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Decomposition of the ILS/USD Exchange Rate into Global and Local Components

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שער החליפין שקל\דולר: פירוק לרכיב גלובלי ולרכיב מקומי

בנצי שרייבר

תקציר

עבודה זו מציעה מתודולוגיה לפירוק השינויים בשער השקל\דולר לרכיב גלובלי-אקסוגני למשק ולרכיב מקומי-שאריתי. פירוק זה הוא בעל חשיבות רבה למנהלי המדיניות המוניטארית, מנהלי מדיניות שער חליפין, ולאחראים על היציבות הפיננסית; זאת לאור ההתייחסות השונה בתגובת המדיניות להתפתחויות ושוקים שמקורם בכלכלה הגלובלית לעומת אירועים שאינם גלובליים.

מתודולוגית הפירוק, שמתאימה לשערי חליפין של משקים קטנים ופתוחים לעומת הדולר, מיושמת בעבודה על התוחלת והשונות של השינויים הרבעוניים בשער השקל\דולר, על שקילות פער הריביות (UIP), על שקילות כח הקניה (PPP), ועל מודל תגובת היתר של Dornbusch (1976) המניח מחירים קשיחים (sticky prices). לשקילויות ה-UIP, ה-PPP ולמודל תגובת היתר נוסף הרכיב הגלובלי שחושב על פי המתודולוגיה המוצעת, ומובהקותו, כמו גם מובהקות השקילויות ומודל תגובת היתר, נבדקו בעזרת פרוצדורות סטטיסטיות שונות (OLS, GARCH(1,1)-M ומשוואות קו-אינטגרציה) – פעם לפני הוספת הרכיב הגלובלי ופעם לאחר ההוספה.

הממצאים מלמדים כי בתקופה הנסקרת, I/1993-II/2009, הרכיב הגלובלי נמצא חיובי ומובהק והוא תרם בין 0.2 ל-0.3 לשינויים בשער החליפין שקל\דולר בכל היישומים והפרוצדורות שנבדקו. ממצאים מובהקים ועקביים אלו מצביעים על חשיבות הכללתו של הרכיב הגלובלי בשקילויות ובמודלים נפוצים במטבע חוץ אשר כוללים בדרך כלל יחסים בילטראליים בין הדולר למטבע מקומי של משק קטן ופתוח ועל כן אינם משקפים התפתחויות של הדולר האמריקאי מול מטבעות של משקים גלובליים.

A decomposition of the ILS/USD exchange rate into a global component and a local component

Ben Z. Schreiber

Abstract

This paper offers a methodology to decomposing the changes in the ILS/USD exchange rate into a global-exogenous component and a local-residual one. This decomposition is of interest to monetary policymakers, exchange rate policymakers, and for financial stability.

The decomposition methodology, which is appropriate for exchange rates of small open economies versus the US dollar, is implemented in this paper on the mean and the variance of the quarterly changes of the ILS/USD, on the Uncovered Interest rate Parity (UIP) and Purchasing Power Parity (PPP), and on Dornbush (1976) overshooting model. Each of these parities/models is examined with and without the global component and its significance is tested using several statistical methods (OLS, GARCH(1,1)-M, and Co-integration equations).

It is found that during the sampled period, I/1993 – II/2009, the global component was positive and significant in all parities/models and contributed 20 to 30 percent of the changes in ILS/USD exchange rate changes. This significant and persistent result points on the importance of including a global component in FX models and parities of small open economies. The fact that a global component is omitted in the current FX parities and models may partially explain their relatively low significant level as they do not consider the behavior of the US dollar against the global currencies.

Introduction

The most common parities in the exchange-rate literature are UIP (Uncovered Interest Rate Parity), PPP (Purchasing Power Parity), and the Dornbusch Overshooting Model (Dornbusch, 1976), which combines UP and PPP. UIP claims that interest rates between two markets at time t predict expected depreciation/appreciation between time t and time t+1, as follows:

(1) $\Delta s_{t+1} = E(s_{t+1})\text{-}s_t = i_t — i_t^*$

where s_t is the log of the nominal exchange rate at time t, $E(s_{t+1})$ is the log of the expected exchange rate at time t+1, and i_t and i_t* are the nominal interest rates—local and foreign—at time t, respectively. UIP assumes unrestricted capital flows, a floating exchange-rate regime, and rational expectations, so that in equilibrium most of the gain that, may be gained by exploiting inter-currency interest spreads, is offset by the expected loss caused by depreciation; otherwise, arbitrage conditions come about. The second parity widely found in the exchange-rate literature—relative PPP—claims that inflation spreads between two economies predict the rate of depreciation, as follows:

(2) $\Delta s_{t+1} = E(s_{t+1})\text{-}s_t = \pi_t - \pi_t^*$

where π, π^* are the local and foreign inflation rates, respectively. This parity, like UIP, assumes free trade among countries and tradable assets.[1] The third common hypothesis allows a possible partial adjustment of prices due to their "stickiness" on the basis of Dornbusch's (1976) Overshooting Model. In this model, the current exchange rate does not converge to the equilibrium rate immediately due to the existence of sticky prices. The convergence equilibrium is expressed as follows:

(3) $\Delta s_{t+1} = E(s_{t+1}) - s_t = -\nu(s_t - \bar{s})$

where $\bar{s} = p_t - p_t^* = E(s_{t+1})$ is an exchange rate consistent with equilibrium according to PPP and p_t and p_t* are the logs of the domestic and foreign price levels, respectively.[2] By adding this expression to Equation (1) under the common

[1] Each of these parities comes in various versions. In UIP, some add to the interest spreads a risk premium that varies over time. In PPP, some replace actual inflation spreads with inflation expectations and add an adjustment process to the parities so that the correspondence is not immediate. Since the purpose of this paper is to present the effects of the proposed decomposition on the basic parities, only some of the versions are presented below.

[2] This equilibrium is also called absolute PPP, in contrast to the relative PPP shown in Equation (2).

assumption that equilibrium values and expected values are given in current terms, we get:

(4) $$s_t = (p_t - p_t^*) + \lambda(i_t - i_t^*) = (p_t - p_t^*) + \lambda \Delta s_{t+1}$$

where $\lambda = -\frac{1}{\nu}$ is the pace of the reversion of the current rate to the equilibrium rate.

Equation (4) is one of the building blocks of Dornbusch's Overshooting Model. According to the equation, the nominal exchange rate is a function of two spreads between the economies: of price levels and of interest rates. Due to the relative stickiness of prices, however, the reversion to equilibrium pursuant to changes in interest spreads is not immediate; its pace depends on λ.

The findings show that UIP does not obtain at most times and in most economies. Meredith and Chin (1998) summarize the findings on UIP as follows:

> Few propositions are more widely accepted in international economics than that uncovered interest parity (UIP) is at best useless—or at worse perverse—as a predictor of future exchange rate movements.

Like UIP, PPP is rarely present. To very long terms, however, there is stronger empirical support for PPP, and less so for UIP, in emerging markets and with an adjustment process (Dornbusch's Overshooting Model).

Small and open economies such as Israel's are strongly affected by the exchange rates of the currencies that are most heavily traded against the U.S. dollar (USD). In particular, the nominal exchange rates of global currencies that reflect global economic developments, such as EUR/USD, should affect the currency rates of small and open economies that have floating exchange-rate regimes. An example of a global-currency effect is the appreciation of the Israel Sheqel (ILS) against the USD in 2006–2007, much of which is credited to depreciation of the USD abroad.

Most studies that attempt to estimate the exchange rate by means of these parities focus on the bilateral relations between each pair of countries and, in particular, against the USD (MacDonald and March, 1999) and not on cross-currency rates. Consequently, the estimation equations omit much of the explanation of changes in the exchange rate of a small and open economy against the USD, thereby limiting the explanatory power of the exchange-rate estimation according to these parities, including the ability to predict the rate. This happens because much volatility in the ILS/USD exchange rate traces to depreciation/appreciation of the American currency abroad and has nothing to do with Israel. According to UIP, for example, rate increases in the Eurozone should cause the EUR to depreciate against all currencies and, in particular, against the USD and the ILS (*ceteris paribus*). Beyond the direct effect of this event, however, we should also expect to find *lagged indirect effects* that affect the ILS/USD exchange rate (e.g., redirection of exports to the U.S. at Europe's expense, and vice versa in imports). This occurrence, however—however important it may be—is not manifested in UIP tests of the ILS/USD rate, as stated.

Although the effect of global currencies against the USD should be reflected across the entire distribution, this paper focuses on the first two moments only—mean and variance. This paper contributes to the literature by estimating the effect of cross-currency rates of major economies against the USD on exchange rates of small and open economies, such as ILS/USD. In particular, the paper proposes a methodology for the decomposition of changes in the ILS/USD rate into two components: a global one, exogenous to the local economy, and a local-residual component, which is the difference between the total change in the ILS/USD exchange rate and the exogenous component. Since according to the existing practice a change in the ILS/USD exchange rate may be affected by cross-currency rates and have nothing whatsoever to do with the local economy, as stated, we will examine the addition of the global components to the aforementioned parities. In other words, we will check for the existence of (1) UIP (by using the proposed methodology) on the yield curve (3 months, 6 months, 1 year, 2 years, and 5 years); (2) PPP by using actual and expected inflation rates; and (3) Dornbusch's Overshooting Model—all of which by adding the global component to the estimation equations. Insofar as this component is found to be significant and raises the significance level of both parities and the Overshooting Model, we may infer that the global component is a missing value in these parities at both economically and statistically.

Given the status of the USD as a global anchor, this decomposition is important for the management of monetary policy and the exchange rate by the central bank, evaluation and understanding of developments in foreign-currency and capital markets and inflation, and monitoring of financial stability in the economy at large. Accordingly, it is important for those active in the FX and capital markets, manufacturers, and economic policymakers.

The rest of this paper is divided into five parts. Part 1 reviews the relevant literature; Part 2 analyzes the effects of global currencies on a local currency by using a triangulated value, such as the effect of the EUR/USD exchange rate on the ILS/USD and ILS/EUR rates. Part 3 presents the methodology to be used in decomposing change in a local-currency exchange rate into global-exogenous and local-residual components by means of an index of global currencies, and assesses the differences between the proposed decomposition and the effective ILS exchange rate. Part 4 tests the decomposition methodology on UIP, PPP, and Dornbusch's Overshooting Model using OLS regressions, GARCH(1,1)-M regressions that do not assume constant variance, and cointegration equations, on the basis of quarterly sample data for I/1993–II/2009. Part 5 summarizes and concludes.

1. Survey of the literature

Cavalo (2006) argues that the main reason for changes in the USD exchange rate in recent years is the interest spread between the USD and other currencies, resulting in considerable carry trading, i.e., taking loans in a low-interest currency and depositing the proceeds in a high-interest currency. According to Cavalo, USD appreciation against the YEN and the EUR in 2005 and its depreciation against these currencies in 2006 were occasioned by changes in spreads and exploitation of the spreads for carry-trade activity. This phenomenon is not in line with UIP empirical tests. Fama (1984), for example and others (for a survey, see Sarno, 2005), found a significant negative relation between interest spreads at time t and depreciation/appreciation at time t+1. This phenomenon is known in the literature as the 'forward premium puzzle'.[3] It has also been found that exchange-rate changes are much more volatile than interest spreads and the volatility of inflation spreads, in contrast to UIP and PPP—in what is called the 'volatility puzzle'. Both puzzles are especially evident in small and open economies such as Israel's. Indeed, in recent years, due to globalization and floating exchange-rate regimes in small and open economies, especially in Israel, maintaining an independent monetary policy has become a complex task (Saxena, 2008) because global long-term interest rates affect local rates even more than domestic monetary policy does (see, for example, Mehl, 2006).

