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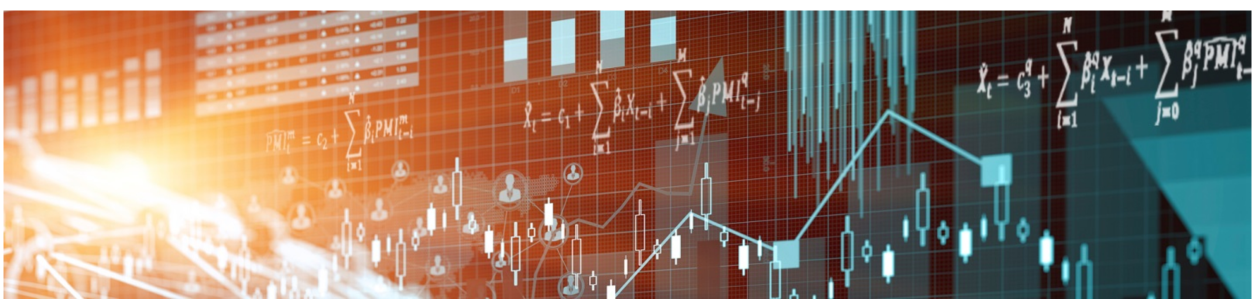
Uncovered Return Parity: Equity Returns and Currency Returns



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Abstract

We propose an uncovered expected returns parity (URP) condition for the bilateral spot exchange rate. URP implies that unilateral exchange rate equations are misspecified and that equity returns also affect exchange rates. Fama regressions provide evidence that URP is statistically preferred to uncovered interest rate parity (UIP) for nominal bilateral exchange rates between the US dollar and six countries (Australia, Canada, Japan, Norway, Switzerland and the UK) at the monthly frequency. An implication of URP is that commodity price changes that affect equity returns thus affect bilateral exchange rates through the equity channel. We find evidence that the Australian, Canadian, Norwegian (post 2001) and UK (post 1992) expected exchange rates increase via the oil-equity channel as oil prices rise, whereas the Japanese and Swiss expected exchange rates decrease.

Bank topics: Asset pricing; Exchange rates; International financial markets
JEL codes: E43, F31, G15

Résumé

Nous proposons une condition de parité des rendements sans couverture anticipés pour les taux de change bilatéraux au comptant. Cette condition implique que les équations de taux de change unilatéral sont mal spécifiées et que les rendements des actions influent également sur les taux de change. Les régressions de Fama tendent à montrer que l'hypothèse de la parité des rendements sans couverture est statistiquement préférable à celle de la parité des taux d'intérêt sans couverture pour expliquer les taux de change bilatéraux nominaux mensuels entre le dollar américain et les monnaies de six pays (Australie, Canada, Japon, Norvège, Suisse et Royaume-Uni). Il découle de cette première hypothèse que les variations des prix des produits de base ayant un effet sur les rendements des actions devraient entraîner des fluctuations des taux de change bilatéraux par le canal des actions. Nous constatons que les taux de change anticipés pour l'Australie, le Canada, la Norvège (après 2001) et le Royaume-Uni (après 1992) augmentent en phase avec les cours du pétrole par le canal des actions du secteur pétrolier, alors qu'ils diminuent pour le Japon et la Suisse.

Sujets : Évaluation des actifs; Taux de change; Marchés financiers internationaux
Codes JEL : E43, F31, G15

Non-Technical Summary

In general, nominal exchange rate dynamics are difficult to relate to macroeconomics fundamentals. For example, the uncovered interest parity puzzle suggests that high interest rate countries tend to have higher expected currency returns, at least in the short-run. In this paper we propose a modification of the interest parity condition. Our modification relaxes the assumption that investors consider an interest rate parity condition, replacing it with an expected return parity condition. Throughout this paper we focus on equity as the additional investment asset.

We augment standard uncovered interest rate parity (UIP) regressions to include a domestic portfolio of interest rate assets and equities (which we term uncovered return parity, URP). An implication of URP is that exchange rate changes are simultaneously determined by domestic and foreign portfolios. Thus, if URP is the correct data generating process for exchange rate dynamics, then unilateral exchange rate models are misspecified. We specify the expected spot exchange rate as a mixture of two URP conditions and estimate using both OLS and a finite mixture model (FMM) for the six countries we consider. (FMM is appropriate if there is heterogeneity in country-specific information regarding aggregate portfolios.) We find empirical evidence in favour of URP and statistically reject that UIP, which is nested in URP, is sufficient to characterize URP. We infer that exchange rate dynamics depend on the domestic return to capital.

The URP estimates suggest that US expected excess equity returns are significant drivers of exchange rate movements for all countries and that US focussed investors are, on average, responsible for roughly 70–90% of the exchange rate dynamics for Canada, Japan and the UK but 10–30% for Australia, Norway and Switzerland using our FMM specification. The FMM estimates of the posterior mixture probabilities are, however, volatile for all the countries we examine. We find evidence that interest rate differentials are, in general, significant explanatory variables for exchange rate dynamics, particularly for US investors. Finally, we note that our results suggest a smaller role for currency risk premia in nominal currency movements for the countries we examine once exchange rates are conditioned on the carry forward return risk.

The URP condition implies that any asset that is correlated with domestic equity returns should also affect currency returns through the equity channel. One potential asset class is commodities. We construct an oil return ‘factor’ that summarizes the sensitivity of excess equity returns to commodity price movements for the six countries in our sample. Our empirical results provide evidence that oil price movements positively affect the currencies of Australia, Canada, Norway and the UK through the equity channel and negatively affect the currencies of Japan and Switzerland.

1 Introduction

In general, nominal exchange rate dynamics are difficult to relate to macroeconomics fundamentals. This observation has been surprisingly robust since Meese and Rogoff (1983) first noted that exchange rate forecasting models were unlikely to beat the random walk prediction. Nominal exchange rate dynamics are also difficult to relate to cross-country differences in nominal interest rates. For example, the uncovered interest parity puzzle suggests that high interest rate countries tend to have higher expected currency returns, at least in the short run.[1] One possibility, which has been explored in the literature, is that existing models either misspecify or ignore risk. Engel (2016) notes that a risk-based explanation for the uncovered interest parity puzzle requires that the ex-ante risk premium is time-varying and covaries with the difference in interest rates. In this paper, we propose an alternative explanation for the interest rate parity puzzle based on a modification of the interest parity condition.

Our modification relaxes the assumption that investors consider an interest rate parity condition, replacing it with an expected return parity condition. Throughout this paper we focus on equity returns as the additional investment asset. However, this choice is largely for expositional clarity as our thesis is that exchange rate dynamics depend on a portfolio of investment returns.[2] The foreign exchange market is a decentralized exchange market with many investors who, we argue, have idiosyncratic portfolio demands.[3] In the Fama regressions we consider, we augment standard uncovered interest rate parity (UIP) regressions to include a domestic portfolio of interest assets and equities (which we term uncovered return parity, URP). We present empirical evidence in favour of URP and statistically reject that UIP, which is nested in URP, is sufficient to characterize URP. We infer that exchange rate dynamics depend on the domestic return to capital.

URP has several implications for spot exchange rate markets. One is that domestic equity returns provide an additional source of exchange rate risk. In a typical UIP environment with risk-neutral investors (and ignoring Jensen's inequality), there is no additional information gained from considering the foreign perspective since the UIP condition is indifferent to the definition of the home country. The same is not true for URP. A second implication of URP is that exchange rate changes are simultaneously determined by domestic and foreign portfolios. If URP is the correct data-generating process for exchange rate dynamics then unilateral exchange rate models are misspecified.

We specify the expected spot exchange rate as a mixture of two URP conditions. We estimate using

[1] See for example, Bilson (1981), Fama (1984), Engel (1996) and Engel (2014) for a discussion and review of the empirical literature.

[2] Thus, an alternative specification of our model could include excess returns to corporate bonds in addition to, or instead of, equity.

[3] We are agnostic about the source of the differences in expectations and posit that several commonly used models such as mean-variance utility, borrowing constraints, consumption demand shocks or information asymmetry would yield such portfolios. In the Appendix, we sketch a simple model with information asymmetry that yields an aggregate portfolio composed of two domestic assets.

both OLS and a finite mixture model (FMM) for the six countries we consider. FMM is appropriate if there is heterogeneity in country-specific information regarding aggregate portfolios. If UIP is statistically preferred to URP, then the additional URP equation should have no additional information for exchange rate dynamics. One challenge for the empirical analysis is measuring expected equity returns. We follow two approaches. Our first approach uses the ex post realized return and controls for potentially spurious correlation by including contemporaneous measures of uncertainty, inflation rates and changes in equity book-to-market. Our second approach uses the three-pass regression filter proposed by Kelly and Pruitt (2013), Kelly and Pruitt (2015) and Guerin, Leiva-Leon, and Marcellino (2016) to extract an expected aggregate equity return factor from publicly listed stocks on country stock exchanges. We show, using the AIC and BIC, that the results support URP over UIP in this regression framework and FMM over OLS.

The URP condition implies that any asset that is correlated with domestic equity returns should also affect currency returns through the equity channel. One potential asset class is commodities. Kilian and Park (2009) and Ready (2017) argue that oil prices affect equity returns, so if the URP channel we identify is correct, then oil prices should affect exchange rates through this channel. We construct an oil return 'factor' again using the three-pass regression filter proposed by Kelly and Pruitt (2013), Kelly and Pruitt (2015) and Guerin, Leiva-Leon, and Marcellino (2016). Our empirical results provide evidence that oil price movements positively affect the currencies of Australia, Canada, Norway and the UK through the equity channel and negatively affect the currencies of Japan and Switzerland.

We find evidence that expected excess equity returns are significant for all countries and that US focussed investors are, on average, responsible for roughly 70–90% of the exchange rate dynamics for Canada, Japan and the UK but 10–30% for Australia, Norway and Switzerland using our FMM specification. The FMM estimates of the posterior mixture probabilities are, however, volatile for all the countries we examine. One interpretation is that the volatility is indicative of high asset mobility between these countries, at least for some asset classes. We find evidence that interest rate differentials are, in general, significant explanatory variables for exchange rate dynamics, particularly for US focussed investors. Finally, we note that our results suggest a smaller role for currency risk premia in nominal currency movements for the countries we examine once exchange rates are conditioned on the carry forward return risk.

The remainder of the paper is structured as follows. The next section presents the related literature. Section 3 presents our parsimonious framework. Section 4 reports the data. Section 5 discusses our empirical findings designed to test our parsimonious model and study the implications for commodities currencies. Finally, section 6 concludes.

2 Related Literature

Our paper is related to four strands of literature.

