# Carry Trade, FX Liquidity, and Commodity Price Shocks*

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ABSTRACT [TO CHANGE]

This paper helps explain fluctuations in the high-yield currencies involved in the carry trade. We show that commodity price shocks drive variations in these currencies but only during episodes of financial distress, as measured by high funding illiquidity, financial uncertainty, or currency volatility. This asymmetric relation is induced by the direct responses of currencies to commodity price shocks rather than by an adjustment in a country's macroeconomic fundamentals. Further, we provide evidence that this asymmetry relates to changes in financial conditions rather than to changes in the business cycle. Overall, these findings contribute to our understanding of the downside risk faced by carry traders.



JEL Codes: C32, F31, G15

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# 1 Introduction

This paper analyzes the asymmetric impact of commodity prices on the carry trade performance across foreign exchange (FX) liquidity conditions. The carry trade is the strategy of borrowing in low-yield currencies and investing in high-yield currencies. One strand of the literature highlights that the performance of this strategy relates positively to commodity price shocks (Ready, Roussanov, and Ward, 2017), whereas a separate strand shows that high-yield currencies deliver large losses during liquidity dry-outs in the FX market (Mancini, Ranaldo, and Wrampelmeyer, 2013). The contribution of this paper is to combine these two channels in a unified framework and to demonstrate that carry trade returns are substantially more exposed to commodity price shocks when FX liquidity decreases.[1]

There are two main implications from our analysis. First, this paper contributes to our comprehension of why carry trade returns vary with the level of FX liquidity. The weak performance of high-yield currencies during liquidity dry-outs can be seen as a direct consequence of adverse commodity price shocks. Second, carry trade investors become exposed to the risk of commodity prices during bad financial conditions, as FX market illiquidity tends to peak during times of financial turbulence.[2] As a result, the compensation that investors demand to incur this commodity price risk contributes to our comprehension of the carry trade risk-return tradeoff and, more generally, of the forward-premium puzzle (Engel, 1984; Fama, 1984).

Our motivation for investigating commodity prices and FX liquidity jointly relies on the following elements. The first one is that currencies of countries which specialize in exporting commodities are typically those that deliver higher yields. As carry traders tend to invest in these (commodity) currencies, carry trade returns should become sensitive to unexpected changes in commodity price changes. Empirically, Bakshi and Panayotov (2013) find that commodity price shocks help predict future carry trade returns, while Ferraro, Rogoff, and Rossi (2015) and Ready et al. (2017) show that currencies of commodity-exporting countries appreciate

[1]More broadly, this paper also relates to the literature linking carry trade returns with exposure to global economic/financial risk factors, such as consumption growth risk (Lustig and Verdelhan, 2007), consumption habits (Verdelhan, 2010), the dollar factor and systematic FX volatility Lustig, Roussanov, and Verdelhan (2011); Menkhoff, Sarno, Schmeling, and Schrimpf (2012), liquidity risk (Mancini et al., 2013), global imbalance risk (Della Corte, Riddiough, and Sarno, 2016), and crash risk (Chernov, Graveline, and Zviadadze, 2018).

[2]Existing empirical evidence indicate that the carry trade tends to deliver large and negative returns as financial conditions deteriorate (Brunnermeier, Nagel, and Pedersen, 2008; Menkhoff et al., 2012).

(depreciate) after a positive (negative) commodity price shock.[3] Existing studies, however, ignore variations of this relation across different FX liquidity conditions, which may mask some important asymmetries in the impact of commodity price shocks on high-yield currencies (and thus on the carry trade return).

The second element of our motivation is that the carry trade strategy tends to yield severe losses when FX liquidity dries out. Empirically, Mancini, Ranaldo, and Wrampelmeyer (2013) document that the unwinding of carry trades (i.e., high-yield currencies are sold and low-yield currencies are bought) is typically associated with a drop of FX liquidity, which, in turn, implies a higher price impact of trades. A drop in FX liquidity should thus amplify the depreciation of high-yield currencies (and the appreciation of low-yield currencies) in the case of shocks inducing the unwinding of the carry trade. This literature, however, remains silent about the nature of the fundamental shocks triggering such changes in carry trade positions. This paper fills this gap by exploiting unexpected changes in commodity prices as a relevant source of shocks.

In this context, carry traders are likely to close their currency positions following an unanticipated decline of commodity prices, and we thus expect these trades to induce greater currency movements when FX liquidity drops. This implies that an adverse commodity prices shocks should lead to a stronger deterioration of the carry trade performance when the FX market becomes more illiquid. We investigate and test this prediction through the lens of a smooth transition-structural vector autoregression model (ST-SVAR). In our specification, FX liquidity shapes the relation between carry trade performance and commodity price shocks in several dimensions. On the one hand, the effect of commodity price shocks on the carry trade performance is conditioned on the degree of FX market liquidity, as captured by a high FX illiquidity regime and a low illiquidity regime. This environment allows us assessing whether the effect differs across FX liquidity conditions. On the other hand, the effect of commodity price shocks on the carry trade performance within a regime is obtained by controlling for the degree of FX liquidity. This specification ensures that commodity price shocks are uncorrelated to unanticipated changes in FX liquidity. Hence, commodity price shocks are not contaminated by the

[3] Amano and Van Norden (1995, 1998), Chen and Rogoff (2003), and Ricci, Milesi-Ferretti, and Lee (2013) document the existence of cointegration relations between exchange rates and commodity prices. On the theoretical side, Ready et al. (2017) design a general equilibrium model that rationalizes the positive relation between high-yield currencies and commodity prices.

behavior of investors jointly trading commodities and currencies, who may thereby change their positions in both markets when FX liquidity conditions vary.[4]

We perform our analysis using monthly data covering the 1986.01 to 2016.12 period. The computation of carry trade returns net of transaction costs, using the currencies of 15 developed countries, follows Menkhoff et al. (2012). The commodity prices are computed from the CRB Spot Commodity Index, following Bakshi and Panayotov (2013). The FX liquidity is measured as the systematic FX (il)liquidity proposed by Karnaukh, Ranaldo, and Söderlind (2015). We define a "low liquidity" regime as when FX illiquidity is in the top quintile and refer to "normal times" otherwise.

Our main result is that the relation between commodity price and carry trade returns is asymmetric and varies across levels of FX liquidity. The proposed econometric approach allows us to evaluate currency responses by conditioning the analysis on a given FX liquidity regime. Unexpected changes in commodity prices drive a large portion of carry trade returns but only during periods of low FX liquidity. The carry trade delivers a cumulative return of 0.52% over 6 months as commodity prices increase by 1% in periods of low FX liquidity. In comparison, the cumulative return is only 0.05% in normal times. Based on a variance decomposition, commodity price shocks explain 10% of the 6-month carry trade returns when FX liquidity is low, but only 0.3% in normal times. Fluctuations in commodity prices thus play a primary role in explaining the performance of the carry trade, in particular when FX liquidity evaporates.

We disentangle the performance of the carry trade by separately investigating the high and low-yield currency portfolios. In periods of low FX liquidity, the explained variation increases to 37.4% for the high-yield currencies (top quintile portfolio) but only increases to 4.7% for for low-yield currencies (bottom quintile portfolio). The effect is thus concentrated within the set of high-yield currencies. This finding is consistent with the view that the high-yield currency portfolio is particularly exposed to commodity price shocks because it regularly contains currencies of commodity exporters (e.g., Australia, Canada, New Zealand, Norway). Hence, high-yield currencies are most sensitive to unanticipated changes in commodity prices. To

[4] For example, the profitability of the carry trade and commodity prices have jointly increased over the period 2002-7 and decreased in 2008, as the latest financial crisis unfolded. Such co-movement has become more relevant over the recent years, in the light of the increasing commodity market financialization (Cheng, Kirilenko, and Xiong, 2014).

provide additional support that commodity price shocks affect carry trade returns through the currencies of commodity exporters, we consider a counterfactual exercise that computes carry trade returns excluding major commodity currencies.[5] We find that the returns of the high-yield currency portfolio become substantially less sensitive to commodity price shocks once commodity currencies are excluded.

The results are robust to the consideration of various FX liquidity proxies. We alternatively condition the analysis on the CBOE option-implied volatility index (VIX), the TED spread, and the level of global FX volatility, as measured by the J.P. Morgan FX Volatility Index for a basket of G7 currencies. All three measures are strongly and negatively correlated with liquidity in the currency market (Mancini et al., 2013; Karnaukh et al., 2015). The TED is a supply-side determinant of FX liquidity, the VIX rather reflects the demand side, while FX volatility increases transaction costs due to higher adverse selection and inventory risk. The results remain qualitatively similar when conditioning on these alternative FX illiquidity proxies. We also reproduce the analysis with the British Pound and the Euro, instead of the US dollar, as the reference currency. Commodity price shocks continue to exert a large and significant influence on the appreciation of high-yield currencies, thus providing evidence that the relation between the US dollar and commodity prices is not the driver of the results.

Overall, our results shed light on the structural and asymmetric relation between commodity prices and currencies involved in the carry trade. We provide evidence that a substantial part of high-yield currency returns during periods of low FX market liquidity is due to unexpected shocks in commodity prices. Carry traders are thus exposed to the performance of the commodity market. This finding suggests that commodity prices contain insightful information that FX market participants can exploit for hedging or speculation purposes.

The remainder of the paper is organized as follows. Section 2 computes the carry trade returns and presents the data on FX liquidity and commodity prices. Section 3 describes our econometric framework, while Section 4 discusses our main empirical findings regarding the structural relation between commodity prices and currency portfolios. Section 5 presents extensions and robustness checks. Section 6 concludes the paper.

[5] Following Ready et al. (2017), we consider the major commodity currencies to be the Australian dollar, the Canadian Dollar, the New Zealand dollar, and the Norwegian krone.

# 2 Data

This section presents and discusses the data on currencies, FX liquidity, and commodity prices that we employ in our empirical study.

## 2.1 Carry trade returns

We first describe the currency data used for computing returns on the carry trade, then present the construction of portfolios and associated returns, and discuss the performance from the perspective of a US investor.