[3] Froot (1990), examining seventy-five studies that looked into UIP, found that the average interest-spread coefficient (equal to the forward premium) in the regressions (Equation 1) is negative at a 0.88 level, contrary to what one would expect according to the parities.

The gap between the UIP/PPP hypothesis and the empirical findings has been explained in several ways. One accepted explanation speaks of a risk premium that varies over time (e.g., Sarantis, 2006). Since the premium is affected by monetary markets in the near term, it should be added to the UIP. The problem is that this premium is unobservable; therefore, some estimate it by using the EGARCH-M procedure (Berk and Knot, 2001). Another explanation offered is a joint hypothesis of investor rationality and examination of the parities. If investors are irrational (e.g., adaptive investors who operate according to technical rules), the inability to corroborate the parities is the result of the adaptive behavior, which clashes with the rationality assumption attached to the UIP. A similar argument is offered for PPP insofar as a major portion of the economy includes nontradable assets. Finally, it has been proposed that the parities should be rejected due to interest and inflation developments from the time outlooks are formulated on the basis of the parities and the subsequent time at which the exchange-rate change is examined. The errors occasioned by the time difference, known as exchange-rate forecast errors, are added to the errors in estimating the risk premium and the errors in predicting inflation (Campbell et al., 2007).

Many have responded to the seeming contradiction between the parities and the empirical findings by trying to reconcile them. Indeed, recent studies show that UIP is obtained to longer terms (Sarno, 2005) and in emerging markets than in the American economy or when USD interest exceeds interest in the countervailing developed economy (Bansal and Dahlquist, 2000). A study that included more than a century of data (Obsfeld and Rugoff, 2000) found support for PPP to especially long terms.

Sussman and Saadon (2007) examined UIP and PPP and added various risks in Israel, assuming that investors are risk-averse, within the framework of cointegration equations. They found that UIP does obtain in the long term and that interest spreads are derived from PPP, among other factors. In studies on Israel, especially in recent years,[4] adding a risk premium to the UIP equation may be problematic because UIP assumes that the interest rates that comprise the interest spread are risk-free, whereas the domestic rate chosen in the studies is that on Makams or government bonds—a rate that seems to lack a premium for sovereign risk or liquidity. Another difference

[4] With the transition to the Basel II principles and the growing involvement of nonresidents in Israel's financial markets.

between the two studies about UIP in Israel and the present study is the reference to different levels of integration. The level of integration of interest rates on the yield curve and the level of inflation spreads was I(1) during the sample period, whereas the rate of change in the ILS/USD exchange rate was stationary, i.e., I(0). Notably, the inflation and interest rates that were examined in the various studies were I(1) on some occasions and I(0) on others. Despite these differences, the commonly found parities (Equations 1 and 2) were tested for two reasons: (1) to predict the future exchange rate, the model examined does not need to have the same level of integration; (2) the studies were performed to examine the existing parities and not to formulate unchallengeable models in econometric terms. Finally, Dornbusch's model was examined using co-integration with a short-term dynamic (a vector error correction); this should strengthen or weaken the conclusions obtained by testing the validity of the common parities (Equations 1 and 2).

Tai (2001) suggests that bilateral running of a local currency and the USD is not the best way to explain the matter. Examining UIP among four Asian countries' currencies against the USD, Tai found that the risk premium is not significant when each currency is run against the USD separately but is significant and moves in the expected directions when they are run in a panel. Mehl (2006) also finds a strong effect of the U.S. and Eurozone interest curve on emerging-market inflation and growth.

2. The effect of global currencies on the nominal exchange rate in a small open economy

According to the triangulated value in exchange rates,[5] efficient FX markets offer only two degrees of freedom, i.e., since two exchange rates are known, the third one is derived from them. The triangulated value exists among all three currencies and, in particular, between the low-tradability currency of a small open economy (hereinafter: "local currency") such as the ILS/USD and a high-tradability currency (hereinafter: "global currency") such as the EUR/USD.[6]

[5] According to the triangulated value, $\frac{ILS}{USD} = \frac{ILS}{EUR} * \frac{EUR}{USD}$. This value holds, however, up to transaction costs and bid-ask spreads.

[6] The USD serves as a numéraire in this example because it is the most commonly used currency today. One may, however, use any other global currency as the numéraire.

The equality of the triangulated variable also obtains for the log of the change from time t–1 to time t, i.e., $c_{S\$} = c_{SE} + c_{E\$}$, where:

$c_{S\$} = Ln\left(\frac{(ILS/USD)}{(ILS/USD)_{-1}}\right)$ is the natural log of the change in the local-currency exchange rate against the USD,

$c_{SE} = Ln\left(\frac{(ILS/EUR)}{(ILS/EUR)_{-1}}\right)$ is the natural log of the change in the local-currency exchange rate against the EUR, and

$c_{\$E} = Ln\left(\frac{(EUR/USD)}{(EUR/USD)_{-1}}\right)$ represents the natural log of the change in the EUR/USD exchange rate. Despite the simultaneous links among the three currencies, however, from an econometric standpoint currencies $ and E affect S but not vice versa, i.e., $c_{S\$}, c_{SE} = f(c_{\$E})$ but, $c_{\$E} \neq f(c_{S\$}, c_{SE})$. The triangulated value makes it clear that if local-currency exchange rate against the EUR is held constant ($c_{SE} = 0$), then the domestic currency against the USD, $C_{S\$}$, will have a fully negative correlation with C_{SE}, and conversely, if we hold the local-currency exchange rate against the USD constant ($C_{S\$}=0$), then the local-currency exchange rate against the EUR (C_{SE}) will have a fully positive correlation with the USD/EUR rate—$C_{\$E}$. These two extreme and opposing propositions reflect a bipolar reality. If we take the ILS as the local currency, for example, the meaning of the first proposition is that despite the increase in the USD/EUR rate (i.e., the EUR gains against the USD), the ILS/EUR rate will remain constant, i.e., the ILS resembles the EUR and, therefore, should gain against the USD. According to the second proposition, the ILS/USD rate remains constant even though the EUR gains against the USD, and therefore the ILS does not depreciate against the EUR. Table 1 presents examples of the various possibilities of ILS/USD, ILS/EUR, and USD/EUR correlations according to both extreme situations, on the assumption that the USD/EUR exchange rate, which is exogenous to the Israeli economy, rose by 20 percent (i.e., the EUR appreciated against the USD) at time 0 relative to time 0.

Table 1

	USD/EUR	ILS/USD	ILS/EUR
1. Time 0	1	4	4
2. ILS follows USD only	1.2	4	4*1.2=4.8
3. ILS follows EUR only	1.2	4/1.2=3.33	4
4. ILS is equally affected by USD and EUR	1.2	3.33+5*(4–3.33)=3.67	4+.5*(4.8–4)=4.4
5 ILS is 70% affected by USD and 30% affected by EUR	1.2	3.33+7*(4–3.33)=3.33	4+.3*(4.8–4)=4.24

At the time 0, the USD/EUR exchange rate was equal to 1, i.e., the ILS/USD rate (ILS 4/USD 1) equaled the ILS/EUR rate (ILS 4/EUR 1). The second and third lines in the table represent the aforementioned extreme cases. On Line 2, the ILS follows the USD; therefore, the EUR appreciation against the USD translates into an equal rate of EUR appreciation against the ILS while the ILS/USD exchange rate remains constant. In Line 3, the opposite extreme assumption obtains, i.e., the ILS follows the EUR; therefore, the EUR appreciation affects only the ILS/USD rate (20 percent appreciation) while the ILS/EUR rate remains constant (ILS 4/EUR 1). Lines 4 and 5 represent specific cases selected from a broad range of possibilities. In Line 4, the EUR appreciation against the USD is equally divided so that all three sides of the triangle—ILS/USD, ILS/EUR, and USD/EUR—change concurrently. Accordingly, the ILS/USD rate stands halfway between the two extremes—3.67 (the mean of ILS 4/USD 1 and ILS 3.33/USD 1) and the ILS/EUR rate will be ILS 4.4 per EUR (the mean of ILS 4/EUR 1 and ILS 4.8/EUR 1). In Line 5, the effect of the USD is weighted at 70 percent against the ILS and 30 percent against the EUR. This line corresponds better than the others to the prevailing situation in Israel, where the USD commands the largest share in capital, trade, and services flows.[7] However, it is difficult to estimate the weight with precision due to lack of data. The ILS/USD exchange rate on the bottom line of the table is ILS 3.80, 70 percent of the distance between the extremes noted above, and the ILS/EUR rate is set at ILS 4.24, 30 percent of the distance between the extremes (ILS 4/EUR 1 and ILS 4.80).

[7] Notably, a distinction should be made between business-room activity, almost all of which takes place vis-à-vis the USD—even when it concerns, for example, imports from Japan—and the economic forces that affect ILS exchange rates against the other currencies. Accordingly, the technical activity of currency conversion in business rooms should have no effect on the exchange-rate trend, be it of the ILS against the USD or the ILS against other currencies.

Since none of the five possibilities in the table lends itself to *a priori* prediction, it is hard to estimate the relations among the three sides of the triangle. One can, however, examine the average effect of a global currency or an index of global currencies on the ILS/USD exchange rate in terms of both mean and variance. The decomposition of the mean and variance of change in the ILS/USD exchange rate into global-exogenous and local-residual components is described in the next section.

3. Decomposing mean and variance of the rate of change of a local currency against the USD into global and local components

Small and open economies such as Israel's, as stated, are heavily affected by the exchange rates of global currencies but do not affect them. It is under this assumption that the USD is traded against m leading global currencies in the global market, where its value is determined. First we define the weighted average (in currency trading volumes) of the m exchange rates of global currencies that have the largest trading volumes against the USD:

$$G = \sum_{j=1}^{m} w_j G_j$$

where G_j is the log of the exchange rate of global currency j against the USD. The share of currency j, w_j, is determined in accordance with trading volumes in this currency—Vol_j[8]: $\sum_{j=1}^{m} w_j = 1$; $TotVol = \sum_{j=1}^{m} Vol_j$; $w_j = \frac{Vol_j}{TotVol}$. We also define S as the log of the ILS/USD exchange rate and use the triangulated value to determine the log of the local-residual component of the ILS against the global currencies in L, so that G + L = S. Since global component G reflects the value of the USD abroad, local-residual component L should reflect developments not directly related to this value. We denote the long-term changes in S, G, and L in subscript:

$$C_G = \sum_{j=1}^{m} w_j C_j \quad (5)$$

and $C_j = Ln\left(\frac{(Curr_j / USD)}{(Curr_j / USD)_{-1}}\right)$ is the rate of change in global currency j {j = 1..m} against the USD.

[8] Plausible alternative weightings exist, e.g., trade volumes or equality. However, the data show that the type of weighting has relatively little effect on the results.

The index of global currencies, C_G, reflects the weighted average of the global change in the USD rate; therefore, it is attributable to global factors that are exogenous to the currency of a small and open economy. Similarly, the local-residual component (C_L), is extracted on the basis of the difference between the total change in the ILS/USD exchange rate and change in the global-currency index against the USD, $C_L = C_S - C_G$, and in mean terms we obtain: $E(C_L) = E(C_G) - E(C_S)$.