The first strand investigates the financial determinants of exchange rates; see for instance Lustig and Verdelhan (2007). This literature seeks to understand the driving forces of a cross-section of currency excess returns using portfolio analysis common in the empirical asset pricing literature. This methodology is also helpful in studying currency return predictability. Lu and Jacobsen (2016) argue that equity returns predict the short leg profits of carry trades, while commodity price changes predict the long leg profits. Passari (2017) builds an investment strategy exploiting the fact that commodity prices forecast exchange rates at daily frequency. This strategy takes a long position in currencies that are expected to appreciate conditional on commodity prices. The data employed in that paper cover the period January 2000 to November 2011, which coincides with the known sharp increases in investments in currency and commodity markets. Cenedese, Payne, Sarno, and Valente (2016) investigate the relationship between equity return differentials and currency returns. They show that a strategy that invests in a country with high expected equity returns and shorts countries with low expected equity returns generates excess returns. However, their analysis concludes that the exchange rate appears to be unrelated to equity return differentials. There are two key differences between this literature and our paper. First, we focus instead on country-specific equity market returns. If exchange rates react asymmetrically to country-specific equity market returns, then this is not well captured by an equity return differential. Second, our focus is to understand how the portfolio compositions of domestic assets relate to exchange rates. We also focus on monthly returns as this horizon is typically difficult for empirical models of UIP.

Secondly, we contribute more broadly to both the empirical and theoretical literature that study the connection between assets prices and exchange rates. A main challenge in this literature consists of identifying the underlying economic transmission mechanism that can explain asset prices, exchange rates and commodity prices. For instance, Hau and Rey (2006) derive an unexpected equity parity condition that links exchange rate to equity returns differentials. Their model assumes that investors cannot perfectly hedge their FX exposure. Pavlova and Rigobon (2007) introduce a demand shock into a standard international asset pricing model. As a result, productivity differences and demand shocks drive endogenous quantities and prices. One paper more closely related to our own is Gyntelberg, Loretan, and Subhanij (2018), which studies how order flows in the foreign exchange, bond and stock markets affect the exchange rate. The authors show that the exchange rates are affected only by FX order flow related to foreign investors' operations in the local stock market. In contrast, bond order flow does not statistically influence movement in exchange rates. Our paper is different from Gyntelberg, Loretan, and Subhanij (2018) in several dimensions: (i) we study eight different countries that account for a majority of daily FX turnover and for a longer sample period; (ii) we study the market-level portfolio allocation by examining how both equity market expectations and nominal interest rates affect the exchange rate; and (iii) we focus on the FX market equilibrium and demonstrate that exchanges rates are a mixture of expected returns for both foreign and domestic investors.

Structural VARs are also widely used in the empirical literature to understand the interconnection between exchange rates and equity returns (Fratzscher, Schneider, and Van Robays 2014, Habib, Bützer, and Stracca 2016). In this paper, we use a parsimonious model of the exchange rate that modifies UIP to include additional asset classes. Because of its simplicity, the UIP condition remains an attractive equilibrium condition and is still actively used by researchers (Kremens and Martin 2017, Engel 2016) and is often central to international macroeconomic models. We illustrate our results simply by including one additional asset class, equities, though we acknowledge that additional asset classes may be interesting to study. Introducing equity returns helps to validate URP, as the condition explicitly requires that commodity prices affect exchange rates at least through the equity returns channel. This is precisely what we find in our empirical work.

In a commodity-dependent economy, either in terms of supply or demand, the profitability of firms may depend on commodity price changes. This includes not only firms that operate directly in the commodity sector but also other firms, as commodity price changes can impact their input costs. Some early research (Chen, Roll, and Ross 1986, Jones and Kaul 1996, Sadorsky 1999) used regression analysis to show that aggregate stock returns have mixed correlation with the oil price changes. However, one concern with these findings is that in a large open economy this empirical strategy can suffer from reverse causality or omitted variable bias as the oil price change and stock returns might be driven by the same underlying factor. Subsequent work (Kilian and Park 2009, Ready 2017) argued that the potential endogeneity issues inherent in the first set of papers can be solved using a structural VAR approach that decomposes supply and demand factors from oil price changes. The main message from this literature is that global demand shocks have sizeable effects on aggregate stock returns. Other papers (Chen 2016, Huang and Miao 2018) have also quantified a non-negligble impact of commodity shocks on a large cross-section of equities returns. Under URP, commodity price changes that affect equity returns matter for exchange rate dynamics. We show in this paper that oil price changes differentially affect the exchange rate dynamics of commodity producers (Australia, Canada, Norway and the UK) and non-commodity producers (Japan and Switzerland).

A final strand of literature studies commodities currencies by highlighting the transmission mechanism or by studying exchange rate forecasting. Chen and Rogoff (2003) and Cashin, Céspedes, and Sahay (2004) show that in small open economies where commodity exports represent a substantial share of their export revenues, commodity price changes constitute a source of terms of trade fluctuation and thus affect real exchange rates. Ready, Roussanov, and Ward (2017) study commodities currencies around the great recession in a general equilibrium model with trade specialization (based on productivity) and endogenous convex shipping cost. The convex trade cost makes consumption smoother in a commodity country compared with consumption in a country that produces manufacturing goods. As a consequence, interest rates will be higher in the commodity country. Concerning the literature on exchange rate forecasting, while nominal exchange rates robustly forecast commodity price movement (Chen, Rogoff, and Rossi 2010), the reverse appears more robust at higher frequency (Ferraro, Rogoff, and Rossi 2015). Our paper adds to this literature—we study exchange rate adjustment driven by commodity shocks and portfolio reallocation across different asset classes.

3 A Simple Framework

UIP relates the expected change in the bilateral spot exchange rate in terms of the difference in interest rates between the countries. Specifically, where S_t is the spot bilateral exchange rate at time t, i_t is the nominal short-term interest rate in the home currency at time t and i_t^* is the nominal short-term interest rate in the foreign currency, then UIP imposes:

$$\frac{\mathsf{E}_t[S_{t+1}]}{S_t} = \frac{1+i_t}{1+i_t^*}, \tag{1}$$

or

$$\frac{\mathsf{E}_t[S_{t+1}](1+i_t^*)}{S_t} = 1 + i_t. \tag{2}$$

The UIP condition is a standard equilibrium condition for a risk-neutral investor since any of the terms in the condition can be expressed as a function of the remaining three. UIP links domestic and foreign interest rates and expected spot rates. For example, if $\frac{\mathsf{E}_t[S_{t+1}](1+i_t^*)}{S_t} > 1 + i_t$ then it would be profitable for an investor to borrow domestically at (gross) rate $1 + i_t$ and invest abroad to earn $\frac{\mathsf{E}_t[S_{t+1}](1+i_t^*)}{S_t}$. As is well documented, the UIP condition fails to find support in the data. Fama (1984) regressions use the ex post spot rate at time $t + 1$ (thus also imposing rational expectations),

$$\Delta log(S_{t+1}) \equiv \Delta s_{t+1} = \alpha + \gamma(i_t - i_t^*) + u_{t+1}. \tag{3}$$

The UIP condition then imposes $\alpha = 0$ and $\gamma = 1$ as testable implications. As we document below, the UIP condition fails to hold for most of our sample of countries, consistent with the literature. One common explanation for the failure of UIP is that investors are not risk neutral and that exchange rate returns are affected by risk premia.

3.1 Equity Returns and UIP

The foreign exchange rate market is characterized by decentralized trading amongst individual investors. Suppose an investor believes that a different domestic asset, for example, an equity index, has a higher expected return than the domestic interest rate. Such an investor would earn higher expected profits borrowing from foreign lenders to invest in the domestic equity index instead of the domestic interest-bearing asset, *ceteris paribus*. Investors may also have different expectations of future spot exchange rates conditional on private information sets. Leverage also increases the expected returns for investors. Thus, conditional on market and private information, solvency and liquidity, and risk tolerances, individual investors' portfolio allocations are likely heterogeneous. Markets aggregate–and market prices reflect–the individual portfolios yielding a country-specific portfolio allocated across domestic assets and an average expected forward spot rate.

As a simple example, consider two domestically denominated assets: an interest-bearing treasury bill and an equity index. Assume some investors expect the payoff from investing in the domestic equity index to be higher than investing in the treasury bill and that the remaining investors expect the payoff from treasury bills to be higher than equity. Each investor compares the payoff from his or her domestic asset choice with the cost of borrowing in the foreign interest rate. Averaging across investors yields an average no-arbitrage return:

$$\mathsf{E}_t[\frac{S_{t+1}(1+i_t^*)}{S_t}] = \mathsf{E}_t\left[\mu(1+i_t) + (1-\mu)(1+\mathsf{E}_t[\tilde{r}_{t+1}])\right], \tag{4}$$

where $\mathsf{E}_t[S_{t+1}]$ is the expected future spot exchange rate (S_t is the current spot) averaged over the market, μ is the aggregate portfolio share in the treasury bill (with return denoted i_t) and $\mathsf{E}_t[\tilde{r}_{t+1}]$ is the market clearing expected equity index return. We note that μ in principle can be negative if, in the aggregate, other domestic investors are short in domestic treasury bills and long in equity. The expected change in the spot exchange rate can be expressed as:

$$\mathsf{E}_t[S_{t+1}]\frac{(1+i_t^*)}{S_t} = \mu(1+i_t) + (1-\mu)(1+\mathsf{E}_t[\tilde{r}_{t+1}]). \tag{5}$$

Equation (5) imposes that, on average, investors cannot borrow in the foreign country and invest in the domestic portfolio to earn profit. We refer to Equation (5) as the URP condition.

As Equation (5) illustrates, the expected value of the change in the spot exchange rate depends on the expected portfolio weight given to the assets. Importantly for empirical Fama regressions, even if expected returns are identical ex ante, if $\mu \neq 1$ then ex post exchange rate will depend on realized equity returns. Thus, a typical argument that interest rates are sufficient should not follow *a fortiori* for typical Fama-type regressions, which use the realized change in the spot exchange rate.

An obvious omission to Equation (5) is the lack of foreign equity assets. In the same way that an investor can leverage foreign borrowing to invest in a portfolio of domestic assets, an investor can also leverage domestic borrowing to invest in a portfolio of foreign assets. Indeed, there are potentially two driving forces behind exchange rate movements: URP from the perspective of the domestic portfolio, and URP from the perspective of the foreign portfolio.

The URP condition for the foreign country, denoted by *, is:

$$\mathsf{E}_t^*[S_{t+1}^*]\frac{(1+i_t)}{S_t^*} = \mu^*(1+i_t^*) + (1-\mu_t^*)(1+\mathsf{E}_t^*[r_{t+1}^*]). \tag{6}$$

It is straightforward to observe that under UIP (and ignoring differences in expectations from Jensen's inequality, e.g., Siegel's paradox, Siegel (1972)), $\mu^* = 1$ and there is no additional information regarding the expected path of the spot exchange rate contained in Equation (6) that is not already present in the domestic URP condition, Equation (5). However, if $\mu^* \neq 1$, then URP from the perspective of an investor in a foreign portfolio does provide additional information for the expected exchange rate change arising from the expected foreign excess equity return.