### 2.1.1 Currency spot and forward rates

We use monthly data for spot exchange rates and 1-month forward exchange rates versus the US dollar over the period from January 1986 to December 2016. Our sample consists of 15 developed countries: Australia, Belgium, Canada, Denmark, Euro area, Finland, France, Germany, Italy, Japan, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom. The Euro series starts in January 1999. We exclude the Euro area countries after this date and keep only the Euro series. The data are obtained from Barclays Bank International (BBI) and Reuters. All series are retrieved via Datastream.

### 2.1.2 Net currency returns

Following the literature, we denote the logarithm of the spot and forward exchange rates as $s$ and $f$, respectively, in units of foreign currency per US dollar. An increase in $s$ means a depreciation of the foreign currency.

In the absence of transaction costs, the monthly log (excess) return on buying the foreign currency $k$ in the forward market and then selling it in the spot market after one month is:

$$rx_{t+1} \equiv i_t^k - i_t - \Delta s_{t+1} \approx f_t - s_{t+1} \tag{1}$$

under the covered interest rate parity condition, where $i^k$ and $i$ denote the 1-month foreign and US dollar nominal risk-free rates.

Our analysis considers returns for currency positions adjusted for transaction costs. We use bid-ask quotes for spot and forward contracts and compute the investor's actual realized net returns. Following Menkhoff et al. (2012), we assume that bid-ask spreads are deducted from returns whenever a currency enters and/or exits a portfolio. The net return for a currency that enters a portfolio at time $t$ and exits the portfolio at the end of the month is computed as $rx^l_{t+1} = f^b_t - s^a_{t+1}$ for a long position. The investor buys the foreign currency or equivalently sells the dollar forward at the bid price ($f^b_t$) in month $t$, and sells the foreign currency or equivalently buys dollars at the ask price ($s^a_{t+1}$) in the spot market in month $t+1$. Conversely, the net return is $rx^s_{t+1} = -f^a_t + s^b_{t+1}$ for a short position.

A currency that enters a portfolio but stays in the portfolio at the end of the month has a net return of $rx^l_{t+1} = f^b_t - s_{t+1}$ for a long position and $rx^s_{t+1} = -f^a_t + s_{t+1}$ for a short position, whereas a currency that exits a portfolio at the end of month $t$ but already was in the current portfolio the month before $(t-1)$ has a return of $rx^l_{t+1} = f_t - s^a_{t+1}$ for a long position and $rx^s_{t+1} = -f_t + s^b_{t+1}$ for a short position. The return of a currency that remains in the portfolio is given by (1). We assume that the investor has to establish a new position in each single currency in the first month (January 1986) and that she has to sell all positions in the last month (at the end of December 2016).

### 2.1.3 Currency portfolios

At the end of each month $t$, we allocate currencies to five portfolios based on their forward discounts $f_t - s_t$. The covered interest rate parity implies that sorting on forward discounts is equivalent to sorting on interest rate differentials. Portfolio 1 contains currencies with the smallest forward discounts (or lowest interest rates) and portfolio 5 contains currencies with the largest forward discounts (or highest interest rates). We rebalance portfolios at the end of each month. Returns for portfolio 1 (i.e., the funding currencies in the carry trade) are adjusted for transaction costs in short positions, whereas portfolios 2–5 (investment currencies) are adjusted for transaction costs in long positions. Finally, we compute the log currency return of a portfolio by taking the (equally weighted) average of the log returns of each currency in the portfolio.

Table I provides descriptive statistics for the five portfolios. All exchange rates and returns are reported in US dollar, and the return statistics are annualized. The Sharpe ratio is defined as the ratio of the annualized mean to the annualized standard deviation. We also report the return difference between the high-yield portfolio (P5) and the low-yield portfolio (P5), which corresponds to a long-short carry trade portfolio (P5-P1) obtained from borrowing money in low interest rate countries and investing in high interest rate countries. Table I shows that average returns increase when moving from portfolio 1 to portfolio 5. After taking into account bid-ask spreads, the zero-cost strategy that goes long in the high-yield portfolio and short in the low-yield portfolio delivers a return of 4.97% and a Sharpe ratio of 0.45. These results are in line with the existing literature (Lustig and Verdelhan, 2007; Lustig et al., 2011; Menkhoff et al., 2012).

Table I [about here]

## 2.2 FX liquidity and commodity prices

The level FX liquidity is a primary dimension of this study, based on the evidence that the carry trade incurs severe losses when FX liquidity dries out (Mancini et al., 2013). Our measure of FX liquidity is the systematic FX (il)liquidity index proposed by Karnaukh et al. (2015). This measure of systematic illiquidity is the average level of illiquidity of 33 currency pairs, mostly based on bid-ask spreads. This index reflects the global level of FX illiquidity, as it captures the average transaction costs of the most traded currencies. The series is obtained from Angelo Ranaldo's website.[6]

Our measure of commodity prices is the CRB Spot Commodity Index (Raw Industrials subindex), available from Datastream. The choice of this index follows the existing literature. In particular, Bakshi and Panayotov (2013) show that this subindex has a forecasting power for future carry trade performance that is similar to the forecasting power of funding liquidity and FX volatility, which are two well-known drivers of carry trade returns. Furthermore, Ready et al. (2017) compare various commodity price sub-indices and find that fluctuations in the commodity prices of the industrial category are most related to exchange rate movements.

[6] Our results remain similar whether or not we include emerging countries. For convenience, we consider the original (although updated) series available publicly.

## 2.3 Descriptive analysis

Figure 1 illustrates how the performance of the currency portfolios varies over time. Panel A shows cumulative returns for the carry trade portfolio for the sample of developed countries. The Panel B disentangles the performance of the long (P5) and the short (P1) portfolios. The profitability of the carry trade in developed countries comes mostly from the long exposure to high-yield currencies.

Figure 1 [about here]

Panel B of Table I reports the correlation coefficients between currency portfolio returns and the variables of interest. The correlation between carry trade returns and commodity index' returns equals 0.27. The positive correlation is strongest for the portfolio of high-yield currencies (0.40), but becomes negative for the portfolio of low-yield currencies (-0.16). The positive correlation for high-yield currencies is consistent with the fact that the carry trade strategy typically implies long exposure to currencies of countries that specialize in exporting commodities. Panel B also indicates that currency portfolio returns move negatively with the level of systematic FX illiquidity. The carry trade strategy appears to be the most sensitive to the liquidity conditions prevailing in the FX market.

Table II provides an analysis that separates periods of high FX illiquidity (top quintile of the systematic FX illiquidity measure) and of low illiquidity (remaining observations). Panel A shows that the carry trade performs poorly in high illiquidity periods, as the return is on average -11.83%. This is consistent with Brunnermeier et al. (2008), who show that periods of constrained liquidity coincide with reductions in carry positions and increases in carry trade losses. We find that negative returns in commodities also coincide with times of high FX illiquidity.

Panel B indicates that the correlation between carry trade returns and commodity returns strengthens when liquidity dries out. The correlation between carry trade returns and the commodity index' returns is 0.54 when FX illiquidity is high, while it is only 0.08 during times of low illiquidity. These results suggest that fluctuations in commodity prices should be an important determinant of the carry trade performance, especially when the FX market is relatively illiquid. Further, the correlation between FX illiquidity and commodity returns becomes more negative in high illiquidity times. It is thus essential to control for FX liquidity conditions when assessing the effect of commodity price changes on the carry trade performance.

Table II [about here]

Overall, these descriptive statistics indicate that the performance of the carry trade is exposed to variations in commodity prices and in FX liquidity. It is thus critical to adequately control for changes in FX liquidity in the examination of the structural relation between carry trade returns and commodity price fluctuations. Further, the relation appears to strengthen with the degree of FX illiquidity. Based on this motivation, we now propose an econometric model to assess the impact of commodity price shocks on the carry trade performance under different liquidity conditions.

# 3 Econometric Framework

In this section, we present the empirical approach to evaluate the structural relation between commodity prices and the performance of the carry trade strategy. We first discuss the econometric specification, and we then elaborate on the estimation method.

## 3.1 Specification

We specify a Smooth Transition - Structural Vector Autoregression (ST-SVAR) to assess the dynamic effects of commodity price shocks on the performance of the carry trade strategy. Importantly, these effects are affected by the liquidity on the FX market in two dimensions. First, the effects are specific to the FX liquidity conditions, namely a high-illiquidity regime (regime H) and a low-illiquidity regime (regime L). Second, the effect within a regime controls for the impact of FX liquidity conditions on commodity prices and the carry trade performance.

We consider a system that admits a smooth transition across the two illiquidity regimes. We denote by $F_t$ the transition function from the low-illiquidity regime (L) to the high-illiquidity regime (H), which is given by:

$$F_t = \frac{1}{1 + \exp[-\gamma(z_t - \delta)]}, \tag{2}$$

where the state variable $z_t = \frac{\ell_t - \mu_\ell}{\sigma_\ell}$ corresponds to the standardized measure of FX illiquidity $\ell_t$ discussed in Section 2 (where $\mu_\ell$ and $\sigma_\ell$ are the mean and standard deviation of $\ell_t$). The parameter $\gamma$ determines the speed of transition across regimes, with $\gamma > 0$. The parameter $\delta$ fixes the threshold between the two regimes. Equation (2) implies that the effects of commodity price shocks on the performance of the carry trade strategy are specific to the illiquidity regime.