Much as we decomposed the mean, we may also decompose the variance of the exchange-rate change into local and global components. First, we define the global variance of the changes in the m global currencies against the USD:

$$\sigma_G^2 = \sum_{i=1}^{m}\sum_{j=1}^{m} w_i w_j Cov\left(C_i, C_j\right)$$

Accordingly, the variance of the local-residual component is:

$$\begin{aligned} \sigma_L^2 &= \sigma^2(\mathrm{C_S} - C_G) = \sigma_S^2 + \sigma_G^2 - 2Cov\ (C_S, C_G) = \\ &= \sigma_S^2 + \sigma_G^2 - 2\sum_{\mathrm{j=1}}^{\mathrm{m}} \mathrm{w_j Cov(C_S}, C_j) \end{aligned} \tag{6}$$

We see that the local variance covariates with the total variance of the local currency (σ_S^2) and the global variance (σ_G^2) but moves against the correlation between the global currencies' exchange rates against the USD and the local currency. The stronger the correlation between the local currency and global currencies is (*ceteris paribus*), the more we would estimate the changes in variance as being global in origin. From another angle, we may explain the changes in the total variance of the local currency by shifting expressions and the equality Cov(x,x) = Var(x):

$$\begin{aligned} \sigma_S^2 &= \sigma_L^2 - \sigma_G^2 + 2Cov\,(C_S, C_G) = \sigma_L^2 - \sigma_G^2 + 2Cov\,(C_G + C_L, C_G) \\ &= \sigma_L^2 + \sigma_G^2 + 2\sum_{\mathrm{j=1}}^{\mathrm{m}} \mathrm{w_j Cov(}\,C_L, C_j) \end{aligned} \tag{7}$$

The stronger the global and local-residual variance and the stronger the correlation between the global currencies and the local-residual components, the greater the total variance of the changes in the local-currency exchange rate will be.

There have been several previous attempts to decompose changes in the ILS/USD exchange rate into global and local factors, as this paper does. Some define the average/median of emerging markets as the global component, others assign this role to the developed markets, and yet others choose a sample of countries that have a statistical distribution of currencies that resembles that of ILS/USD (Zilberberg and Sociano, 2006). The methodology proposed here has two advantages: (1) a currency not traded extensively against the USD does not affect the global currencies' exchange rates against the USD; this allows us to generate a global component that reflects USD appreciation/depreciation abroad and is also exogenous to the ILS. (2) It allows us to relax the preliminary assumption that the ILS exchange rate belongs to a peer group (benchmark) of some kind. Weighting the index of global currencies by trading volumes, however, is not the only possibility.

In many cases, one may identify USD appreciation or depreciation against the other currencies. In these cases, the USD typically appreciates or depreciates against the ILS and the global component at similar rates. As for other currencies such as the EUR, the change in the global component should be the product of the change in the EUR and the EUR's share in the index of global currencies. Accordingly, the heavier the weight of a currency in the global component, the more effect it will have. In some cases, however, the USD/EUR exchange rate changes but the global component exchange rate does not yet change ($C_G = 0$ in Equation 5) or even decreases. This happens if the increase in the USD/EUR exchange rate is offset by a concurrent and equally strong decrease in the exchange rates of the other currencies that constitutes the global component.

The difference between the proposed decomposition and an effective exchange rate

The effective ILS exchange rate, calculated on a daily basis in Israel (otherwise known as the nominal effective exchange rate—NEER), is a simple geometric mean[9] in which the weights of the "basket" currencies are calculated on the basis of Israel's foreign-trade data (including multilateral trade, i.e., trade between third countries and Israel), with the minimum volume of trade set at >0.5 percent of Israel's total trade (resulting in thirty-three countries and twenty-four currencies). To gauge the differences between the proposed decomposition and the effective exchange rate, let B denote the effective exchange rate as determined on the basis of a basket of N global currencies (including the USD):

[9] See Sofer (2005). The countries included are the U.S.; developed countries: Eurozone, UK, Japan, Australia, Canada, Switzerland, Denmark, and Sweden; and emerging markets: Brazil, China, Cyprus, Hong Kong, India, Malaysia, Mexico, the Philippines, Poland, Russia, Singapore, S. Africa, S. Korea, Taiwan, Thailand, and Turkey.

(8) $$B = \prod_{j=1}^{N} \left(\frac{ILS}{Curr_j}\right)^{W_j}$$

where ILS/Curr$_j$ is the ILS exchange rate against currency j and W_j is the weight of the currency (commensurate, as stated, with Israel's volume of trade—W_j = $Tr_j/\Sigma Tr_j$—with Tr_j denoting Israel's trade with country j). We assume that the N currencies are the same m currencies included in the proposed decomposition, including the USD, i.e., N = m + 1. What this means is that the currencies most heavily traded against the USD belong to the same economies that do the most trade with Israel (excluding the USD). Taking a log from both sides of the equation, we get:

(9) $$Ln(B) = W_1 Ln(\frac{ILS}{Curr_1}) + W_2 Ln(\frac{ILS}{Curr_2}) + ... + W_N Ln(\frac{ILS}{Curr_N})$$

Decomposing the remaining currencies other than ILS/USD on the basis of the triangulated value, we get:

$$Ln(B) = W_1 Ln(\frac{ILS}{USD}) + W_2 Ln(\frac{ILS}{USD}\frac{USD}{Curr_2}) + ... + W_N Ln(\frac{ILS}{USD}\frac{USD}{Curr_N})$$

and after aggregating expressions for the ILS/USD exchange rate ($W_1+W_2+\ldots+W_N$ = 1), we get:

$$Ln(B) = Ln(\frac{ILS}{USD}) + W_2 Ln(\frac{USD}{Curr_2}) + ... + W_N Ln(\frac{USD}{Curr_N})$$
$$= Ln(\frac{ILS}{USD}) - W_2 Ln(\frac{Curr_2}{USD}) - ... - W_N Ln(\frac{Curr_N}{USD})$$

In other words, the "basket" exchange rate equals the ILS/USD rate less the index of the cross-currency rates of the m global currencies against the USD. After substituting, we obtain:

(10) $$Ln(\frac{ILS}{USD}) = Ln(B) + W_2 Ln(\frac{Curr_2}{USD}) + ... + W_N Ln(\frac{Curr_N}{USD})$$

Equation (10) may be expressed in terms of changes between time t–1 and time t. Thus, in terms of the proposed decomposition, the change in the ILS/USD rate is the result of the change in the global component and the local-residual component, as follows: $C_S = C_L^* + C_G^*$, where $C_S = Ln(\frac{ILS}{USD}\Big|_t) - Ln(\frac{ILS}{USD}\Big|_{t-1})$ is the change in the ILS/USD exchange rate as before, $C_G^* = W_2 \Delta Ln(\frac{Curr_2}{USD}) + ... + W_N \Delta Ln(\frac{Curr_N}{USD})$ is a weighted average of cross-currency changes against the USD (global component), and $C_L^* = \Delta Ln(B)$ is the local-residual component. (Δ represents a change — the log exchange rate at time t less the log exchange rate at time t–1.) Now we look for conditions of equality between the global component according to the proposed deconstruction—C_G (Equation 5)—and the global component derived from the effective exchange rate, C_G^*. This is because if $C_G^* = C_G$, then $C_L^* = \Delta Ln(B) = C_L$, i.e., the local-residual component of the proposed decomposition will be equal to the effective exchange rate. As we recall, the global component comprises the m global currencies, excluding the USD, whereas the nominal effective exchange rate comprises m + 1 = N global currencies, including the USD. Thus, the difference between the two series of weights—that of the effective exchange rate (Equation 8) and that of the proposed decomposition (Equation 5)—is related to the absence of the ILS in the global component. First, we need to standardize the trading volumes of the currencies for the absence of the ILS in the following way: $Vol_j = \frac{Tr_j}{1 - W_1} \; \forall j$, where Vol_j reflects the trading volumes of the global currencies against the USD (in the global component of the proposed decomposition), Tr_j are the trading volumes of these global-currency countries with Israel (in the global component of the effective exchange rate), and W_1 is the weight of the USD in Israel's total foreign trade. Given this standardization, if the trading volumes in the global currencies against the USD (in the global component of the proposed decomposition) standardized to the USD exchange rate are equal to the total trade of the global-currency countries with Israel (in the global component of the effective exchange rate), the effective exchange rate and the proposed decomposition will be equal. Only in such a case will the weights of the trading volumes in the global currencies against the USD be equal to the weights of Israel's trade with these countries ($C_G^* = C_G$) and only thus will the local-residual component of the proposed decomposition be the effective exchange rate. By and large, however, these conditions are unlikely to occur. (The differences that actually occurred from 2008 onward between the effective exchange rate and the global component are shown in the next section, in Figure 2.)

Integrating the proposed decomposition into Dornbusch's Overshooting Model

To conclude this part of the paper, we show how the proposed decomposition into global and local-residual components is reflected in the Overshooting Model (Equation 4) and, specifically, the importance of the pace of different currencies' reversion to equilibrium. As we recall, according to the Overshooting Model, a bilateral exchange rate is a function of price spreads and interest spreads with reversion pace, λ ,of the current exchange rate to the equilibrium rate. If we disregard the dimension of time and, as stated above, predict the log of the ILS/USD exchange rate, S, by means of the global component (the log of the global-currency index against the USD—G) and the local-residual component (the log of the USD exchange rate against the global currencies—L), we get:

$$G = (p_G - p_S) + \lambda_{GS}(i_G - i_S)$$

$$L = (p_L - p_G) + \lambda_{LG}(i_L - i_G)$$

(11) $$S = G + L = (p_L - p_S) + \lambda_{GS}(i_G - i_S) + \lambda_{LG}(i_L - i_G) = (p_L - p_S) + \lambda_{LS}(i_L - i_S)$$

where subscripts S, G, and L represent the USD, the global currencies, and the ILS, respectively; i and p represent interest and inflation, and coefficients λ_{GS}, λ_{LG}, and λ_{LS} represent the pace of reversion to the equilibrium exchange rate. Since Equation (11) represents the bilateral relations between each pair of currencies (or indices) at equilibrium, the following must obtain:

(12) $$\lambda_{GS}(i_G - i_S) + \lambda_{LG}(i_L - i_G) = \lambda_{LS}(i_L - i_S)$$

Assuming in the first stage that all coefficients of reversion to equilibrium are equal, $\lambda_{GS} = \lambda_{LG} = \lambda_{LS} = \lambda$, as the Overshooting Model does, we immediately obtain the equality in Equation (12). Absent this assumption, however, the pace of reversion to equilibrium becomes very meaningful. In the literature (e.g., Ferreira et al., 2007), the pace of reversion to equilibrium, λ, has been found to be faster in emerging markets than in developed ones. Accordingly, let us assume that $\lambda_{GS} > \lambda_{LG} \cong \lambda_{LS}$. Now, if we insert Equation (1) into Equation (11), we get:

(13) $$\Delta S_{t+1} = \frac{\lambda_{GS}}{\lambda_{LS}} \Delta G_{t+1} + \frac{\lambda_{LG}}{\lambda_{LS}} \Delta L_{t+1}$$

In this formulation, the expected change in the ILS/USD exchange rate is a function of the expected changes in the global and the local-residual components. However, since we have assumed that $\lambda_{GS} > \lambda_{LG} \cong \lambda_{LS}$, the coefficient of the global component, $\frac{\lambda_{GS}}{\lambda_{LS}}$, outweighs that of the local-residual component, $\frac{\lambda_{LG}}{\lambda_{LS}}$ (*ceteris paribus*). This result demonstrates the importance of the global component in explaining the future exchange rate even within the framework of the Overshooting Model.

