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Deviations From Uncovered Interest Parity: A Global Guide to Where the Action Is

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Abstract

Ex-post deviations from uncovered interest parity (UIP) – realized differences between dollar returns on identical assets of different currencies – equal the real interest differential plus real exchange rate growth. Among industrialized countries, UIP deviations are largely explained by unanticipated real exchange rate growth, but among developing countries, real interest differentials are "where the action is." This observation is due to the greater variability of inflation in developing countries, but may also stem from higher and more variable risks and capital controls in these countries. Also, among developing countries with moderate inflation, offsetting comovements of real interest differentials and real exchange growth support the sticky-price hypothesis.

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Contents

SUMMARY

Ex-post deviations from uncovered interest parity (UIP) – differences between U.S. dollar returns on identical assets of different currencies – by definition equal the sum of the real interest differential and real exchange rate growth. This identity may provide clues to explain UIP deviations: given certain assumptions, the real interest differential reflects a risk premium. The paper explores this relationship for 34 countries, both industrialized and developing. The variance of UIP deviations is decomposed into four elements: the variances of the real interest differential, anticipated real exchange rate growth, unanticipated real exchange rate growth, and the covariances of the latter two elements with the real interest differential. Among industrialized countries, the variance of UIP deviations is mainly due to unanticipated real exchange rate growth, while movements in the real interest differential play only a small role. For developing countries, by contrast, variability in real interest differentials is "where the action is" to a much greater degree. This observation is due to the greater variability of inflation in developing countries, but may also stem from higher and more variable risks and capital controls in these countries. Also, there are substantial offsetting comovements between real interest differentials and real exchange rate changes for developing countries with moderate inflation, but not for those with high inflation. This observation lends support to the sticky-price hypothesis.

I. INTRODUCTION

According to the uncovered interest parity (UIP) hypothesis, expected rates of return on identical assets in two different countries, *inclusive* of (spot) exchange rate growth, should be equal. As an *ex-post* proposition, UIP has been widely tested for industrialized countries. [1] However, in much of this research, UIP has fared poorly. Particularly in the post-Bretton-Woods period, deviations from UIP have been substantial and often serially correlated.

Thus, while still a fundamental idea, the validity of UIP is nonetheless widely debated. While deviations from UIP may represent unexploited profit opportunities, such an explanation is not appealing. Instead, UIP deviations are often presumed to stem from either differences in risk between countries, capital immobility, or both.

By definition, UIP deviations are the sum of two elements, namely the real interest differential between two countries and real bilateral exchange rate growth. And, the *variance* of UIP deviations equals the variance of the real interest differential plus that of real exchange rate changes plus (twice) the covariance term.

These decompositions may help explain the nature of UIP deviations. For example, when real exchange rate changes are mean zero and unpredictable and capital is freely mobile the real interest differential reflects a risk premium. This point was stressed by several authors in the finance literature, including Fama (1984), Korajczyk (1985), and Levine (1989). [2]

Among industrialized countries, both the *level* and the *variance* of real interest differentials tend to be small relative to those of real exchange rate growth. [3] Indeed, such observations may reflect the similar nature of risks among industrialized countries, a relatively stable risk differential, and (nominal) exchange rate flexibility. [4]

In this light, it might be useful to compare developing countries with industrialized ones. Risk, the nature of shocks, the variability of inflation, and the use of capital controls all differ

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[1] A recent paper on this topic is McCallum (1994). A formally equivalent way of expressing UIP is that the forward exchange rate is an unbiased predictor of the future spot rate. For industrialized countries, research has often expressed UIP in this way; for example, see Hakkio and Rush (1989).

[2] For work on risk premia in foreign exchange markets see also Hodrick (1983) and Marston (1997).

[3] This is noted by Gokey (1994).

[4] See, for example, the Mishkin's (1984) discussion of the relative variability of real interest differentials and real exchange rates.

substantially between industrialized and developing countries. Presumably then, real interest differentials should be 'where the action is' to explain UIP deviations in these countries. [5]

However, UIP deviations in developing countries have received much less attention than in industrialized countries. This is surprising, given the growing importance of developing countries in world capital markets, with increasingly open capital accounts, liberal domestic financial systems, and flexible exchange rates.

This paper thus examines UIP deviations in 34 countries, both industrialized and developing. Two key questions are asked.

First, does UIP work? To address this question, tests for the mean and stationarity of *ex-post* UIP deviations are presented. Overall, the evidence favors UIP: for all 34 countries, deviations from UIP are mean-zero and stationary.

Second, *if* there are deviations from UIP, *why* do they occur? To address this issue, both the *level* and the *variance* of UIP deviations are decomposed into the above mentioned elements, namely real interest differentials and real exchange rate growth. In addition, real exchange rate growth is decomposed into anticipated and unanticipated elements. [6] Accordingly, the variance of UIP deviations equals the variance of the real interest rate differential plus the variances of anticipated and unanticipated growth of the real exchange rate, plus the corresponding covariances. [7]

Thus, the roles of real interest differentials and real exchange rate movements (in both levels and variances) are examined, in both industrialized and developing countries. As mentioned above, such decompositions lend insight into the underlying economic explanation for UIP deviations. For example, under certain circumstances the real interest differential measures the risk premium (see, for example, Fama (1984), Korajczyk (1985), and Levine (1989)).

As a natural extension, the paper also discusses the *covariances* of real exchange rate changes and real interest differentials. Several papers (Campbell and Clarida (1987), Meese and Rogoff

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[5] Historically, developing countries have closed their capital accounts and fixed their exchange rates more than industrialized countries, But recently, developing countries have opened their capital accounts and permitted more exchange rate flexibility.

[6] Addressing a related question, Clarida and Gali (1994) and Baxter (1994) decompose industrialized country real exchange rate changes into temporary and permanent components. Also, Marston (1997) studies forecast errors in foreign exchange markets for industrialized countries.

[7] For similar approaches, see Gokey (1994) and Marston (1997).

(1988), Edison and Pauls (1993), Baxter (1994), and Clarida and Gali (1994)) link these covariances to key elements of an economy's underlying structure, namely the degree of price flexibility and the relative importance of real and nominal shocks. Since the data set includes countries whose underlying structures are presumably different, it is well-suited to address such issues.[8]

The analysis yields several conclusions. First, as noted above, UIP 'works', in the sense that ex-post deviations from UIP are mean zero and stationary. Second, suggesting that UIP deviations do not primarily represent unexploited profit opportunities, the unanticipated component of real exchange rate growth accounts for more of the variance in UIP deviations than the anticipated component, in all but one country. For the majority of countries, the variation of anticipated real exchange rate growth comprises 30 percent or less of the total deviation from UIP.