The vector $X_t = \begin{pmatrix} \ell_t & p_t & q_{CT,t} \end{pmatrix}'$ contains the variables of interest, where $\ell_t$ is the illiquidity on the FX market, $p_t$ is the logarithm of commodity prices, and $q_{CT,t}$ captures the logarithm of the carry trade performance (long P5, short P1).[7] The set of variables $X_t$ is governed by regime-specific contemporaneous interactions $\Theta_s$ and dynamic feedbacks $\Phi_s$, with $s = L, H$. Specifically, we propose the following ST-SVAR process:

$$X_t = \left( \Phi_{L,0} + \sum_{i=1}^{p} \Phi_{L,i} X_{t-i} \right) (1 - F_{t-1}) + \left( \Phi_{H,0} + \sum_{i=1}^{p} \Phi_{H,i} X_{t-i} \right) F_{t-1} + U_t, \tag{3}$$

$$\Omega_t = (\Theta_L \Theta_L') (1 - F_{t-1}) + (\Theta_H \Theta_H') F_{t-1}. \tag{4}$$

Equation (3) specifies the dynamics of the variables $X_t$, whereas Equation (4) describes the scedastic structure of the statistical innovations $U_t$. The vector $U_t$ captures the statistical innovations, which are assumed to be normally distributed, $U_t \sim N(0, \Omega_t)$.

The lower triangular matrix $\Theta_s^{-1}$ captures the contemporaneous interactions across the variables in regime $s$, where $s = L, H$. The ordering of the variables in $X_t$ implies that the liquidity conditions, $\ell_t$, are predetermined. Also, the commodity prices, $p_t$, are affected by the contemporaneous liquidity conditions, $\ell_t$, but not by the current performance of the carry trade strategy, $q_{CT,t}$. Finally, the performance of the carry trade, $q_{CT,t}$, is influenced by the current liquidity conditions, $\ell_t$, and commodity prices, $p_t$. These current interactions imply that the liquidity conditions, $\ell_t$, affect both commodity prices, $p_t$, and the carry trade performance, $q_{CT,t}$. This accords with the fact that commodity markets are highly "financialized", so that it is conceivable that carry traders are active in both commodity and foreign exchange markets. As such, both markets are likely to respond to the same underlying forces, which are related to the liquidity conditions. We also assume that the elements in the second column of the lower

[7] We alternatively consider the logarithm of the performance of P1 and P5 separately to analyze the impact of commodity price shocks on the low and high-yield currency portfolios.

triangular matrix $\Theta_s$ capture the impact responses of the variables to a commodity price shock. In this context, a commodity price shock does not instantaneously affect the liquidity conditions, although it immediately alters the carry trade performance.[8]

The unrestricted matrices $\Phi_{s,i}$ (where $i = 1, \ldots, p$) capture the dynamic feedbacks. This allows the possibility that each variable of interest has forecasting power on all the other variables, and, as such, it admits bi-directional Granger causality between all pairs of variables. The feedback matrices $\Phi_{s,i}$ shapes the dynamic responses of the different variables following a commodity price shock. Also, the unrestricted vector $\Phi_{s,0}$ includes the intercepts. In addition, system (3)–(4) assumes that the transition function between the high-illiquidity and low-illiquidity regimes is dated in $(t-1)$ to avoid simultaneous interactions between the variables of interest included in $X_t$ and the state variable $z_t$.

Finally, the ST-SVAR allows to compute the dynamic responses of all the variables of interest following the various shocks occurring in state $s$. In turn, these responses are used to construct two measures that are economically meaningful. First we compute the dynamic elasticities as the cumulative return of the carry trade strategy over $k$ months following a commodity price shock that generates an instantaneous 1% increase in commodity prices. Analyzing the elasticity offers the advantage of adequately comparing the reactions of the carry trade performance across illiquidity regimes; that is, we rule out the case that a stronger carry trade response in a certain regime is the mechanical consequence of a larger commodity price shock in that regime.

The second measure relates to variance decomposition. We determine the fraction of the forecast error variance that is attributable to commodity price shocks. We can thus assess the contribution of commodity price fluctuations in explaining the performance of the carry trade. To ease the interpretation, the dynamic elasticities and the variance decomposition are constructed under the assumption that the FX market remains in the same illiquidity regime over the horizon under consideration.

[8]Commodity demand shocks may differ from commodity supply shocks (Kilian, 2009). However, given the focus of our study, disentangling the source of these shocks is beyond the scope of this paper.

## 3.2 Estimation

Admittedly, the joint estimation of all parameters involved in the ST-SVAR is challenging because this system is highly non-linear in the parameters. To avoid this difficulty, we follow an approach that is closely related to that in Auerbach and Gorodnichenko (2012). This approach relies on the 'specific-to-general' strategy proposed by Granger (1993).

First, as suggested by Granger and Terasvirta (1993), we fix the parameters of the transition function (2), rather than estimating their values. We calibrate the speed of transition across regimes, $\gamma$, as well as the threshold, $\delta$, such that it leads to a relevant interpretation of the illiquidity regimes. To do so, the threshold is calibrated to $\delta = 0$, which implies that $F_t = 0.5$ when $z_t = 0$. In addition, $\gamma$ is determined such that $\Pr(F_t > 0.8) = 0.2$, which ensures that the FX market is about 20 percent of the time in the high-illiquidity regime. From this calibration and the state variable measuring the FX illiquidity, $z_t$, we construct the time series for $F_t$.

Second, we determine the lag structure of the ST-SVAR process. To do so, using the time series for $F_t$ we estimate Equation (3) by ordinary least squares (OLS) for alternative lag structures. We then apply the Akaike Information Criterion (AIC) to select the number of lags, $p$. The AIC indicates that $p = 2$, whether we consider the performance of the carry trade or of the individual currency portfolios (P1 and P5).[9]

Third, we use maximum likelihood (ML) to jointly estimate the coefficients involved in the two-regime system (3)–(4), namely, the parameters related to the contemporaneous interactions, $\Theta_s$, dynamic feedbacks, $\Phi_{s,1}$ and $\Phi_{s,2}$, and intercepts, $\Phi_{s,0}$. For this purpose, we apply the Monte Carlo Markov Chain (MCMC) procedure developed by Chernozhukov and Hong (2003). We also use the MCMC algorithm to construct the medians and the 90 percent confidence intervals for the dynamic elasticities and variance contributions in each illiquidity regime, as well as for the differences in elasticities and variance contributions between the two illiquidity regimes.[10]

[9] Note that the Bayesian Information Criterion (BIC) suggests that $p = 1$. Empirically, similar dynamic elasticities and contributions are obtained under $p = 1$ and $p = 2$. These results are available upon request.

[10] The MCMC procedure is explained in detail in Appendix A.

# 4 Main Results

In this section, we analyze the effects of commodity price shocks on the carry trade performance. We start by the unconditional case (i.e., obtained without conditioning on illiquidity regimes). We then discuss the main results of the paper, which relate to the effects conditional on different liquidity conditions.

## 4.1 Unconditional analysis

We begin by performing an unconditional analysis to explore the structural relation between commodity prices and the performance of the carry trade. This analysis relies on a restricted version of system (3)–(4), which involves a single regime. This unconditional case will prove to be a useful benchmark against which we can compare the results from the conditional specification associated with different liquidity conditions.

Figure 2 displays the results of this special case. Panel A shows the dynamic elasticities for the different currency portfolios of interest: the low-yield currency portfolio (P1), the high-yield currency portfolio (P5), and the carry trade (long P5, short P1). The effect of a commodity price shock on the performance of the carry trade strategy is both statistically and economically significant. The reported elasticity reveals that a 1% unanticipated increase in commodity prices induces an instantaneous carry trade return of 0.20%. The effect tends to increase with the horizon, reaching a peak of 0.44% after 5 months.

The carry trade is positively exposed to commodity price fluctuations because the response is larger for the high-yield (P5) than for the low-yield (P1) currency portfolio. Specifically, the elasticity of P5 is 0.45 at impact (0.75 at the peak), whereas the elasticity of P1 is 0.25 (0.31 at the peak). These results show that a long position in high-yield currencies combined with a short position in low-yield currencies is particularly profitable after an unexpected increase in commodity prices. This result controls for the effect of FX liquidity conditions on currency returns.[11]

Figure 2 [about here]

[11] We obtain similar dynamic elasticities when we replace the systematic FX illiquidity measure in the system by the TED or the CBOE option-implied volatility index (VIX), which are two alternative measures of FX liquidity (see Section 5.1).

Panel B exhibits the contribution of commodity price shocks in explaining the performance of the currency portfolios through a variance decomposition. Commodity price shocks explain 3.24% of the initial variation in the carry trade performance, and up to 9.32% at the 9-month horizon. Notably, the contribution is larger for high-yield currencies than for low-yield currencies. In particular, the explained variation is 13.25% for P5 (up to 25.02%), while the contribution is always smaller than 10% for P1. Overall, these findings reveal that commodity price shocks explain a substantial fraction of the variation in the carry trade performance, and that the effect concentrates among high-yield currencies.

This unconditional analysis provides relevant information about the exposure of the carry trade performance to commodity price shocks. Yet it likely masks the possibility that the reaction varies across different liquidity conditions. The main focus of this paper is to study, through a conditional analysis, the existence of an asymmetry underlying the relation between commodity prices and the performance of the carry trade strategy.

## 4.2 Conditional analysis by liquidity conditions

We now examine how the structural relation between commodity prices and the performance of the carry trade varies in periods of high versus low FX illiquidity. We carry this analysis by estimating the system (3)–(4) with two regimes to capture time-varying FX liquidity conditions.

Figure 3 and Table III report the dynamic elasticities by FX illiquidity regime for the currency portfolios. Panels A show a severe asymmetry in the relation between the carry trade performance and commodity prices across FX liquidity conditions. In times of high FX illiquidity, the elasticity is 0.20 at impact and increases monotonically to 0.60 after 12 months. In contrast, periods of low FX illiquidity imply lower elasticity (0.09 at impact), which decreases over time to become statistically insignificant after 7 months. Commodity price shocks thus have a large and long-lasting effect on the profitability of the carry trade when the FX market is relatively illiquid, whereas the effect is small and short-lived when the FX market is liquid. The difference in elasticities across FX liquidity conditions is sizable and, moreover, statistically significant for all horizons.