4. Testing the proposed decomposition on a sample of daily data for the I/1993–II/2009 period

To test the proposed decomposition, we took daily readings of the exchange rates of twelve currencies. The weights of the currencies, corresponding to volumes of trading in the global foreign-currency market, were culled from a three-year BIS survey published in September 2007 (*Triennial Central Bank Survey of Foreign Exchange and Derivative Market Activity*). According to the survey, the currencies in which the daily volume of trading surpassed 1 percent of total FX trading (including spot, forward, option, and swap transactions) in April 2007 were the euro, the yen, the pound sterling, the Swiss franc, the Australian dollar, the Canadian dollar, the Swedish krona, the Norwegian krone, the New Zealand dollar, the Mexican peso, the Singapore dollar, and the Korean won.[10] On the basis of these weights and the monthly rate of change of each currency, the following were determined: a global currency index (the global component) according to Equation 5 (twelve currencies), the local-residual component, and the global and local-residual component of the variance of change in the ILS/USD exchange rate according to Equation 7. Table 2 presents basic statistics on the twelve currencies, the global and local-residual component in the ILS/USD exchange rate, and rates of return and inflation.

[Insert Table 2 here]

The table shows that only four currencies—EUR, YEN, GBP, and CHF (Swiss franc)—account for approximately three-fourths of the global index. During the sample period, the USD appreciated against the global-currencies index by a minuscule 0.04 percent on quarterly average, as against 0.53 percent against the ILS. The currencies that comprise the global-currency index are strongly heterogeneous. Thus, among these currencies (excepting the Mexican peso), the yen and the CHF

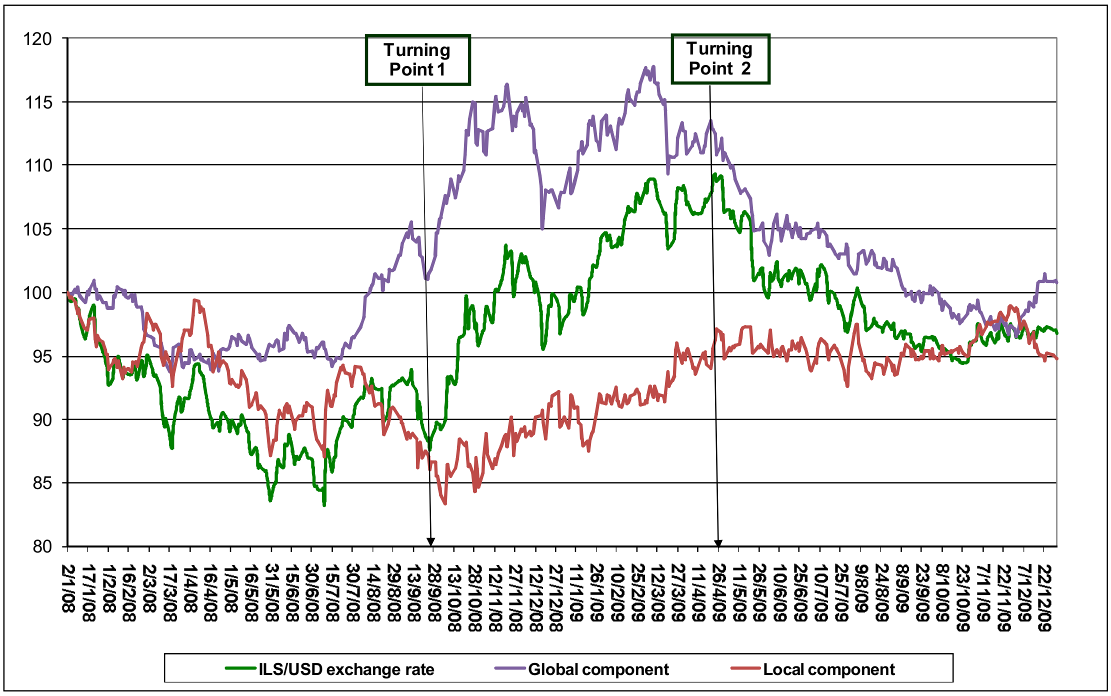
[10] The Hong Kong dollar, although enumerated among the global currencies, was removed from the index because it is indexed to the USD.

depreciated against the USD at quarterly rates of 0.39 percent and 0.46 percent, respectively, while the AUD and the NZD dollar appreciated 0.24 percent and 0.36 percent, respectively, in quarterly terms. Notably, these currencies were popular carry-trade currencies during the sample period, with loans taken in YEN and CHF (at an average twelve-month yield of 0.8 percent and 2.3 percent, respectively) and deposits made in NZD and AUD (at average twelve-months yields of 7.1 percent and 5.9 percent, respectively). This evidence is consistent with Cavalo's (2006) claim that changes in the USD exchange rate in recent years were occasioned mainly by the interest spread between the USD and other currencies, resulting in intensive carry-trading activity.

The bottom part of Table 2 presents nominal yields on Israel and U.S. government bonds at various times and also inflation and real-yield spreads. As the table shows, Israel yields exceeded American yields by far and the size of the disparity correlated negatively with term to maturity. Thus, the average spread was 4.47 percent to three months to maturity as against 2.86 percent to five years. Since the inflation spreads were also positive, especially at the beginning of the period, the real-yield spread was also positive. Notably, on the basis of UIP and PPP one would expect the ILS to depreciate against the USD, as indeed happened.

An example of the insights that the proposed decomposition may yield can be seen in the development of the global and local-residual components in the January 2008–June 2009 period (Figure 1).

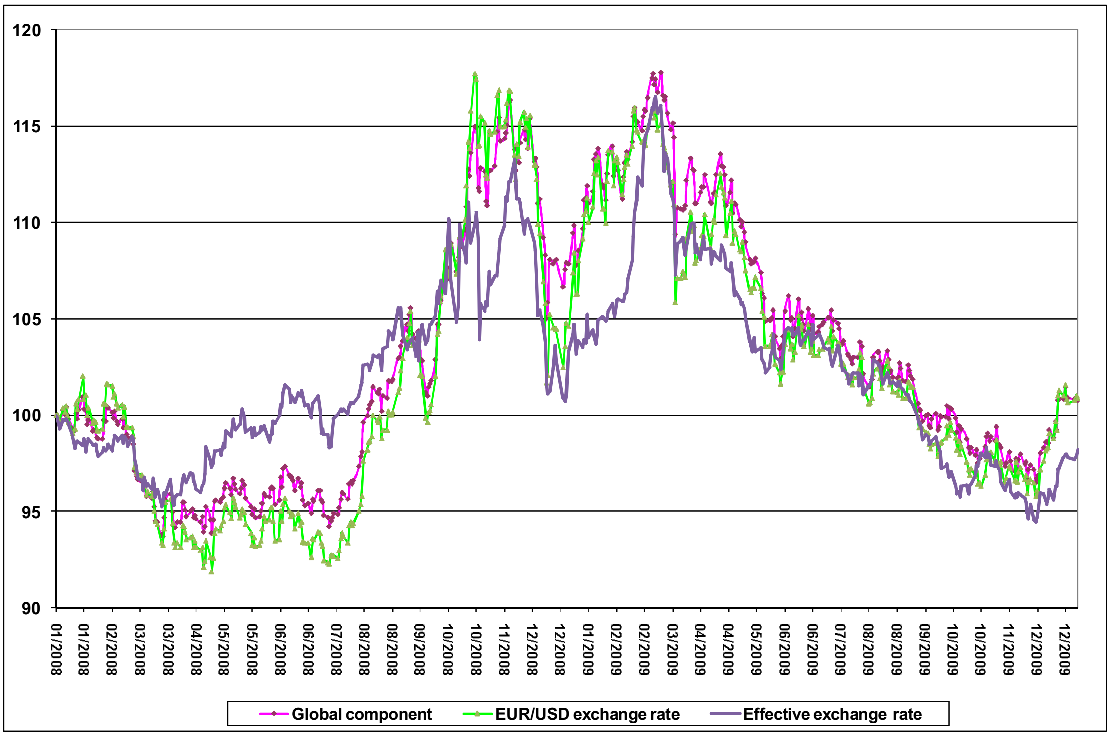
Figure 1: Decomposition of ILS/USD Exchange Rate into Global and Local Components (January 2008 = 100)



As the graph shows, the ILS/USD exchange rate changed direction twice during the relevant period (the green lines): appreciation from the beginning of 2008 to July, depreciation from July 2008 to April 2009, and renewed appreciation from then until the end of June 2009. The decomposition into global-exogenous and local-residual components will help us to analyze these developments. Notably, the local factor accommodates the effect of many factors, such as Israel's risk premium, the influence of domestic macroeconomic policy, and the Bank of Israel's intervention in the FX market. Although this study does not distinguish among the factors that affect the local component, an analysis of developments by means of this decomposition is of interest. The relatively steep appreciation from the beginning of the period to the first turning point (15 percent) was occasioned by a combination of the global component (mild 5 percent depreciation of the USD abroad) and the local-residual component (10 percent). Notably, the local-residual component decreased despite USD 25 million in daily purchases by the Bank of Israel; thus, during that time the effect of the other pro-appreciation factors outweighed that of the Bank of Israel's pro-depreciation FX purchases. At the first turning point, where the trend of the ILS/USD exchange rate switched from appreciation to depreciation, two things happened (on almost the same day): the USD began to appreciate against the other currencies and the Bank of Israel stepped up its daily purchases from USD 25 million to USD 100 million. Through the first week of August, both components, local and global, were pro-depreciation. From the second week of August onward, the local-residual component decreased until it bottomed out in early October 2008 (83). At this time, the Lehman Brothers investment bank collapsed and Israel realized that the subprime crisis was more serious, and might have a more material effect on the domestic economy, than had been commonly thought. Indeed, from then until the end of the period, the local-residual component rose by 14 percent (from 83 to 97) as the Bank of Israel continued to buy USD 100 million per day. The second turning point in the ILS/USD exchange rate took place in April 2009 and traced to a combination of USD depreciation abroad (the global component) and stability in the local-residual component. The correlation between the components was not constant across this period. Thus, in two-thirds of 377 daily observations the global and the local-residual components moved in the same direction (up or down); in the rest of the observations, they moved in opposite directions. We may summarize the analysis by estimating that the global component not only had a very meaningful effect on the development of the ILS/USD exchange rate but even preceded and determined the trend of the rate during most of that time, relative to the local-residual component.

To complete the picture, Figure 2 shows the differences in development among the effective exchange rate (source: Bank of Israel website), the EUR/USD rate, and the global component during the period shown in Figure 1.