URP can be expressed using a log-linear specification. Making use of the approximation that $log(1+x) = x$ if x is small, then an ex post Fama (1984) regression specification for Equation (5) is:

$$\Delta s_{t+1} = \alpha + \rho_1 i_t + \rho_2 \mathsf{E}_t[r_{t+1}] - \gamma i_t^* + u_{t+1}, \tag{7}$$

where α should equal zero and URP requires $\rho_1 + \rho_2 = 1$, $\gamma = 1$ to jointly hold. Although i_t may be known at time t, $\mathsf{E}_t[r_{t+1}]$ is not, and thus ex post regressions may have the classical error-in-variables problem if $\rho_2 \neq 0$ and the realized value of $r_{t+1} = \mathsf{E}_t[r_{t+1}] + \nu_{t+1}$, where ν_{t+1} is assumed to be mean zero measurement error. We discuss this issue in our empirical analysis below.

One issue to address is the (possible) non-stationarity of the data. While this is primarily a sample-specific issue, for the countries and time periods we examine, conventional tests of the interest rate series fail for the most part to reject that they have a unit root. Certainly, the interest rates tend to move downwards over the sample period. This is a known issue in international finance. Fortunately, for our sample, the interest rate differentials do not have a unit root.[4] We therefore choose to represent the unilateral URP regressions as (and analogously for the foreign portfolio perspective):

$$\Delta s_{t+1} = \alpha + \gamma(i_t - i_t^*) + \eta(\mathsf{E}_t[r_{t+1}] - i_t) + u_{t+1}, \tag{8}$$

where URP implies $\gamma = 1$, $\eta \neq 0$, whereas UIP requires $\alpha = 0$, $\gamma = 1$ and $\eta = 0$.

It is straightforward to derive the analogous log-linear specification for Equation (6). Setting $S_j = 1/S_j^*$ for period j, there are thus two possible URP equations for the bilateral exchange rate corresponding to home and foreign portfolios:

$$\Delta s_{t+1} = \begin{cases} \alpha + \gamma(i_t - i_t^*) + \eta(\mathsf{E}_t[r_{t+1}] - i_t) + u_{t+1} \\ -\alpha^* + \gamma^*(i_t - i_t^*) - \eta^*(\mathsf{E}_t^*[r_{t+1}^*] - i_t^*) + u_{t+1}^* \end{cases}, \tag{9}$$

[4]The results from these diagnostic tests are available upon request.

where we have, for expositional convenience, used the approximation that $\Delta s^*_{t+1} = -\Delta s_{t+1}$.[5] Although the approximation $\Delta s^*_{t+1} = -\Delta s_{t+1}$ is convenient, it ignores the effect of the expectation operator over the future spot rate. For URP, because of Jensen's inequality, either α or α^* may be non-zero.

Conceptually, one implication of Equation (9) is that bilateral exchange rate changes are realizations of two underlying, and competing, models of exchange rate determination. This would also imply that a unilateral model, such as URP for one country in a bilateral-pair, may be misspecified. In particular, the regression errors from a unilateral model would include the omitted foreign URP condition.

We make three observations regarding URP: (1) UIP is nested in URP and requires $\mu = \mu^* = 1$; (2) URP implies a correlation between expected domestic portfolio returns and expected exchange rate changes; (3) URP implies that any variable that affects expected domestic portfolio returns will affect expected exchange rate changes through that channel. In our empirical analysis, we provide evidence that $\mu \neq 1$ and $\mu^* \neq 1$, evidence that domestic equity returns are correlated with exchange rate changes, and evidence that commodity prices affect exchange rates through the portfolio channel.

3.2 Empirical Specification

The bilateral URP condition complicates empirical analysis since it requires taking a stand over the distribution of the residuals and the stationarity of the mixture. We estimate the URP condition using two strategies. The first strategy is to combine both equations in (9) and estimate using OLS. This approach yields a regression equation:

$$\Delta s_{t+1} = \alpha + \gamma(i_t - i^*_t) + \eta(\mathsf{E}_t[r_{t+1}] - i_t) - \eta^*(\mathsf{E}_t[r^*_{t+1}] - i^*_t) + e_{t+1}. \tag{10}$$

The OLS specification imposes that the conditional expectation of the exchange rate is identical for both countries of the bilateral pair (*i.e.*, that the distribution of e_{t+1} is identical for both countries). This restriction is potentially unpalatable if investors' information is country-specific, e.g., Van Nieuwerburgh and Veldkamp (2009). The OLS specification also imposes that the mixture probabilities are time-invariant.

As a second strategy, we estimate using a finite mixture model (FMM), assuming normally distributed errors and that the expected mixture proportion, π, is constant.[6] The FMM specification is appropriate for our theory as it implies that information heterogeneity over expected excess returns may be country-specific and it relaxes the requirement that posterior mixture probabilities are constant.

Given observations at time $t+1$, the model is specified as follows:

$$f(\Delta s_{t+1}|\Omega_{t+1}) = \pi f\big(\frac{u_{t+1}}{\sigma}\big) + (1-\pi) f\big(\frac{u^*_{t+1}}{\sigma^*}\big),$$

[5] This approximation implies that α^* and η should be different in sign than if considered purely from the foreign-country perspective.

[6] We acknowledge that relaxing this assumption may be important; however, we leave this for future work. The FMM model is widely used both in statistics and econometrics to model classification, clustering, multimodality or unobserved heterogeneity (see Compiani and Kitamura (2016) for a survey of the literature).

where $u_{t+1} = \Delta s_{t+1} - \alpha - \gamma(i_t - i_t^*) - \eta(r_{t+1} - i_t)$ and $u_{t+1}^* = \Delta s_{t+1} - \alpha^* - \gamma^*(i_t - i_t^*) - \eta(r_{t+1}^* - i_t^*)$ are defined respectively from the perspective of the domestic and foreign investor; f is the probability density function of a normal distribution, and Ω_{t+1} the information set available. We specify π as a (conditional) logit function depending on a constant, i.e., $\pi = \frac{1}{1+\exp(\gamma)}$. This model specification follows the description of Wong and Li (2001).

For a sample of $t = 1, 2, \cdots, T$ observations, the likelihood function is:

$$L_T(\theta) = \prod_{t=1}^{T-1} \left(\pi f\big(\frac{u_{t+1}}{\sigma}\big) + (1-\pi) f\big(\frac{u_{t+1}^*}{\sigma^*}\big) \right),$$

where $\theta = \big(\alpha, \gamma, \eta, \alpha^*, \gamma^*, \eta^*, \sigma, \sigma^*\big)$.

Estimation of this model is challenging because the mixture distribution is not observed. We follow the literature and use the Expectation Maximization (EM) algorithm to estimate the mixture. Let $Z = (Z_1, \cdots, Z_T)$ be a two-dimensional random vector (z_t, z_t^*) with $z_t = 1$ if Δs_{t+1} is defined from the perspective of the home economy investor and $z_t = 0$ otherwise. Note that $z_t^* = 1 - z_t$. The complete-data likelihood used in the EM procedure is obtained by augmenting the information set with Z.[7] The likelihood for URP can be expressed as:

$$L_T(\theta) = \prod_{t=1}^{T-1} \left(\pi f\big(\frac{u_{t+1}}{\sigma}\big) \right)^{z_t} \left((1-\pi) f\big(\frac{u_{t+1}^*}{\sigma^*}\big) \right)^{1-z_t}.$$

There are two steps involved in the EM algorithm. The first step (Expectation step) estimates the expected value of component membership z_t, and the second step (Maximization) maximizes the conditional likelihood with respect to the model parameters.

To evaluate whether there is empirical support for our mixture model, and potential misspecification more generally, we also compare our mixture model estimates with those obtained from the OLS URP specifications we described above. We report the AIC and BIC to evaluate whether including additional information from the foreign country's URP condition improves the statistical properties of the model.

4 Data

We focus on Australia (AUS), Canada (CAN), Japan (JPN), Norway (NOR), Switzerland (SWZ) and United Kingdom (UK) as the home countries and the United States (USA) as the foreign country. These countries have not only well-developed financial markets but also liquid currency markets. They represent around 70% of the overall average daily turnover in the foreign exchange market (see the 2016 BIS tri-annual survey). We use financial data for each country consisting of the bilateral USD exchange rate, one-month interest rate, the stock market index, the USD price of West Texas Intermediate oil (wti), the change in the price-to-book

[7] We perform our analysis with the command *fmm* in Stata (Deb 2012).

ratio, a measure of US stock market volatility, vix, and separate equity returns for each stock listed on the benchmark exchange. The latter data we use to construct equity and commodity factors for each country in our sample, which we discuss below. All data come from Datastream and the sample runs monthly from January 1984 to December 2016. We employ the observations of the last trading day of each month as representing the entire month.

Our bilateral nominal exchange rates are quoted as the number of units of the domestic currency per unit of the US dollar. In this case, an increase of the exchange rate corresponds to a depreciation of the domestic currency.[8] In terms of interest rate data, we use one-month deposit rates for all countries except Norway, where we use instead the one-month interbank rate. We use Datastream Total Market Country Index series as our proxy for each country's equity index. In particular, we used the series with mnemonic TOTMKAU (AUS), TOTMKCN(CAN), TOTMKJP(JPN), TOTMKNW(NOR), TOTMKSW(SW), TOTMKUK(UK) and TOTMKUS (USA). Table 7 in the Appendix presents some summary statistics for each of the main series we use in our empirical work.

Since UIP is nested in URP and UIP is a well-studied relationship, we begin by documenting some empirical results regarding UIP for our sample of countries. Table 1 presents estimates of the UIP regression:

$$\Delta s_{t+1} = \alpha + \gamma(i_t - i_t^{US}) + e_{t+1}.$$

The UIP condition is rejected for Canada and Japan at the 5% level, is marginally significant for Australia and Switzerland and cannot be rejected at the 10% level for Norway and the UK. As is typical for UIP regressions, the in-sample fit as measured by R^2 is very poor (under 0.01 for all countries). Moreover, the only apparent reason that the UIP condition is not rejected for all countries is that the standard error of the estimate of γ is relatively very large. The imprecision of the estimate leads to the non-rejection rather than the point estimate of γ. Theoretically, if i_t is a sufficient statistic for investment returns, then there is no reason that γ should be imprecisely estimated.

To motivate the empirical analysis that follows, we present in Table 8 in the Appendix some sample correlations between exchange rates and the URP variables. As one would expect, there is very little correlation between interest rate differentials and exchange-rate changes. The same is not true, however, for the correlation between exchange rate changes and equity returns or between exchange rate changes and the equity premium. For all countries except Norway and the UK, the correlation coefficients are all 0.25 or greater in absolute value. While these correlations are supportive of URP, they may also be spurious.

[8]Or alternatively "Up" is "Down".