Figure 3 and Table III [about here]

We decompose the carry trade into the high-yield (P5) and the low-yield (P1) currency portfolios and respectively report the results in the Panels B and Cs of Figure 3 and Table III. The elasticity for high-yield currencies displays a pattern that is similar, in both liquidity regimes, to the elasticity obtained for the carry trade. That is, the magnitude and the dynamics of the elasticities greatly vary across FX liquidity conditions. High-yield currencies strongly react to unexpected fluctuations in commodity prices when FX liquidity dries out, and the reaction increases with the horizon. In contrast, elasticities for low-yield currencies are modest and about the same magnitude across the FX illiquidity regimes. Further, the difference in elasticities across FX liquidity conditions is never statistically significant. Hence, the relation between low-yield currencies and commodity prices does not appear to vary with the degree of liquidity in the FX market. In sum, these results suggest that a long position in high-yield currencies coupled with a short position in low-yield currencies is especially sensitive to unanticipated commodity price fluctuations during periods of high FX illiquidity. We provide evidence that this asymmetry in the relation between the carry trade performance and commodity prices arises exclusively from the conditional responses of high-yield currencies to commodity price shocks.

The results are qualitatively similar for the variance decomposition. Figure 4 and Table III present the percentages of fluctuations in the currency portfolio returns explained by commodity price shocks. Panels A indicate a marked asymmetry across liquidity regimes in the contribution of commodity price shocks to the carry trade performance. During high FX illiquidity, the explained variance is initially 2.69% and increases to 13.44% after 12 months. In comparison, the contribution is always smaller than 0.50% when the FX market remains relatively liquid. Moreover, the difference in the explained variance between FX liquidity regimes is statistically significant for all horizons.

Figure 4 [about here]

The contribution is both higher and more asymmetric for the high-yield than for low-yield currency portfolio. Commodity price shocks explain between 18.60% and 47.43% of the high-yield currency returns in times of high illiquidity, while the explained variance ranges between 4.67% and 9.65% in times of low illiquidity. The difference across FX liquidity conditions is always statistically significant. Hence, commodity price fluctuations constitute a critical determinant of the high-yield currency performance, especially when FX liquidity evaporates. In comparison, commodity price shocks explain a much lower fraction of the low-yield currency performance, regardless of the liquidity conditions. The contribution ranges from 4.69% to 8.21% during high illiquidity episodes and from 0.63% to 4.70% in low illiquidity periods. The difference in contributions across the FX liquidity conditions remains negligible and generally statistically insignificant.

Taken altogether, our findings demonstrate that the influence of commodity price fluctuations on the carry trade performance strongly varies across liquidity conditions. That is, the structural relation is asymmetric: the carry trade profitability is statistically and economically more exposed to changes in commodity prices as FX liquidity dries out. Importantly, the asymmetric relation between commodity prices and the carry trade performance is exclusively induced by a strong sensitivity of high-yield currencies to commodity price shocks when FX illiquidity is high, given that the reaction of low-yield currencies is about the same across FX liquidity conditions. Also, unexpected increases (decreases) in commodity prices explain a substantial part of the appreciation (depreciation) of high-yield currencies during episodes of low FX illiquidity. These findings help explain the carry trade reversals observed during times of high FX illiquidity, which tend to be associated with both a decline in commodity prices and a depreciation of high-yield currencies relative to the U.S. dollar.

# 5 Extensions

## 5.1 Alternative FX liquidity conditions

We now consider three alternative measures of FX illiquidity: the TED spread, the VIX, and the level of FX volatility.

### 5.1.1 Data

The TED spread captures the level of funding liquidity, which plays central role in the foreign exchange market. This measure is defined as the interest rate difference between 3-month euro interbank deposits (LIBOR) and 3-month US Treasury bills. A large spread is associated with reduced willingness of banks to provide funding in the interbank market and, therefore, with lower liquidity for currency traders. Consistent with this view, Mancini et al. (2013) provide evidence that that market-wide FX liquidity drops when traders' funding liquidity (proxied by the TED spread) decreases. Karnaukh et al. (2015) further show funding conditions are key supply-side determinants of FX liquidity.

The VIX reflects uncertainty and fear from the perspective of investors. Karnaukh et al. (2015) show that the VIX a demand-side factor of FX (il)liquidity. This is consistent with the evidence that movements of currencies are strongly related to variations in the VIX (see Brunnermeier et al. (2008); Menkhoff et al. (2012)). As investors tend to trade in the same direction, liquidity evaporates.

The level of FX volatility is given by the J.P. Morgan FX Volatility Index for a basket of G7 currencies (VXY), following Mancini et al. (2013). The series is a liquidity-weighted basket of 3-month at-the-money implied volatilities form FX options. This option-implied volatility measure captures the degree of uncertainty in the FX market for developed currencies. Transaction costs (bid-ask spreads) tend to increase with FX volatility due to higher adverse selection and inventory risk (Stoll 1978). Confirming this view, Mancini et al. (2013) and Karnaukh et al. (2015) show that FX liquidity decreases with FX volatility. The TED spread and the VIX are taken from the Federal Reserve Bank of St. Louis, while the FX volatility measure is extracted from Bloomberg.

### 5.1.2 Alternative controls

As a first robustness analysis, we examine the unconditional relation between the carry trade performance and commodity prices when we include these alternative measures into the system. The objective is to assess how commodity price shocks affect carry trade returns when we control for variations in these FX liquidity conditions.

Figure 5 shows that the impact of (unanticipated) commodity price movements on the carry trade performance remains very similar across the different specifications. That is, the profitability of the carry trade remains substantially exposed to commodity price shocks, whether we control for variations in the TED spread, the VIX, or the level of FX volatility.

Figure 5 [about here]

### 5.1.3 Alternative regimes

We now use these alternative FX liquidity proxies in the conditional analysis and report the results in Figure 6. We illustrate the conditional elasticities when the high illiquidity regime reflects a high TED spread in Panel A, a high VIX in Panel B, and a high level of FX volatility in Panel C. The results lend support to the baseline specification, in particular regarding the asymmetry across regimes. The impact of commodity price shocks on the carry trade performance is generally larger in periods of high FX illiquidity than in normal times. Although each of these proxies capture a different dimension of FX liquidity, the overall pattern is similar. Therefore, FX liquidity plays an essential role for understanding the relation between the performance of the carry trade and commodity prices

Figure 6 [about here]

## 5.2 Without commodity currencies

One channel that makes the carry trade payoff vary with commodity prices is the fact that the investment portfolio typically contains currencies of commodity exporters. An increase in commodity prices is good news for such countries, which thereby appreciates the currency, and increases the return of the carry trade. This effect is strongest when FX illiquidity is low.

This effect should weaken when we exclude the major commodity currencies from the analysis. To test this hypothesis, we compute the carry trade strategy without the Australian dollar, the Canadian Dollar, the New Zealand dollar, and the Norwegian krone. Figure 7 displays the results in this restricted case. The relation is no longer statistically or economically significant at impact (although it becomes significant after 2 months) and the asymmetry vanishes for the first 7 months. These results confirm that the presence of commodity currencies in the carry trade is a central determinant of the positive and asymmetric relation between high-yield currencies and commodity prices.

Figure 7 [about here]

### 5.3 Alternative reference currencies

The currency portfolios are from the perspective of a U.S. investor, as the US dollar is the reference currency. We now consider alternative reference currencies for robustness. Figure 7 shows the results for the high-yield currency portfolio when we replace the US dollar by the British Pound (Panel B) or the Euro (Panel C). We focus our analysis on the high-yield portfolio for two reasons. First, this portfolio is the primary driver of the strong and asymmetric relation between the carry trade performance and commodity prices. Second, the carry trade is US dollar-neutral strategy, as it involves a long and a short position in two portfolios whose reference currency is the US dollar. Hence, replacing the US dollar by another currency is not particularly informative for the long-short strategy.

The aim of this analysis is to ensure that the performance of high-yield currencies following a positive commodity price shock is not the mere reflection of a depreciation of the US dollar. This concern arises because, as most commodities are traded in US dollar, a depreciation of the US dollar makes commodities cheaper for non-US-dollar-based consumers, thereby increasing their demand for commodities. This demand effect thus induces a negative correlation between the US dollar and commodity prices. Figure 7 confirms that this channel is not the driver of our results. We find that commodity price shocks exert a large and significant influence on the appreciation of high-yield currencies, even when measured against the British Pound or the Euro.

## 6 Conclusion

In this paper, we examined the impact of commodity price changes on the carry trade performance and explored how this relation varies according to the degree of FX liquidity. To do so, we computed responses of currency portfolios following an unexpected change in commodity prices under different regimes to capture variations in the liquidity facing carry traders. Our analysis covers the performance of the carry trade based on 15 developed countries over the period from January 1991 to October 2016.

Our empirical findings reveal that the profitability of the carry trade strongly and statistically improve (deteriorate) following an unexpected increase (decrease) in commodity prices. The effect is concentrated in the portfolio of high-yield currencies and during periods of liquidity dry-outs. This result holds for various indirect measures of FX liquidity, as captured by the TED spread, the VIX, and the level of FX volatility. Moreover, the variance decomposition suggests that commodity price shocks explain a large fraction of the high-yield currency fluctuations, in particular when FX liquidity evaporates.

Overall, we find strong support for an asymmetric structural relation between commodity prices and the carry trade performance across FX liquidity conditions. Such an asymmetry helps enrich our understanding of the role of adverse commodity prices in the weak profitability of the carry trade during episodes of financial distress.

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# 7 Appendix A: MCMC Estimation Procedure

The MCMC procedure to estimate the dynamic elasticities and variance decompositions from the ST-SVAR process relies on a random-walk Metropolis-Hastings algorithm. This algorithm involves the following steps.

