the exchange rate equation. Thus their "FIML" estimates simply minimize the generalized variance of their system, as it stands, which will generally yield inconsistent estimates.

The RID model offers a quick way to see the final point. Substituting (7) into (6) yields (19), which clearly links the RID and the RIDRE exchange rate equations. (Just set $\theta = -1/\lambda c_2$.) And through this linkage, we return to the discussion of consistent estimation initiated in section 2.2.

$$s_t = \left(1 + \frac{1}{\theta\lambda}\right)(m_t - \phi y_t + \lambda\pi_t) - \frac{1}{\theta\lambda}p_t + \nu_t - \frac{1}{\theta\lambda}\upsilon_{m,t} \tag{19}$$

We now predict a negative coefficient on p that was previously expected on i. In addition, the coefficient on m is now predicted to be greater than unity. However, we have seen that (19) is not generally a valid regression equation. To get a true reduced form, we need to use (8) to substitute for p.

In order to get to an estimable reduced form, we multiply both sides of the s and i equations by $(1-\rho_m L)$, where L is the lag operator, and then substitute for p. Making some concessions to minimizing notation, we can write the observable reduced form for the RIDRE model as (20), (21), and (22) subject to the same cross-equation restrictions as before.

$$\tilde{s}_t = (1 - c_2)\tilde{m}_t + c_2\tilde{p}_t - \phi(1 - c_2)\tilde{y}_t + \lambda(1 - c_2)\tilde{\pi}_t$$
$$+ c_2 v_{p,t} - \frac{1}{\lambda(1 - c_2\delta - \rho_m)}\eta_{m,t} \tag{20}$$

$$\tilde{i}_t = -(1/\lambda)\tilde{m}_t + (1/\lambda)\tilde{p}_t + (\phi/\lambda)\tilde{y}_t + (1/\lambda)(v_{p,t} + \eta_{m,t}) \tag{21}$$

$$p_t = \delta s_{t-1} + (1 - \delta)p_{t-1} + \pi_{t-1} + v_{p,t} \tag{22}$$

Here $\tilde{p}_t = \delta s_{t-1} + (1 - \delta - \rho_m)p_{t-1} + \pi_{t-1}$ but for the remaining variables $\tilde{x}_t = x_t - \rho_m x_{t-1}$.

In contrast with equation (15), which was used by Driskill and Sheffrin (1981), an unrestricted single-equation estimation of (20) can provide consistent parameter estimates for a RIDRE economy.[14] One way to look at this is very useful: the instrumental-variables results reported in Table 1 give us a better single-

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[14]Since the price equation fits pretty well, we might not expect this to make a large difference—and it does not. A similar accommodation could be made for the 'exogenous' variables in the model, but since assuming block diagonality of the covariance matrix is a standard treatment of the forcing variables, we do not pursue this point here.

equation approach to the RIDRE model than do the results in Table 2. Bluntly put, the Driskill and Sheffrin single-equation results add nothing to our understanding of the RID model.

The RIDRE columns of Table 3 report a corrected estimation of the RIDRE model: interest rates are measured as absolute one-month rates, we impose the implied restriction between c_2 and the structural parameters, we retain the core-inflation variable and restrict its coefficient in the price equation and the exchange rate equation, we impose equal autoregressive parameters on the exchange rate and interest rate equations, and we acknowledge the endogeneity of p in the RIDRE system. The results using the original sample are shown in the column RIDRE:78 of Table 3.[15]

The results from the RIDRE model produce the predicted signs for λ and δ, and λ differs significantly from zero (δ just misses). However ϕ is clearly insignificant at the at any interesting significance level. Our estimate of the price adjustment coefficient (δ) is close to that of Driskill and Sheffrin, but our estimate of λ—the interest rate semi-elasticity of money demand—is not of the same order of magnitude as theirs. In contrast with the Driskill and Sheffrin estimate, conversion to a per annum basis (roughly, division by 1200) shows our estimate of λ to be plausible. The final structural parameters also satisfy both the stability and overshooting conditions. Nevertheless, a likelihood-ratio test still rejects the theoretically implied overidentifying restrictions.[16] Our overall conclusion is that the results reported in column RIDRE:78 of Table 3 offer slightly better empirical support for the RIDRE model than those reported by Driskill and Sheffrin.

4   Estimation over an Extended Sample

In this section we update our empirical analyses and examine the RID model's recursive coefficient estimates.

4.1   The RID Model

Recall the first row of results in Table 1, which reports the rather promising OLS coefficient estimates reported by Frankel (1979). These results generated extensive empirical work on the RID model in the late 1970s. Initially this research corroborated Frankel's encouraging results, but extension of the sample period

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[15]The Frankel (1979) data we obtained is unfortunately fully transformed, so to respond to the concerns we have enumerated we use *IFS* data even for this estimation over the original sample. Standard errors are constructed under the assumption that the innovations are normally distributed.