Third, comparing industrialized and developing countries, the 'action' for UIP deviations occurs in different places. Among industrialized countries most of the 'action' is found in real exchange rate changes (confirming previous research). By contrast, among developing countries, there is much more 'action' in real interest differentials. This is primarily due to more the more variable inflation rates associated with these countries. However, additional explanations include the higher and more variable risks and capital account restrictions associated with developing countries. And, inflation may contain information about these other variables.

Fourth, despite the importance of the real interest differential for most developing countries, the variability of real exchange rate growth remains an important component of UIP deviations for all but a few of these countries. Specifically, real interest differentials vary most, and real exchange rate growth rates least, in high-inflation countries such as Argentina, Brazil, and Turkey.

In some cases, real exchange rate growth and real interest differentials covary negatively. Among moderate inflation countries, this negative covariance can be substantial, although not enough for movements in the two variables to entirely cancel one another out. As several papers in the business cycle literature note (Campbell and Clarida (1987), Meese and Rogoff (1988), Edison and Pauls (1993), Baxter (1994), and Clarida and Gali (1994)), such an observation would support the hypothesis of sticky prices.

The remainder of the paper is organized as follows. Section II reviews basic identities regarding the UIP proposition and presents some preliminary of its validity, namely tests for the means and stationarity of ex-post UIP deviations. Section III discusses previous work from the finance literature that relates real interest differentials to risk premia. Section IV develops the decomposition of UIP deviations into real interest differentials and real exchange

[8] For a comparison of the business cycle between industrialized and developing countries, see Kydland and Zarzaga (1997).

rate growth (unanticipated plus anticipated). Section V presents empirical results. Section VI extends the analysis to the covariances of real interest rates and real exchange rates. Section VII presents some conclusions and directions for future research.

II. Deviations from UIP: Preliminary Identities and Tests

According to the uncovered interest parity (UIP) proposition, rates of return on identical debt instruments in two different countries, *inclusive* of (spot) exchange rate changes will be equal. *Ex-ante,* UIP implies that:

$$S^e_{t+x} = S_t + \ln\left[(1+i_t)/(1+i^*_t)\right] \tag{1}$$

where i_t and i^*_t are home and foreign (i.e., U.S.) nominal interest rates, S_t is the *logarithm* of the exchange rate at time t, and the superscript 'e' denotes an expected value. Equation (1) may of course be approximated as $S^e_{t+x} = S_t + i_t - i^*_t$.

To test a theory like (1), the measurement of expectations often poses difficulties. This paper uses a common assumption, namely that of rational expectations: on average, expected and realized values are equal. Accordingly, this paper will examine *ex-post* deviations from UIP (ω_t):

$$\omega_t \approx S_t - S_{t-x} + i_{t-x} - i^*_{t-x} \tag{2}$$

According to equation (1), rates of return should be equal across international borders ($E(\omega)=0$), assuming freely mobile capital and hence no capital controls. Equation (2) is applied to data from 34 industrialized and developing countries. Countries are divided into five groups: Industrialized, Other European Countries, Latin America, Asia, and South Africa.[9] All data, taken from the International Monetary Fund's *International Financial Statistics*, are monthly from 1986:1 to 1997:4, except where noted. The data encompass a wide variety of exchange rate, capital account, and domestic financial regimes. However, criteria for inclusion in the data set included exchange rate and interest rate flexibility (free or

[9] Industrialized countries are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. Other (less industrialized) European countries are Greece, Iceland, and Turkey. Latin American countries are Argentina, Brazil, Chile, Mexico, Uruguay, and Venezuela. Asian countries are India, Indonesia, Korea, Malaysia, Pakistan, Phillippines, Singapore, and Thailand. For all countries, data are monthly from 1986:1 to 1997:4, except Argentina (1986–1990), Venezuela (1989–1995), and Indonesia (1987–1995). Since all interest rates refer to 3 month deposits, x = 3. However, tests with *annual* depreciations (x = 12) yielded similar results, available on request from the author.

managed) and, partial (if not full) openness of the capital account.[10] Table 1 presents several tests related to equation (1). The first and most simple test is whether the sample mean of ω_t is statistically different from zero. Thus, the table presents sample means and variances of ω_t, and t-ratios (means divided by standard deviations). Second, to see whether ω_t fluctuates around a mean or drifts boundlessly, three popular stationarity tests are applied to ω_t: the Augmented Dickey Fuller (ADF), and the Zt and $Z\alpha$ tests, due to Phillips (1987) and Phillips and Perron (1988).[11] Third, following some recent tests for purchasing power parity (Cumby (1996)), the *half-life* of deviations from UIP are calculated. Assuming an autoregressive process for UIP deviations, namely $\omega_t = a + b\ \omega_{t-1} + \text{error}_t$, the half-life of a UIP deviation is $\ln(.5)/\ln(b)$.

As a preliminary issue, Table 1 suggests, UIP 'works' in two senses. First, the mean of ω is not statistically different from zero for any country: in no case does the t-ratio (the mean of ω divided by its standard deviation) exceed unity. Second, ω is stationary for all countries. Finally, the half-life statistics indicate that for all countries, half of the deviations from UIP die out within two to three months. This finding holds across all countries, industrialized and developing. This finding is especially striking in light of the wide use of capital controls in developing countries. [12]

The table shows some differences in the variance of ω among groups. Overall, var(ω) is lowest for Asian countries and highest for Latin American countries. The most extreme values of var (ω) are found in Brazil, Argentina, Mexico, Turkey, and Venezuela. The variance of ω

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[10] The time period under examination is one of increasing exchange rate and interest rate flexibility and capital account openness. Among industrialized countries, Canada, Japan, United Kingdom, and Switzerland have freely floating exchange rates, while Greece has a managed float and Iceland's exchange rate is pegged to a basket. The remaining industrialized countries and other European countries belong to the European Monetary Union. Among Latin American countries, Brazil, Chile, Uruguay, and Venezuela are managed floaters; Argentina and Mexico used both managed and free floats. Among Asian countries, Korea, Malaysia, Pakistan, and Singapore are managed floaters, India, Indonesia, and the Phillippines are free floaters, while Thailand was pegged to a basket.

[11] Cointegration tests for UIP for several industrialized countries against the U.S. are found in Hunter (1992) and Edison and Melick (1995). In a similar vein, Meese and Rogoff (1988) and Edison and Pauls (1993) examine the relationship between the *level* of the real exchange rate and the real interest differential.

[12] Indeed, this finding suggests that, to control rates of return, capital controls are ineffective. For other evidence favoring this viewpoint see Johnston and Ryan (1994).