**Step 1**: The starting values $\Upsilon^{(0)}$ of the parameters are set as follows, where $\Upsilon = \begin{pmatrix}\Upsilon'_L & \Upsilon'_H\end{pmatrix}'$, $\Upsilon_s = \begin{pmatrix}\Phi'_{s,0} & vec(\Phi_{s,1})' & vec(\Phi_{s,2})' & vec(\Theta_s)'\end{pmatrix}'$, and $s = L, H$. First, the starting values of $\Phi_{s,0}$, $\Phi_{s,1}$, and $\Phi_{s,2}$ are obtained from OLS estimates. To do so, Equation (2) is rewritten as:

$$\begin{aligned} X_t = {} & \Phi_{L,0}[1 - F_{t-1}] + \Phi_{L,1}[X_{t-1}(1 - F_{t-1})] + \Phi_{L,2}[X_{t-2}(1 - F_{t-1})] \\ & + \Phi_{H,0}[F_{t-1}] + \Phi_{H,1}[X_{t-1}F_{t-1}] + \Phi_{H,2}[X_{t-2}F_{t-1}] + U_t, \end{aligned}$$

where the regressors (the terms in brackets) are computed from the observations of the variables incorporated in $X_t$ and the constructed time series for $F_t$ (as explained in the text). Second, the starting values of $\Theta_s$ are obtained from ML estimates. The log likelihood function corresponds to:

$$\log L = const - \frac{1}{2}\sum_{t=2}^{T}\log|\Omega_t| - \frac{1}{2}\sum_{t=2}^{T}U'_t\Omega_t^{-1}U_t,$$

where $U_t$ is evaluated by the OLS residuals, $\Omega_t = (\Theta_L\Theta'_L)(1-F_{t-1})+(\Theta_H\Theta'_H)F_{t-1}$, and $F_t$ is computed as above.

**Step 2:** The candidate parameter values are drawn from the following equation:

$$\Xi^{(n)} = \Upsilon^{(n)} + \upsilon^{(n)},$$

where $\Xi^{(n)}$ contains the candidate parameter values for the chain $n + 1$, $\Upsilon^{(n)}$ captures the current parameter values for the chain $n$, and $\upsilon^{(n)}$ includes shocks that are normally distributed with means zero and a variance-covariance matrix $\Sigma$, with $\Sigma = diag(\eta|\Upsilon^{(0)'}|)$ and $\eta > 0$.

**Step 3:** The current parameter values for the chain $n+1$ are generated as follows:

$$\Upsilon^{(n+1)} = \begin{cases} \Xi^{(n)} \text{ with probability } \wp = \min\{1, \exp[\log L(\Xi^{(n)}) - \log L(\Upsilon^{(n)})]\} \\ \Upsilon^{(n)} \text{ otherwise} \end{cases},$$

where $L(\Upsilon^{(n)})$ and $L(\Xi^{(n)})$ are respectively the values of the likelihood functions evaluated at the current parameter values of the chain and at the candidate parameter values.

**Step 4:** Steps 2 and 3 are computed for $n = 1, \ldots,$100,000. In this exercise, the coefficient $\eta$ is set such that the acceptance rate for the candidate draws $\wp$ is about 30 percent, as suggested in Gelman, Carlin, Stern, and Rubin (2004).

**Step 5:** The first 20,000 draws are burned. The remaining 80,000 draws are exploited to generate the parameter values $\Upsilon^{(n)}$, where $n =$ 20,001, ..., 100,000. Chernozhukov and Hong (2003) show that the median of $\Upsilon^{(n)}$ yields a consistent estimate of $\Upsilon$ under standard regularity conditions of ML estimators.

**Step 6**: The generated parameter values $\Upsilon^{(n)}$ are used to compute the dynamic responses as:

$$\Psi_{s,k}^{(n)} = \begin{pmatrix} I_3 & 0 \end{pmatrix} \begin{pmatrix} \Phi_{s,1}^{(n)} & \Phi_{s,2}^{(n)} \\ I_3 & 0 \end{pmatrix}^k \begin{pmatrix} \Theta_s^{(n)} & 0 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} I_3 \\ 0 \end{pmatrix},$$

where $I_3$ is the identity matrix of dimension 3 and $k = 1, \ldots, 12$. These responses capture the reactions of all the variables involved in $X_t$ occuring $k$ months after the various shocks in state $s$, where the shocks are positive and normalized to one standard deviation. It is assumed that the illiquidity regime remains the same over the entire horizon $k = 1, \ldots, 12$.

**Step 7**: The generated dynamic responses are employed to calculate the dynamic elasticities from the following ratio:

$$\varepsilon_{s,k}^{(n)} = \frac{e_3' \Psi_{s,k}^{(n)} e_2}{e_2' \Psi_{s,0}^{(n)} e_2},$$

where the column vector $e_i$ has a value one on the $i^{th}$ element and zero elsewhere. The term $e_3' \Psi_{s,k}^{(n)} e_2$ corresponds to the dynamic response of the performance for the portfolio of interest (i.e. carry trade, P1, or P5) $k$ months after a commodity price shock, while $e_2' \Psi_{s,0}^{(n)} e_2$ is the impact response of commodity prices to a commodity price shock. The elasticities measure the percentage variations of the performance of the portfolio arising $k$ months after a commodity price shock, where the latter leads to an instantaneous

1% increase of commodity prices in state $s$. The estimate of the dynamic elasticity at horizon $k$ in state $s$ corresponds to the median of $\varepsilon_{s,k}^{(n)}$. The 90 percent probability interval of the dynamic elasticity is obtained from the $5^{th}$ and $95^{th}$ percentiles of $\varepsilon_{s,k}^{(n)}$. Moreover, the estimate and the 90 percent confidence interval of the difference in the elasticities across the liquidity conditions are recovered form the median and the $5^{th}$ and $95^{th}$ percentiles of the difference $\varepsilon_{H,k}^{(n)} - \varepsilon_{L,k}^{(n)}$.

**Step 8**: The generated dynamic responses are also used to perform a variance decomposition. Specifically, the contributions of commodity price shocks in accounting for the fluctuations in the performance for the portfolio of interest can be computed as follows:

$$c_{s,k}^{(n)} = \left[ \frac{\sum_{j=1}^{k} \left( e_3' \Psi_{s,j}^{(n)} e_2 \right)^2}{\sum_{i=1}^{3} \left[ \sum_{j=1}^{k} \left( e_3' \Psi_{s,j}^{(n)} e_i \right)^2 \right]} \right] \times 100.$$

As before $e_3' \Psi_{s,k}^{(n)} e_2$ represent the dynamic responses of the performance for the portfolio of interest (i.e. carry trade, P1, or P5) following a commodity price shock. Also, $e_3' \Psi_{s,k}^{(n)} e_1$ and $e_3' \Psi_{s,k}^{(n)} e_3$ are the dynamic responses of the performance of the portfolio to the other shocks. The estimate of the percentage of the variance in the $k$-month forecast errors for the performance of the portfolio explained by commodity price shocks in state $s$ is the median of $c_{s,k}^{(n)}$. The 90 percent probability interval of the contribution is obtained from the 5th and 95th percentiles of $c_{s,k}^{(n)}$. Also, the estimate and the 90 percent confidence interval of the difference in the contributions across the illiquidity regimes correspond to the median and the $5^{th}$ and $95^{th}$ percentiles of the difference $c_{H,k}^{(n)} - c_{L,k}^{(n)}$.

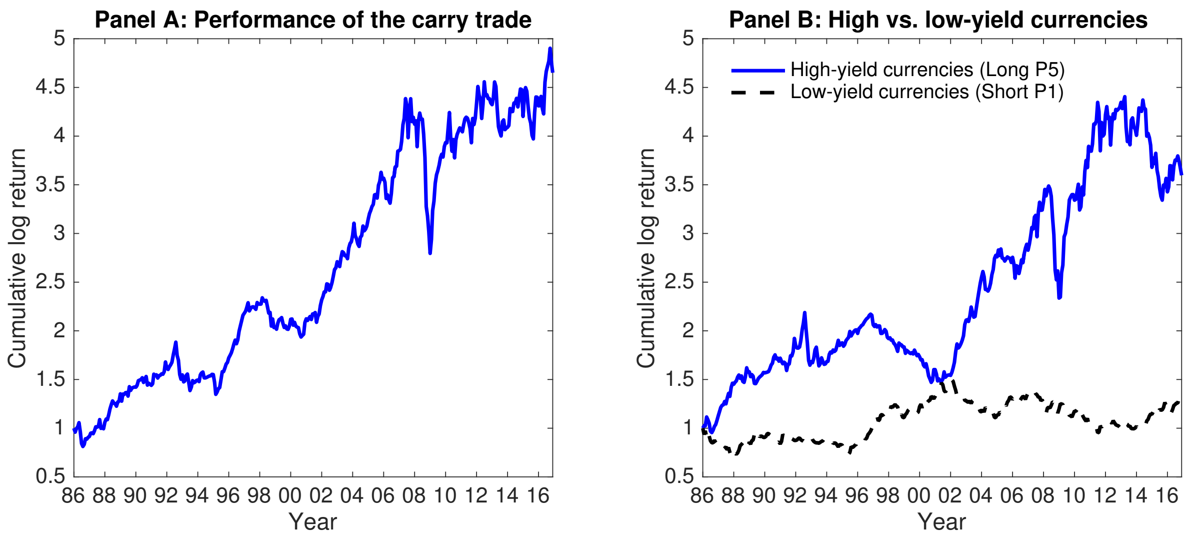


**Figure 1: Performance of the currency portfolios.** Panel A displays the cumulative returns of the carry trade. Panel B shows the payoff of the portfolio (P5) that is long in the 20% of currencies with the highest forward discounts and the portfolio (P1) that is short in the 20% of currencies with lowest forward discounts. Currency returns are monthly excess returns in U.S. dollars and adjusted for transaction costs using bid-ask spreads. The sample period is January 1986 to December 2016.