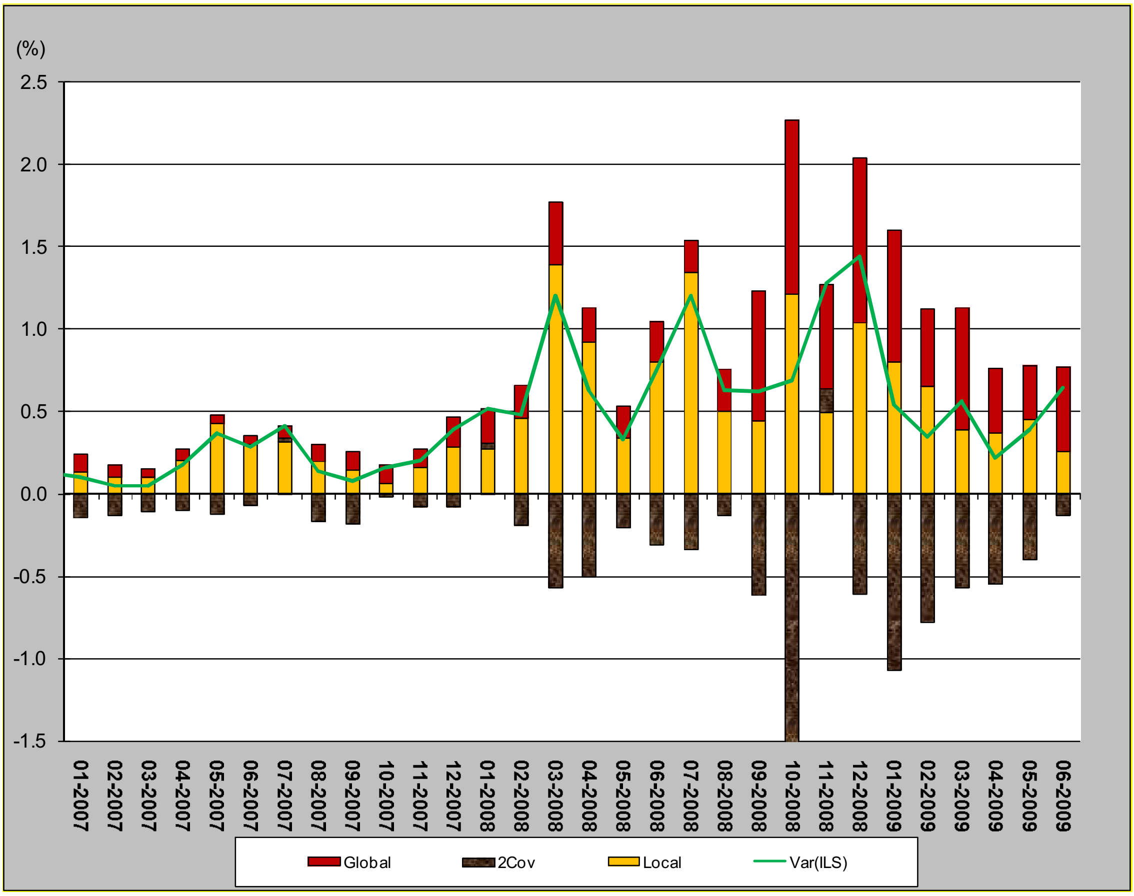
Figure 2: Development of EUR/USD Exchange Rate, Global Component, and Effective Exchange Rate (January 2008 = 100)



The graph shows that the global component and the EUR/USD exchange rate moved similarly. This happened because the EUR/USD rate accounts for 36 percent of the global component. However, there are perceptible differences between the series, especially at the beginning of the period. Relative to these two series, the effective ILS exchange rate, which includes both the USD and the twelve other global currencies, was less volatile during the period; the standard deviations of the EUR/USD exchange rate and the global component were 7 percent higher than the standard deviation of the effective exchange rate, which was 4.85 percent. This happened because USD appreciation/depreciation against global currencies is partly offset by the effective exchange rate (against the ILS) and is not expressed as it is in the global component.

Much like the decomposition of the mean of the ILS/USD exchange-rate change into global and local-residual factors, the variance of the rate may be decomposed in accordance with Equation 7. Figure 3 shows this decomposition.

Figure 3: Development of Components of Variance in ILS/USD Exchange-Rate Changes, 1/2007–6/2009



The variance of changes in the ILS/USD exchange rate—Var(ILS)—was calculated on the basis of daily changes in each calendar month. This variance is a positive function of the variance of changes in the global-exogenous component, the variance of changes in the local-residual component, and the correlations between the local component and the global currencies (2Cov). As we see, the total variance was much greater in 2008 than in 2007 and 2009. The Bank of Israel's intervention in trading in March 2008 made the local component of the variance and, in turn, of the total variance much larger, probably against the background of a change in the non-intervention policy that the Bank had been practicing in recent years. The ILS/USD variance peaked in December 2008, largely due to an increase in the correlations between the ILS and the global currencies coupled with an upturn in global-currency variance. The latter development took place when the USD suddenly stopped appreciating against these currencies (Figure 1); the increase in the correlations between these currencies and the ILS is explained by the global nature of this phenomenon of the USD against the global currencies, including the ILS in this case. Since the beginning of 2009, total variance has declined and reverted to values that, while higher than those typical of 2007, are normal.

Testing UIP and PPP using OLS regressions

Below we test the validity of UIP and relative PPP with the help of OLS regressions and in accordance with Equations (1) and (2). These tests, shown in Table 3 below, are the most widely used for the examination of these parities in the literature.

[Insert Table 3 here]

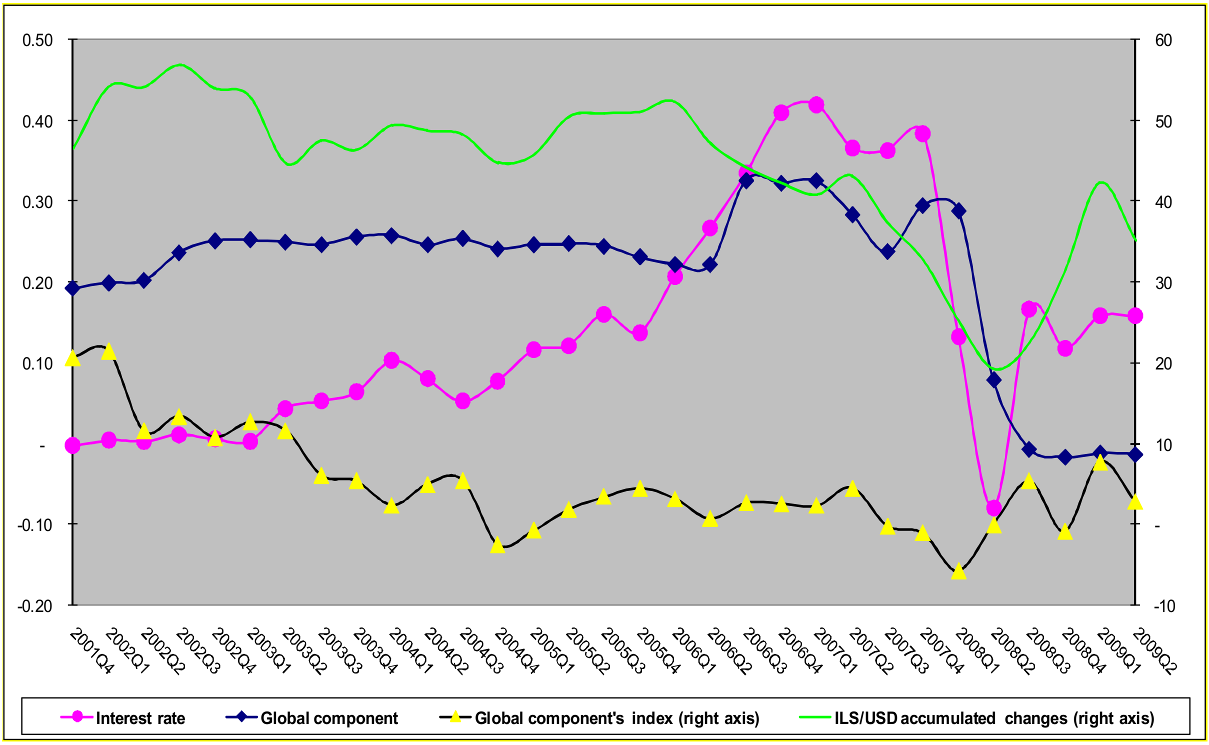
The top part of the table tests UIP in two ways. The first is the basic form, following Equation (1)— $\Delta s_{t+1} = \alpha + \beta_1 i_t + \beta_2 i_{USA,t} + \varepsilon_\tau$—where $i_{USA,t}$ is the USD interest rate. The second way also includes global component G and a dummy variable for the subprime crisis, Sub, which receives the value of 1 from III/2008 to the end of the period: $\Delta s_{t+1} = \alpha + \beta_1 i_t + \beta_2 i_{USA,t} + \gamma G_t + Sub + \varepsilon_\tau$. The addition of the global factor should improve the explanatory power of the regression, especially in situations of bilateral changes between global currencies and the USD that are exogenous to the ILS/USD exchange rate (e.g., an interest-rate increase in the Eurozone). Three autocorrelation factors were added to the regression to deal with serial correlation. PPP is examined in a similar fashion in the bottom part of the table (Panel B).

Analysis of the results shows that the directions of the coefficients in the basic regression (Panel A1) are consistent with the UIP hypothesis, i.e., $\beta_1 > 0$; $\beta_2 < 0$, and $\alpha \approx 0$. However, they are not significant in any of the regressions, thus explaining the generally meager explanatory power of all the regressions (Adj. $R^2 \approx 0$). Of course, it was also impossible to confirm the hypothesis that $\beta_1 =1$; $\beta_2 = -1$ by using a Wald test to examine the parities. In Panel A2, global component G (and a dummy variable for the subprime crisis) was added to the regressions shown in Panel A1 in order to estimate the contribution of the global factor to explaining the change in the ILS/USD exchange rate in the succeeding quarter. The addition of a global component to the regression that tests the UIP hypothesis enhanced the total explanatory power; coefficient γ was positive and significant in all regressions and fell within a very narrow range (0.21–0.24)—a result that shows the importance of global currencies in the UIP explanation. Furthermore, except for the five-year interest-spread regression, the values of coefficients β_1 and β_2 were similar across the time structure of the interest spreads. The bottom panel of Table 3 shows three versions of PPP. Panel B1 presents the results of the basic regression, in which, as in the basic UIP regression, the signs of the coefficients are consistent with the parities ($\beta_1 > 0$; $\beta_2 < 0$; and $\alpha \approx 0$) but the level of significance and the overall explanatory power of the equation are very low. When the global factor in Panel B2 is added, the explanatory power of the regression improves mainly due to the significance of the global-component coefficient (γ), which was found to be positive at levels resembling those in the regressions that tested UIP (Panel A2). Still, the hypothesis that $\beta_1 = 1$; $\beta_2 = -1$ cannot be confirmed by a Wald test for PPP. Finally, the results did not change meaningfully when actual inflation spreads (one year trailing) were replaced with the spreads of one-year-ahead inflation outlooks in Israel and the U.S. (Panel B2). Accordingly, in Panel B, too, the addition of the global components made a meaningful and significant contribution to explaining the changes in the ILS/USD exchange rate in the succeeding quarter, in the range of 0.19–0.20 percentage point—similar to the levels reported in Panel A2.[11]

Given the considerable changes in the status of the ILS and the USD abroad in recent years, the coefficients in the regression probably changed over time. The development of the interest-spread coefficients and the global component in the regression, together with the cumulative changes in the ILS/USD exchange rate in the succeeding quarter and in the global component, are shown in Figure 4.

[11] In a test for redundant variables, this variable was significant at a 5 percent level, at least, in all regressions.

Figure 4: Development of Coefficients of 6-Month Yield Spread and the Global component in 36-Quarter Rolling Regression, ILS/USD accumulated changes, and Global component's index (Implicit Running Averages)



The development of the series in the graph may be divided into two subperiods. The first starts at the beginning of the sample period[12] and ends in 2005 (hereinafter: the first period); during this time, the coefficients were stable the ILS appreciated gently. This contrasts with the right-hand part of the graph (hereinafter: the second period), which shows a great deal of volatility, occasioned among other things by the entry of nonresidents into the Israeli market and the subprime crisis. In the first period, the global component of the regression was rather stable at 0.2 while the interest-spread component rose in a measured fashion. This increase coincided with the arrival of nonresident investors in Israel and the exploitation of ILS/USD interest spreads (carry trading). Throughout the first period, the ILS/USD exchange rate was stable and the index of foreign currencies lost a small amount of ground against the USD (on the basis of cumulative percent changes from I/1993 onward). This indicates that the ILS was stable against the USD but appreciated against the global currencies. From the beginning of the second period (2005) to 2008, the coefficient of the global

[12] Since this is a 36-quarter rolling regression, the first date in the graph is 2001Q4, i.e., the regression at this point in time relates to 1993Q1–2001Q4.

component in the regression increased and the interest-spread coefficient in the regression increased even more. This phenomenon, as stated, is explained by the steadily growing influence of nonresidents on the ILS/USD exchange rate via their portfolio investments (debt and equity) in the domestic market and their exit from this market, in comparison with the beginning of the first period, in which their involvement in the market was inconsequential. Concurrently, the ILS appreciated against both the USD and the global currencies (which held their ground against the USD, more or less). From the middle of 2008 to almost the end of the period, the ILS depreciated against both the dollar and the global currencies, whereas the coefficient of the global component of the regression zeroed out and the interest-rate coefficient reverted to its low mid-2005 level of 0.16. These changes indicate that the changes in the economic variables did affect the coefficients in the UIP-testing regression, particularly during the subprime crisis. The graph also shows that the global-currency index preceded the ILS/USD exchange rate by at least one quarter throughout the period.[13] This finding is consistent with the fact that the global component was positive and significant in all regressions.