Table 1: UIP Regression Estimates by Country

	Dependent variable: Δs_{t+1}					
	AUS	CAN	JPN	NOR	SWZ	UK
	(1)	(2)	(3)	(4)	(5)	(6)
Interest difference: $i_t - i_t^*$	-0.964	-1.061	-1.316	0.353	-1.334	-1.454
	(0.835)	(0.794)	(0.933)	(0.920)	(1.031)	(1.218)
Constant	0.297	0.078	-0.413	-0.022	-0.375	0.236
	(0.252)	(0.129)	(0.215)	(0.206)	(0.224)	(0.183)
			H0: $\alpha = 0$ & $\gamma = 1$			
F-stat	3.091	4.290	3.152	0.477	2.594	2.031
p-value	0.047	0.014	0.044	0.621	0.076	0.133
Observations	395	395	395	371	395	395
R^2	0.003	0.003	0.005	0.001	0.005	0.006

Notes: These estimates are based on OLS regression with Newey-West standard errors reported in parentheses. The model specification is given by: $\Delta s_{t+1} = \alpha + \gamma(i_t - i_t^{US}) + e_{t+1}$. We compute change in exchange rate as log differences in nominal exchange. We compute the interest rate differential with respect to the USA. F-stat refers to the F-statistic for a Wald test that $\hat{\gamma} = 1$ and $\hat{\alpha} = 0$. p-value refers to the asymptotic p-value of the test. *p<0.1; **p<0.05; ***p<0.01.

4.1 Equity Index Expectations and the Three-Pass Regression Filter

One difficulty with the interpretation of Table 8 is that contemporaneous correlations between exchange rates and equity returns may reflect omitted factors or spurious correlation between errors in expectations. In our empirical analysis, we use two strategies to identify a causal channel between equity returns and exchange rate changes. The first strategy we employ is to include additional proxy variables for the omitted variables or spurious correlation in errors in expectations. Our proxy variables are the country-level inflation rates and the one-period difference in the vix and the price-to-book ratios. These variables capture the future state of the economy through local monetary policy (inflation rate), global risk aversion (vix) and economic growth (price-to-book).

Our second, and preferred, strategy is to construct a measure of $\mathsf{E}_t[r_{t+1}]$ using the three-pass regression methodology of Kelly and Pruitt (2013), Kelly and Pruitt (2015) and Guerin, Leiva-Leon, and Marcellino (2016). Our application of the three-pass regression framework to extract forward-looking expectations follows Kelly and Pruitt (2013), albeit tailored to variables of our interest. The three-pass regression methodology uses partial least squares to extract common factors. To illustrate, define $r_{i,t}$ as the excess equity return of firm i at date t and define r_{t+1} as the excess equity index return at time $t+1$.[9] For each firm, regress:

[9] Excess returns are defined over risk-free rate.

$$r_{i,t} = \alpha_i + \phi_i r_{t+1} + u_{i,t}. \tag{11}$$

ϕ_i captures the sensitivity of the excess return for firm i at time t to the excess equity index return at time $t+1$. Let I represent the (maximum) number of firms. Then it follows that there are I estimates of ϕ_i. The next step is to use the estimated $\hat{\phi}_i$ as data in a second, cross-sectional regression:

$$r_{i,t} = \beta_t + F_t \hat{\phi}_i + v_{i,t}. \tag{12}$$

F_t is the latent factor at time t based on the estimated factor loadings from the firm-level, time-series regressions. One particularly attractive feature of this approach, as noted by Kelly and Pruitt (2013), is that using these factors in a third-step, predictive regression is asymptotically consistent even if the factors themselves embed multiplicative bias since any OLS forecast is invariant to affine transformations of regressors. Thus, we may ignore the generated regressor bias for the variance of the estimates in our analysis of URP. Finally, we note that F_t contains only time t information that is correlated with the realized return r_{t+1}. In the empirical analysis that follows, we use F_t to proxy for $\mathsf{E}_t[r_{t+1}]$.[10]

We construct expected equity factors, F_t, for each of the countries in our data using monthly data on listed stocks in that country's main stock exchange (see Section A.2 for details). We also construct three-pass oil-equity factors, f_t^{wti}, replacing r_{t+1} in Equation (11) with wti_{t+1}. The three-pass oil-equity factors capture the extent to which time t equity valuations embed expectations of time $t+1$ oil prices. As Figure 2 in the Appendix illustrates, the oil-equity factor appears to sort countries by the degrees to which their exchange rates are sensitive to oil prices through the equity channel.

5 Empirical Results

In this section, we examine the empirical support for the URP condition. We show that the portfolio channel highlighted by the URP condition we propose appears to have support in the data using either F_t or r_{t+1} for $\mathsf{E}_t[r_{t+1}]$, even if we condition the latter on possibly omitted variables.

5.1 OLS Estimates

For each of the six countries we examine (Australia, Canada, Japan, Norway, Switzerland and the UK), we estimate the OLS specification of URP and test the nested restriction that UIP is valid. As we have discussed above, we construct three-pass regression factors for r_{t+1} using the cross-section of stock returns for each country.[11] Our preferred regressions examine URP using these factors and we report the results in Table 2 in columns labelled (2) for each country.

[10] This is consistent with a rational expectations interpretation of F_t as the information at time t that could have been used to predict r_{t+1}.

[11] Figures 2 and 3 in the Appendix present the descriptive statistics and the dynamics of these factors.

We also consider a second OLS specification that uses the realized equity returns, r_{t+1}. We include the change in the VIX, the change in the price-to-book ratio for that country's equity index, and the inflation rate as controls. As we noted above, the principal concern with including r_{t+1} in the regression specification is that errors in expectations for Δs_{t+1} and r_{t+1} are correlated and thus the regression specification is invalid. If the controls are correlated with the errors in expectations, then the remaining errors may be orthogonal. We include these regressions in columns labelled (1) in Table 2.

The results reported in Table 2 suggest evidence in favour of URP, as we can reject, using our preferred specification, the nested hypothesis of UIP for all countries except Norway. Also, the regression R^2 for the URP condition is several orders of magnitude higher than the R^2 for the UIP condition that we reported above, though there are notable differences between Australia and Canada and the remaining countries. While the domestic expected excess equity returns appear significant for Australia, Canada, Japan and Switzerland, they are insignificant for Norway and the UK. For Australia, Canada and Norway, US excess equity returns are significant, while for the UK neither are significant. One issue that we wish to highlight, however, is the difference in the specifications. For almost all countries, the estimates, and their significance, are quite different between specifications (1) and (2), which suggests that the proxy controls may not, in fact, properly account for correlation in the errors in expectations.

Table 2: Uncovered Return Parity: OLS

	Dependent variable: Δs_{t+1}											
	AUS		CAN		JPN		NOR		SWZ		UK	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Interest difference: $i_t - i_t^*$	-1.633	-0.888	-0.222	-0.800	-1.019	-1.372	1.049	0.348	-0.356	-1.005	1.230	-1.537
	(1.244)	(0.779)	(0.849)	(0.757)	(0.984)	(0.947)	(1.157)	(0.957)	(1.124)	(1.022)	(1.458)	(1.193)
Domestic equity factor: F_t	-0.089	-0.091**	0.034	-0.096**	0.362***	0.064*	0.140*	-0.001	0.559***	0.128**	0.343***	0.068
	(0.122)	(0.033)	(0.066)	(0.029)	(0.079)	(0.032)	(0.059)	(0.025)	(0.097)	(0.045)	(0.090)	(0.052)
Foreign equity factor: F_t^*	-0.180	-0.194***	-0.237**	-0.099***	0.014	0.002	-0.400***	-0.095*	-0.450***	-0.037	-0.471***	-0.065
	(0.112)	(0.046)	(0.078)	(0.023)	(0.106)	(0.040)	(0.113)	(0.039)	(0.132)	(0.048)	(0.096)	(0.044)
Constant	0.780*	0.169	0.358*	-0.013	-0.249	-0.395	0.513	-0.052	-0.064	-0.341	0.563**	0.225
	(0.312)	(0.229)	(0.170)	(0.111)	(0.251)	(0.215)	(0.265)	(0.203)	(0.278)	(0.223)	(0.209)	(0.182)
	H0: $\alpha = 0$ & $\eta = 1$											
F-Stat	2.406	4.880	2.118	5.723	9.958	3.849	4.232	0.409	13.64	4.116	8.754	2.881
p-value	0.067	0.002	0.098	0.001	0.000	0.010	0.006	0.747	0.000	0.007	0.000	0.036
Obs	323	395	323	395	323	395	323	371	323	395	323	395
R^2	0.278	0.169	0.290	0.181	0.097	0.022	0.143	0.026	0.187	0.030	0.186	0.014

Notes: Specification (1) is OLS URP with realized excess returns and controls; (2) is OLS URP with expected excess returns. These estimates are based on OLS regression with Newey-West standard errors reported in parentheses. F-stat refers to the F-statistic for a Wald test that $\hat{\eta} = 1$ and $\hat{\alpha} = 0$. p-value refers to the asymptotic p-value of the test. Stars refer to the asymptotic significance: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$.

5.2 FMM Estimates

One concern with the results reported in Table 2 is that the OLS specification combines the two bilateral URP conditions into a single estimating equation. Our second approach is to estimate using FMM, assuming normally distributed errors.[12]

Table 3 presents the estimates from the bilateral URP regressions for each of the countries in our sample. We again consider two specifications for the expected excess equity returns: (1) using the realized value and controls; and (2) using the equity factor. One feature of FMM that is absent from the OLS specification is the estimate of the expected mixture proportion. Focussing on our preferred specification using the equity factor, and reported in columns labelled (2), there is an evident range in the importance of domestic portfolios for the countries we consider. The country with the highest expected share of the domestic URP condition is Switzerland with 82.1%, while the UK is the lowest with 15.4%. Since, in the FMM specification, the foreign share is always the US, this suggests that the importance of US factors may vary significantly for the countries we examine.

There are several other points that emerge from close inspection of our preferred specification in columns labelled (2). First, the interest rate differential is significant for all countries in at least one of the unilateral URP equations. For Switzerland, the interest rate differential is only significant for the domestic URP condition; however, the domestic URP condition accounts for 82.1% of the expected exchange rate change. For the UK, the interest rate differential is only significant for the US URP condition; however, the US URP condition accounts for 84.6% of the expected exchange rate change. Thus, interest rate differentials appear to be, broadly, significant for expected exchange rate changes.

A second observation is that domestic expected excess equity returns are significant for Australia, Canada, Japan and Switzerland but not for Norway and the UK. For Norway, US expected excess returns are significant; while for the UK, neither domestic nor US expected excess returns are significant for our sample period.

A third observation is that the regression constant is significant for Japan and Switzerland. This may suggest that $\Delta s^*_{t+1} = -\Delta s_{t+1}$ is a poor approximation for these countries. This, in turn, suggests that Jensen's inequality may be an important consideration. In particular, it may suggest that these currencies have higher variance in their expected exchange rate changes.

Finally, the estimated residual variance is always significant and typically suggests a 2–3 order of magnitude difference in the relative residual variances for the country-specific URP conditions.

[12] We acknowledge that relaxing the assumption of normally distributed errors may be important; however, we leave this for future work.