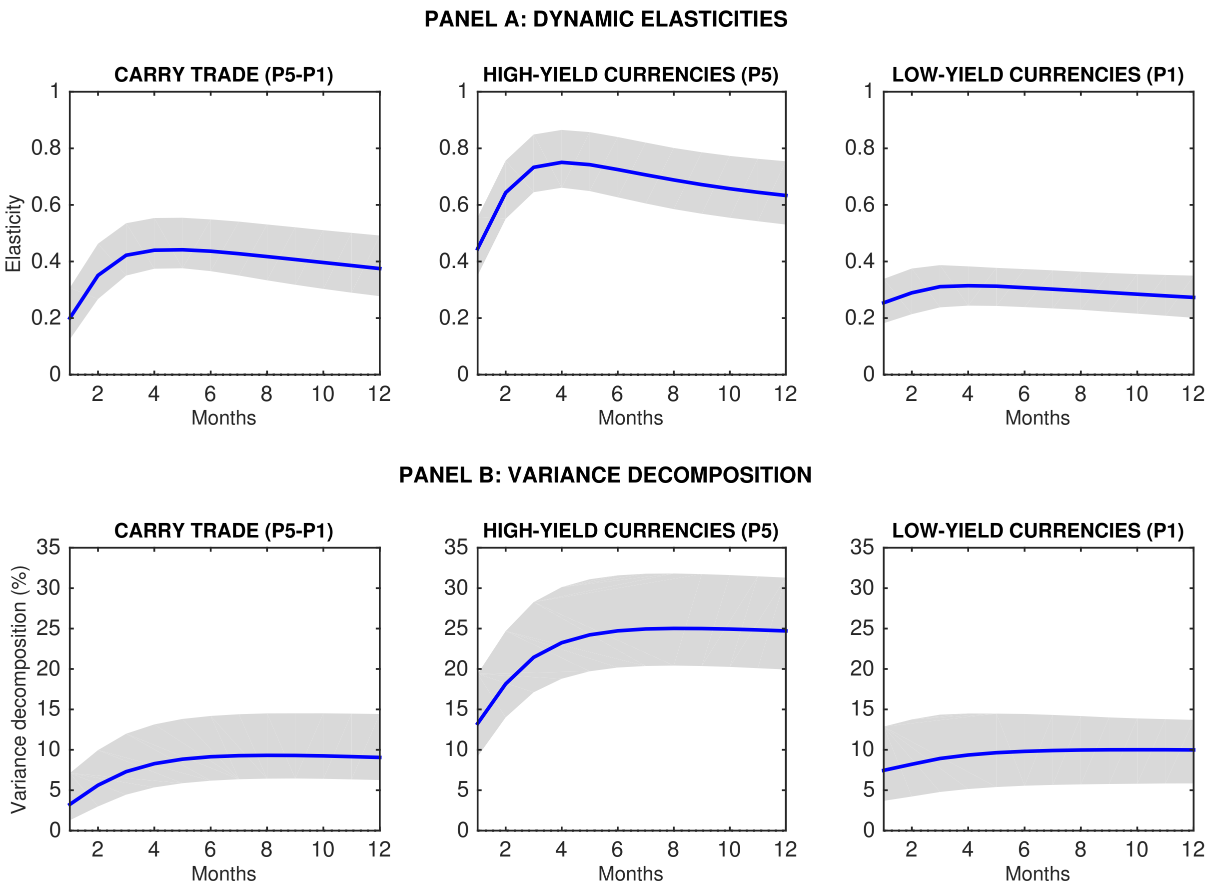


**Figure 2: Unconditional analysis.** Panel A displays the performance of currency portfolios following a positive commodity price shock. The reported elasticity indicates the cumulative return over a given horizon following a 1% increase in commodity prices. Panel B shows the variance decomposition, which corresponds to the contribution of the commodity price shock in explaining the variance of the cumulative return forecast error over a given horizon. The left panels present the results for the carry trade, the middle panels the results for the high-yield currency portfolio (P5), and the right panels show the results for the low-yield currency portfolio (P1). The carry trade is the strategy that is long P5 and short P1. Grey areas indicate 90 percent confidence intervals. The data are described in Section 2. The sample period is January 1991 to October 2016.

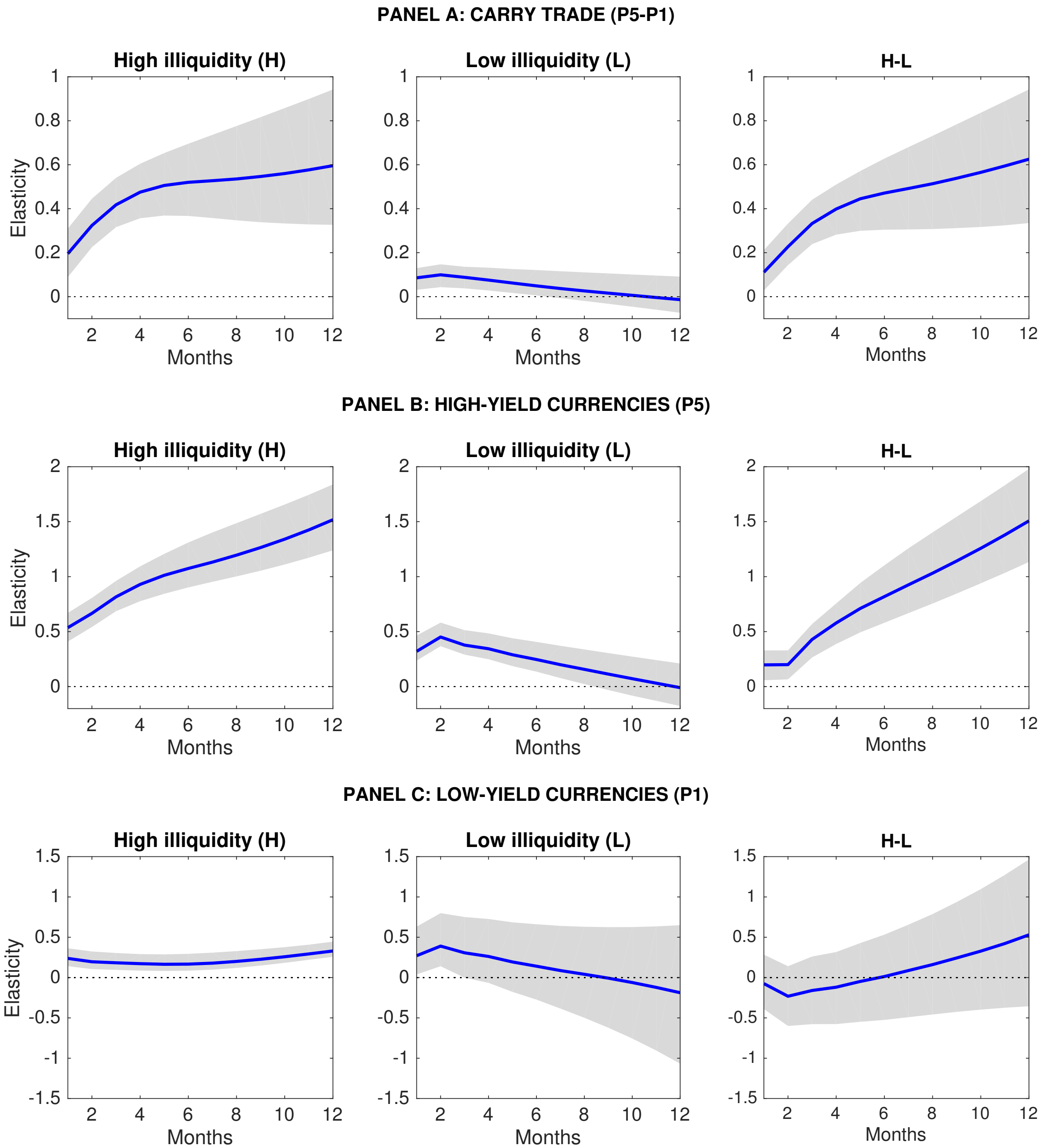


**Figure 3: Conditional analysis – Elasticities.** The figure displays the conditional performance of currency portfolios following a positive commodity price shock. The reported elasticity indicates the cumulative return over a given horizon following a 1% increase in commodity prices. The results for the carry trade are in Panel A, the results for the high-yield currency portfolio (P5) in Panel B, and the results for the low-yield currency portfolio (P1) in Panel C. The carry trade is the strategy that is long P5 and short P1. The left panels correspond to times of high FX illiquidity, the middle panels correspond to times of low FX illiquidity, and the right panels report the difference between the two. Grey areas indicate 90 percent confidence intervals. The data are described in Section 2. The definition of the regimes is discussed in Section 3. The sample period is January 1991 to October 2016.