[16]A referee offered the interesting suggestion that we test the restrictions individually. While there is no unique formulation of such restrictions, most of the intuitive formulations given in the text can be tested. Individual Wald tests reject none of the RID restrictions. However, as a group they are rejected. Equality of the two autoregressive parameters is rejected in the RID model, but not in the RIDRE model. Because of its dependence on the entire model structure, the speed of adjustment restriction cannot be tested independently of the other restrictions.

past 1978 offered a dramatic contrast. Baillie and Selover (1987) offer a representative example from the mid-1980s: they find that monthly German and U.S. data over the sample 1973.03–1983.12 strongly reject the RID model. Most disturbing is their result that the OLS estimate of the coefficient on the relative money supply is significant but of the wrong sign. (They find similar problems for other countries.) Significant, perversely-signed coefficients on relative money supply are a common finding in later work—a startling problem for any "monetary" approach. Baillie and Selover note that correcting for serial correlation in the residuals eliminates the sign difficulties, but then all estimated coefficients appear insignificantly different from zero.

The OLS:98 and AR1:98 rows of Table 1 report results for the sample 1974.07–1998.11, indicating that serious difficulties continue plague the RID model even in an extended data set. The associated instrumental-variables regressions, reported in the IV0:98 and IV1:98 rows, are no better. Both analyses include an intercept dummy for the German unification (uni), which takes on a value of 1 after January 1991, when the money supply data series (m) includes data for the former GDR.

The difficulties with the basic RID model can be displayed even more dramatically. Figure 1 plots the recursive OLS estimates for the RID model. The parameter estimates meander, appearing upon causal inspection to follow a random walk. There is no evidence of parameter stability. (The "constrained version" of the model—with the coefficient on the money supply constrained to unity—yields similar results.)

[[[Figure 1 about here.   ]]]

As we concluded in section 3, the IV estimates in Table 1 are preferred to the estimates in Table 2. Figure 2 displays the instrumental-variables recursive coefficient estimates for the RID model given an AR(1) correction.[17] The situation is quite different: the parameter estimates no longer move dramatically over time. (One exception is the jump in the interest rate coefficient immediately following unification.) However, the spot rate now appears unrelated to the explanatory variables, with the short-term interest rate being a partial exception. From these two figures we must conclude that Frankel's empirical validation of the RID model was pure historical accident.

[[[Figure 2 about here.   ]]]

4.2   The RIDRE Model

We also reestimate the RIDRE model over the extended sample. As with the RID model, our analysis includes an intercept dummy for the German unification (uni). Although we have severely criticized the single equation estimates in Table 2, the table includes extended sample (:98) results for the purpose of

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[17]The AR(1) correction is chosen simply for ease of comparison with the Frankel results. Corrections for higher-order autoregressive processes yield the same qualitative results.

comparison. These are in general agreement with the replication (:78) results. Only the price equation looks at all promising, and that is driven largely by the inertia in the relative price level.[18]

Surprisingly, the results of the FIML estimation of the simultaneous equation system implied by the RIDRE model are a bit more promising. For the extended sample, these results are shown in the RIDRE:98 column of Table 3. Qualitatively, the results match those from the RIDRE:78 column, except that δ now clearly differs significantly from zero and ϕ is positive (but still insignificant). Recalling that we are working with monthly absolute rates of return, our estimate for the interest rate semi-elasticity of money demand (λ) is of reasonable magnitude. (The unification dummy coefficients are not reported; surprisingly the dummy coefficient is significant only for the price equation.) The conditions for exchange rate overshooting and monotonic saddle-path dynamics are satisfied. However, as with the shorter sample, there is no support for the RIDRE overidentifying restrictions. Using a likelihood ratio test, the restrictions are overwhelmingly rejected. Once again, we do not find much evidence to support the RIDRE model, although our results remain more favorable than those reported by Driskill and Sheffrin (1981). As in the replication study, we obtain some encouragement from the FIML estimations, while the single equation estimates are thoroughly discouraging.

Table 3 also reports RIDRE results for a post-unification sample. Looking at column RIDRE:uni, we find that the choice of sample makes little difference to the outcome. The results are almost identical to the RIDRE:78 and RIDRE:98 results.

5   Conclusion

As the empirical performance of the simple monetary approach to the determination of flexible exchange rates deteriorated, interest in the Dornbusch (1976) "sticky price" model of exchange rate overshooting grew apace. Frankel (1979) offers the classic empirical formulation of this model: his real interest differential (RID) model. He supports the Dornbusch model against the simple monetary approach model. However, Driskill and Sheffrin (1981) show that Frankel's coefficient estimates are inconsistent. They also stress the desirability of testing the theoretically implied overidentifying restrictions. They therefore develop an empirical rational-expectations version of the Frankel model: the RIDRE model.