Table 3: Uncovered Return Parity: FMM

	Dependent variable: Δs_{t+1}											
	AUS		CAN		JPN		NOR		SWZ		UK	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
	Home URP											
Interest difference: $i_t - i_t^*$	-5.606**	-2.394**	3.831	5.746	-2.366*	6.697	-5.499***	-2.965***	2.708	-3.755*	12.450***	4.636
	(1.818)	(0.783)	(2.434)	(3.468)	(1.057)	(4.215)	(1.142)	(0.820)	(1.905)	(1.626)	(3.194)	(7.210)
Equity factor: F_t	0.035	-0.118***	-0.045	-0.408***	0.337***	0.220**	0.091	0.015	0.642***	0.145***	0.550*	0.023
	(0.175)	(0.022)	(0.128)	(0.080)	(0.084)	(0.068)	(0.056)	(0.028)	(0.103)	(0.041)	(0.253)	(0.218)
Constant	1.331**	0.355	0.055	-0.333	-0.387	0.527	0.366	0.197	-0.002	-0.691*	0.200	0.615
	(0.451)	(0.297)	(0.330)	(0.257)	(0.245)	(0.596)	(0.407)	(0.262)	(0.391)	(0.288)	(1.037)	(0.828)
Residual var	4.306***	4.665***	5.474***	5.760***	6.508***	17.13***	4.238***	5.471***	9.174***	7.165***	6.905***	23.280*
	(0.753)	(0.724)	(0.903)	(0.953)	(1.366)	(4.236)	(0.821)	(1.052)	(1.030)	(1.126)	(1.202)	(9.489)
Logit constant	-0.106	-0.726*	0.485	0.542	-2.408**	0.875	0.152	-0.669	-0.607	-1.521	1.585***	1.705*
	(0.365)	(0.354)	(0.360)	(0.377)	(0.826)	(0.615)	(0.321)	(0.418)	(0.354)	(0.910)	(0.473)	(0.673)
Share Domestic	0.526	0.674	0.381	0.368	0.917	0.294	0.462	0.661	0.647	0.821	0.170	0.154
	USA URP											
Interest difference: $i_t - i_t^*$	3.995	2.849	-2.037*	-2.458***	8.611	-4.405***	4.860***	5.860***	-6.636***	13.86	-2.112	-3.160*
	(2.641)	(2.554)	(0.872)	(0.586)	(13.81)	(1.239)	(0.997)	(1.509)	(1.350)	(9.509)	(1.336)	(1.436)
Equity factor: F_t^*	-0.734***	-0.563***	-0.205***	-0.0656**	-0.174	0.0371	-0.584**	-0.401***	-0.263***	-0.144	-0.281***	-0.0133
	(0.219)	(0.081)	(0.061)	(0.022)	(0.267)	(0.038)	(0.212)	(0.067)	(0.069)	(0.165)	(0.069)	(0.038)
Constant	-0.150	-0.364	0.327**	0.167	0.812	-0.709**	0.403	-0.336	-1.043**	1.134	0.645**	0.213
	(0.644)	(0.580)	(0.123)	(0.129)	(1.781)	(0.266)	(0.411)	(0.479)	(0.397)	(0.852)	(0.210)	(0.187)
Residual var	7.708***	14.930***	1.407***	1.218***	23.100	5.611***	8.246***	12.370***	2.139*	19.760***	3.764***	5.272***
	(1.139)	(2.186)	(0.304)	(0.292)	(21.590)	(1.189)	(1.261)	(1.911)	(0.846)	(5.678)	(0.419)	(0.850)
Obs	323	395	323	395	323	395	371	323	323	395	323	395

Notes: Specification (1) is FMM URP with realized excess returns and controls; (2) is FMM URP with expected excess returns. The equity factors are scaled by 100. These estimates are based on Gaussian two-mixture regressions with robust standard errors reported in parentheses. Share Domestic is the expected share of the domestic URP channel for exchange rate changes. p-value refers to the asymptotic p-value of the test. Stars refer to the asymptotic significance: *p<0.05; **p<0.01; ***p<0.001.

To evaluate whether there is empirical support for our mixture model, and potential misspecification more generally, we also compare our mixture model estimates with those obtained from the single equation URP specifications we described above. We report the AIC and BIC in Table 4 to evaluate whether including additional information from the foreign country's URP condition improves the statistical properties of the model. We report two model specifications: URP estimated by OLS and URP estimated by FMM. The AIC results unambiguously support URP over UIP. The results for AIC also unambiguously support FMM over OLS. However, for Japan and Switzerland the BIC suggests that OLS UIP may be preferred. The difference between AIC and BIC for Japan and Switzerland is due to the difference $2k - ln(n)k$ penalty term applied to the number of parameters, k, in the FMM URP, $k = 9$, versus UIP, $k = 3$. We remind the reader that UIP was rejected as a nested hypothesis for Japan and Switzerland. Nevertheless, the BIC criterion also marginally favours OLS URP over FMM URP for Japan and Switzerland. Again, the difference appears due to the number of parameters estimated under FMM, $k = 9$, versus OLS, $k = 4$, which suggests that the parameter restrictions embedded in OLS may be reasonable. We conclude that URP appears to have support in the data we examine and that FMM appears on balance the preferred specification. We also note that our empirical investigation of URP is, by design, focussed only on portfolios comprised of equities and short-term treasuries. It would seem probable that broader portfolios would yield even more conclusive evidence for URP but that investigation is beyond the scope of this paper.

5.3 The Commodity Channel

The URP condition implies that any asset that is correlated with domestic equity returns should also affect currency returns through the equity channel. An example of such potential assets are commodities. Kilian and Park (2009) and Ready (2017) argue that oil prices affect equity returns; so if the URP channel we propose is valid, then oil prices should affect exchange rates through this channel. URP is unlike UIP, where there is no theoretical possibility for exchange rate returns to depend directly on oil prices.

We use the oil-equity factors described above to examine, using FMM, whether expectations over oil price changes affect expected exchange rate returns. We estimate Equation (9) replacing the equity factor with the oil-equity factor. The oil-equity factor captures the extent to which current equity prices reflect the next month's WTI change. It is also a measure of the oil sensitivity of domestic equity returns.[13]

Table 5 presents FMM estimates of URP using the oil-equity factor. The results suggest that the countries we examine can be clustered into three groups for the domestic channel of URP: the Australian and Canadian expected exchange rates rise (fall) with increases (decreases) in the oil-equity factor; the Japanese and Swiss expected exchange rates fall (rise) with increases (decreases) in the oil-equity factor; and the Norwegian and UK expected exchange rates are insignificantly affected by the oil-equity factor. For the US channel of URP,

[13] We also investigate an oil-equity factor constructed using contemporaneous equity excess returns and oil price changes and find similar results.

Table 4: Information Criterion for URP

		AIC	BIC
	OLS UIP	2057.335	2069.272
AUS	OLS URP	2028.794	2044.710
	FMM URP	1996.406	2032.216
	OLS UIP	1660.400	1672.337
CAN	OLS URP	1644.527	1660.442
	FMM URP	1592.099	1627.909
	OLS UIP	2050.974	2062.910
JPN	OLS URP	2052.970	2068.885
	FMM URP	2034.272	2070.082
	OLS UIP	1920.813	1932.561
NOR	OLS URP	1915.937	1931.602
	FMM URP	1888.969	1924.214
	OLS UIP	2075.235	2087.172
SWZ	OLS URP	2076.445	2092.361
	FMM URP	2062.569	2098.379
	OLS UIP	1977.290	1989.226
UK	OLS URP	1976.583	1992.499
	FMM URP	1952.573	1988.383

Notes: The AIC and BIC refer to the Akaike and Bayes information criterion from Table 1 and from columns labelled (2) in Tables 2 and 3.

the expected exchange rates fall with increases in the oil-equity factor for all countries except Japan (recall that the approximation $\Delta s^*_{t+1} = -\Delta s_{t+1}$ implies that interpretation of the coefficient on $F_t^{oil,*}$ is the inverse of that for F_t^{oil}).

5.4 Robustness

One concern with the results for Norway and the UK presented in Tables 3 and 5 is that both countries have experienced structural changes that may affect URP over the sample period. Since June 2001, the Norwegian stock exchange, the Oslo Bors, has been dominated by a single firm, Statoil, which accounts for roughly 20–25% of the total market capitalization. Given the construction of our equity factors, the entry of a dominant firm could be problematic for the equally weighted market expected return. To account for the Statoil effect, we split our sample for Norway at June 2001 and re-estimate the equity and oil-equity factors for the post-June 2001 period. For the UK, the exchange rate crisis of 1992 saw the UK exit the currency corridor preceding the introduction of the Euro. Expected currency returns under a managed float confound at least two dynamics: the role of fundamental factors such as the URP and the expectation of the continuance of the managed float. To account for the ERM effect, we split our sample for the UK at September 1992. However, we do not re-estimate the equity factor or oil-equity factor for only the post ERM period since there is no reason to believe that the expectations embedded in the existing equities should have been affected.

Table 6 presents FMM estimates for the equity and oil-equity factors for Norway post June 2001 and the UK post September 1992. In each case, the domestic equity or oil-equity factor is significant. In particular, the results for the oil-equity factor suggest that Norway and the UK should be considered similar to Australia and Canada in so much as expected exchange rates rise (fall) with increases (decreases) in the oil-equity factor. There is also evidence that the expected exchange rates fall with increases in the oil-equity factor for the US channel. Overall, the estimates also suggest that the majority of exchange rate movements in the expected exchange rates are driven by the US channel.

5.5 Posterior Mixture Probabilities

One feature of the FMM methodology is that it yields estimates of the posterior probability of group membership. Figure 1 presents the estimated posterior probabilities for the domestic URP share of the expected exchange rate movements using the equity factor URP specification from columns labelled (2) in Table 3. Two features stand out. First, the estimated posterior share is volatile for all of the countries in the sample. The second common feature is that the posterior probabilities appear to be on average in the range $0.7 - 0.9$ for Australia, Norway and Switzerland or in the range $0.1 - 0.3$ for Canada, Japan and the UK. Both observations support the central thesis of this paper that exchange rate models from the perspective of

Table 5: Uncovered Return Parity: Oil-Equity Factor

	Dependent variable: Δs_{t+1}					
	AUS	CAN	JPN	NOR	SWZ	UK
	Home URP					
Interest difference: $i_t - i_t^*$	4.738	10.820**	6.288	-5.634***	-4.489**	-2.800
	(4.123)	(4.190)	(4.079)	(1.500)	(1.484)	(1.466)
Oil factor: F_t^{oil}	-0.198***	-0.231***	0.105***	0.012	0.035**	-0.026
	(0.058)	(0.027)	(0.029)	(0.018)	(0.013)	(0.015)
Constant	-1.089	-0.285	0.850	0.387	-0.992**	-0.027
	(0.904)	(0.397)	(0.632)	(0.316)	(0.376)	(0.234)
Residual var	14.170***	5.887***	16.240***	4.854***	7.066***	4.390***
	(3.681)	(1.140)	(3.992)	(1.096)	(1.474)	(0.910)
Logit constant	0.929	0.925*	0.939	0.221	-0.860	-1.587*
	(0.484)	(0.449)	(0.492)	(0.361)	(0.674)	(0.717)
Share Domestic	0.283	0.284	0.281	0.445	0.703	0.830
	USA URP					
Interest difference: $i_t - i_t^*$	-3.389	-1.508*	-3.558**	4.444***	7.781	14.040
	(1.746)	(0.712)	(1.095)	(0.919)	(4.337)	(9.636)
Oil factor: $F_t^{oil,*}$	-0.107***	-0.048**	-0.035	-0.193***	-0.117**	-0.165***
	(0.031)	(0.016)	(0.019)	(0.021)	(0.043)	(0.036)
Constant	0.484	-0.047	-0.602*	-0.506	1.370	-0.074
	(0.444)	(0.149)	(0.257)	(0.303)	(0.765)	(1.047)
Residual var	4.942***	1.971***	4.897***	7.576***	9.393*	7.997*
	(0.875)	(0.491)	(0.760)	(1.162)	(4.383)	(3.336)
Obs	324	324	324	324	324	324

Notes: These estimates are based on Gaussian two-mixture regressions with robust standard errors reported in parentheses. The equity factors are scaled by 100. Share Domestic is the expected share of the domestic URP channel for exchange rate changes. Stars refer to the asymptotic significance: *p<0.05; **p<0.01; ***p<0.001.