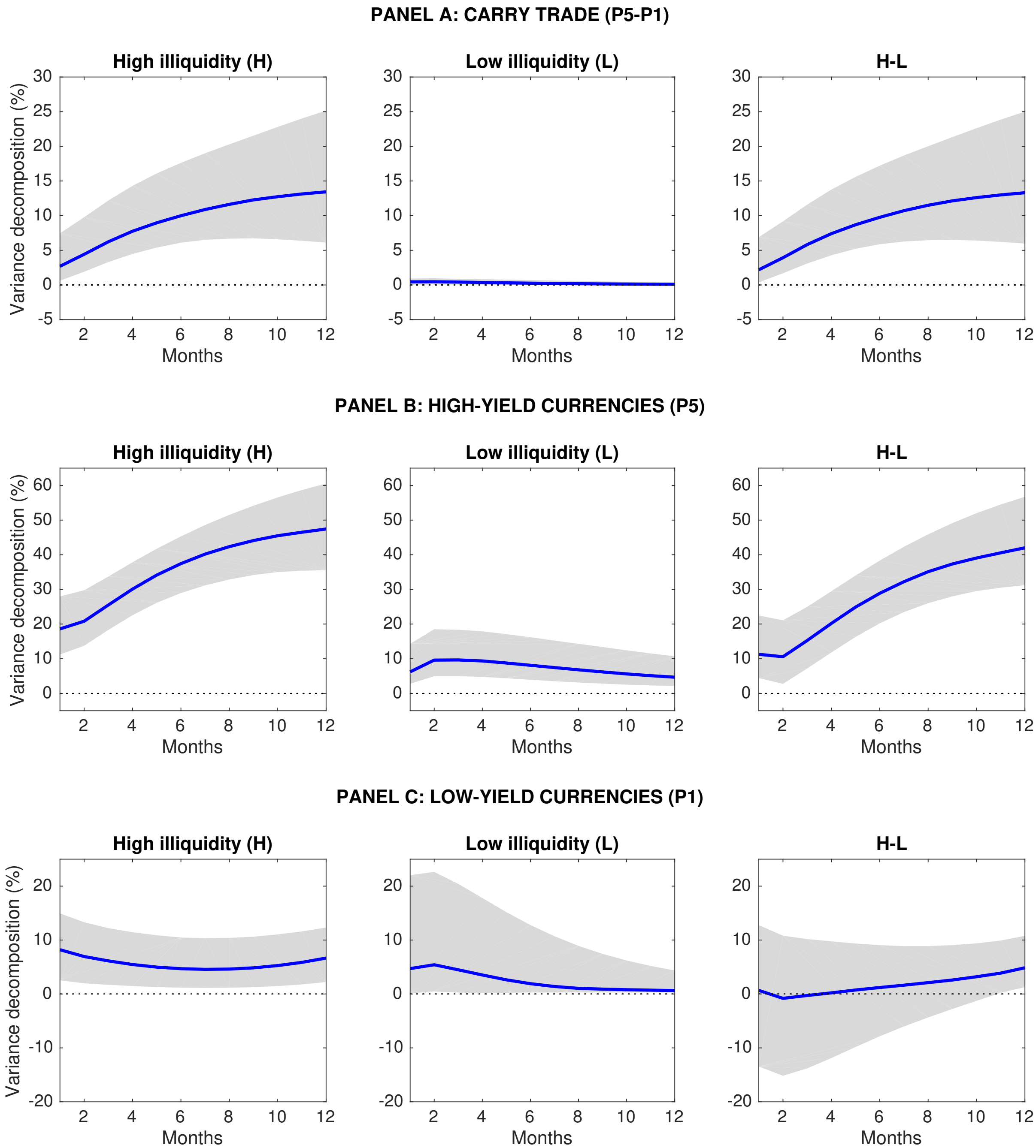


**Figure 4: Conditional analysis – Variance decomposition.** The figure displays the conditional variance decomposition of currency portfolio returns. The variance decomposition corresponds to the contribution of the commodity price shock in explaining the variance of the cumulative return forecast error over a given horizon. The results for the carry trade are in Panel A, the results for the high-yield currency portfolio (P5) in Panel B, and the results for the low-yield currency portfolio (P1) in Panel C. The carry trade is the strategy that is long P5 and short P1. The left panels correspond to times of high FX illiquidity, the middle panels correspond to times of low FX illiquidity, and the right panels report the difference between the two. Grey areas indicate 90 percent confidence intervals. The data are described in Section 2. The definition of the regimes is discussed in Section 3. The sample period is January 1991 to October 2016.

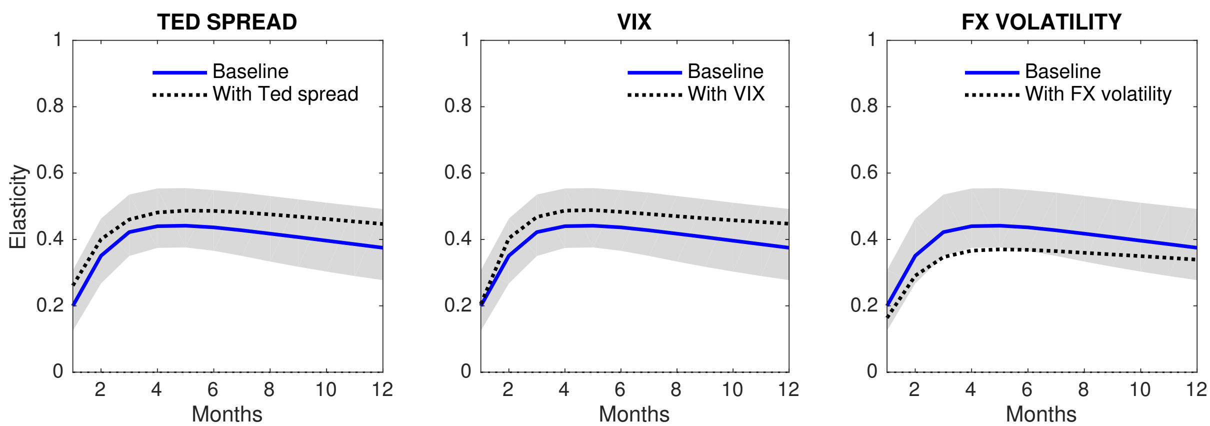


**Figure 5: Extensions – Unconditional analysis with alternative controls.** The figure compares the unconditional predictions when controlling for various measures of FX liquidity. The panels display the performance of the carry trade following a positive commodity price shock. The carry trade is the strategy that is long the high-yield currency portfolio and short the low-yield currency portfolio. The reported elasticity indicates the cumulative return over a given horizon following a 1% increase in commodity prices. The variable of control is either the level of systematic FX liquidity (baseline model), the TED spread, the CBOE option-implied volatility index (VIX), or the J.P. Morgan FX Volatility Index for G7 currencies. Grey areas indicate 90 percent confidence intervals. The data are described in Sections 2 and 5. The sample period is January 1991 to October 2016 for systematic FX liquidity and January 1986 to December 2016 for the TED spread, the VIX, and FX volatility.

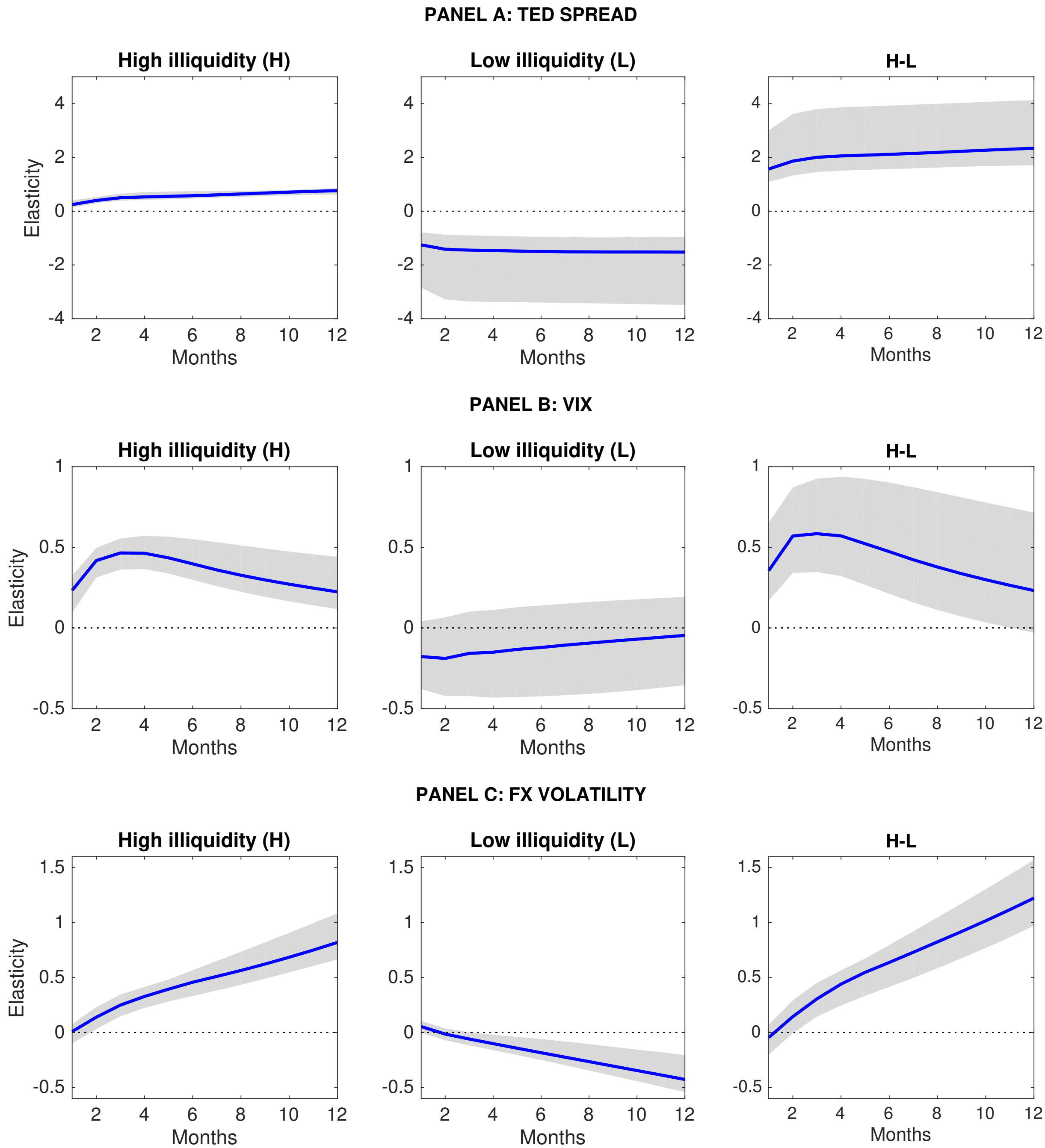


**Figure 6: Extensions – Conditional analysis with alternative FX liquidity regimes.** The figure displays the conditional performance of the carry trade following a positive commodity price shock for alternative FX liquidity regimes. The reported elasticity indicates the cumulative return over a given horizon following a 1% increase in commodity prices. The FX liquidity regimes are determined by the TED spread in Panel A, by the CBOE option-implied volatility index (VIX) in Panel B, and by the level of FX volatility for the G7 countries in Panel C. The left panels correspond to times of high FX illiquidity, the middle panels correspond to times of low FX illiquidity, and the right panels report the difference between the two. Grey areas indicate 90 percent confidence intervals. The data are described in Section 5. The definition of the regimes is discussed in Section 3. The sample period is January 1986 to December 2016.