Table 1. Deviations from UIP (ω): Summary Statistics

	Mean	Variance	T-Ratio	ADF	Zt	Zα	Half-life
Austria	-0.025	0.052	-0.109	-5.291	-4.515	-36.914	3.034
Belgium	-0.015	0.051	-0.067	-5.019	-4.461	-36.123	3.250
Canada	-0.016	0.007	-0.194	-5.303	-5.015	-43.528	2.370
Denmark	-0.038	0.051	-0.167	-4.780	-4.405	-35.693	3.221
Finland	-0.031	0.057	-0.130	-5.192	-4.419	-35.174	3.051
France	-0.035	0.045	-0.166	-5.047	-4.441	-36.199	3.263
Germany	-0.025	0.052	-0.109	-5.243	-4.507	-36.816	2.945
Ireland	-0.049	0.044	-0.235	-4.999	-4.496	-35.764	2.963
Italy	-0.040	0.053	-0.175	-5.813	-4.509	-36.792	3.217
Japan	-0.022	0.063	-0.085	-5.479	-4.551	-37.715	3.150
Netherlands	-0.027	0.052	-0.118	-5.210	-4.485	-36.473	3.139
Norway	-0.036	0.041	-0.177	-5.146	-4.588	-38.698	2.942
Spain	-0.024	0.051	-0.106	-4.872	-4.535	-36.781	2.508
Sweden	-0.036	0.052	-0.159	-4.948	-4.342	-34.847	3.329
Switerzerland	-0.017	0.067	-0.065	-4.999	-4.458	-35.875	2.867
United Kingom	-0.036	0.054	-0.155	-6.165	-4.504	-36.490	3.066
Mean, Ind. Ctry	**-0.029**	**0.049**	**-0.139**	**-5.219**	**-4.514**	**-36.868**	**3.020**
Greece	-0.042	0.039	-0.214	-5.280	-4.513	-37.126	3.159
Iceland	-0.031	0.044	-0.146	-4.506	-4.408	-35.652	2.009
Turkey	0.074	0.151	0.190	-4.701	-4.699	-38.847	1.920
Mean, Oth. Eur. Ctry	**0.000**	**0.078**	**-0.057**	**-4.829**	**-4.540**	**-37.208**	**2.363**
Argentina	0.552	5.190	0.242	-3.064	-3.039	-16.986	2.363
Brazil	-0.150	0.551	-0.203	-5.276	-5.339	-45.797	2.363
Chile	-0.052	0.015	-0.425	-4.321	-5.089	-43.604	2.693
Mexico	0.009	0.143	0.024	-4.198	-4.433	-35.253	1.869
Uruguay	-0.007	0.006	-0.094	-3.627	-4.393	-32.999	1.817
Venezuela	0.010	0.095	0.260	-4.538	-3.528	-21.117	0.473
Mean, Lat. Am	**0.060**	**1.000**	**-0.033**	**-4.171**	**-4.303**	**-32.626**	**1.930**
excl. Arg. And Brazil	**-0.010**	**0.065**	**-0.059**	**-4.171**	**-4.361**	**-33.243**	**1.713**

Table 1. (Contd.) Deviations from UIP (ω): Summary Statistics

	Mean	Variance	T-Ratio	ADF	Zt	Zα	Half-life
India	0.044	0.031	0.246	-4.573	-4.970	-42.302	2.043
Indonesia	-0.021	0.001	-0.685	-3.011	-4.039	-28.035	3.457
Korea	-0.056	0.006	-0.739	-2.738	-3.675	-25.038	2.613
Malaysia	0.011	0.010	0.107	-4.307	-4.258	-33.364	6.600
Pakistan	0.062	0.011	0.581	-4.275	-4.306	-34.727	3.012
Phillippines	-0.057	0.017	-0.438	-3.387	-4.378	-34.851	3.214
Singapore	-0.013	0.007	-0.160	-4.715	-4.575	-36.184	3.172
Thailand	-0.025	0.002	-0.562	-4.636	-4.738	-40.106	3.671
Mean, Asia	**-0.007**	**0.011**	**-0.206**	**-3.956**	**-4.367**	**-34.326**	**3.473**
South Africa	-0.004	0.054	-0.017	-4.964	-5.610	-52.360	2.872

Notes: All data are monthly from 1986:1 to 1997:4, except Argentina (1986:1 to 1990:4) and Indonesia (1987:1 to 1997:4). T-ratio is the mean of ω divided by its standard deviation. ADF, Zt and Zα are the Augmented Dickey Fuller test, Phillip's Za and Zt tests, respectively. lag length was 4; other lag lengths yield similar results. The 90 and 95 percent critical values for the ADF and Zt tests are -2.58 and -2.89, respectively. The 90 and 95 percent critical values for the Za test are -13.7 and -19.8, respectively.

for the industrialized countries is somewhat less than for the other European countries and Latin America, but greater than that for Asian countries.

III. UIP DEVIATIONS, REAL INTEREST DIFFERENTIALS, AND RISK PREMIA: PREVIOUS WORK

An equivalent way to express (1) is in terms of the real interest rate differential between two countries and real exchange rate growth:

(1')
$$S^e_{t+x} = S_t + \ln [(1+r_t)/(1+r^*_t)]*[(1+\pi^e_t)/(1+\pi^{*e}_t)]$$

where expected *real* interest rates at home and abroad are $r^e = (i_t - \pi^e_t)/(1+\pi^e_t)$ and $r^{*e} = (i^*_t - \pi^{*e}_t)/(1+\pi^{*e}_t)$ respectively, where π^e_t and π^{*e}_t are home and foreign expected rates of inflation (the growth of the logarithm of home and foreign prices, P and P^* respectively). The corresponding *ex-post* deviation from UIP is: [13]

(2')
$$\omega_t \approx \rho_t + \Delta q_t$$

where $\rho_t = r_t - r^*_t$ is the real interest differential and $q_t = S_t - P^*_t + P_t$ is the logarithm of the bilateral real exchange rate, and $\Delta q = q_{t+x} - q_t$ is its growth rate. Thus, expression (2') shows that the deviation from UIP equals the real interest rate differentials plus the logarithmic change in the real exchange rate.