Table 6: Statoil and the Exchange Rate Mechanism

	Dependent variable: Δs_{t+1}			
	NOR Post-Statoil	UK Post-ERM	NOR Post-Statoil	UK Post-ERM
	Equity Factor		Oil Factor	
	Home URP			
Interest difference: $i_t - i_t^*$	0.845	23.430***	-7.772**	17.280**
	(5.381)	(4.927)	(2.649)	(5.507)
Equity or oil factor: F_t or F_t^{oil}	-0.368***	-0.226**	-0.134**	-0.119**
	(0.664)	(0.0703)	(4.676)	(4.315)
Constant	-0.302	0.197	-0.811	-0.183
	(1.044)	(1.123)	(0.537)	(1.121)
Residual var	7.405***	11.410**	5.589***	9.841**
	(2.207)	(3.534)	(1.270)	(3.292)
Logit constant	0.617	1.824***	0.503	1.524**
	(0.521)	(0.450)	(0.532)	(0.464)
Share Domestic	0.350	0.139	0.377	0.179
	USA URP			
Interest difference: $i_t - i_t^*$	-2.818	-1.091	3.464	-1.510
	(2.575)	(2.085)	(2.175)	(2.249)
Equity or oil factor: F_t^* or $F_t^{oil,*}$	-0.608	-0.020	-0.187***	-0.381*
	(0.725)	(0.033)	(2.415)	(1.865)
Constant	0.007	-0.074	0.200	-0.110
	(0.568)	(0.242)	(0.432)	(0.280)
Residual var	8.523***	4.141***	7.055***	3.892***
	(1.939)	(0.569)	(1.361)	(0.594)
Obs	185	292	185	292

Notes: These estimates are based on Gaussian two-mixture regressions with robust standard errors reported in parentheses. The equity factors are scaled by 100. Share Domestic is the expected share of the domestic URP channel for exchange rate changes. Stars refer to the asymptotic significance: *p<0.05; **p<0.01; ***p<0.001.

one country are essentially misspecified. Of perhaps greater interest is that to better understand exchange rate movements, it would appear necessary to investigate the economic forces that cause the sharp changes in the estimated posterior share. We leave such investigation for future research.

6 Conclusion

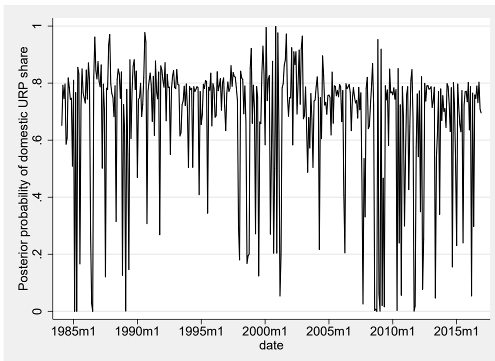
In this paper, we have made two contributions to understanding currency markets. First, we have suggested an augmented parity condition, URP, to help to understand the driving factors of currency returns. We show empirical evidence that our portfolio channel is operative and that it can go some way to understanding exchange rate changes.

Second, both as part of a logical test of URP and also of interest in its own right, we have proposed a channel through which commodity prices affect currency markets. We show that countries can be differentiated in terms of the sensitivity and direction in which commodity price changes affect their bilateral USD exchange rates. In particular, we find evidence that Australia and Canada, and probably Norway and the UK, are commodity currencies. We also find evidence that the Yen and Swiss France are sensitive to commodity prices in the opposite direction.

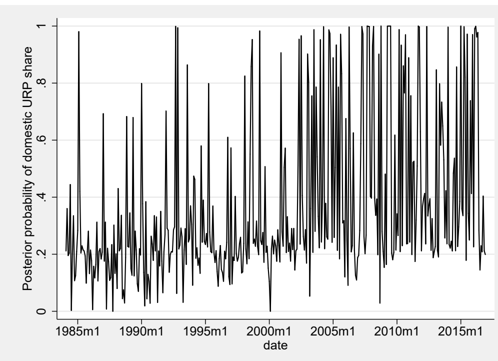
Recently, Chien, Lustig, and Naknoi (2015) and Dou and Verdelhan (2015) have suggested that differences across investors may play a valuable role in explaining currency markets. We note that our setting may possibly be extended to include incomplete markets, as the portfolio uncertainty wedge we propose would also drive a wedge in the exchange rate in an incomplete-market setting. Indeed, the scope for future research appears to include a number of possible avenues in addition to risk, for example: time-varying portfolio composition effects; time-varying US URP shares; and even simply extending across additional assets, maturities and countries.

Figure 1: Posterior Estimate of Domestic Share

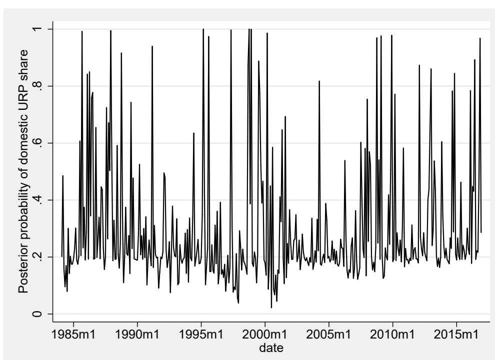
(a) AUS



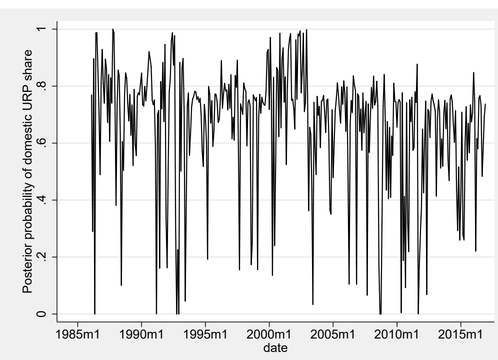
(b) CAN



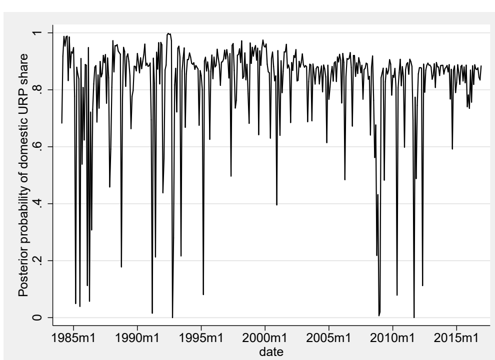
(c) JPN



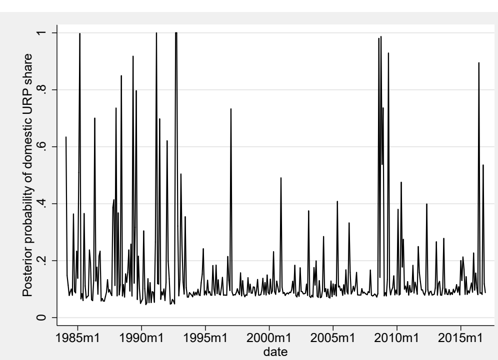
(d) NOR



(e) SWZ



(f) UK



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A Appendix

A.1 Summary Statistics

Table 7: Summary Statistics

	AUS	CAN	JPN	NOR	SWZ	UK
			Interest rate differential : $i_t - i_t^*$			
mean	0.245	0.055	-0.180	0.173	-0.131	0.138
sd	0.197	0.110	0.173	0.231	0.178	0.157
skew	0.861	0.505	-0.203	1.364	0.317	0.916
kurt	0.660	0.813	-1.206	4.721	0.264	0.047
AR(1)	0.974	0.944	0.984	0.919	0.976	0.965
adf	-3.350	-2.540	-2.599	-3.016	-3.070	-4.434
p.value	0.063	0.349	0.324	0.148	0.125	0.010
n	397	397	397	373	397	397
			Equity returns : r_t			
mean	0.900	0.772	0.302	0.967	0.800	0.853
sd	4.894	4.111	5.580	6.616	4.555	4.517
skew	-3.336	-1.374	-0.362	-1.070	-1.262	-1.146
kurt	32.379	6.338	1.134	3.330	4.798	5.197
AR(1)	0.002	0.129	0.114	0.148	0.163	0.048
adf	-7.731	-7.580	-6.516	-7.621	-6.549	-7.378
p.value	0.010	0.010	0.010	0.010	0.010	0.010
n	395.000	395.000	395.000	395.000	395.000	395.000
			Pseudo Equity premium : $r_{t+1} - i_t$			
mean	0.320	0.383	0.148	0.480	0.597	0.380
sd	4.888	4.123	5.584	6.625	4.559	4.512
skew	-3.443	-1.391	-0.393	-1.220	-1.284	-1.212
kurt	33.361	6.396	1.160	3.736	4.841	5.429
AR(1)	0.002	0.134	0.116	0.164	0.164	0.046
adf	-7.645	-7.465	-6.486	-7.266	-6.473	-7.306
p.value	0.010	0.010	0.010	0.010	0.010	0.010
n	395.000	395.000	395.000	371.000	395.000	395.000
			Exchange rate : Δs_t			
mean	0.048	0.011	-0.185	0.011	-0.208	0.027
sd	3.436	2.129	3.262	3.215	3.373	2.947
skew	0.682	0.614	-0.357	0.459	-0.042	0.306
kurt	2.583	4.997	1.458	1.183	0.784	2.183
AR(1)	0.055	-0.042	0.041	0.010	-0.011	0.073
adf	-7.067	-6.982	-7.138	-7.467	-7.272	-7.948
p.value	0.010	0.010	0.010	0.010	0.010	0.010
n	396	396	396	396	396	396

Notes: This table reports monthly summary statistics based on the full-sample estimates using interest rate differential, equity returns, equity premium, change in exchange rate. We compute change in exchange rate as log differences in nominal exchange. The equity return is the log differences of the country index. We compute the interest rate differential with respect to the USA. All variables are multiplied by 100.