In this paper, we attempt a replication and update of these classic studies. Replication of the Driskill and Sheffrin results proves problematic. We find the data cut less decisively against the RIDRE model

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[18]This summary is intentionally brief since we have argued that the IV estimates in Table 1 are of much greater interest. Nevertheless, a graph of the recursive coefficient estimates is available on request. These are volatile and, to the extent that they converge, tend to be perversely signed. It may be worth noting that the addition of an energy price regressor eliminates some parameter instability without altering the qualitative conclusions.

than suggested by Driskill and Sheffrin, but it is still the case that its performance is poor. The RIDRE model also proves more stable than the RID model, but the theoretically implied overidentifying restrictions prove increasingly unacceptable. It does not appear to be a good model of exchange rate determination. In contrast, we successfully replicate the supportive Frankel results. However, upon extending the sample we find that all support for the RID model vanishes, and the recursive coefficient estimates provide devastating evidence against the model. We are forced to conclude that Frankel's validation of the RID model was pure historical accident.

Our negative results are indeed stark, and it is worth emphasizing that we have focused only on the *in-sample* properties of these models. Many researchers will find the decisive lack of support for the very attractive real-interest-differential model disappointing and puzzling. We stress that we have reviewed the difficulties of only the best known and most popular empirical approaches to the overshooting model—the simple RID model of Frankel (1979) and the RIDRE model of Driskill and Sheffrin (1981). We intend our negative results for these empirical models to highlight the futility of relying of them for anything beyond introductory pedagogy, but we also intend this as a spur to the elaboration of more fruitful empirical implementations of the Dornbusch (1976) approach to exchange rate determination. Researchers may even find it fruitful to consider modifications of the basic RID model. Possible directions for research include incorporation of a more general VAR model of the exogenous variables, use of a partial-adjustment formulation for money demand, consideration of the role of aggregate demand variables, and the incorporation of monetary policy reaction functions.

Appendix

Data

IFS Data

Monthly data for the period 1974.07 to 1998.11 are taken from the June 1999 CD of the *International Financial Statistics*. For the U.S., the bond-equivalent T-bill rate is used as the short rate, but the *IFS* series starts at 1974.09 and so two observations are taken from the very similar T-bill series. The data were transformed as follows. Money, income, and prices are transformed into logs of the ratios of German to U.S. data. Interest rates, which the *IFS* reports in annual percentage terms, are divided by 1200 to get one-month absolute returns. Interest differentials are formed as the log of the ratio of the gross monthly rates. Following Frankel (1979) and Driskill and Sheffrin (1981), π is the long-rate differential.

Series	IFS Code
German Data	
Spot Rate	134..RF.ZF...
M1	13439MACZF...
Industrial Production	13466..CZF...
CPI	13464...ZF...
Short (call) rate	13460B..ZF...
Long (bond) rate	13461...ZF...
U.S. Data	
M1	11159MACZF...
Industrial Production	11166..CZF...
CPI	11164...ZF...
Short (bill) rate	11160C..ZF...
Short (bill, bond equiv.) rate	11160CS.ZF...
Long (bond) rate	11161...ZF...

Frankel (1979) Data

For the convenience of the reader, the original Frankel data set is provided here.[19]

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Variable names and definitions
ECENDM : US cents per DM exchange rate, monthly average.
EDMOOL : ln(DM per US$ exchange rate)
         i.e. EDMOOL=ln[1/(ECENDM/100)]
GRM1   : ln(German M1/US M1)
         German : end of month, seasonally adjusted, billions of marks.
         US : averages of daily figures, seasonally adjusted, billions $.
GRPRD  : ln(German Industrial Production/US Industrial Production)
         German : index, seasonally adjusted.
         US : index, seasonally adjusted.
GR3MR  : Short run interest rate differential: ln[(1+i)/(1+i*)]
         German and US : Representative bond equivalent yields on
         major 3-4 month money mkt instruments, excluding T-Bills.
GRLGR  : Long term interest rate differential
         German and US : Long term govt bond yield, at or near
         end of month.
GRINC  : CPI inflation differential.
         Average logarithmic rate of change over preceding year.
         German: Cost of Living, seasonally adjusted.
         US : Urban dwellers and clerical workers.
NOTES:
(1) Interest rates have been divided by 400 to convert from
    percent per annum terms to the absolute three month rate of return.
    See Frankel (1979), Appendix B.
(2) Details of data sources are also available in Appendix B.
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MONTH	ECENDM	EDMOOL	GRM1	GRPRD	GR3MR	GRLGR	GRINC
7401	35.529	1.03482	-0.705403	-0.0290141	0.00716584	0.00531212	-0.004626
7402	36.844	0.998478	-0.700128	-0.022614	0.00603159	0.00728513	-0.00555666
7403	38.211	0.962047	-0.706315	-0.0323052	0.00433751	0.00659773	-0.00696727
7404	39.594	0.926493	-0.703321	-0.0250189	-0.00343709	0.00635195	-0.00671987
7405	40.635	0.900541	-0.703285	-0.0314035	-0.00593088	0.00705627	-0.00807256
7406	39.603	0.926266	-0.698878	-0.0500564	-0.0068417	0.00712959	-0.00946475
7407	39.174	0.937157	-0.687457	-0.0387001	-0.00538289	0.00713	-0.0106479
7408	38.197	0.962414	-0.682861	-0.0726745	-0.00649652	0.00527149	-0.00903268
7409	37.58	0.978699	-0.678647	-0.0666476	-0.00319306	0.00583462	-0.0107211