Several previous authors, including Fama (1984), Korajczyk (1987), and Levine (1989), have suggested that deviations from UIP (non-zero ω) represent either a risk premium (as measured by the real interest differential) or an unexpected change in the real exchange rate. To formalize this idea, the initial step is to decompose real exchange rate growth into anticipated and unanticipated components. Taking an atheoretical approach, market participants might estimate a regression like:

(3)
$$q_{t+x} = \gamma_0 + \gamma_1 q_t + \mathbf{Z}_t\gamma_i + \epsilon_t$$

where $\mathbf{Z}_t$ is a matrix of variables known at or before time t, γ_i is a vector of corresponding coefficients, and ϵ_t is a zero-mean serially uncorrelated error term. Several variables might be included in **Z**, including inflation rates, nominal exchange rate changes, and interest rates. If the real exchange rate follows a random walk without drift, $\gamma_0 = 0$, $\gamma_1 = 1$ and $\gamma_i = 0$ for all i. In this case, all movements of ω are unexpected. Since the no-drift assumption might be too strong, a plausible alternative might be that $\gamma_1 = 1$ and $\gamma_i = 0$ for all i.

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[13] As above, expectations are assumed to be rational. The logarithm of any expected variable equals the logarithm of its realized value plus a random, mean-zero error.

Applying the above ideas to the question of UIP deviations, Korajczyk (1986) and Levine (1989) use a framework similar to (3) to test the *joint* null hypotheses that (a) UIP deviations ω and the real interest differential ρ move together one-to-one, and (b) ω_t is not predictable with any other information available at or before time t (that is $\gamma_1 = 1$ and $\gamma_i = 0$).[14]

However, for industrialized countries, the data cast doubt on this joint hypothesis. While Korajczyk (1986) was initially unable to reject it, Levine (1989, 1991) used an extended dataset and rejected a similar hypothesis for several industrial countries.[15] Thus, according to his results, in industrialized countries, ω does not move one-to-one with ρ and can be explained by elements of matrix $\mathbf{Z}_t$.

The analysis raises several questions. For example, while testing the above joint hypothesis reveals whether UIP deviations are predictable, it does not tell how important is the predictable component relative to *total* deviations from UIP. Reasonably, one might ask 'What percentage of the variation in ω is explained by **Zb**?' and 'Would this percentage be large enough to interest either researchers or market participants?'.[16] Also, as movements in Δq may be offset by those in ρ, one might wish to know the covariance of ρ and Δq.

Gokey's (1994) approach provides a way to partially address these questions. He decomposes the *variance* of the ex-post deviation from UIP:

$$\text{var}(\omega) = \text{var}(\rho) + \text{var}(\Delta q) + 2\,\text{cov}(\rho,\Delta q) \tag{4}$$

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[14] More precisely, they estimate variants of the equation:

$$\omega_t = a_0 + a_1\,\rho_t + \mathbf{Z}_t\mathbf{b} + u_t$$

where **b** is the vector of coefficients associated with $\mathbf{Z}_t$, and u_t is a mean zero error term. Their joint null hypothesis is that $a_0=0$, $a_1=1$ and all elements of **b** equal 0 (i.e., that ω entirely represents changes in the risk premia). Rejection of the hypothesis that **b** equals 0 implies that some portion of Δq (and thus ω) is predictable.

[15] See also Huang (1990).

[16] For example, transactions costs may prevent market participants from profiting from small but predictable asset price movements.

While identity (4) is not a formal hypothesis test, it does summarize the relative importance of different sources of deviation from UIP, namely risk, changes in the real exchange rate, and the covariance of these two components.[17]

For several industrialized countries, Gokey finds that movements in the real exchange rate are substantially more important than those in the risk premia to explain the deviations from UIP. In his study, var (Δq) accounts for 60 to 80 percent of var (ω), while var (ρ) accounts for about 10 percent. Moreover, among these countries, there is little comovement between real exchange rate growth and real interest differentials.

IV. Incorporating Anticipated and Unanticipated Real Exchange Rate Growth

While equation (4) helps explain the role of real interest rate differentials and real exchange growth in deviations from UIP, it is not well-suited to examine whether real exchange rate growth (and hence UIP deviations) are anticipated or unanticipated. However, a modification of (4) will remedy this drawback. First, consider a less restrictive form of equation (3), where $\gamma_1 = 1$ but elements of the γ_i are not restricted to zero. The unanticipated and anticipated components of real exchange rate growth are $\epsilon_t = \Delta q_{t+x} - \gamma_0 - \mathbf{Z}_t\gamma_{i.}$ and $\theta_t = \gamma_0 + \mathbf{Z}_t\gamma_{i.}$, respectively .[18] The deviation from UIP is thus written :

$$\omega = \rho + \theta + \epsilon \tag{5}$$

Next, noting that $\text{cov}(\theta, \epsilon) = 0$, expression (4) is now written:

$$\text{var}(\omega) = \text{var}(\rho) + \text{var}(\theta) + \text{var}(\epsilon) + 2[\text{cov}(\rho, \theta) + \text{cov}(\rho, \epsilon)] \tag{4'}$$

The interpretation of the first three terms is straightforward: they tell us how much of the variation in ω is due to changes in the real interest rate differential, anticipated changes in the real exchange rate and unanticipated real exchange rate growth.

Of course, to asses the importance of the real interest differential as a determinant of UIP deviations, the covariance terms must also be considered. A negative covariance between ρ and Δq (negative values for cov (ρ, θ) and var(ρ, ϵ)) implies that changes in the real interest differential will be offset to some degree by those in real exchange rate growth. Also,

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[17] Note also that this approach does not require the assumption of unrestricted capital mobility.

[18] In a similar vein, Baxter (1994) decomposes the real exchange rate into temporary and permanent components. Also, for another decomposition of real interest differentials and real exchange rate growth into anticipated and unanticipated components, see Marston (1997).

the covariance terms pertain to some recent issues in business cycle research. These issues are discussed in Section VI, below.

V. The Decomposition of UIP Deviations: Empirical Results

This section presents decomposition (4') and related statistics for the 34 countries discussed above. Results are reported as follows. First, as a preliminary step, the estimation of real exchange rate equation (3) is discussed. Second, results for decomposition (4') are presented. Third, the roles of the real interest differential and real exchange rate elements are discussed. (Issues relating to the *covariance* terms are discussed in Section VI, below.)

To estimate equation (3), a set of explanatory variables for the vector **Z** must be chosen. Good candidate variables for **Z** include nominal exchange rate growth $\Delta S_t = S_t - S_{t-j}$, the inflation differential $(\pi_t - \pi^*_t)$, where $\pi_t = P_t/P_{t-j} - 1$, $\pi^*_t = P^*_t/P^*_{t-j} - 1$ and the interest rate differential $i_t - i^*_t$. While several variations of this equation were tried, estimates with monthly inflation and exchange rate growth (j = 1) are presented. Estimates include explanatory variables for the current period and 6 lags. [19]

Table 2 lists several summary statistics from estimates of equation (3), namely the R^2- and F-statistics for the exclusion of nominal exchange rate growth ΔS_t, the nominal interest differential $i_t - i^*_{t}$., the inflation differentials $\pi_t - \pi^*_t$, and the combination of these three variables. The results of this table confirm some previous research (see, for example Levine (1989)). For most countries, real exchange rate movements do not follow a random walk. Rather, in 20 out of 34 cases, the null hypothesis that past variables contain no information useful for predicting future real exchange rates (i.e., the exclusion test for all variables) is rejected at the 90 percent level or better.