A.2 Estimation of the Three-pass Equity Factor

We use monthly individual stocks data listed on the major exchange in each country. These stock exchanges are: Australia, Toronto, Oslo, NYSE, Tokyo, London and Zurich. All these data come from Datastream and cover the period January 1984 to December 2016 and are denominated in local currency. To mitigate the effects of outliers, we apply a couple of screening procedures common in the literature (Ince and Porter 2006, Chui, Titman, and Wei 2010, Hou, Karolyi, and Kho 2011, Lee 2011, Bali, Engle, and Murray 2016). First, we truncate small firms in each country by treating as missing data the returns of the 5% lowest market capitalization. This imputation procedure is done period by period. Second, we apply a winzorization

Table 8: Correlations between Exchange Rates, Interest Rates and Equity Returns

	AUS	CAN	JPN	NOR	SWZ	UK
			Interest rate differential: $i_t - i_t^*$			
Equity returns	0.025	-0.051	0.009	-0.091	-0.054	0.016
Equity premium	-0.024	-0.084	0.001	-0.123	-0.067	-0.036
Exchange rate	-0.053	0.005	-0.083	-0.007	-0.070	-0.066
			Equity returns: r_t			
Interest rate differential	0.025	-0.051	0.009	-0.091	-0.054	0.016
Equity premium	0.998	0.998	0.999	0.999	0.999	0.997
Exchange rate	-0.350	-0.413	0.132	-0.107	0.258	0.080
			Pseudo Equity premium: $r_{t+1} - i_t$			
Interest rate differential	-0.024	-0.084	0.001	-0.123	-0.067	-0.036
Equity returns	0.998	0.998	0.999	0.999	0.999	0.997
Exchange rate	-0.352	-0.410	0.136	-0.099	0.260	0.084
			Exchange rate: Δs_t			
Interest rate differential	-0.053	0.005	-0.083	-0.007	-0.070	-0.066
Equity returns	-0.350	-0.413	0.132	-0.107	0.258	0.080
Equity premium	-0.352	-0.410	0.136	-0.099	0.260	0.084

Notes: This table reports monthly correlation based on the full-sample estimates using interest rate differential, equity returns, equity premium, change in exchange rate. We compute change in exchange rate as log differences in nominal exchange. The equity return is the log differences of the country index. We compute the interest rate differential with respect to the USA.

technique by imputing the 0.1% lowest value to the 0.1% quantile threshold and the 99.9% highest to the 99.9% quantile threshold (Bali, Engle, and Murray 2016, Chapter 1). Following the truncation and winzorization procedure, we keep firms that have more than 10% of data (i.e., firms with less than 90% of missing data) or alternatively firms with at least 40 observations. And finally, we treated as missing data any return above 300% that is reversed within one month.

Table 9: Summary Statistics on the Size of the Cross-Section of Equity Returns by Country and Year

	AUS			CAN			JPN			NOR			SWZ			UK			USA		
year	min	median	max	min	median	max	min	median	max	min	median	max	min	median	max	min	median	max	min	median	max
1984	43	45	45	84	86	91	673	674	674	16	16	16	44	44	46	218	232	236	693	709	724
1985	45	45	46	93	94	95	674	674	675	16	18	18	46	48	48	236	242	245	725	738	759
1986	46	46	49	95	102	117	675	675	675	18	20	21	48	52	61	247	255	261	763	786	833
1987	49	55	59	119	124	131	675	676	762	21	21	21	64	68	75	268	272	276	845	871	905
1988	59	92	125	132	136	371	763	1061	1106	21	21	21	77	78	85	276	290	303	908	922	937
1989	127	157	171	378	400	456	1113	1162	1304	21	22	22	85	91	93	308	312	319	941	950	966
1990	171	176	181	464	610	623	1313	1432	1473	22	23	23	93	112	112	323	324	324	970	990	1000
1991	181	182	188	625	644	667	1480	1566	1610	23	24	25	112	112	115	325	326	328	1002	1026	1062
1992	188	197	197	667	685	701	1616	1628	1649	25	26	32	115	115	119	328	328	333	1074	1124	1157
1993	197	202	211	703	718	736	1651	1664	1699	32	32	32	119	122	123	334	340	346	1167	1222	1286
1994	215	237	255	742	769	799	1712	1746	1828	33	36	38	123	126	126	347	358	367	1297	1356	1397
1995	260	266	274	801	814	839	1843	1892	1956	38	41	43	127	130	133	372	378	403	1404	1435	1504
1996	280	428	444	846	867	899	1967	2000	2070	45	48	49	133	134	139	408	422	445	1515	1562	1636
1997	444	464	476	908	954	994	2081	2106	2166	49	56	62	140	141	143	451	466	479	1649	1698	1767
1998	480	496	505	1006	1052	1087	2173	2184	2215	63	66	71	143	148	155	483	491	499	1778	1842	1881
1999	511	517	543	1092	1117	1173	2224	2245	2286	71	72	74	155	158	164	500	504	515	1886	1942	2027
2000	561	594	632	1183	1210	1310	2297	2337	2408	74	77	78	164	170	176	522	555	581	2031	2080	2136
2001	644	662	675	1321	1368	1390	2431	2472	2531	79	82	84	176	180	181	589	606	620	2143	2168	2200
2002	680	698	718	1391	1415	1441	2548	2588	2624	84	87	88	181	182	183	627	649	662	2204	2232	2261
2003	720	728	763	1446	1466	1489	2637	2671	2706	88	89	89	184	185	185	666	675	693	2266	2281	2315
2004	783	816	864	1496	1535	1580	2725	2772	2830	90	94	96	185	187	188	699	726	787	2327	2372	2430
2005	886	935	981	1594	1651	1707	2846	2892	2945	98	104	112	189	192	196	811	884	947	2441	2495	2556
2006	997	1044	1110	1722	1785	1847	2964	3025	3084	113	118	128	197	200	203	967	1016	1062	2563	2610	2671
2007	1136	1213	1304	1858	1940	2045	3106	3159	3198	129	139	146	203	207	212	1075	1112	1151	2688	2756	2817
2008	1345	1386	1404	2068	2161	2233	3206	3224	3236	148	152	155	217	224	228	1156	1174	1188	2834	2862	2885
2009	1404	1411	1428	2233	2265	2306	3244	3258	3271	155	155	156	229	230	232	1190	1193	1197	2886	2894	2924
2010	1443	1462	1492	2313	2374	2446	3273	3288	3299	156	160	165	232	234	236	1199	1220	1247	2933	2986	3032
2011	1520	1569	1607	2473	2556	2636	3304	3320	3343	166	170	173	236	238	242	1253	1271	1297	3045	3108	3155
2012	1619	1640	1660	2646	2763	2857	3353	3369	3395	174	174	176	242	243	246	1298	1314	1332	3166	3228	3279
2013	1671	1684	1693	2870	2912	2932	3410	3432	3444	176	178	180	246	247	247	1340	1360	1375	3290	3376	3439
2014	1681	1689	1693	2925	2933	2936	3443	3444	3444	180	180	180	247	247	247	1374	1374	1375	3438	3439	3439
2015	1677	1680	1682	2914	2923	2928	3442	3444	3444	180	180	180	247	247	247	1370	1372	1375	3436	3438	3439
2016	1672	1675	1677	2914	2925	2928	3442	3442	3442	178	179	180	247	247	247	1368	1369	1371	3432	3434	3436
2017	1673	1673	1673	2926	2926	2926	3442	3442	3442	180	180	180	247	247	247	1369	1369	1369	3431	3431	3431

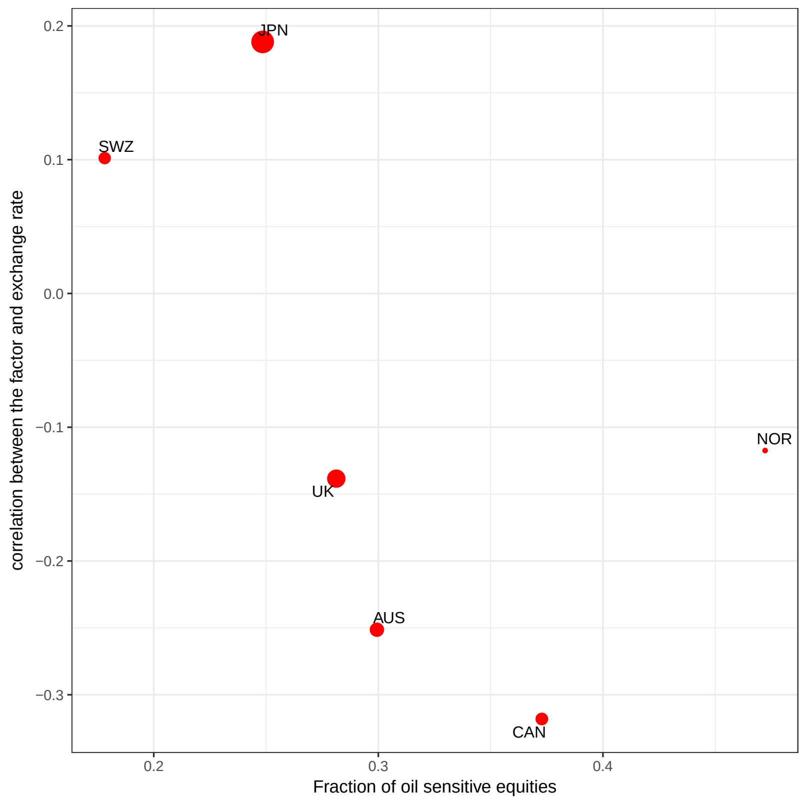
Notes: This table reports the minimum, median and maximum number of equity returns in the sample per country and year.