Testing UIP and PPP using GARCH(1,1)-M regressions

Notwithstanding the contribution of the global component, the predictive power of the regressions based on UIP and PPP is very low. Some (e.g., Berk and Knot, 2001) argue that the main reason for the inability to corroborate UIP and PPP is heteroskedasticity over time or the risk premium that the basic regressions do not include. To correct this, some run ARCH/GARCH regressions, which make it possible to estimate heteroskedasticity and an unobserved risk premium in the markets (a latent variable). To isolate the effect of the global component within this elastic ARCH/GARCH framework, we ran the estimation equations once in a standard form—GARCH(1,1)-M—and then again with the addition of the global component in both equations, mean and variance:

(14) Basic regression:

$$\Delta s_{t+1} = \mu + \gamma\sigma_t + \beta_1 i_t + \beta_2 i_{USA,t} + \varepsilon_t$$
$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2$$

[13] A Granger causality test did not enable us to refute the hypothesis that the global-currency index does not statistically drag the ILS/USD exchange rate at a significance level of 0.01 but not vice versa.

where the upper equation is that of the mean future exchange-rate change (ΔS_{t+1}) and the lower equation is of conditional variance (σ_t^2); μ and α_0 are the constants, γ is the risk-premium coefficient (which we expect to be negative for domestic interest i_t as it includes a risk premium), $i_{USA,t}$ is the USD interest rate, α_1 represents the market/variance from the previous period, and β reflects the persistence of the conditional variance. As before, dummy variable Sub and global component C_G were added to the basic regression, as follows:

(15) Expanded regression:

$$\Delta s_{t+1} = \mu + \gamma\sigma_t + \beta_1 i_t + \beta_2 i_{USA,t} + \delta_1 C_{G,t} + \phi \cdot Sub + \varepsilon_t$$
$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2 + \delta_2 C_{G,t}$$

The relevant equations for the testing of PPP are shown in the bottom panel of Table 4; instead of the interest spreads, Panel B2 shows the U.S./Israel inflation spreads that actually existed in the past year (π_t - $\pi_{USA,t}$) and Panel B3 shows the expected inflation spreads to one year ahead [E(π_t) - E($\pi_{USA,t}$].

[Insert Table 4 here]

The table elicits several findings[14]:

1. In accordance with the basic regression (Equation 14 and panels A1 and B1), the signs of the interest-rate coefficients in the mean equations are only sometimes consistent with UIP and PPP ($\beta_1 > 0$; $\beta_2 < 0$; and $\mu \approx 0$) while in accordance with the expanded regression (Equation 15 and panels A2, B2, and B3), the directions are consistent in all cases (except the two-year interest spread).
2. The global component in the expanded regression was, as expected, positive in the mean equation ($\delta_1 > 0$) and negative in the variance equation ($\delta_2 < 0$) in all cases. With two exceptions, it was also significant. This means that the contribution of the global component was 0.2 in the UIP mean equation, 0.3 in the PPP mean equation, and much smaller and similar (around –0.004), although very significant, in the variance equations of both parities. Furthermore, the

[14] To make sure that the results obtained pass the accepted statistical tests, the residues were examined in the regression by means of a Q-Test correlogram test with 28 lags, an R^2 correlogram test with up to 28 lags, a serial correlation (LM) test with up to four lags, and a Jarque-Berra normality test for the residues that were standardized. In all cases, the residues behaved like white noise, i.e., they passed all four tests.

coefficients of the global component in all equations were similar to each other and also to the results obtained when the OLS equation was run (Table 3); this strengthens the reliability of the results.

3. The coefficient of the estimated risk premium (γ) was negative, as expected, in the UIP mean equations (except for three months) but was positive in the PPP mean equations. However, the significance of the positive coefficient was low; strong significance was found only in regressions that had negative coefficients.
4. The dummy variable, Sub, reflecting the subprime crisis, was significant in all regressions, as expected, and reduced the expected change in the succeeding-quarter ILS/USD exchange rate by 0.10–0.19.

Testing Dornbusch's (1976) Overshooting Model with a VEC system

One of the problems with UIP and PPP is that they take into account partial relations between interest spreads and exchange rates or inflation spreads and exchange rates but do not address correlations among the three sides of the triangle: exchange rates, interest spreads, and inflation spreads. One possible way to accommodate all these variables in one analytical framework that also allows consideration of the lagged effect of prices due to price "stickiness" was proposed by Dornbusch (1976). In fact, there are five cointegration variables that we wish to examine in regard to the effect of a deviation in any of them that has a near-term impact on the others, assuming that the long-term relations persist. A general formulation of the relations among the five variables included in vector $X_t^{'} = (s_t, i_t, i_t^*, p_t, p_t^*)$ allows us to take a short-term dynamic into account while preserving the long-term parities in UIP ($i_t = i_t^*$) and PPP ($s_t = p_t - p_t^*$). Having shown above that the global component helps to explain future changes in the ILS/USD exchange rate, we will add it to vector X in order to obtain vector $X_t^{'} = (s_t, i_t, i_t^*, p_t, p_t^*, g_t)$, which accommodates k = 6 variables.

This formulation of a general Vector Error Correction (VEC) model has the following appearance (see Caporale et al., 2001):

(16) $\Delta s_t = \delta_1(s_t - p_t + p_t^*) + \delta_2(i_t - i_t^*) + f_1(\Delta X_{t-j}) + \varepsilon_{1t}$

(17) $\Delta p_t = \delta_3(s_t - p_t + p_t^*) + \delta_4(i_t - i_t^*) + f_2(\Delta X_{t-j}) + \varepsilon_{2t}$

(18) $\Delta p_t^* = \delta_5(s_t - p_t + p_t^*) + \delta_6(i_t - i_t^*) + f_3(\Delta X_{t-j}) + \varepsilon_{3t}$

(19) $\Delta i_t = \delta_7(s_t - p_t + p_t^*) + \delta_8(i_t - i_t^*) + f_4(\Delta X_{t-j}) + \varepsilon_{4t}$

(20) $$\Delta i_t^* = \delta_9(s_t - p_t + p_t^*) + \delta_{10}(i_t - i_t^*) + f_5(\Delta X_{t-j}) + \varepsilon_{5t}$$

(21) $$\Delta g_t = \delta_{11}(s_t - p_t + p_t^*) + \delta_{12}(i_t - i_t^*) + f_6(\Delta X_{t-j}) + \varepsilon_{6t}$$

Where, ΔX_{t-j} {j = 0..n} represents the short-term dynamic and e_{kt} {k = 1..6) is the noise component. Using equations (16)–(21), the short-term dynamic may be tested when the changes at time t in each equation are a function of the parities in previous periods and of lags, and on the (empirically corroborated) assumption that both parities, UIP and PPP, exist in the long term. According to the Overshooting Model, we would expect a faster return to equilibrium after a shock in UIP than in PPP, since arbitrage is more expensive and less practicable in the commodities market than in the interest market. Furthermore, we would expect $\delta_1 < 0$; $\delta_2 < 0$ according to the Overshooting Model, since one would expect the pairing of real depreciation and the narrowing of the interest spread (e.g., due to monetary loosening) to induce nominal depreciation, given the model's assumption of "sticky prices."[15]

Econometric formulation of the model

Let us assume a p-order VAR model: $X_t = A_1 X_{t-1} + ... + A_p X_{t-p} + \varepsilon_t$, where X_t is the vector at integration level I(1) with a $k = 6$ dimension and e_t is a noise factor distributed as $e \sim NIID(0, \Sigma)$. The vector may be presented as follows:

(22) $$\Delta X_t = \Pi X_{t-1} + \Gamma_1 \Delta X_{t-1} + ... + \Gamma_p \Delta X_{t-p+1} + \varepsilon_t$$

Where, $\Pi = \sum_{i=1}^{p} A_i - \mathrm{I}$; $\Gamma_i = -\sum_{j=i+1}^{p} A_j$. It is also known that if matrix of coefficients Π maintains integration level r (k > r), then matrices α and β exist in dimension k x r, so that $\Pi = \alpha\beta'$ and the product, $\beta' X_t$ is at integration level I(0). In fact, r represents the number of cointegration relations in equation system X_t and every column in β is a cointegration vector, whereas the columns of α are "adjustment coefficients" because they map the vectors of the cointegration to the various equations in equation system (16)–(21) above.

The first stage in running the VEC was to run unit tests in order to make sure that none of the series is stationary. In practice, the series in vector X were examined by

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[15] Comprehensive analysis of the relations and coefficients in the co-integration equations (16)–(21) is beyond the scope of this study. (For elaboration and discussion, see Dornbusch, 1976.)

means of the following tests: Augmented Dickey-Fuller (ADF), PP (Phillips Perron, 1998), DFLGS (Dickey-Fuller GLS; see Elliot, Rothenberg, and Stock, 1996), and KPSS (Kwiatkowski, Phillips, Schmidt, and Shin, 1992). In all tests, the stationariness hypothesis was refuted at a 1 percent significance level whether the test included a trend or not.

The next stage was the adaptation of a Johansen (1991) unrestricted cointegration test in order to find the most appropriate model for the series in vector X. The model chosen on the basis of the Schwartz information criterion (SIC) does not include a constant or a linear trend and its number of lags was p=2. Furthermore, as before, the dummy variable Sub, representing the subprime crisis, was added to the foregoing six variables. By running the model chosen along with a trace test and a maximum eigenvalue test, we found that a single cointegration equation at 5 percent significance level exists in vector X. The results of the model and the long-term restrictions (PPP and UIP) in accordance with equations (16)–(21) are shown in Table 5.

[Insert Table 5 here]

The table shows that the coefficients of the single cointegration equation (β'_1 in Panel A3) are consistent with PPP but not with UIP. Specifically, the sign of the local interest rate (i_t) is the opposite of what the parities would have us expect. The cointegration vector also indicates that the global component has a positive and highly significant effect on the ILS/USD exchange rate. The adjustment coefficient for the exchange rate is –0.21, i.e., the reversion to equilibrium takes around five quarters, slightly longer than what Sussman and Saadon (2007) found.[16] Furthermore, the adjustment coefficient of the global component is 0.16, meaning reversion to equilibrium after about a year and a half. Generally, prices and interest rates revert to equilibrium more quickly in Israel than in the U.S., as happens in other emerging markets as well (Ferreira et al., 2007). The adjustment coefficients also show that $\delta_1 < 0$; $\delta_2 < 0$, as expected.

[16] Despite the similarity between Sussman and Saadon's result (twelve months) and five quarters, there are several differences between their study and this one. First, our study examines the log ILS/USD exchange rate and price indices in accordance with Dornbusch's (1976) model and not annual rates of change. Second, Sussman and Saadon's data are monthly whereas these are quarterly; third, different sample periods are used. Specifically, the years 2008 and 2009 were acutely affected by the subprime crisis.