Table 3, the main table of the paper, shows the sources of UIP deviations, i.e., 'where the action is'. First, the variance terms var (ω) (repeated from Table 1 for convenience), var(ρ), var (θ) and var(ϵ), are presented. Second, *as ratios to var(ω)*, the table presents var(ρ), var (θ) and var(ϵ) plus the covariance terms 2*cov(ρ, θ) and 2*cov(ρ, ϵ). Finally, t-statistics from the bi-variate regressions of ρ on θ and ρ on ϵ are reported in the rightmost columns.

Consider first the relative importances of real interest differentials and real exchange rate changes to UIP deviations, as measured by the ratios var (Δq)/ var (ω) = [var (θ) + var(ϵ)]/var (ω) and var (ρ)/var (ω), respectively. Here, industrialized and developing countries differ. Among industrialized countries, the variation in real exchange rate growth (anticipated

[19] For example, annualized month-to-month rates were also used, i.e., ($(P_{t-j}/P_{t-j-1})^{12}$ - 1) and ($(S_{t-j}/S_{t-j-1})^{12}$ - 1). Estimates with these measures yielded qualitatively similar results.

Table 2. Real Exchange Rate Equation

$$\Delta q_{t+x} = \gamma_0 + Z_t \gamma_i + \epsilon_t$$

		F-Tests for exclusion			
	R^2	ΔS	i-i*	π-π*	All
Austria	0.204	0.759	0.311	1.997	1.280
Belgium	0.236	2.824	1.251	2.322	1.572
Canada	0.372	2.685	1.740	1.306	3.100
Denmark	0.256	2.202	0.540	1.893	1.627
Finland	0.285	1.106	3.273	1.883	2.088
France	0.244	1.730	0.406	2.912	1.663
Germany	0.177	1.918	0.737	1.490	1.070
Italy	0.232	1.937	1.774	0.577	1.571
Japan	0.317	1.883	3.429	2.057	2.393
Netherlands	0.144	1.428	0.172	0.890	0.851
Norway	0.225	0.761	2.026	2.128	1.497
Sweden	0.372	2.433	3.349	2.261	2.959
Switzerland	0.208	2.372	0.691	1.166	1.336
United Kingdom	0.193	1.266	1.306	1.057	1.158
Greece	0.283	1.712	0.307	2.775	1.827
Iceland	0.272	1.847	2.155	3.794	1.949
Ireland	0.261	1.787	1.501	1.375	1.533
Spain	0.257	0.757	2.096	2.382	1.757
Turkey	0.179	2.171	0.705	1.272	1.135
Argentina	0.642	3.589	2.728	4.228	2.557
Brazil	0.220	2.481	1.009	0.452	1.330
Chile	0.294	1.705	0.603	1.886	1.690
Mexico	0.223	2.280	0.432	0.773	1.470
Uruguay	0.589	1.079	7.148	3.834	4.216
Venezuela	0.250	0.394	3.774	1.322	2.117
India	0.177	0.531	0.831	1.080	0.839
Indonesia	0.212	0.645	1.850	1.234	1.140
Korea	0.504	3.827	1.458	1.328	4.574
Malaysia	0.348	3.157	0.851	1.141	2.793
Pakistan	0.149	0.547	0.838	0.801	0.604
Phillippines	0.158	0.624	0.087	1.136	0.710
Singapore	0.450	0.811	3.692	1.926	3.573
Thailand	0.316	2.710	0.870	1.701	1.920
South Africa	0.456	4.301	1.077	3.800	4.363

Notes: q = log of spot real exchange rate(other currency per dollar) S = log of spot nominal exchange rate(other currency per dollar), i-i* = nominal interest rate differential (US minus other country), π-π* = inflation differential. $Z_t = (\Delta S_t, i\text{-}i^*_t, \pi\text{-}\pi^*_t)$, lags 0 to 6.

Table 3. Sources of Variance in UIP Deviations (var(ω))

	Variances				**As a fraction of var(ω)**					**T-Ratios**	
	var(ω)	**var(ρ)**	**var(θ)**	**var(ϵ)**	**var(ρ)**	**var(θ)**	**var(ϵ)**	**c(ρ,θ)**	**c(ρ,ϵ)**	**t(ρ,θ)**	**t(ρ,ϵ)**
Austria	0.052	0.001	0.010	0.039	0.027	0.184	0.755	0.01	0.02	0.88	0.90
Belguim	0.051	0.001	0.012	0.038	0.013	0.225	0.750	0.00	0.01	0.19	0.64
Canada	0.007	0.001	0.003	0.005	0.110	0.421	0.711	-0.03	-0.21	-0.72	-4.74
Denmark	0.048	0.002	0.009	0.041	0.050	0.189	0.857	-0.06	-0.04	-3.62	-0.99
Finland	0.057	0.001	0.017	0.043	0.021	0.298	0.747	-0.06	-0.01	-4.35	-0.42
France	0.045	0.001	0.010	0.033	0.012	0.233	0.733	0.00	0.02	0.07	1.26
Germany	0.052	0.001	0.008	0.041	0.015	0.162	0.794	0.02	0.01	2.09	0.58
Ireland	0.044	0.002	0.011	0.035	0.052	0.247	0.792	-0.09	-0.01	-4.51	-0.15
Italy	0.052	0.001	0.015	0.041	0.013	0.284	0.784	-0.05	-0.03	-5.48	-1.47
Japan	0.064	0.001	0.019	0.042	0.015	0.303	0.664	0.01	0.00	1.14	0.29
Netherlands	0.053	0.001	0.007	0.044	0.020	0.136	0.835	-0.01	0.01	-0.55	0.62
Norway	0.039	0.001	0.009	0.033	0.036	0.237	0.828	-0.05	-0.05	-3.40	-1.61
Spain	0.051	0.001	0.014	0.041	0.019	0.267	0.797	-0.07	-0.01	-6.35	-0.65
Sweden	0.052	0.002	0.020	0.034	0.040	0.384	0.661	-0.04	-0.05	-1.65	-1.74
Switzerland	0.069	0.001	0.014	0.053	0.011	0.198	0.776	0.02	0.00	2.02	-0.08
United Kingdom	0.054	0.001	0.011	0.045	0.027	0.197	0.840	-0.02	-0.05	-1.36	-1.72
Mean, Ind. Ctry	**0.049**	**0.001**	**0.012**	**0.038**	**0.030**	**0.248**	**0.770**	**-0.025**	**-0.023**	**-1.600**	**-0.581**
Greece	0.039	0.007	0.012	0.035	0.180	0.319	0.913	-0.30	-0.11	-9.16	-1.59
Iceland	0.045	0.005	0.011	0.030	0.107	0.244	0.656	0.01	-0.01	0.28	-0.31
Turkey	0.155	0.050	0.017	0.080	0.322	0.112	0.517	-0.03	0.08	-1.00	1.15
Mean, Oth. Eur.	**0.080**	**0.021**	**0.014**	**0.049**	**0.203**	**0.225**	**0.695**	**-0.109**	**-0.015**	**-3.294**	**-0.248**
Argentina	5.190	2.497	1.057	0.590	0.481	0.204	0.114	0.02	0.18	0.22	3.00
Brazil	0.567	0.569	0.030	0.118	1.003	0.053	0.208	-0.02	-0.25	-0.38	-3.23
Chile	0.015	0.008	0.003	0.010	0.514	0.210	0.651	-0.29	-0.08	-5.63	-0.83
Mexico	0.147	0.033	0.023	0.082	0.227	0.157	0.559	-0.05	0.11	-1.56	1.75
Uruguay	0.006	0.008	0.005	0.006	1.223	0.826	1.026	-0.89	-1.19	-5.62	-7.12
Venezuela	0.095	0.022	0.039	0.362	0.227	0.414	0.438	-0.12	0.04	-1.68	0.57
Mean, Lat. Am	1.003	0.523	0.193	0.195	0.613	0.311	0.499	-0.225	-0.197	-2.443	-0.977
excl. Arg ,Braz.	**0.066**	**0.018**	**0.018**	**0.115**	**0.548**	**0.402**	**0.669**	**-0.339**	**-0.280**	**-3.625**	**-1.406**