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[19] Jeffrey Frankel could not provide his data. These data were provided to us by Steve Haynes as a photocopy of the photocopy he received from Jeffrey Frankel. The "NOTES" were on this photocopy. Data entry was double-keyed. Legibility was difficult for a few entries, for which we consulted Steve Haynes.

7410	38.571	0.95267	−0.681847	−0.0694745	0.00102617	0.00688706	−0.011359
7411	39.836	0.920399	−0.661905	−0.0536235	−0.00100262	0.00552243	−0.0129882
7412	40.816	0.896097	−0.63908	−0.0557512	−0.003179	0.00391237	−0.014606
7501	42.292	0.860572	−0.636935	−0.0271721	0.00194107	0.00315779	−0.01282
7502	42.981	0.844413	−0.631584	−0.0148937	−0.000369944	0.0025715	−0.0122385
7503	43.12	0.841183	−0.621506	−0.00598106	−0.00162696	0.00188483	−0.0100461
7504	42.092	0.865312	−0.611944	−0.014006	−0.00300767	0.000733901	−0.0094186
7505	42.546	0.854585	−0.608514	−0.0433361	−0.00160451	0.000196166	−0.00784676
7506	42.726	0.850363	−0.606938	−0.0668053	−0.00332784	0.000881035	−0.00679852
7507	40.469	0.904634	−0.605622	−0.0739891	−0.00537686	0.00068545	−0.0080178
7508	38.857	0.945283	−0.593259	−0.0859548	−0.00673348	0.00124803	−0.00622968
7509	38.191	0.962571	−0.57023	−0.0950046	−0.00730053	0.00073462	−0.00415864
7510	38.737	0.948375	−0.567142	−0.076592	−0.00481411	0.00173784	−0.00400194
7511	38.619	0.951426	−0.562665	−0.0776953	−0.00446927	0.00127356	−0.00439498
7512	38.144	0.963802	−0.547561	−0.0755666	−0.00422103	0.00166547	−0.00371816
7601	38.425	0.956462	−0.547406	−0.0766602	−0.00304033	0.000734638	−0.00342034
7602	39.034	0.940737	−0.552476	−0.0709593	−0.00388087	−0.000171147	−0.00213181
7603	39.064	0.939969	−0.552262	−0.0863566	−0.00388087	−0.000638012	−0.00183525
7604	39.402	0.931354	−0.555894	−0.0705184	−0.00378296	−0.000343263	−0.00187819
7605	39.035	0.940712	−0.546603	−0.0798158	−0.00521153	9.81204E-05	−0.00304452
7606	38.797	0.946828	−0.529804	−0.0836664	−0.0039259	0.000539277	−0.00330287
7607	38.842	0.945668	−0.54214	−0.0882677	−0.00254304	0.000758857	−0.00323899
7608	39.538	0.927908	−0.535831	−0.0928478	−0.00219775	0.00083312	−0.00242852
7609	40.169	0.912075	−0.537179	−0.0711749	−0.0019507	0.000122536	−0.00332925
7610	41.165	0.887582	−0.541304	−0.068112	−0.00130874	−9.82359E-05	−0.00413946
7611	41.443	0.880852	−0.541023	−0.0795496	−0.0006673	−0.000270631	−0.00296455
7612	41.965	0.868334	−0.567005	−0.0863497	0.000123456	0.000196714	−0.00217253
7701	41.792	0.872465	−0.539816	−0.072254	−0.000296839	−0.0016696	−0.0026383
7702	41.582	0.877503	−0.530119	−0.0805466	−0.00042031	−0.00191503	−0.00480856
7703	41.812	0.871987	−0.532405	−0.0787976	−0.0006673	−0.00277501	−0.00579993
7704	42.119	0.864672	−0.54306	−0.102085	−0.0006673	−0.00373558	−0.00728356
7705	42.394	0.858164	−0.535128	−0.117486	−0.00358083	−0.00366149	−0.0068723
7706	42.453	0.856773	−0.534082	−0.114498	−0.00330902	−0.00358809	−0.00688643
7707	43.827	0.824921	−0.53446	−0.129819	−0.00358222	−0.00444961	−0.00565952
7708	43.168	0.840071	−0.530506	−0.116673	−0.00481411	−0.00435328	−0.00671564
7709	43.034	0.84318	−0.526279	−0.119565	−0.00565108	−0.00511573	−0.00682872
7710	43.904	0.823165	−0.527039	−0.121729	−0.00653736	−0.0052616	−0.00576209
7711	44.633	0.806697	−0.511927	−0.116591	−0.00629003	−0.00528567	−0.00701683
7712	46.499	0.76574	−0.531105	−0.101501	−0.00799526	−0.00602296	−0.0077475
7801	47.22	0.750353	−0.483731	−0.0850789	−0.00853824	−0.00678419	0
7802	48.142	0.731015	−0.472505	−0.124607	−0.00878691	−0.00710474	0