The imposition of long-term restrictions such as UIP and PPP was rejected at a high level of significance (Panel B). Thus, the probability of accepting UIP is rejected on the basis of a chi-square (χ^2) test with one degree of freedom at a 0.03 level and the probability of accepting PPP is rejected at the lower significance level of 0.08. In contrast, the imposition of a restriction involving both parities together, UIP and PPP, is not rejected in a χ^2 test with two degrees of freedom (0.10)—seemingly indicating that the combination of both parities has more explanatory power than each parity separately.

To determine whether the global component, g_t, is significant in explaining the ILS/USD exchange rate in the cointegration equation, a restriction that zeroes this component was imposed (Panel B4). The rejection of the restriction at a high level of significance seems to indicate the importance of the global component, much like all the regressions that were run previously in different statistical procedures (OLS and GARCH-M). It is also noteworthy that the imposition of all these restrictions, except that of the global component, changed the signs of the coefficients (the left side of the table in Panel B) compared to the coefficients in the unrestricted equation (Panel A3).

5. Summary and conclusions

This study presented a methodology for the decomposition of the exchange rates of currencies of small and open economies, such as Israel's, into global and local-residual components. The global component, exogenous to the domestic economy, is represented by an index of global currencies weighted by daily trading volumes in global markets (the twelve currencies that had the largest trading volumes in 1/2002–12/2007, according to BIS data). The local-residual component is the difference between the local-currency exchange rate against the USD and the global component. This method of decomposition is best suited to the currencies of small economies that are affected by, but do not affect, the USD exchange rate abroad; it allows us to analyze developments in the mean and variance of changes in the local-currency exchange rate against the USD.

The study also presents the differences between the effective ILS exchange rate, which includes the USD, and the proposed decomposition.

The proposed decomposition is immensely important for those who manage monetary and exchange-rate policy and those responsible for financial stability in small and open economies that are affected by global developments, such as Israel. This is because reference to endogenous local-residual factors is totally different from reference to developments and shocks originating in the global economy, which are not always reflected in the effective exchange rate.

The proposed decomposition was tested on two common parities in foreign exchange—Uncovered Interest Rate Parity (UIP) and Purchasing Power Parity (PPP)—and on the Overshooting Model (Dornbusch, 1976), which assumes "sticky prices." Three methods of testing were used: two statistical procedures (OLS and GARCH(1,1)-M) and a system of cointegration equations. The sample included daily readings of exchange rates, interest rates, and prices in I/1993–II/2009. In all three tests, the global component was added to the estimation equations and its significance and that of the equations were tested both before and after the global component was added.

The findings show that the global component has both a positive and a significant effect on the ILS/USD exchange rate and its changes according to both parities, the Overshooting Model, and all statistical procedures that were run; it contributed 0.2–0.3 to changes in this rate.

The effect of the global component was uneven during the sample period. Since 2005, as foreign investors began to arrive and Israel continued to integrate into the global economy, the effect of the global component increased in tandem with the effect of interest spreads on the mean ILS/USD exchange rate and less so on the volatility of the rate. The subprime crisis, however, induced acute changes in the effect of the global components; therefore, it should be considered an outlier.

This significant and consistent finding demonstrates the importance of including the global component in the common foreign-currency parities and models that usually include bilateral relations between the USD and a local currency of a small and open economy and, therefore, do not reflect developments of the USD against the currencies of economies of global importance.

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Table 2: Basic statistics (%) on Global curencies versus the USD, yield gaps, and inflation gaps, I/1993 - II/2009

Currency	Ticker	Weight (by daily voumes, BIS)	Quarterly change (means)	Standard deviation	Skewness	Kurtosis	Min	Max
Global Currencies								
Euro	**EUR**	38.3	0.19	4.86	0.13	-0.12	-11.16	12.88
Japanese Yen	**JPY**	17.1	-0.39	6.42	-0.52	0.73	-18.33	16.41
British Pound	**GBP**	15.5	0.13	4.51	-0.93	6.32	-19.89	13.89
Swiss Frank	**CHF**	7.0	-0.46	5.35	-0.59	0.15	-14.81	9.44
Australian Dollar	**AUD**	6.9	0.24	5.99	-0.65	1.24	-19.03	15.40
Canadian Dollar	**CAD**	4.3	-0.13	3.74	0.16	2.04	-8.57	13.55
Swedish Krone	**SKR**	3.0	0.12	5.29	0.35	0.31	-12.30	14.02
Norwegian Krone	**NOR**	2.2	-0.12	5.25	0.23	2.40	-16.50	17.07
New Zeland Dollar	**NZL**	2.0	0.34	5.87	-0.36	0.45	-14.53	14.33
Mexican Peso	**MEX**	1.3	2.18	7.73	2.87	10.39	-7.93	40.19
Singaporian Dollar	**SIG**	1.2	-0.19	2.90	1.01	1.06	-5.08	9.31
Korean Won	**KOR**	1.1	0.73	8.56	4.18	27.53	-14.54	56.31
Global Currency Index		**100**	**0.04**	**5.68**	**1.12**	**6.22**	**-16.06**	**25.93**
Israeli Shekel	**ILS**	0.15	0.53	3.85	0.11	0.42	-8.32	11.00
Local component			0.49	6.68	-0.03	4.35	-25.07	24.04
Israeli Government Bonds								
Three Months			8.65	4.47	17.85	-113.87	0.31	17.55
Six Months			8.57	4.47	20.00	-113.70	0.59	17.21
Twelve Months			8.52	4.18	21.55	-110.82	1.01	16.24
Two Years (56 quartes)			8.27	4.02	62.83	-63.01	1.74	17.19
Five Years (44 quartes)			7.94	2.93	57.21	-66.10	3.20	15.04
Ten Years (33 quartes)			7.08	1.71	122.98	95.56	4.71	11.41
American Government Bonds								
Three Months			4.18	1.82	-49.69	-117.73	0.60	6.81
Six Months			4.29	1.80	-46.98	-115.07	1.11	7.00
Twelve Months			4.47	1.78	-40.36	-101.38	1.19	7.75
Two Years (56 quarters)			4.24	1.75	-38.03	-86.30	0.76	7.70
Five Years (44 quarters)			4.74	1.45	-18.79	-62.62	1.55	7.83
Ten Years (33 quarters)			5.15	1.20	5.60	-36.27	2.21	7.82
Yield Gap between Israel and American Government Bonds								
Three Months			4.47	3.65	5.01	-132.83	-1.53	11.44
Six Months			4.15	3.78	1.74	-127.86	-2.97	11.42
Twelve Months			4.05	3.40	5.48	-135.18	-1.56	10.11
Two Years (56 quarters)			4.24	3.17	53.46	-87.20	-0.60	11.08
Five Years (44 quarters)			3.12	2.14	84.35	-22.04	-0.17	7.88
Ten Years (33 quarters)			2.86	1.85	126.13	108.03	0.35	7.59
Inflation Gap between Israel And the US								
Twelve Months (moving average)			2.39	4.61	21.94	-128.53	-4.44	11.75
Real rate Gap between Israel and the US								
Three Months			2.08	2.75	-7.60	77.38	-5.28	8.56
Six Months			1.76	2.79	-42.57	95.17	-6.11	7.78
Twelve Months			1.67	2.82	-10.31	73.68	-5.27	8.23

This table presents weights and basic statistics of the major global currencies. A currency (except USD) is defined as global if its daily volume was greater than 1% of the total volume of all currencies (BIS, 2007). It can be seen that the Shekel weakened against the USD in the sample period but the USD remained stable versus the global currencies. American government bonds are T-bills up to one year and T-notes otherwise, while Israeli government bonds are *Makam* up to one year and Shahar otherwise.

Table 3: Effect of Global component on UIP and PPP, I/1993–II/2009

A1. Basic regression: $\Delta s_{t+1} = \alpha + \beta_1 i_t + \beta_2 i_{USA,t} + Sub + \varepsilon_t$

Explanatory variables	3 months Coef	3 months T-Stat	6 months Coef	6 months T-Stat	12 months Coef	12 months T-Stat	2 years Coef	2 years T-Stat	5 years Coef	5 years T-Stat
α	–0.01	–0.60	–0.01	–0.62	–0.01	–0.80	–0.01	–0.85	–0.02	–0.89
β_1	0.20	1.51	0.20	1.61	0.22	1.56	0.21	1.10	0.00	0.85
β_2	–0.14	–0.43	–0.13	–0.41	–0.10	–0.29	–0.02	–0.06	0.13	0.21
AR(1)	0.11	0.83	0.12	0.92	0.13	0.96	0.15	0.98	0.18	1.12
AR(2)	0.02	0.12	0.00	0.01	0.01	0.10	–0.00	–0.00	0.01	0.07
Sub	–0.31	**–2.01**	–0.32	**–2.07**	–0.32	**–2.10**	–0.31	–1.82	–0.30	–1.71
Adj. R^2	0.01		0.01		0.01		–0.01		–0.02	
D.W.	1.99		1.99		1.99		2.01		2.02	
Wald (β_1 =1, β_2=–1)	—		—		—		0.0001		—	

A2. Regression incl. the Global component: $\Delta s_{t+1} = \alpha + \beta_1 i_t + \beta_2 i_{USA,t} + \gamma C_{G,t} + Sub + \varepsilon_t$

Explanatory variables	3 months Coef	3 months T-Stat	6 months Coef	6 months T-Stat	12 months Coef	12 months T-Stat	2 years Coef	2 years T-Stat	5 years Coef	5 years T-Stat
α	0.00	0.27	0.00	0.17	0.00	0.00	0.00	0.21	0.00	0.03
β_1	0.14	1.03	0.14	1.01	0.14	0.94	0.13	0.63	0.00	0.79
β_2	–0.25	–0.76	–0.20	–0.60	–0.16	–0.46	–0.23	–0.51	–0.32	–0.52
γ	0.22	**3.33**	0.22	**3.27**	0.21	**3.23**	0.24	**3.25**	0.23	**2.94**
AR(1)	–0.12	**2.81**	–0.12	**–2.78**	–0.12	**–2.78**	–0.14	**–2.85**	–0.14	**–2.81**
AR(2)	0.22	1.61	0.23	1.67	0.24	1.72	0.28	1.82	0.30	1.93
AR(3)	0.17	1.13	0.16	1.07	0.17	1.15	0.19	1.19	0.19	1.18
Sub	–0.43	**–2.93**	–0.43	**–2.94**	–0.44	**–2.98**	–0.45	**–2.79**	–0.46	**–2.71**
Adj. R^2	0.19		0.19		0.19		0.19		0.18	
D.W.	2.04		2.04		2.04		2.08		2.13	
Wald (β_1 =1, β_2=–1)	—		—		—		—		—	

B. PPP test

Explanatory variables	B1. Basic regression $\Delta s_{t+1} = \alpha+\beta_1\pi_t+\beta_2\pi_{USA,t}$ $+Sub+\varepsilon_t$ Coef	T-Stat	B2. incl. Global component $\Delta s_{t+1} = \alpha+\beta_1\pi_t+\beta_2\pi_{USA,t}$ $+\gamma C_{G,t} +Sub+\varepsilon_t$ Coef	T-Stat	B2. incl. Global component and inflation outlooks $\Delta s_{t+1} = \alpha+\beta_1 E(\pi_t)+\beta_2 E(\pi_{USA,t}) +$ $\gamma C_{G,t} +Sub+\varepsilon_t$ Coef	T-Stat
α	0.01	0.49	0.02	1.31	0.03	0.94
β_1	0.10	0.99	0.07	0.62	0.00	0.16
β_2	–0.35	–0.58	–0.71	–1.29	–0.01	–0.83
γ			0.22	**3.34**	0.24	**3.39**
AR(1)	0.10	0.66	–0.14	**–3.34**	–0.14	**–3.00**
AR(2)	0.01	0.06	0.19	1.31	0.28	1.82
AR(3)	–0.27	–1.75	0.16	1.07	0.18	1.10
Sub			–0.38	**–2.63**	–0.45	**–2.75**
Adj. R^2	–0.01		0.21		0.20	
D.W.	1.93		2.05		2.08	
Wald (β_1 =1, β_2=–1)	—		—		—	

In the regressions, the explained variable is the change in the ILS/USD exchange rate in the succeeding quarter. C_G is the global component, α is the constant, and coefficients β_1 and β_2 represent return on the ILS and on the USD, respectively, according to the UIP hypothesis and ILS and USD inflation, respectively, according to the PPP hypothesis. The closer β_1 is to 1 and the closer β_2 is to –1, the parities are not rejected. Dummy variable Sub is assigned the value of 1 in I/2009 and II/2009 and reflects the results of the subprime crisis. The AR components represent a correction for autoregressivity and operator E represents inflation expectations instead of inflation itself—π. As the table shows, the global component is significant in all regressions; hence its importance. Furthermore, the interest and inflation coefficients move in the expected direction according to the parities. However, according to the Wald tests (R^2 with two degrees of freedom), the parities do not hold (β_1<>1, β_2<>–1).