Table 3. (Cont'd)Sources of Variance in UIP Deviations (var(ω))

	Variances				As a fraction of var(ω)					T-Ratios	
	var(ω)	var(ρ)	var(θ)	var(ϵ)	var(ρ)	var(θ)	var(ϵ)	c(ρ,θ)	c(ρ,ϵ)	t(ρ,θ)	t(ρ,ϵ)
India	0.032	0.007	0.005	0.031	0.204	0.155	0.970	-0.16	-0.17	-5.76	-2.20
Indonesia	0.001	0.003	0.000	0.002	2.600	0.454	1.783	-0.75	-3.08	-3.94	-10.96
Korea	0.005	0.002	0.004	0.004	0.436	0.649	0.743	-0.54	-0.29	-6.66	-3.02
Malaysia	0.010	0.001	0.003	0.006	0.105	0.296	0.555	0.05	-0.01	1.69	-0.17
Pakistan	0.011	0.003	0.001	0.011	0.298	0.113	0.984	-0.01	-0.38	-0.44	-4.29
Phillippines	0.017	0.004	0.002	0.015	0.262	0.120	0.886	-0.02	-0.24	-0.78	-2.99
Singapore	0.007	0.001	0.003	0.004	0.077	0.387	0.567	-0.03	0.00	-0.88	-0.11
Thailand	0.002	0.001	0.001	0.002	0.654	0.344	0.938	-0.16	-0.78	-1.90	-6.55
Mean, Asia	**0.011**	**0.003**	**0.002**	**0.009**	**0.580**	**0.315**	**0.928**	**-0.202**	**-0.620**	**-2.334**	**-3.785**
South Africa	0.055	0.002	0.028	0.033	0.041	0.508	0.610	-0.12	-0.04	-5.08	-1.51

Legend: var(ω), var(ρ), var(θ), var(ϵ): variances of UIP deviation, real interest differential, anticipated and unanticipated real exchange rate changes; c(θ,ρ)=[covariance of θ and ρ] * 2; c(ϵ,ρ)=[covariance of θ and ρ] * 2; t(θ), t(ϵ)= t-statistics from bivariate regression of ρ on θ, ϵ respectively.

plus unanticipated) accounts for nearly all of var (ω), while var (ρ) accounts for less than 5 percent for all industrialized countries except Canada and Ireland and less than 2 percent in about half of these countries. In the remaining countries, with few exceptions, var (ρ) comprises a substantially greater share of var (ω). Among the other European countries, var (ρ) comprises on average 13 percent of var (ω); among Latin American and Asian countries, this fraction is closer to 60 percent. At the same time, the importance of var (Δq) differs across countries. As a fraction of var (ω), the variability of real exchange rates growth is lowest among several high inflation countries, namely Turkey, Argentina, Brazil, Mexico, and Venezuela.

Note next the relative importance of anticipated versus unanticipated components of real exchange rate growth, var(θ) and var(ϵ), respectively. While the evidence presented in Table 1 favors UIP, predictable real exchange rate changes not canceled by offsetting movements in ρ nonetheless suggest unexploited profit opportunities. However, for most industrial, other European, Asian, and Latin American countries excluding Argentina and Brazil, var (ϵ) comprises about 70 percent of var (ω) versus 30 percent for var (θ). For Argentina, var(θ) comprises about 20 percent versus 11 percent for var(ϵ); for Brazil, var(θ) comprises about 5 percent versus 20 percent for var(ϵ).

What explains the cross-country differences in the importance of real interest differential variability var(ρ)/var(ω)? Why is there more 'action' in var(ρ) among developing countries than among industrialized ones? It is natural to look first at the inflation differential, $\pi - \pi^*$ since ρ by definition equals $(i - i^*)$ minus $(\pi - \pi^*)$. And, quickly comparing industrialized and developing countries suggests a cross-country relationship between var(ρ) and var ($\pi - \pi^*$), since var ($\pi - \pi^*$) (as a fraction of var (ω)) is substantially greater among developing countries than among industrialized ones. [20]

Figure 1 shows a plot of (the logarithms of) var(ρ)/var (ω) and var($\pi - \pi^*$)/var (ω). [21] The plot more strongly supports a positive relationship between the two variables. Of course, such an observed relationship is inconsistent with Fisher hypothesis under perfect information. However, the plot might be consistent with price stickiness. Or, even if prices were not sticky, such a plot migh reflect a relationship between var(ρ) and the *unanticipated* component of var ($\pi - \pi^*$). For either case, movements in the nominal interest differential in response to those of the inflation differential would not be sufficient to keep the real interest differential constant.