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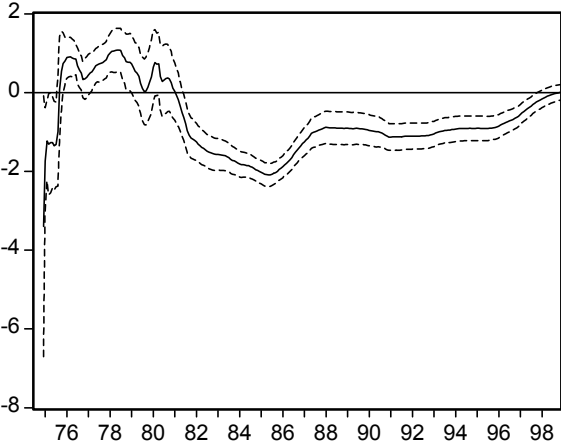
FIGURES

Figure Captions

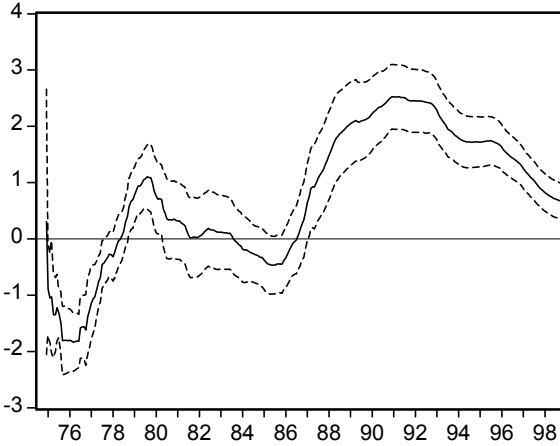Figure 1: RID Model, Recursive Coefficient Estimates (OLS)
Figure 2: RID Model, Recursive Coefficient Estimates (IV1)
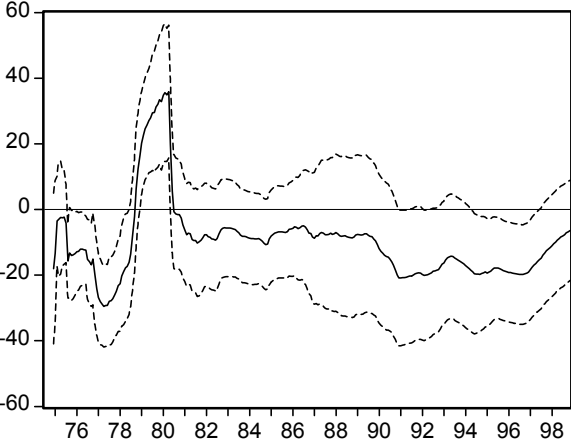
Figure 1: RID Model, Recursive Coefficient Estimates (OLS)
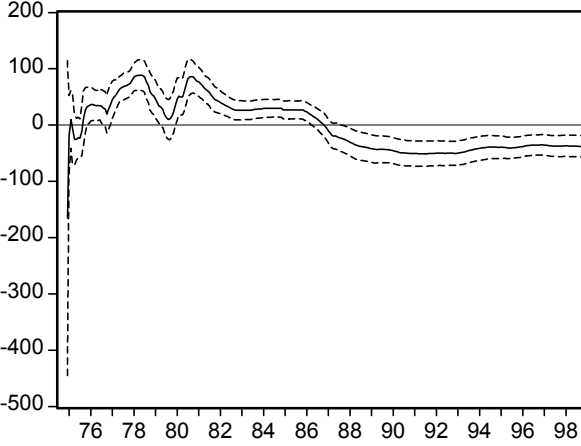