Table 4: Effect of Global component on UIP and PPP — GARCH-M Regressions

A1. Basic regression: $\Delta s_{t+1} = \mu + \gamma\sigma_t + \beta_1 i_t + \beta_2 i_{USA,t} + Sub + \varepsilon_t \quad ; \quad \sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2$

	3 months		6 months		12 months		2 years		5 years	
Mean equation	**Coef**	**Z-Stat**	**Coef**	**Z-Stat**	**Coef**	**Z-Stat**	**Coef**	**Z-Stat**	**Coef**	**Z-Stat**
μ	–2.28	**–5.16**	–2.35	**–5.81**	–4.03	**–4.60**	–3.69	**–4.26**	–1.54	**–4.45**
γ	0.07	**4.66**	0.09	**4.90**	0.14	**4.90**	0.11	**3.97**	0.04	**2.51**
β_1	0.07	0.88	0.15	**2.43**	0.17	**2.97**	0.27	**6.13**	–0.00	**–2.36**
β_2	0.03	0.14	–0.31	–1.39	–0.01	–0.07	–0.04	–0.23	0.67	**2.84**
Variance equations										
α_0	0.00	**7.39**	0.00	**8.49**	0.00	**14.63**	0.00	29.31	0.00	**6.59**
α_1	0.28	**3.67**	0.35	**3.66**	0.26	**3.07**	0.31	4.05	0.26	**3.56**
β	–0.79	**–12.41**	–0.78	**–10.11**	–0.84	**–14.91**	–0.77	–18.76	–0.94	**–27.31**
SIC	–3.33		–3.34		–3.35		–3.24		–3.11	
D.W.	2.08		2.10		2.03		1.82		1.85	

A2. Regression including The Global component:

$$\Delta s_{t+1} = \mu + \gamma\sigma_t + \beta_1 i_t + \beta_2 i_{USA,t} + \delta_1 C_{G,t} + \phi \cdot Sub + \varepsilon_t$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2 + \delta_2 C_{G,t}$$

	3 months		6 months		12 months		2 years		5 years	
Mean equation	**Coef**	**Z-Stat**	**Coef**	**Z-Stat**	**Coef**	**Z-Stat**	**Coef**	**Z-Stat**	**Coef**	**Z-Stat**
μ	0.10	0.04	–0.27	–0.27	–0.73	–0.61	–2.22	–2.41	–0.27	–0.39
γ	0.00	0.02	0.01	0.27	0.02	0.54	0.09	2.55	–0.01	–0.17
β_1	0.14	0.93	0.19	1.61	0.19	1.59	–0.08	–0.50	0.00	1.61
β_2	–0.30	–1.22	–0.31	–0.92	–0.25	–0.84	–0.05	–0.13	–0.10	–0.21
δ_1	0.19	2.00	0.20	**2.42**	0.20	**3.21**	0.19	**3.40**	0.19	**3.13**
ϕ	–0.11	**–0.27**	–0.12	**–4.27**	–0.10	**–4.42**	–0.15	**–5.60**	–0.13	**–4.50**
Variance equations										
α_0	0.00	**294.02**	0.00	1.01	0.00	0.71	0.00	0.86	0.00	1.50
α_1	–0.06	–0.30	–0.02	–0.40	0.03	0.27	–0.08	–1.27	–0.11	–0.93
β	0.24	1.03	0.18	0.22	0.59	1.05	1.00	**17.81**	0.52	1.08
δ_2	–0.004	–0.56	–0.004	**–3.02**	–0.001	–0.94	–0.003	**–3.83**	–0.004	**–5.46**
SIC	–3.21		–3.07		–3.16		–3.00		–2.74	
D.W.	2.02		1.96		2.07		2.04		2.06	

B. PPP test with GARCH(1,1)-M

	B1. Basic regression		B2. Regression incl. the Global component		B2. Regression incl. the Global component and inflation outlooks	
	π = i (substituting A1)		**π = i (substituting A2)**		**E(π) = i (substituting A2)**	
Mean equation	**Coef**	**T-Stat**	**Coef**	**T-Stat**	**Coef**	**T-Stat**
μ	0.73	**–3.42**	1.57	0.92	1.12	0.89
γ	0.04	**3.13**	–0.03	–0.51	–0.00	–0.08
β_1	0.05	0.81	0.12	1.46	0.00	1.10
β_2	–0.48	–1.69	–0.90	–1.57	–0.01	–1.50
δ_1			0.31	**2.91**	0.28	**2.80**
ϕ			–0.16	**–5.83**	–0.19	**–3.18**
Variance equations						
α_0	0.00	**3.88**	0.00	**9.62**	0.00	**10,772**
α_1	0.63	**3.90**	0.06	0.59	0.12	0.62
β	–0.40	–3.86	0.16	0.71	0.27	1.45
δ_2			–0.004	**–6.38**	–0.004	**–5.47**
SIC	–3.26		–3.21		–3.01	
D.W.	1.76		1.90		1.76	

Table 5: Co-integration Tests

A1. Matrix of β unrestricted cointegration coefficients

Cointegration equation	$\Pi(g_{t-1})$	$\Pi(i^*_{t-1})$	$\Pi(i_{t-1})$	$\Pi(p^*_{t-1})$	$\Pi(p_{t-1})$	$\Pi(s_{t-1})$
β_1^*	7.44	–38.77	–39.45	–2.56	1.70	–17.71
β_2^*	2.64	–30.29	–5.88	–7.86	5.18	–10.87
β_3^*	0.61	20.32	65.05	4.67	–2.98	–0.95
β_4^*	–3.68	7.13	19.18	1.38	–0.88	5.66
β_5^*	–3.03	–78.49	94.70	5.98	–3.35	7.15
β_6^*	–2.84	24.20	–18.55	–3.62	–2.68	15.15

A2. Matrix of α - unrestricted adjustment parameters

Change in equation	α_6	α_5	α_4	α_3	α_2	α_1
Δs_t	0.002	–0.004	0.002	0.000	0.012	0.012
Δp_t	0.000	0.001	–0.001	0.004	–0.003	0.004
Δp^*_t	0.001	0.000	–0.002	0.002	–0.000	–0.001
Δi_t	0.001	–0.001	0.000	0.000	–0.003	0.003
Δi^*_t	0.001	0.001	–0.000	–0.001	–0.000	0.001
Δg_t	0.004	0.002	0.014	0.009	0.002	–0.009

A3. Normalized unrestricted cointegration equation (α_1' and β_1')

	$\Pi(g_{t-1})$	$\Pi(i^*_{t-1})$	$\Pi(i_{t-1})$	$\Pi(p^*_{t-1})$	$\Pi(p_{t-1})$	$\Pi(s_{t-1})$
The coefficients - β_1'	–0.42	2.19	2.22	0.14	–0.10	1
standard error (S.E.)	(0.3568)	(0.96468)	(1.2055)	(0.1139)	(0.05316)	
	$\Delta(g_{t-1})$	$\Delta(i^*_{t-1})$	$\Delta(i_{t-1})$	$\Delta(p^*_{t-1})$	$\Delta(p_{t-1})$	$\Delta(s_{t-1})$
The coefficients - α_1'	0.16	–0.01	–0.05	0.02	–0.08	–0.21
standard error (S.E.)	(0.1291)	(0.01483)	(0.0226)	(0.01783)	(0.03155)	(0.0816)

B. Test of long-term restriction significance (UIP, PPP, and global component) and restrained cointegration coefficients

: Significance of restrictions		Restricted cointegration coefficients					
B1. UIP	$i_t = i^*_t$	$\Pi(g_{t-1})$	$\Pi(i^*_{t-1})$	$\Pi(i_{t-1})$	$\Pi(p^*_{t-1})$	$\Pi(p_{t-1})$	$\Pi(s_{t-1})$
χ2 test, 1 degree of freedom	4.53	–0.58	0.77	–0.77	–0.68	0.45	1
Probability of obtaining restriction	0.03						
B2. PPP	$S_t = p_t - p^*_t$	$\Pi(g_{t-1})$	$\Pi(i^*_{t-1})$	$\Pi(i_{t-1})$	$\Pi(p^*_{t-1})$	$\Pi(p_{t-1})$	$\Pi(s_{t-1})$
χ2 test, 1 degree of freedom	3.09	–0.64	2.56	2.68	–0.58	0.42	1
Probability of obtaining restriction	0.08						
B3. UIP+PPP	$i_t = i^*_t$, $S_t = p_t - p^*_t$	$\Pi(g_{t-1})$	$\Pi(i^*_{t-1})$	$\Pi(i_{t-1})$	$\Pi(p^*_{t-1})$	$\Pi(p_{t-1})$	$\Pi(s_{t-1})$
χ2 test, 2 degrees of freedom	4.54	–0.56	0.79	–0.79	–0.61	0.39	1
Probability of obtaining restriction	0.10						
B4. Meaningless global component	$g_t = 0$	$\Pi(g_{t-1})$	$\Pi(i^*_{t-1})$	$\Pi(i_{t-1})$	$\Pi(p^*_{t-1})$	$\Pi(p_{t-1})$	$\Pi(s_{t-1})$
χ2 test, 1 degree of freedom	6.26	—	2.15	–1.60	1.50	–1.02	1
Probability of obtaining restriction	0.01						

Panel A presents unrestricted cointegration equations (cointegration coefficients and adjustment coefficients; Panel B presents the long-term significance of the restrictions. Dummy variable Sub, representing the period of the subprime crisis, was added to all equations (and receives the value of 1 from III/2008 to end of sample period).

In Panel A, the matrices were normalized in the following manner: $\beta' S_{11} \beta = 1$, where S_{11} is the equation according to Johansen (1991). The unrestricted cointegration coefficients are consistent with the PPP hypothesis but not with the UIP hypothesis. Accordingly, restraining the coefficients by the UIP hypothesis is rejected at a 0.03 significance level, whereas the PPP hypothesis is not rejected; likewise the imposition of a double restriction according to PPP and UIP, which are not rejected. In all trials, the coefficient of the global component moves in the expected direction and is strongly significant, thus demonstrating the importance of its inclusion in the cointegration equation.