Table 10: Summary Statistics of Stock Returns by Country and Year

	AUS		CAN		JPN		NOR		SWZ		UK		USA	
Year	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1984	0.623	4.746	-0.975	3.340	0.973	3.736	2.326	7.926	0.019	2.133	1.591	4.301	-0.226	4.028
1985	2.522	3.201	2.365	2.264	1.416	1.711	0.864	7.157	3.676	3.087	1.789	3.263	2.315	3.919
1986	2.729	4.980	1.456	2.731	1.876	4.799	-3.565	3.768	1.253	4.271	2.453	3.211	0.715	4.243
1987	-2.228	13.697	-0.836	10.175	1.751	5.663	0.637	8.585	-2.265	9.967	1.426	11.275	-0.462	10.807
1988	-0.715	4.738	-1.361	3.117	2.196	4.572	1.972	4.949	2.123	3.099	0.931	2.829	1.535	2.972
1989	-0.777	5.079	-1.363	5.671	3.429	3.288	4.287	6.812	0.693	2.620	0.693	4.741	1.353	2.714
1990	-4.361	3.180	-2.912	5.848	-3.705	11.656	-0.567	6.756	-1.979	4.925	-2.236	4.509	-1.600	5.819
1991	2.941	3.429	-1.136	3.220	-0.554	8.213	-0.660	6.483	-0.360	3.497	0.775	5.001	2.847	3.880
1992	-0.544	3.493	1.142	6.424	-2.880	5.436	-4.536	6.301	-0.817	2.904	0.320	5.976	1.334	3.416
1993	3.992	5.048	4.152	4.896	0.536	8.254	5.841	6.306	3.547	2.501	3.361	2.541	1.423	2.314
1994	-0.901	5.356	-2.053	4.713	1.430	4.691	0.214	4.415	-0.391	3.028	-0.242	4.212	-0.595	2.531
1995	0.036	3.760	0.655	3.945	-0.681	6.056	1.577	2.677	0.487	2.151	0.930	1.886	1.881	2.033
1996	2.086	3.929	2.663	7.453	-0.898	4.785	2.952	2.764	0.960	2.024	0.949	2.357	1.206	3.735
1997	-2.776	5.484	-3.858	6.147	-5.071	5.978	2.029	4.720	2.265	2.807	0.378	2.126	1.700	4.090
1998	-1.852	6.511	-4.375	7.324	-0.141	7.787	-4.229	6.704	0.926	7.072	-1.446	5.351	-0.683	7.023
1999	2.612	4.002	-0.063	3.965	1.342	6.431	3.141	4.298	1.643	2.555	2.895	3.333	0.501	3.591
2000	-2.528	10.849	-1.225	11.608	-1.258	4.671	-0.285	4.568	0.712	2.397	-0.638	3.323	-0.982	4.780
2001	-2.217	6.577	-3.450	5.639	-0.997	4.655	-1.799	5.669	-2.645	5.953	-2.035	7.193	0.636	6.977
2002	-1.704	3.451	-0.322	6.328	-1.294	3.846	-4.120	6.390	-2.752	5.651	-2.773	5.205	-1.531	5.975
2003	2.064	5.886	3.615	4.453	2.771	3.851	4.382	5.523	2.034	4.204	2.844	4.697	3.732	3.940
2004	0.245	4.021	-0.427	3.611	1.968	5.770	2.547	5.892	1.057	2.570	0.920	2.950	1.405	3.759
2005	-0.631	4.147	0.517	4.234	3.463	2.747	3.593	4.778	2.084	2.546	0.577	3.589	0.239	3.451
2006	1.494	4.118	1.756	5.871	-2.008	4.643	1.941	3.373	2.113	2.750	0.479	2.896	1.118	3.202
2007	-0.077	4.428	-0.733	5.412	-2.069	3.763	0.063	3.204	0.589	3.709	-1.245	3.334	-0.507	3.343
2008	-9.489	9.506	-10.074	12.461	-4.272	7.138	-8.151	10.043	-4.308	6.529	-6.880	7.753	-5.452	9.126
2009	3.757	5.982	4.223	4.552	0.742	6.351	2.086	5.688	1.530	5.623	2.817	6.024	2.658	8.389
2010	0.134	6.417	2.113	5.389	0.485	6.037	0.592	5.588	1.054	2.683	1.244	4.116	1.487	6.302
2011	-3.435	5.325	-3.480	5.321	-0.519	3.131	-3.339	5.031	-1.749	3.469	-2.105	3.315	-1.034	5.780
2012	-1.930	5.098	-3.077	5.446	1.340	5.421	0.197	4.857	0.478	2.269	-0.033	3.840	1.006	3.705
2013	-2.069	6.553	-3.309	4.453	3.317	5.481	1.586	3.101	1.111	1.704	0.990	2.906	2.598	2.799
2014	-2.277	3.974	-1.879	5.781	0.997	2.936	-0.869	2.796	0.729	1.218	-1.474	2.103	-0.007	3.300
2015	-0.885	3.826	-2.989	3.135	0.581	3.784	-1.552	3.333	0.122	2.935	-1.424	2.706	-1.149	3.751
2016	0.426	3.435	3.078	4.894	0.326	4.916	0.820	3.855	0.407	1.823	-0.095	2.996	0.738	4.730

Notes: This table reports mean and standard deviation and number of equity returns in the sample by year and country. More precisely, these statistics are based on the universe of all equity returns that satisfies our screening procedure. The mean and standard deviation of returns are all in percentage based on local currency.

Figure 2: Correlation between Oil-equity and Exchange Rate



B A Simple Model

We assume that there is a continuum of measure 1 investors, indexed by $j \in [0, 1]$, and three assets: interest-bearing domestic bonds, i; risky domestic equity, r; and interest-bearing foreign bonds, i^*.[14] We assume that investors hold potentially heterogeneous beliefs regarding the market returns. Following Alvarez, Atkeson, and Kehoe (2002), Vissing-Jørgensen (2002), Guvenen and Kuruscu (2006) and Zervou (2013), we assume that asset markets are segmented such that a measure m of investors do not have access to risky domestic equity.[15] However, all investors potentially have access to both domestic and foreign interest-bearing bonds.[16]

We assume that all investors receive a signal, Ω_t^j, regarding the expected excess return on equity, $r_{t+1} - i_t$.[17] For an investor $j \in [0, m)$, Ω_t^j is irrelevant for domestic portfolio allocations since these investors do

[14]For simplicity, we assume that $i^* > \mathsf{E}_t^i[r_{t+1}^*]$ for all investors j.

[15]We assume that m is a constant fraction for the purposes of our exposition but we return to this assumption in our empirical analysis below.

[16]One conceptual method to view this assumption is that some investors are prohibited from holding equities. Examples of such investors are bond mutual funds, bond index funds, pension funds or institutional investors with regulatory (i.e., VaR) constraints.

[17]Given risk-neutrality, without loss of generality we assume that Ω_t^j is an index such that $\Omega_t^j \in [0, 1]$.

Figure 3: Cumulative Three-pass Oil-equity Factor by Country

not participate in the equity market. However, for an investor, $j \in [m, 1]$, Ω_t^j is informative, as the investor can construct a portfolio of the two assets to invest until period $t + 1$:

$$\gamma_t^j(1 + i_t) + (1 - \gamma_t^j)(1 + \mathsf{E}_t^j[r_{t+1}|\Omega_t^j]), \tag{13}$$

where γ_t^j and $1-\gamma_t^j$ are the portfolio shares on interest-bearing bonds and risky equities, respectively, and Ω_t^j is the information set of agent $j \in [m, 1]$ over the expected returns for equity. To account for short-selling, we assume that $\gamma_t^j > \underline{\gamma}$, where $\underline{\gamma} < 0$ is a leverage constraint on short-selling.[18] A risk-neutral investor j should, in theory, hold whichever asset he or she believes has the highest expected return depending on Ω_t^j, thus $\gamma_j^t = \{\underline{\gamma}, 1\}$. This is equivalent to assuming a threshold for the information index, $\Omega_t^j > \bar{\Omega}$ to determine $\gamma_t^j = \underline{\gamma}$.

Because markets are segmented, we do not impose that the expected market rates of return for i_t and r_{t+1} are equal. In an environment with a continuum of agents with hetergeneous beliefs over prices, there is no theoretical reason to impose $\gamma_t^j = 1\ \ \forall j$.

[18] We note that this restriction not overly restrictive and allows short-selling in a particular asset since there is no requirement that $\gamma_t^j \geq 0$.

The availability of a foreign bond and currency exchange yields a standard no-arbitrage condition for expected future spot exchange rates for each investor j who equates in expectation the return on a domestic portfolio or a foreign investment. Since all investors are risk-neutral then a no-arbitrage condition yields:

$$\mathsf{E}_t^j[\frac{[S_{t+1}](1+i_t^*)}{S_t}] = \begin{cases} (1+i_t) & \text{if } \Omega_t^j < \bar{\Omega} \\ \underline{\gamma}(1+i_t) + (1-\underline{\gamma})(1+E_t^j[r_{t+1}]) & \text{otherwise.} \end{cases} \tag{14}$$

Two features of Equation (14) stand out. First, except in pathological cases, agents with different information sets will have different beliefs regarding $\mathsf{E}_t^j[S_{t+1}]$. Second, in this simple model, the expectations of the future spot rate depend on the distribution of beliefs over domestic equity returns and not the market segmentation. Thus, trading in spot exchange rate markets may provide an outside opportunity for trading on expected domestic equity returns even for an investor $j \in [0, m)$ who is otherwise unable to trade equities directly.

B.1 Market Expectations

While individual investors may have heterogenous beliefs over domestic equity returns and, by extension, the no-arbitrage value of the future spot exchange rate, there is, ex post, only one realization of S_{t+1}. Thus, S_{t+1} summarizes the information heterogeneity and portfolio allocations of investors. From the perspective of an investor (or econometrician), the market aggregates the information of market participants.

We define the average expectation of the future spot exchange rate as $\mathsf{E}_t[S_{t+1}] = \int_0^1 \mathsf{E}_t^j[S_{t+1}]dj$. Similarly, we define the average expectation of a variable x as $\mathsf{E}_t[x] = \int_0^1 \mathsf{E}_t^j[x]dj$ with the exception of the future equity return, $\tilde{\mathsf{E}}_t[r_{t+1}] = \int_m^1 \mathsf{E}_t^j[r_{t+1}]dj$.[19] Simple rearrangement of Equation (14) conditioning on market segmentation (to account for the trading restrictions) yields an average expected future spot exchange rate:

$$\mathsf{E}_t[S_{t+1}] = \mathsf{E}_t\left[m(1+i_t) + (1-m)\big(\rho_t(1+i_t) + (1-\rho_t)(\underline{\gamma}(1+i_t) + (1-\underline{\gamma})(1+\tilde{\mathsf{E}}_t[r_{t+1}]))\big)\right]\frac{S_t}{(1+i_t^*)}, \tag{15}$$

where $\rho_t \in [0, 1]$ is the fraction of potential domestic equity investors, $j \in [m, 1]$, for whom $\Omega_t^j < \bar{\Omega}$. Rearranging the term inside the expectation yields and writing $\mathsf{E}_t[\tilde{r}_{t+1}] = \mathsf{E}_t[\tilde{\mathsf{E}}_t[r_{t+1}]$:

$$\begin{aligned} \mathsf{E}_t[S_{t+1}] &= \mathsf{E}_t\left[\mu_t(1+i_t) + (1-\mu_t)(1+\mathsf{E}_t[\tilde{r}_{t+1}])\right]\frac{S_t}{(1+i_t^*)} \\ \mu_t &= m + (1-m)(\underline{\gamma} + \rho_t(1-\underline{\gamma})). \end{aligned} \tag{16}$$

The source of any underlying variation in μ_t comes from uncertainty over the share of potential equity investors j for whom the information signal is $\Omega_t^j < \bar{\Omega}$. The source of variation in $\mathsf{E}_t[S_{t+1}]$ is variation in μ_t and the expected equity returns. Importantly, the market expectation of the future spot rate, except in degenerate cases, does not equal the individual no-arbitrage expectations. Thus, an investor $j \in [0, m)$

[19] The difference in the expectations given our assumption of a continuum of agents is purely expositional because the density of the information signal is not conditioned on m.

whose information yields an expectation of an excess equity return will prefer the RHS of Equation (14) as $\mathsf{E}_t[S_{t+1}]$ is greater than the no-arbitrage expected value of $\mathsf{E}_t^j[S_{t+1}]$ given by Equation (14).