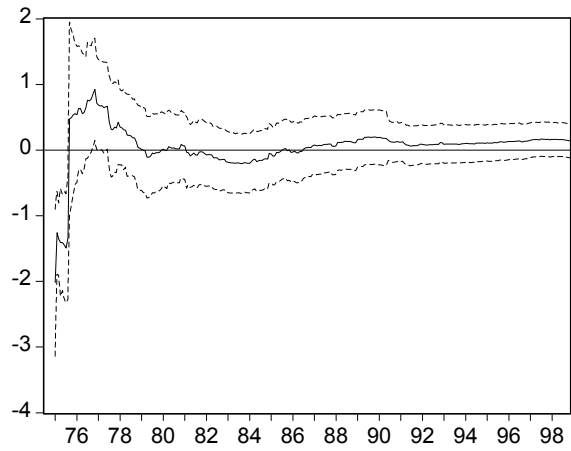
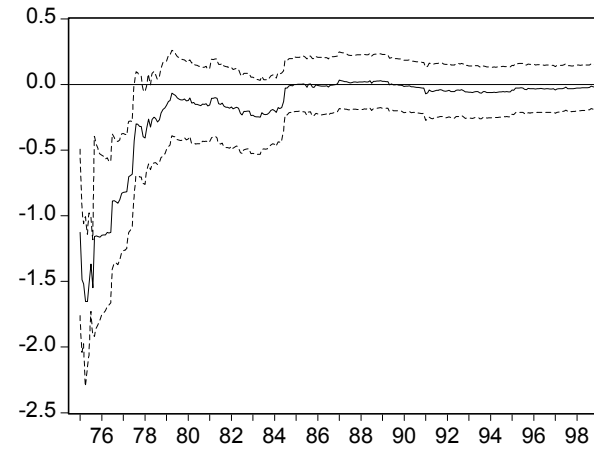Coefficient on M

Coefficient on Y
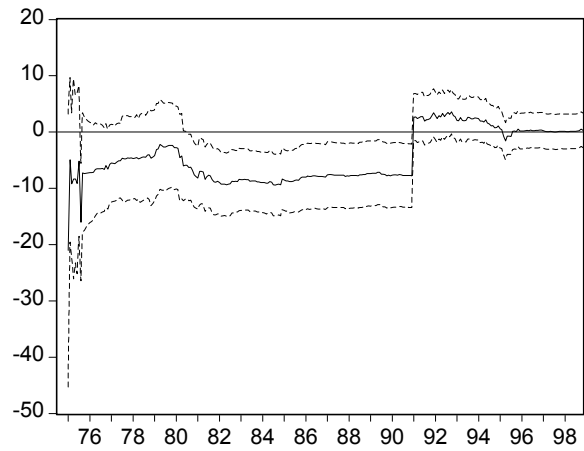
Coefficient on I

Coefficient on ILR
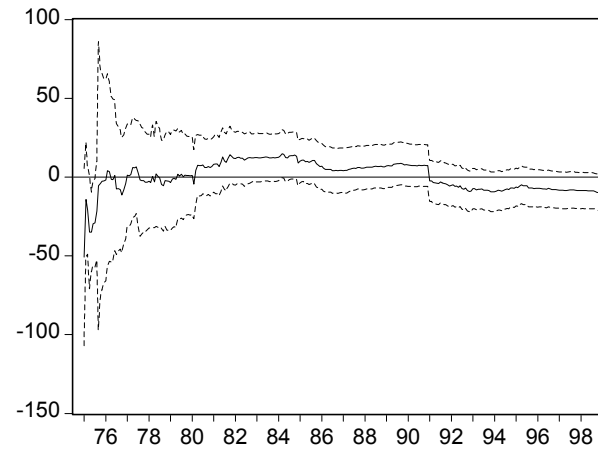
Figure 2: RID Model, Recursive Coefficient Estimates (IV1)