But, if either of the above two explanations were to be true, we would also expect to see a corresponding relationship between the variance of the real exchange rate var(Δq) and var($\pi - \pi^*$). To see this, note first that real exchange rate growth by definition equals nominal

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[20] For the less industrialized European countries, Latin America, and Asia, these shares are about 22 percent, 167 percent, and 45 percent, respectively. Among industrialized countries, the inflation differential accounts for about 2 percent of var (ω).

[21] Logarithmic scaling facilitates graphing.

FIGURE 1

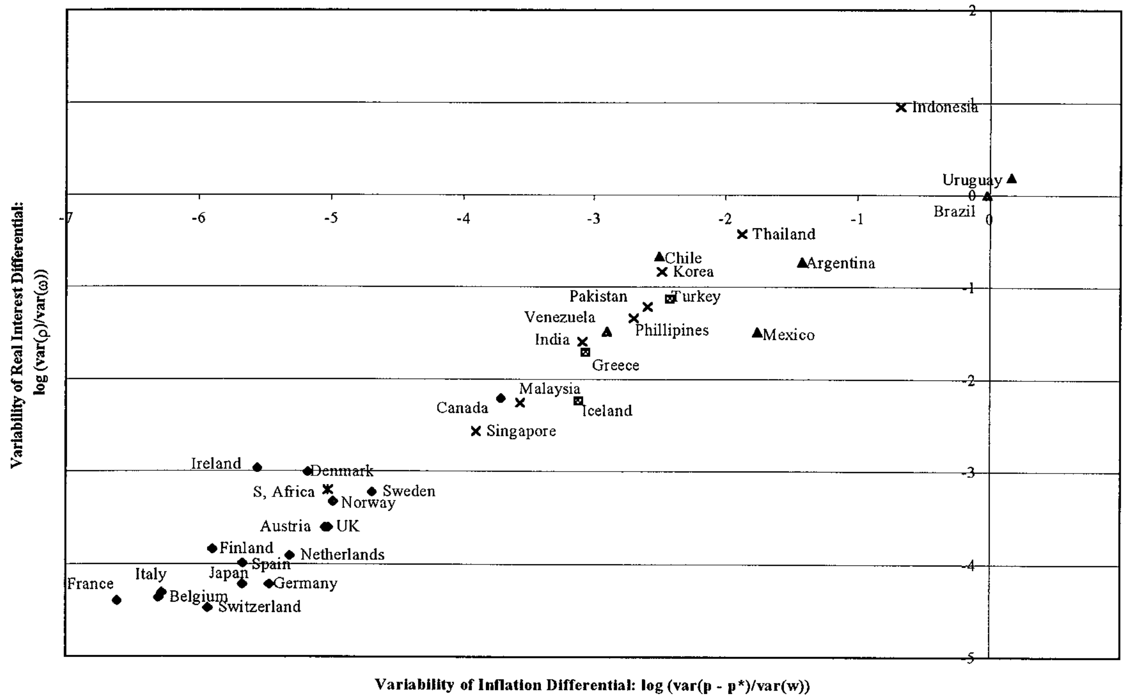
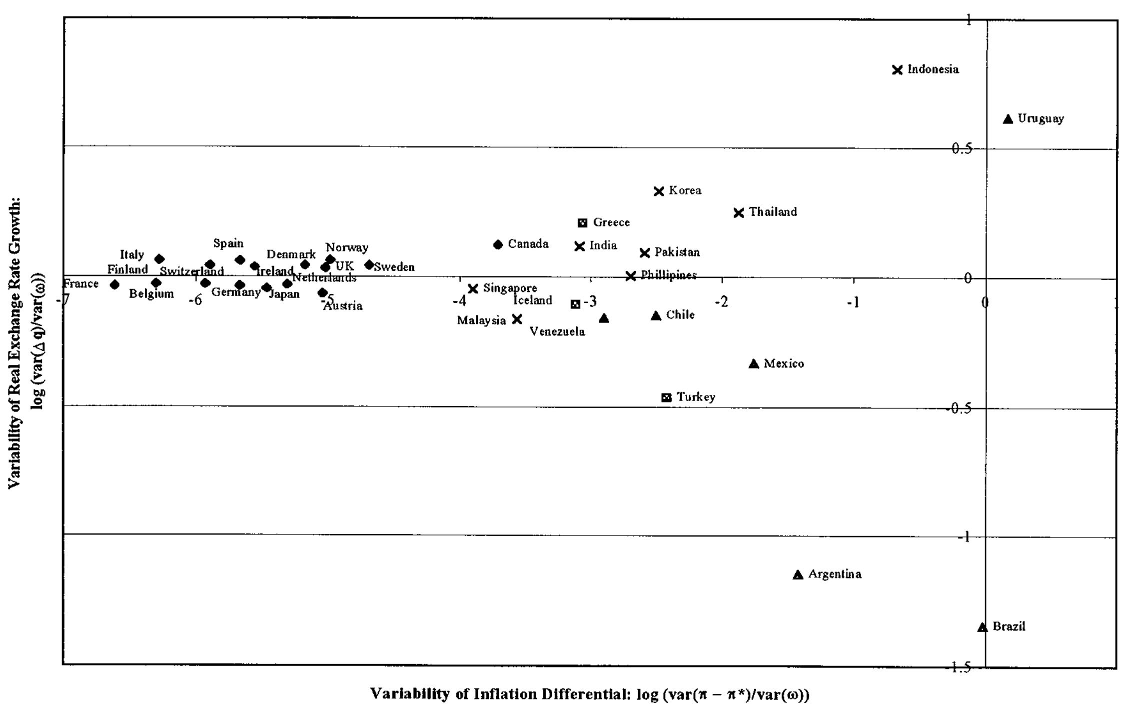


FIGURE 2



exchange rate growth (ΔS) plus the inflation differential ($\pi - \pi^*$). With either sticky prices or unanticipated inflation, an argument analagous that for interest rates (above) would hold: movements in the nominal exchange rate in response to those of the inflation differential would not be large enough to keep the real exchange rate constant.

Figure 2 shows a plot of (the logarithms of) var(Δq)/var (ω) and var($\pi - \pi^*$)/var (ω). Unlike figure 1, the plot does *not* suggest a clear relationship between the two variables. However, figure 2 does clearly show that the *dispersion* of the variance of real exchange rate growth var(Δq)/var (ω) rises with the variability of the inflation differential (i.e. as var($\pi - \pi^*$)/var (ω) rises). The countries with less variable inflation differentials --- primarily the industrialized countries --- behave like one another in terms of the variability of Δq. By comparison, countries with more variable inflation differentials --- primarily the developing countries --- display values of var(Δq)/var (ω) that can be much higher --- or much lower --- than their industrialized counterparts.