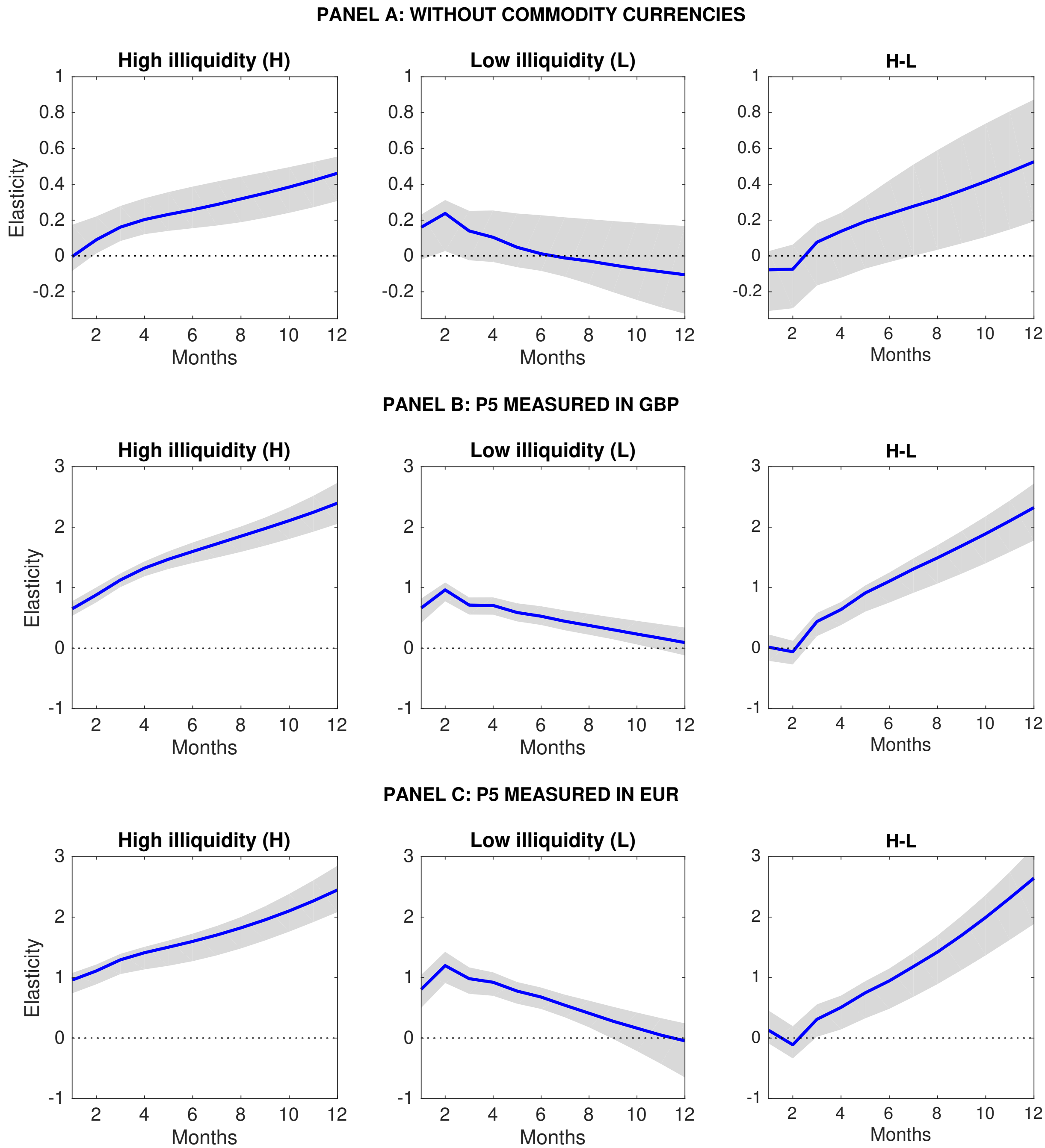


**Figure 7: Extensions – Alternative specifications.** The figure displays the conditional performance of the carry trade following a positive commodity price shock for alternative samples. The reported elasticity indicates the cumulative return over a given horizon following a 1% increase in commodity prices. Panel A reports the results of the carry trade when commodity currencies (AUD, CAD, NOK, NZD) are excluded in the computation. Panels B and C report the results of the high-yield currency portfolio when measured in GBP and EUR, respectively. The left panels correspond to times of high FX illiquidity, the middle panels correspond to times of low FX illiquidity, and the right panels report the difference between the two. Grey areas indicate 90 percent confidence intervals. The data are described in Section 5. The definition of the regimes is discussed in Section 3. The sample period is January 1991 to October 2016.

| Portfolio | P1 | P2 | P3 | P4 | P5 | P5-P1 |
|---|---|---|---|---|---|---|
| Panel A: Currency portfolio returns | | | | | | |
| Mean | -0.831 | -0.364 | 1.548 | 1.603 | 4.141 | 4.972 |
| Std. dev. | 9.383 | 9.237 | 9.252 | 9.567 | 11.106 | 11.044 |
| Sharpe ratio | -0.089 | -0.039 | 0.167 | 0.168 | 0.373 | 0.450 |
| Panel B: Correlation with commodity returns and FX illiquidity | | | | | | |
| Commodity returns | -0.163 | 0.347 | 0.308 | 0.377 | 0.403 | 0.267 |
| FX illiquidity | -0.076 | -0.120 | -0.146 | -0.263 | -0.247 | -0.328 |

**Table I : Descriptive statistics of the currency portfolio returns.** The Panel A reports mean returns, standard deviations, and Sharpe ratios of currency portfolios sorted monthly on time $t-1$ forward discounts. Portfolio 1 contains the 20% of currencies with the lowest forward discounts, whereas Portfolio 5 contains currencies with the highest forward discounts. The carry trade (P5-P1) denotes the strategy that is long in Portfolio 5 and short in Portfolio 1. Moments are computed on annualized excess returns in U.S. dollars with bid-ask spread adjustments. Returns for Portfolio 1 (Portfolios 2–5) are adjusted for transaction costs that occur in a short (long) position in currencies. Panel B reports the correlations between individual portfolio return and returns of the CRB commodity index and the systematic FX illiquidity measure of Karnaukh et al. (2015). Section 2 provides a description of the data. The sample period is January 1986 to December 2016, except for the statistics that involve FX liquidity (January 1991 to October 2016).

| | Low FX illiquidity | | High FX illiquidity | |
|---|---|---|---|---|
| | Mean | Std | Mean | Std |
| Panel A: Portfolio returns, commodity returns, and FX illiquidity | | | | |
| Carry trade | 0.0834 | 0.0976 | -0.1183 | 0.1516 |
| High-yield currencies (P5) | 0.0627 | 0.0977 | -0.0648 | 0.1598 |
| Low-yield currencies (P1) | -0.0207 | 0.0909 | 0.0535 | 0.1063 |
| Commodity | 0.0423 | 0.0823 | -0.0677 | 0.1627 |
| FX illiquidity | -1.9400 | 1.2039 | 7.1776 | 2.5831 |
| Panel B: Correlation with commodity returns | | | | |
| Carry trade return | 0.0763 | | 0.5402 | |
| P5 return | 0.2518 | | 0.6210 | |
| P1 return | 0.1886 | | 0.1630 | |
| FX illiquidity | -0.1421 | | -0.3405 | |

**Table II : Portfolio returns, commodity returns, and FX liquidity.** Panel A reports conditional statistics of currency portfolio returns, commodity returns, and the level of FX illiquidity. Panel B reports the correlations with commodity returns. The sample is split into two parts based on the level of FX illiquidity. Periods of high illiquidity correspond to times when the level of systematic FX illiquidity is in the top quintile, whereas periods of low illiquidity capture the remaining observations. Section 2 provides a description of the data. The means and standard deviations (Std) are based on monthly data and are annualized. The sample period is January 1991 to October 2016.

| | Elasticity | | | Variance decomposition | | |
|---|---|---|---|---|---|---|
| Horizon | High (H) | Low (L) | H−L | High (H) | Low (L) | H−L |
| **Panel A: Carry trade (P5-P1)** | | | | | | |
| 1 | 0.195*** | 0.086*** | 0.111*** | 2.692*** | 0.447*** | 2.186*** |
| 3 | 0.418*** | 0.088*** | 0.333*** | 6.231*** | 0.417*** | 5.821*** |
| 6 | 0.520*** | 0.049* | 0.471*** | 9.988*** | 0.260*** | 9.760*** |
| 12 | 0.596*** | −0.013 | 0.625*** | 13.435*** | 0.103*** | 13.310*** |
| **Panel B: High-yield currencies (P5)** | | | | | | |
| 1 | 0.536*** | 0.321*** | 0.198*** | 18.598*** | 6.206*** | 11.267*** |
| 3 | 0.816*** | 0.377*** | 0.429*** | 25.495*** | 9.652*** | 15.253*** |
| 6 | 1.074*** | 0.246*** | 0.818*** | 37.434*** | 8.106*** | 28.876*** |
| 12 | 1.518*** | −0.010 | 1.507*** | 47.427*** | 4.667*** | 42.004*** |
| **Panel C: Low-yield currencies (P1)** | | | | | | |
| 1 | 0.238*** | 0.271** | −0.075 | 8.208*** | 4.704*** | 0.663 |
| 3 | 0.183*** | 0.307 | −0.160 | 6.135*** | 4.484*** | −0.282 |
| 6 | 0.167*** | 0.141 | 0.013 | 4.687*** | 1.908*** | 1.196 |
| 12 | 0.330*** | −0.188 | 0.530 | 6.657*** | 0.630*** | 4.858*** |

**Table III : Main results.** The table reports the conditional performance of currency portfolios following a positive commodity price shock. The elasticity indicates the cumulative return over a given horizon following a 1% increase in commodity prices. The variance decomposition corresponds to the contribution of the commodity price shock in explaining the variance of the cumulative return forecast error over a given horizon. The results for the carry trade are in Panel A, the results for the high-yield currency portfolio (P5) in Panel B, and the results for the low-yield currency portfolio (P1) in Panel C. The carry trade is the strategy that is long P5 and short P1. The table reports results in times of high and low FX illiquidity separately, and for the difference between the two. The data are described in Section 2. The definition of the regimes is discussed in Section 3. The sample period is January 1991 to October 2016.