Coefficient on M

Coefficient on Y

Coefficient on I

Coefficient on ILR

TABLES

Table 1: RID Model: Replication and Extensions

	m_t	y_t	i_t	π_t	uni	R^2	D.W.	ρ
Equation 6 (dep. var.= s_t)								
OLS:f79	.87*	-.72*	-1.55	28.65*		.80	.76	
	(.17)	(.22)	(1.94)	(2.70)				
OLS:78	.87*	-.72*	-1.55	28.65*		.80	.76	
	(.17)	(.22)	(1.94)	(2.70)				
IV0:78	.90*	-.67*	-3.19	29.10*		.79	.73	
	(.19)	(.28)	(5.11)	(3.02)				
OLS:98	0.002	.66*	-6.40	-38.00*	-.13*	.50	.04	
	(.10)	(.16)	(7.63)	(9.46)	(0.05)			
IV0:98	-.10	.80*	-22.90	-27.41*	-.06	.49	.05	
	(.14)	(.21)	(18.19)	(14.24)	(.08)			
AR1:f79	.31	-.33*	-.259^a	7.72*		.91		.98
	(.25)	(.20)	(1.96)	(4.47)				
AR1:78	.30	-.32	-2.61	8.01*		.91	1.34	.98
	(.26)	(.21)	(2.06)	(4.62)				.07
IV1:78	.40	-.37*	-.71	5.90		.91	1.32	1.00*
	(.25)	(.21)	(1.37)	(4.43)				(0.06)
AR1:98	.14	0.00	-7.65*	-2.78	0.02	.98	1.34	.99*
	(.13)	(0.08)	(2.69)	(5.95)	(0.03)			(0.01)
IV1:98	.14	-0.02	.29	-9.70*	0.01	.98	1.37	.99*
	(.13)	(0.09)	(1.53)	(5.71)	(0.03)			(0.01)
Equation 6 with Constraint (dep. var.= $s_t - m_t$)								
OLS:f79		-0.69*	-1.77	30.17*		.92	.79	
		(0.21)	(1.91)	(1.68)				
OLS:78		-.69*	-1.77	30.17*		.92	.79	
		(.21)	(1.91)	(1.68)				
IV0:78		-.51*	-7.44	30.76*		.90	.64	
		(.28)	(5.26)	(1.92)				
OLS:98		.54*	31.21*	-65.47*	-.40*	.67	.07	
		(.18)	(7.74)	(10.53)	(0.05)			
IV0:98		.27	57.39*	-81.54*	-.49*	.66	.10	
		(.22)	(13.81)	(12.79)	(0.06)			
AR1:f79		-0.41*	-1.55	10.13*		.96		0.98
		(0.22)	(2.11)	(4.82)				
AR1:78		-.40*	-1.54	10.61*		.96	1.36	.97
		(.22)	(2.22)	(4.99)				0.05
IV1:78		-.29	-8.69*	30.72*		.94	1.72	.75*
		(.27)	(2.48)	(3.78)				(.14)
AR1:98		-0.01	-7.44*	-2.06	0.03	.99	1.32	1.00*
		(0.09)	(2.89)	(6.38)	(0.03)			(0.01)
IV1:98		-0.03	-.90	-7.80	0.02	.99	1.34	1.00*
		(0.09)	(1.62)	(6.08)	(0.03)			(0.01)

Notes:

Standard errors are in parentheses. Constants not reported.

*: |t-ratio| > 1.65. **uni**: German unification dummy (1991.01–1998.11).

OLS: ordinary least squares; **IV0**: instrumental variables (see text); **AR1**: AR(1) correction (iterated Cochrane-Orcutt for replications); **IV1**: instrumental variables with AR1 correction.

f79: Frankel (1979, Tables 1 & 3); **78**: Frankel data, 1974.07–1978.02; **98**: *IFS* data, 1974.07–1998.11.

Data: monthly, FRG & USA. (see appendix).

^{a} See footnote 4.

Table 2: DS81 Model: Single Equation Estimation

Exchange Rate Equation		variable(predicted effect on s_t)					R^2	D.W.	ρ
	c	$m_t(>1)$	$p_t(<0)$	$y_t(<0)$	$\pi_t(>0)$	uni			
OLS:DS81	-4.66*	0.80*	1.92*	-0.70*	0.05*		0.81	0.78	
	(-0.51)	(0.17)	(0.82)	(-0.19)	(0.009)				
OLS:78	0.49*	0.94*	2.03*	-1.22*	20.01*		0.86	1.21	
	(0.21)	(0.14)	(0.47)	(0.20)	(2.91)				
OLS:98	0.32*	-0.34*	0.82*	0.004	-54.85*	0.03	0.62	0.05	
	(0.06)	(0.09)	(0.09)	(0.14)	(7.21)	(0.04)			
AR1:DS81	-4.75	0.37	-0.66	-0.36*	0.014		0.98	1.29	0.98
	(0.54)	(0.27)	(-0.88)	(-0.19)	(0.01)				(0.03)
AR1:78	1.95*	0.39*	-1.55*	-0.30	3.38		0.93	1.40	1.04*
	(0.46)	(0.22)	(0.75)	(0.19)	(3.86)				(0.03)
AR1:98	0.57*	0.14	0.35	-0.02	-9.49*	0.02	0.98	1.37	0.99*
	(0.20)	(0.13)	(0.47)	(0.08)	(5.55)	(0.03)			(0.01)