It is not possible to fully reconcile the observations of Figures 1 and 2 in this paper. However, one partial (and tentative) reconciliation of these two charts regards risk. As discussed above, ρ may capture risk differentials not directly related to exchange rates or goods markets, such as default risk. Such differentials between industrialized and developing countries may exceed (and vary more) than those among industrialized countries. And, while a risk differential is difficult to measure, inflation may be related to risk. If so, inflation may help measure risk, and the inflation differential might help measure the risk differential.

VI. Extension: Covariance Between Real Interest Differentials and Real Exchange Rates

The covariance terms in equation (4'), cov(ρ, θ) and cov(ρ,ϵ) (whose sum equals cov (ρ, Δq)) are important for two reasons. First, by definition, a negative covariance between ρ and Δq implies that changes in the real interest differential will be offset to some degree by movements in real exchange rate growth, thus reducing the deviation from UIP.

Second, and more substantively, these covariances may pertain to deeper elements of an economy's structure, namely the degree of price flexibility and the relative importance of real an nominal shocks. According to widely-used monetary models, if goods prices are sticky (following Dornbusch's (1976) assumption) there should be a short-run negative relationship between the real exchange rate and the real interest differential (see Meese and Rogoff (1988)). Previous research, applied to industrialized countries, fails to uncover such a relationship. Instead, several authors (Meese and Rogoff (1988), Edison and Pauls (1993), Baxter (1994), and others) find evidence favoring a long-run relationship between the real exchange rate and the real interest differential. Such a relationship should exist if real (rather than monetary) shocks are important.

Equation (4') suggests an alternative short-run (but not long-run) interpretation. Specifically, real exchange rate growth -- both anticipated and unanticipated components -- should be negatively correlated with the real interest differential. To see this, consider a permanent upward shock to the money supply in the foreign country of *x* percent. Holding all else constant, in the long run, a country's currency will depreciate equiproportionately (i.e., S_{t+x} rises by *x* percent). According to the overshooting hypothesis, in the short run, the country's interest rate falls (i.e., ρ *rises*) and the current exchange rate (S_t) depreciates (rises) by more than *x* percent, causing both a current depreciation (i.e., the *level* of q_t rises) but also an offsetting *fall* in (expected) real exchange rate growth, since $\Delta q_t = q_{t+x} - q_t$.

Equivalently, the relationship between ρ and Δq may be explained by changes in the inflation differential $\pi - \pi^*$, since price level adjustment (i.e., a rise in expected inflation) is reflected in both a fall in the real interest rate (i.e., a rise in ρ) and a rise in the rate of real appreciation (i.e., a fall in Δq). Thus, a negative relationship between the real interest differential and the *growth* of the anticipated component of the real exchange rate ($cov(\rho, \theta) < 0$) is consistent with sticky prices and exchange rate overshooting.

Empirically, among industrialized countries and other European countries, with the exception of Greece, covariances between ρ and Δq, while generally negative (and in some cases statistically significant), are small, in most cases under 10 percent of var(ω). By contrast, covariances between ρ and Δq for developing countries are somewhat larger than those of industrialized countries.

However, there are important differences among the developing countries. Specifically, there are sizable, statistically-significant negative correlations between ρ and Δq (i.e., the sum of cov (ρ, θ) and var(ρ, ϵ)) in the Asian and moderate inflation Latin American countries (for example Chile). By contrast, these correlations are (absolutely) smaller and, with some exceptions, statistically insignificant, among countries with higher inflation rates, such as Argentina, Brazil, and Venezuela. This contrast may reflect a grater degree of price flexibility that occurs under high inflation. [22]

Regarding the predictable component of real exchange rate growth, estimates of cov(ρ, θ) less than zero are present in all country groups. In 13 of the 34 countries, bivariate regressions of ρ on θ yield a coefficient that is negative and statistically significant. This covariance term exceeds (absolutely) 10 percent of var (ω) in several developing countries (most of which have moderate inflation), namely Greece, Chile, Uruguay, Venezuela, India, Korea, and Thailand. And, negative comovements between θ and ρ are weaker in higher inflation countries, again potentially reflecting more price flexiblity in these economies.

[22] More correctly, this observation may reflect *upward* price flexibility under high inflation. When inflation falls, these same economies are characterized by rigid labor markets.

VII. Conclusions and Directions for Future Research

This paper has re-examined a fundamental proposition of international economics, namely uncovered interest parity (UIP). As a starting point, the identity that UIP deviations equal the real interest rate differential plus real exchange rate growth is highlighted. A natural extension of this idea, investigated in previous research, links the real interest differential to differences in risk, assuming that real exchange rate changes are an unpredictable residual.

For industrial countries, previous research has found both that the real exchange rate can be predicted with past information and that real exchange rate changes, rather than real interest differentials, are the variable component of UIP deviations.

This paper extended previous work in two ways. First, a more diverse set of countries was considered than in previous research. Second, the variance of real exchange rate changes was further decomposed into a predictable and an unpredictable component.

The data yield striking differences in the behavior of UIP deviations between industrialized and developing countries. While real exchange rate changes almost exclusively explain UIP deviations among industrialized countries, real interest differentials are considerably more important in the less industrialized European countries, Latin America, and Asia. Another finding relates to the relative importance of anticipated versus unanticipated changes to the real exchange rate. The results suggest that, as a component of UIP deviations, unanticipated changes to the real exchange rate are more important than anticipated ones, especially among the industrialized countries. Finally, in several countries (primarily low inflation industrialized countries), the anticipated real exchange rate changes are substantially offset by changes to the real interest differential, consistent with Dornbusch's (1976) theory of sticky prices and exchange rate overshooting.

The paper provided three tentative explanations for such observed differences between industrialized and developing countries. First, among industrialized countries, inflation differentials are lower and less variable than those between industrialized and developing countries. Second, industrial countries are more 'alike' one another than developing countries, in that risk differences are lower and less variable. Third, capital controls, both actual and expected, are more common in developing countries than in industrialized ones. Fourth, due to higher inflation, prices rise more rapidly in most developing countries than in industrialized ones.

There are several interesting directions for future research. Alternative decompositions might help further pinpoint the sources of deviations from UIP. Another interesting extension would be to examine if and how the stylized facts discussed in this paper have changed over time, in light of increasing capital market openness. Finally, regarding broader business cycle issues, researchers might benefit from examining a richer data set, one in which the nature of shocks differs across countries.

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