Interest Rate Equation		variable(predicted effect on i_t)					R^2	D.W.	ρ
	c	$m_t(<0)$	$p_t(>0)$	$y_t(>0)$		uni			
OLS:DS81	31.52*	0.90	12.16	12.38*			0.20	0.52	
	(17.71)	(4.58)	(18.54)	(6.79)					
OLS:78	0.004	-0.003	-0.01	0.05*			0.21	0.51	
	(0.01)	(0.01)	(0.04)	(0.02)					
OLS:98	-0.01*	-0.004*	-0.003*	0.02*		0.01*	0.66	0.34	
	(0.001)	(0.001)	(0.001)	(0.001)		(0.0003)			
AR1:DS81	1.27	-23.11*	-1.78	6.40			0.71	2.10	0.82
	(16.49)	(7.53)	(26.35)	(6.09)					(9.41)
AR1:78	-0.03	-0.03*	0.04	0.02			0.70	2.07	0.80*
	(0.02)	(0.02)	(0.05)	(0.02)					(0.07)
AR1:98	-0.001	-0.0002	-0.01	0.003		0.0004	0.92	1.65	0.95*
	(0.002)	(0.002)	(0.01)	(0.002)		(0.001)			(0.02)

Price Equation		variable(predicted effect on p_t)					R^2	D.W.	
	c		$p_{t-1}(<1)$	$s_{t-1}(>0)$	$\pi_t(>0)$	uni			
OLS:DS81	0.08		0.81*	0.03*	0.0006		0.94	1.39	
	(0.05)		(0.09)	(0.01)	(0.0008)				
OLS:78	0.01		0.96*	0.003	0.08		0.97	1.35	
	(0.03)		(0.07)	(0.02)	(0.51)				
OLS:98	-0.01*		0.99*	0.01*	0.33*	0.002*	1.00	1.59	
	(0.001)		(0.002)	(0.001)	(0.18)	(0.001)			

Notes:

*: |t-ratio| > 1.65 (estimated standard errors in parentheses).

OLS: Ordinary Least Squares; **AR1**: AR1 correction. **DS81**: Driskill and Sheffrin (1981, Table 2);

78: Frankel data (1974.07–1978.02); **98**: IFS data (1974.07–1998.11).

Data: monthly, FRG & USA (see appendix). **uni**: unification dummy (1991.01–1998.11).

Table 3: DS81 and RIDRE Models: System Estimation

Model:	DS81	DS81:78	RIDRE:78	RIDRE:98	RIDRE:uni
π included?	no	no	yes	yes	yes
$\rho_s = \rho_m$?	no	no	yes	yes	yes
Parameter					
δ	0.04*	0.01	0.03	0.02*	0.02*
	(0.01)	(0.01)	(0.02)	(0.001)	(0.01)
λ	-0.06*	495.24	55.30*	39.33*	61.83*
	(0.02)	(1728.56)	(11.77)	(3.11)	(11.45)
ϕ	0.21	0.32	-0.05	0.05	-0.05
	(0.14)	(0.20)	(0.20)	(0.08)	(0.13)
ρ_m	0.95*	0.78*	0.71*	1.01*	0.98*
	(0.07)	(0.14)	(0.11)	(0.01)	(0.02)
ρ_s	1.01*	1.00*	—	—	—
	(0.03)	(0.03)			
c_2	complex	-0.13	-0.45	-0.88	-0.49
$1 + \delta(c_2 - 1)$	complex	0.98	0.96	0.97	0.97
Likelihood-Ratio Test of RIDRE Restrictions:					
Parameters	8	8	7	10	7
Restrictions	5	5	8	8	8
LR Statistic	65.52	33.38	76.64	251.19	149.43
$\mathcal{X}^2_{df}(.01)$	15.09	15.09	20.09	20.09	20.09

Notes:

Asymptotic standard errors are in parentheses.

δ: price adjustment parameter; λ: interest rate semi-elasticity; ϕ: income elasticity; ρ_m: AR(1) parameter for the interest rate equation. ρ_s: AR(1) parameter for the exchange rate equation (if not restricted to equal ρ_m).
DS81: Driskill and Sheffrin (1981, Table 3); **DS81:78**: DS81 model, Frankel data, 1974.07–1978.02; **RIDRE:78**: RIDRE model, IFS data, 1974.07–1978.02; **RIDRE:98**: RIDRE model, IFS data, 1974.07–1998.11; **RIDRE:uni**: RIDRE model, IFS data, 1991.01–1998.11.
Data: monthly, FRG & USA (see appendix).